AGÊNCIA PORTUGUESA DO AMBIENTE

# PORTUGUESE INFORMATIVE INVENTORY REPORT 1990 – 2015

## SUBMITTED UNDER

## THE NEC DIRECTIVE (EU) 2016/2284 AND

## THE UNECE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Amadora

March, 15th 2017

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To obtain a copy of this report, the Nomenclature for Reporting (NFR) tables or any other information concerning methodologies, activity data or emission factors, and also to send comments and suggestions, please contact:


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# Preface

The UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and related Protocols require Parties to provide each year an update of its inventory for the pollutants concerned, following adopted guidelines for estimating and reporting emission data. The revised guidelines (ECE/EB.AIR/128), for application in 2015 and subsequent years, include technical changes approved at the thirty-seventh session of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) (Geneva, 9–11 September 2013), as well as further changes proposed and agreed to by the Executive Body at its thirty-second session (Geneva, 9–13 December 2013).

The guidelines define the format for reporting emission data (Nomenclature For Reporting/NFR) and offer guidance on how to provide supporting documentation, through an Informative Inventory Report (IIR), which describes the activity data, emission factors, methodologies applied in the calculation, and explanation of the whole process of inventory preparation.

This 2017 Portuguese submission includes inventory emission data provided in the latest version of the templates "NFR14", which accompanies this report.

This IIR refers to the 2017 Portuguese inventory submission on air pollutant emissions for the period 1990-2015. It includes estimates for carbon monoxide (CO), nitrogen oxides ($NO_x$), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides ($SO_x$), ammonia ($NH_3$), Particulate Matter (TSP, $PM_{10}$, $PM_{2.5}$ and for the first time BC), heavy metals and persistent organic pollutants (POPs).

The report was prepared by the Portuguese Environmental Agency (*Agência Portuguesa do Ambiente*), Ministry for the Environment, which is the national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions.

The geographical coverage of the report refers to the EMEP grid, and consequently excludes the two Autonomous Regions of Azores and Madeira Islands.

Ministry for the Environment

# Table of Contents

# EXECUTIVE SUMMARY

## Background information on air emission inventories

As a Party to the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP), Portugal is requested to provide each year an update of its inventory of air pollutant emissions, taking into account the most recent adopted Reporting Guidelines for estimating and reporting emission data (Guidelines for reporting emissions and projections data under the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/128)).

The UNECE Guidelines require that Parties prepare an Informative Inventory Report (IIR) as part of their annual submission. The IIR should contain information related to methodologies, emission factors, activity data, and should give explanations concerning any recalculations of historical inventories, in order to ensure transparency and enable the inventory review.

This report was prepared in order to comply with the international commitments under the UNECE. It presents a description of the methods, assumptions and background data used in the preparation of the 2015 national inventory submission of air pollutants covered by the CLRTAP and related Protocols. The methodologies applied refer as far as possible to the international agreed guidelines such as the EMEP/CORINAIR guidebook or the IPCC Guidelines.

The national inventory of air pollutants aims to cover all substances considered by the international agreements - UNFCCC and CLRTAP - and the EU regulations - (EU) 525/2013 of the European Parliament and of the Council of 21 May 2013, (EU) 749/2014 of 30 June 2014, and the new NEC Directive (EU) 2016/2284.

The inventory has been continuously developed and improved in order to include more pollutants and more complete and reliable estimates.

This report presents estimates for the following gaseous air pollutants: carbon monoxide (CO), nitrogen oxides ($NO_x$), and non-methane volatile organic compounds (NMVOC). Data are also reported for sulphur oxides ($SO_x$), ammonia ($NH_3$), Particulate Matter (TSP, $PM_{10}$, $PM_{2.5}$ and BC), heavy metals (HM) and persistent organic pollutants (POP). The period covered is 1990-2015.

The report is generally structured in accordance with format approved by the UNECE instances.

The national inventory covers emissions occurring in the whole Portuguese territory, i.e., mainland Portugal and the two autonomous regions of Madeira and Azores Islands. As the EMEP scope excludes the islands, this report and related NFR tables refer to the Mainland Portugal only.

Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for all years in the period from 1990 to 2015, i.e., the inventory is internally consistent.

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 from forest.

## Differences between CLRTAP and UNFCCC/ European Commission Monitoring Mechanism reporting

There are some differences in data submitted to the UNECE/CLRTAP Secretariat and the UNFCCC Secretariat and the EU Commission concerning SO2, NOx, NMVOC and CO emissions, which refer to:

- geographical coverage: UNFCCC refers to the national territory, while the UNECE/ CLRTAP refer to the EMEP grid that excludes Madeira and Azores Autonomous Regions;
- aviation: there are differences in the emissions between the NIR and the IIR which result from the difference in terms of coverage. While NIR covers domestic LTOs and cruise emissions in all territory (including islands), IIR covers only LTO in the continental mainland area, either domestic or international LTO.
- navigation: differences refer to the different coverage between NIR and IIR. While NIR covers domestic movements in all territory, IIR does not cover emissions in the islands of Madeira and Azores. The separation of navigation emissions between mainland continental area and islands was determined according with the number of domestic docks in the seaports from mainland and islands.

## Summary of emissions trends

Following the guidance the international methodological Guidelines/Guidebook the main sources of air pollutants are now divided in the four following sectors: Energy, Industrial Processes and Product Use (IPPU), Agriculture and Waste. Wildfires and natural biogenic emissions are reported as memo items. The sources of air pollutants are discussed in detail in the sectoral chapters 3 to 7 of this report.

Next figures present the emissions trends for the years 1990-2015. A deeper analysis of the sectoral emission trends is presented in chapter 2.

Figure ES. 1 – Main pollutants and particulate matter total emissions

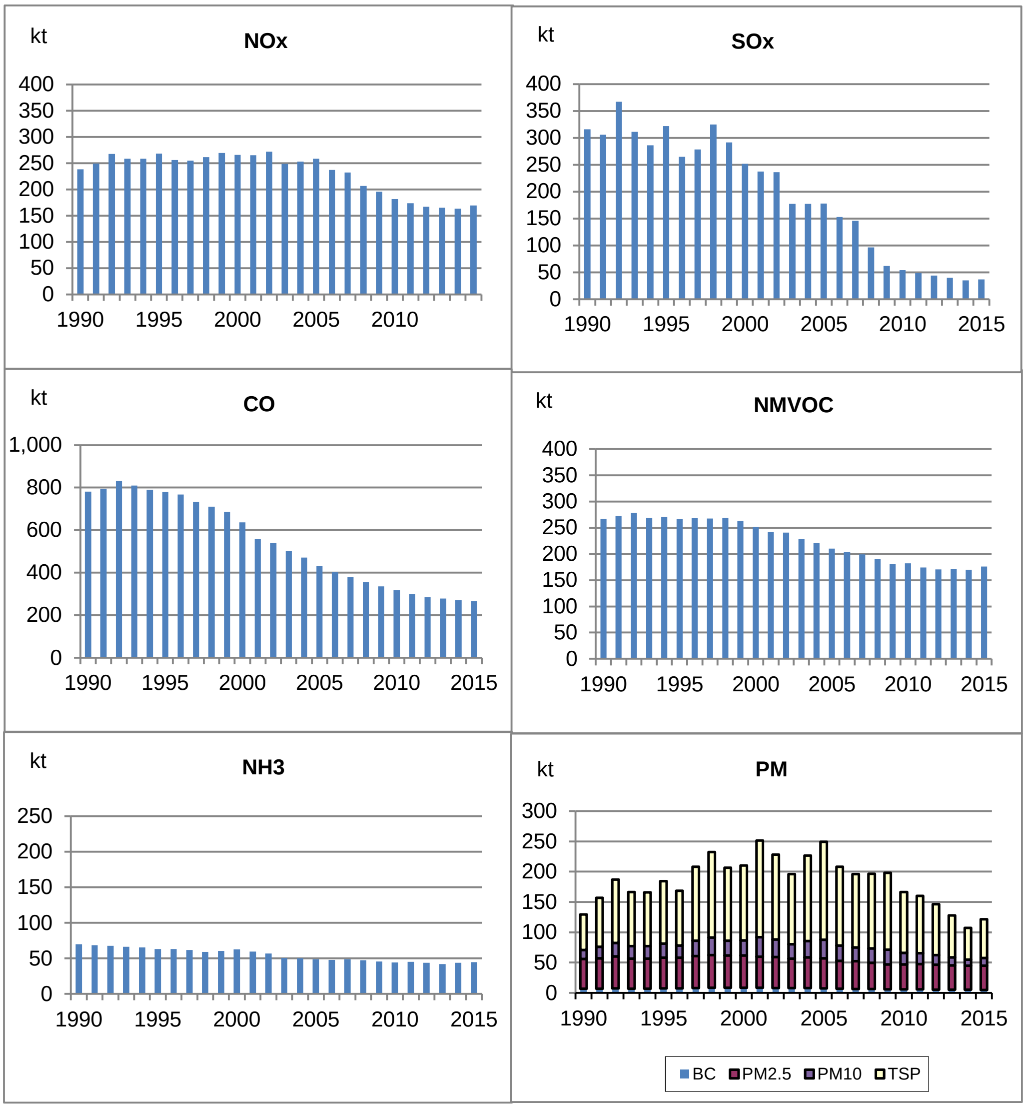



Figure ES. 2 – Percentage variation of main pollutant emissions: 1990-2015 period

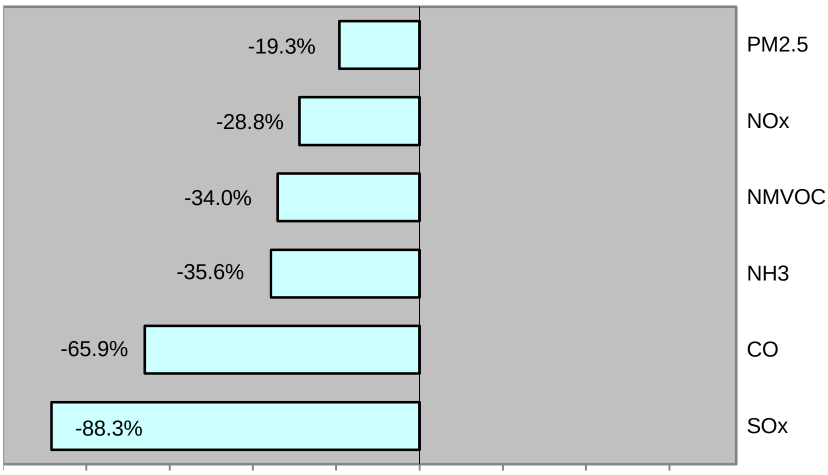


Figure ES. 3 – Heavy metals total emissions

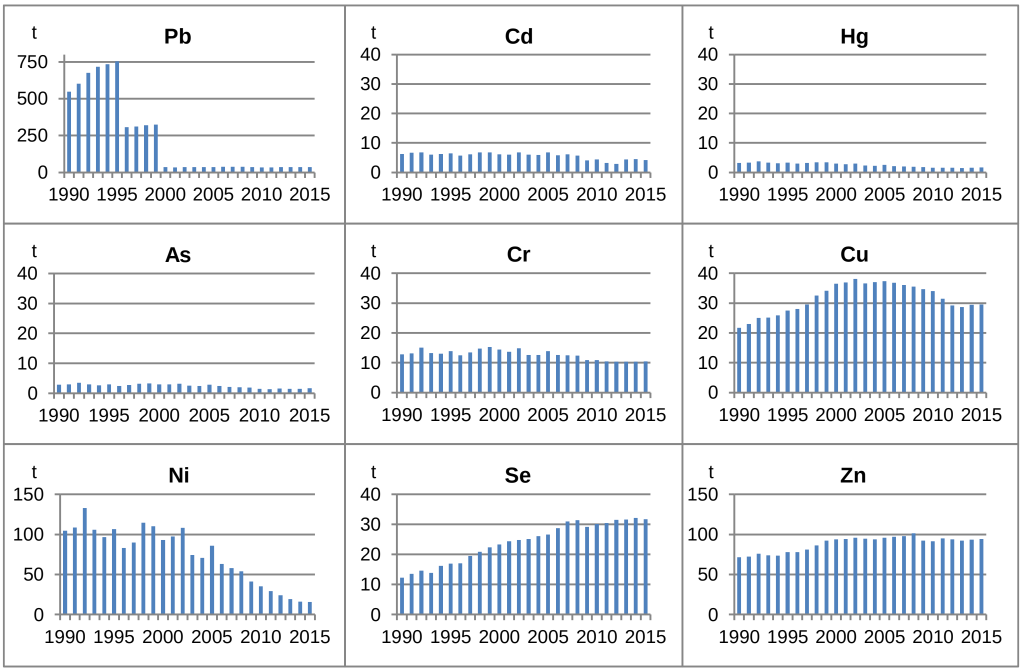



Figure ES. 4 – Percentage variation of HM emissions: 1990-2015

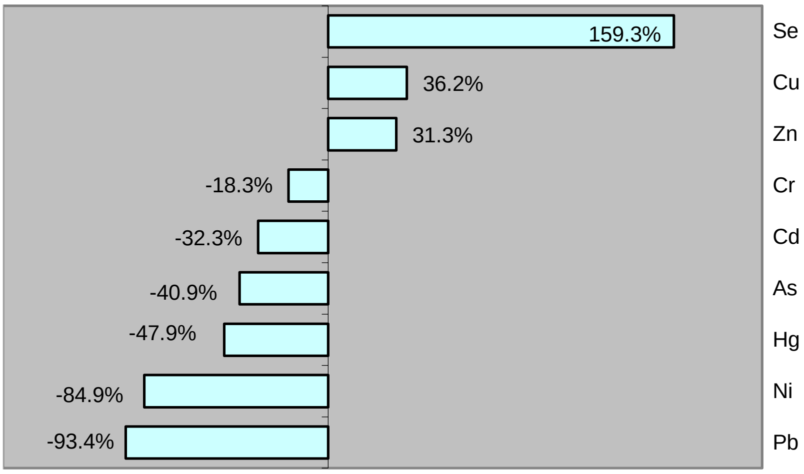



Figure ES. 5 – Persistent organic pollutant total emissions

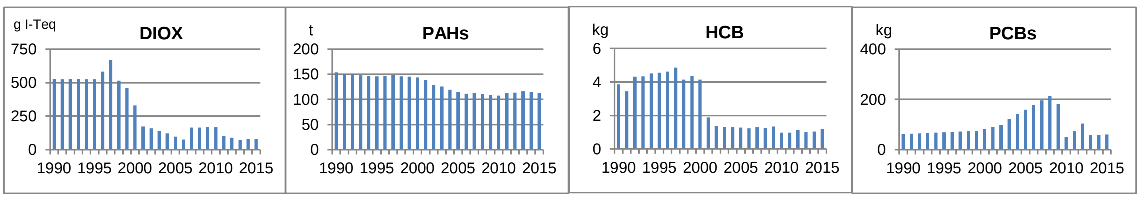
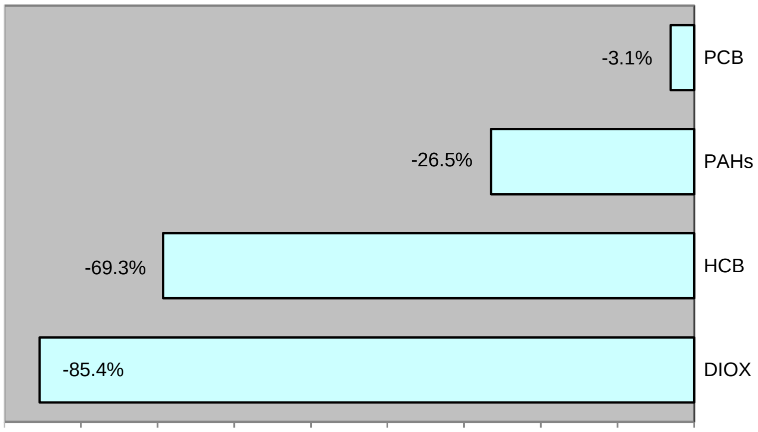


Figure ES. 6 – Percentage variation of Persistent organic pollutant total emissions: 1990-2015




## General assessment of completeness

### Pollutants

The inventory covers several gaseous air pollutants: GHGs emissions not covered in this report, carbon monoxide (CO), nitrogen oxides ($NO_x$), sulphur oxides ($SO_x$), non-methane volatile organic compounds (NMVOC), ammonia ($NH_3$), Particulate Matter, Heavy Metals and POPs.

### Emission sources

The 2015 inventory is generally complete in coverage of emission sources. However there are still some emissions not estimated due to unavailability of emission factors. (Annex A)

### Time coverage

Emissions are estimated for each civil year from 1990 to 2015.

### Geographical coverage

The national inventory covers emissions occurring in the whole Portuguese territory, i.e., mainland Portugal and the two autonomous regions of Madeira and Azores Islands. As the EMEP scope excludes the islands, this report refers to the Mainland Portugal.

## Future developments

Future improvements are defined under the Methodological Development Plan (PDM) which is settled each year in the context of the National Inventory System (SNIERPA) and is developed under the responsibility of APA in cooperation with the sectoral Focal Points. The PDM pretends to reflect the results of the various review processes, as the UNFCCC and UNECE/CLRTAP 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.

A detailed explanation of the sectoral future improvements are presented in each source specific sub-chapter.

A synthesis of the main development priorities are:

- further development of country specific emissions factors for combustion in energy industries;
- improvement of the completeness of the inventory taking into account the latest methodological guidance available;
- development of the uncertainty analysis.

# 1 INTRODUCTION

## 1.1 Background information on air emission inventories

### 1.1.1 History of national inventories

Air emission inventories in Portugal were only initiated in the late eighties/ early nineties of last century, when the first estimates of $NO_x$, $SO_x$ and VOC emissions from combustion where made under the development of the National Energetic Plan (PEN - Plano Energético Nacional), and emissions from combustion and industrial processes were made under OECD inventory and under CORINAIR85 program. A major breakthrough occurred during the CORINAIR90 inventory realized during 1992 and 1993 by General-Directorate of Environment (DGA, presently the Portuguese Environment Agency - APA). This inventory exercise, aiming also EMEP and OECD/IPCC, extended the range of the pollutants ($SO_x$, $NO_x$, NMVOC, $CH_4$, CO, $CO_2$, $N_2O$ and $NH_3$) and emission sources covered, including not only combustion activities but also storage and distribution of fossil duels, production processes, use of solvents, agriculture, urban and industrial wastes and nature (forest fires and NMVOC from forest). Information received under the Large Combustion Plant (LCP) directive was also much helpful to improve inventory quality and the individualization of Large Point Sources, as well as statistical information received from the National Statistical Institute (INE) allowing the full coverage of activity data for most emission sources. The CORINAIR90 Default Emission Factors Handbook (second edition), updating the first edition from CORINAIR85 was used extensively in the development of the current inventory and it was also a key point in the amelioration of the inventory.

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

Since its first compilation, the Portuguese inventory has been continuously amended mainly from the use of more detailed methodologies, better access to underlying data allowing the development of the comprehensiveness of the inventory, and better database storage and calculation structure. Changes in methodology, source coverage or scope of the data were reflected in the estimation of the emissions for the different years considered (1990-2015), i.e., the inventory is internally consistent. Some major studies have contributed to the improvement of the inventory:

- Study of VOC emissions in Portugal, in 1995. This study made in collaboration with FCT (Faculdade de Ciências e Tecnologia) led to an important improvement in emission estimates from solvent sector, which is still used as basic information source for this sector;
- Study of Emission and Control of GHG in Portugal (Seixas et al, 2000). This project aimed the first development of projections toward 2010 and the identification of control measures to

accomplish the Kyoto Protocol. This also led to improvements in the inventory: extension of the inventory including for the first time also carbon dioxide sinks (forest); a fist attempt to estimate solid waste methane emissions from urban solid wastes using a Tier2 approach and, in general terms, a better insight into additional parameters used in the inventory methodologies, and that has resulted from interaction with several institutional agents: General Directorate of Energy, Ministry of Agriculture; and the inter-ministerial transport group;

- Study (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 APA (LCP Directive) and Statistical Information received at DGEG: Energy Balances. The 1990s – DGE (2003);
- PNAC 2004 (National Plan for Climate Change) approved by Ministers Council and published recently in the National Official Journal (OJ nº 179, 31 July 2004, I Série B/ Resolução do Conselho de Ministros nº 119/2004);
- PNAC 2006 (National Plan for Climate Change) approved by Ministers Council and published in the National Official Journal (OJ nº 162, 23 August 2006, I Série B/ Resolução do Conselho de Ministros nº 104/2006)
- Sectorial Studies and Proposal for a PTEN (National Plan on Emission Ceilings);
- PNALE (National Plan for Allocation of Emissions) 2005-2007 or Portuguese PNALE I, adopted by Ministers Council (Resolução do Conselho de Ministros n.o 53/2005) and published in the National Official Journal (OJ nº 44, 3 March 2005, I Série B);
- Bilateral meetings (APA/UE) for the determination of the Baseline Scenario under the CAFE program (IA,2004);
- Methodological Development Programme (PDM) under the implementation of the National Inventory System;
- UNFCCC reviews, in particular the in-depth review (September/October 2004), and the centralised review (October 2005);
- UNFCCC in-depth review of the Initial Report in May 2007, which fixed the Assigned Amount for the first commitment period;
- CLRTAP stage 3 in-depth review realised from 6-10 October 2008;
- Consistency reports under the EC MMD (Dec. 280/2004/EC);
- 2012 technical review of the greenhouse gas emission inventory of Portugal under Decision 406/2009/EC;
- UNFCCC in-depth review of the 2012 GHG inventory (24-29 September);
- UNECE/CLRTAP stage 3 review (June 2013);
- UNFCCC centralized reviews of the GHG inventories (2013-2016);

- Effort Sharing Decision (ESD) review of the 2016 GHG inventory.

The inventory covers several gaseous air pollutants, such as GHGs emissions (not covered in this report), carbon monoxide (CO), nitrogen oxides ($NO_x$), sulphur oxides ($SO_x$), non-methane volatile organic compounds (NMVOC), ammonia ($NH_3$), Particulate Matter, Heavy Metals and POPs.

Emissions are estimated for each civil year from 1990 to 2015.

The inventory covers emissions occurring in the whole Portuguese territory, i.e., mainland Portugal and the two autonomous regions of Madeira and Azores Islands. Emissions from air traffic and navigation realized between places in territorial Portugal, including movements between mainland and islands, are also include in national emission total. As the EMEP scope excludes the islands, this report refers only to Mainland Portugal.

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 from forest fires and natural biogenic emissions (memo items).

## 1.2 Institutional arrangements for inventory preparation

### 1.2.1 Institutional arrangements in place

A new legal national arrangement has been adopted (Council of Ministers Resolution no. 20/2015) in order to take into account the recent developments at international level relating to the UNFCCC and the Kyoto Protocol, and the new monitoring and reporting requirements provided at the EU level by Regulation (EU) 525/2013 of the European Parliament and of the Council of 21 May 2013, on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC, and the Commission Implementing Regulation (EU) 749/2014 of 30 June 2014 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) No 525/2013 of the European Parliament and of the Council, and the requirements under the CLRTAP and the NECD.

This national system for the inventory (SNIERPA) contains a set of legal, institutional and procedural arrangements that aim at ensuring the accurate estimation of emissions by sources and removals by sinks of air pollutants, as well as the communication and archiving of all relevant information.

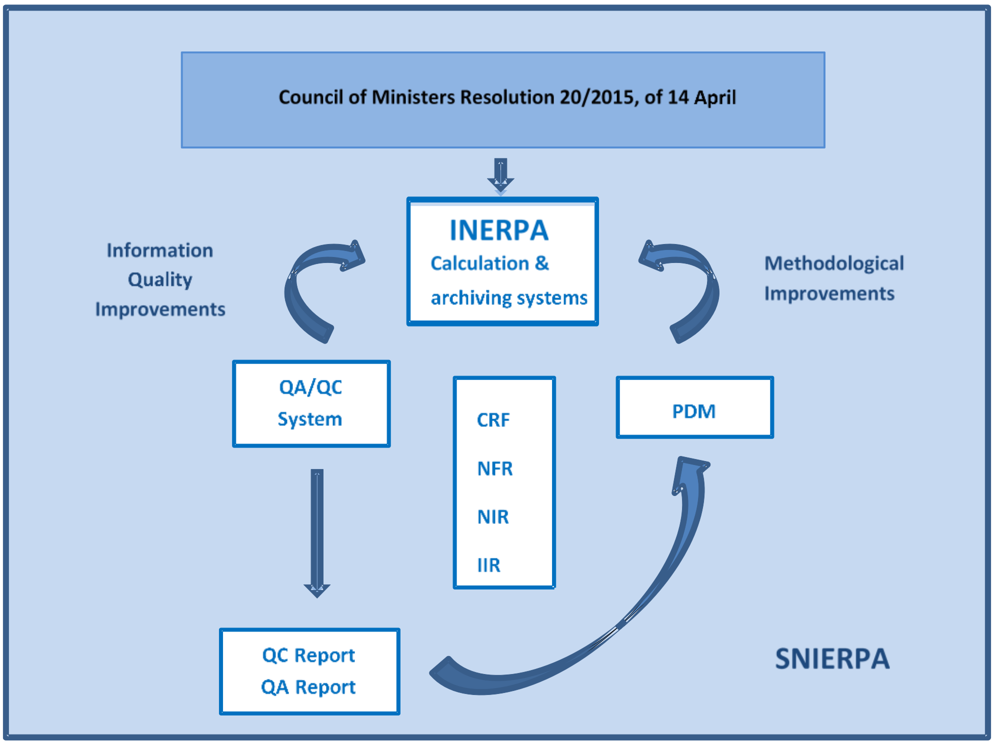
The principal objective of the SNIERPA is to prepare in a timely manner the National Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants (INERPA), in accordance with the directives defined at international and EC levels, in order to make easier and more cost-effective the tasks of inventory planning, implementation and management.

SNIERPA defines the entities relevant for its implementation, based on the principle of institutional cooperation. This clear allocation of responsibilities is essential to ensure that the inventory takes place within the defined deadlines and complies with international requirements.

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

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

**Figure 1.1 – SNIERPA's main elements relations**




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

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

The APA, is the Responsible Body responsible for: the overall coordination and updating of the National Emissions Inventory (INERPA); the inventory's approval, after consulting the Focal Points and the involved entities; and its submission to EC and international bodies to which Portugal is associated, in the several communication and information formats, thus ensuring compliance with the adopted requirements and directives. The Climate Change Department (DCLIMA) is the unit responsible for the general administration of the inventory and for all aspects related to its compilation, reporting and quality management. Data from different sources is collected and processed by the inventory team, who is also responsible for the application of QA/QC procedures, the assessment of uncertainty and key category analysis, the compilation of the CRF tables and the preparation of the NIR, the response to the review processes and data archiving and documentation.

The sectorial Focal Points work with APA/DCLIMA in the preparation of INERPA, and are responsible for fostering intra and inter-sectorial cooperation to ensure a more efficient use of resources. Their main task includes coordinating the work and participation of the relevant sectorial entities over which it has jurisdiction. It is also the Focal Points duty to provide expert advice on methodological choice, emission factor determination and accuracy of the activity data used. Focal Points play a vital role in sectorial quality assurance and methodological development. They are also responsible for the production of statistical information and data publication that are used in the inventory estimates.

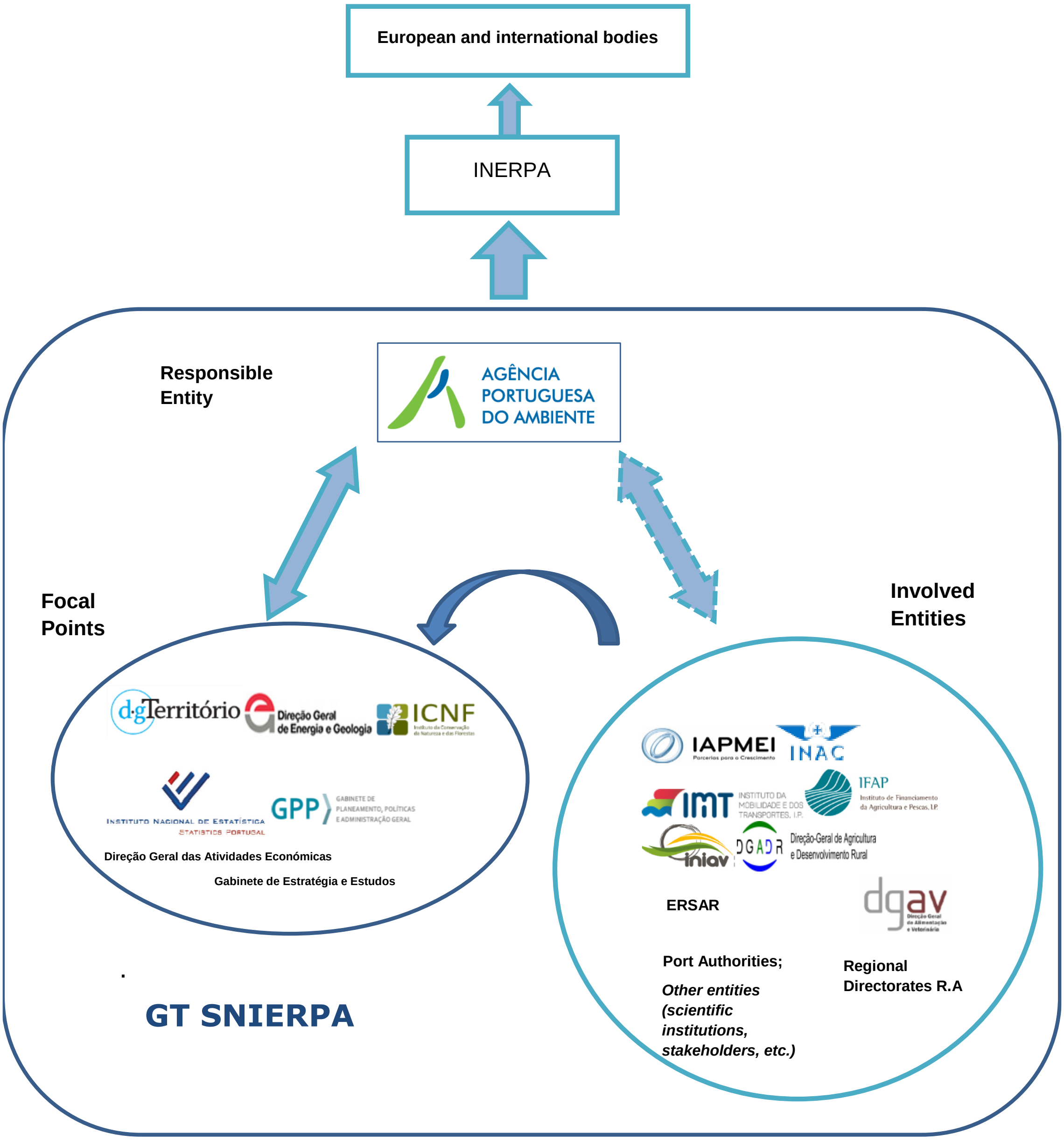
The involved entities are public or private bodies which generate or hold information which is relevant to the INERPA, and which actions are subordinate to the Focal Points or directly to the Responsible Body.

All governmental entities have the responsibility to ensure, at a minimum, co-funding of the investment needed to ensure the accuracy, completeness and reliability of the emissions inventory.

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

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

Figure 1.1 – Main bodies of the national system (SNIERPA)




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

The RCM (Council of Ministers Resolution 20/2015, of 14 April) also includes a procedure for the official consideration of the inventory, defining, in its article 12, that the final approval of INERPA is the responsibility of APA, after hearing the focal points (FP) and the involved entities (IE).

## 1.3 Inventory Preparation Process

### 1.3.1 Responsibility

APA is the national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions. According to these attributions, APA makes an annual compilation of the Portuguese Inventory of air emissions which includes 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 APA.

The designated representative is:

Agência Portuguesa do Ambiente, I.P. (Portuguese Environmental Agency)

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### 1.3.2 Overview of inventory planning

All the participating organizations represented in SNIERPA support the annual production of the national inventories and the fulfillment of the reporting requirements.

Future planned improvements are compiled annually for each sector by the relevant inventory experts and the inventory coordinator, having as a basis the issues raised and the recommendations from the annual review processes and the problems identified from the application of QA/QC procedures, as well as future new reporting obligations. All identified items are gathered in a Methodological Development Plan (PDM – *Plano de Desenvolvimento Metodológico*) which is updated every year. Each issue identified is attributed a priority, considering its importance from the key categories assessment, the level of uncertainty associated and the economic and technical resources available.

Each year, typically in June according to the agreed calendar of INERPA, APA, as coordinator of SNIERPA, organizes a kick off meeting to plan and launch, in coordination with the sectoral focal points and the involved entities, the work for the following inventory submission(s). Bilateral meetings occur as necessary as consequence of this meeting aiming at discussing the specific issues related to each sector and to agree on the actions to be implemented in the framework of SNIERPA during this inventory compilation regarding the next submission.

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

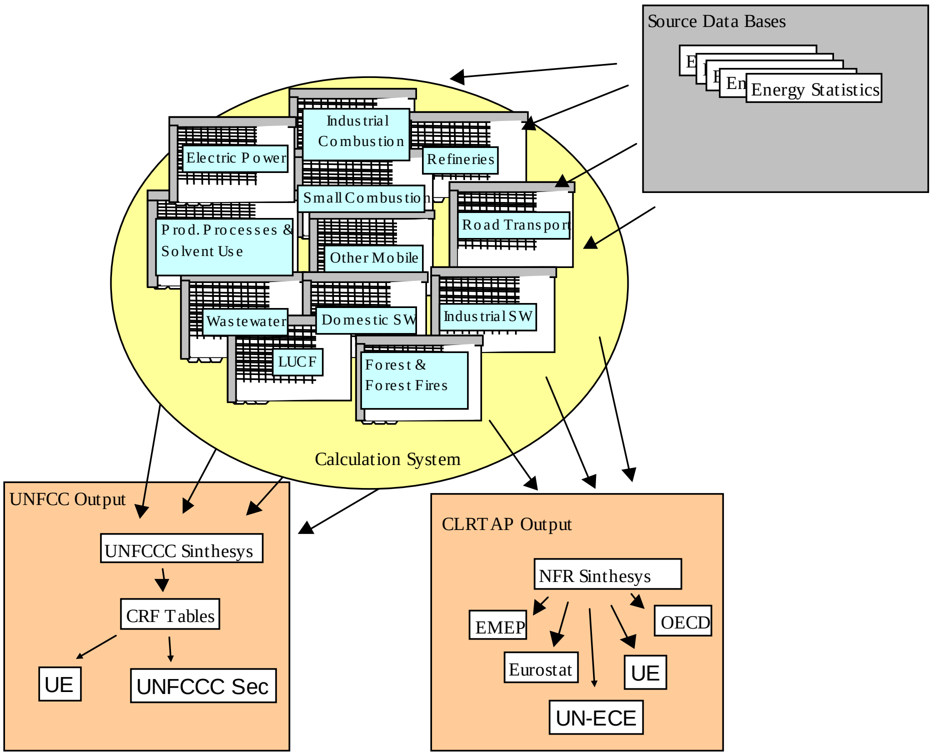
Table 1.1 - Calendar for the inventory process

| Date | Task | Process | Tasks |
|---|---|---|---|
| May - June | - Elaboration of QA/QC plan<br>- Definition/update of inventory development priorities (PDM) | Inventory Planning | - setting of quality objectives<br>- identification of priorities taking into account the latest reviews and QA/QC checks |
| June | Kick-off meeting of SNIERPA WG for the launch of the annual inventory work | Inventory Planning | - discussion of the QA/QC plan<br>- discussion and of the inventory development priorities (PDM) |
| June - December | - end September: deadline for rotine data collection/ delivery by FP and/or IE to the APA<br>- end October: deadline for the implementation of Methodological Development Plan (PDM) improvements | Inventory Compilation/ Improvement/ Verification | - approval of the QA/QC plan and of the PDM<br>- collection of activity data and EFs update<br>- implementation of methodological improvements<br>- estimation of emissions/ removals<br>- aplication of QA/QC checks<br>- uncertainty and KC assessment<br>- archiving of information<br>- preparation of submissions by the inventory team |
| *15 January* | *Preliminary CRF and Short NIR submission to EC (DG CLIMA) [Monitoring Mech. of GHG under EU]* | *Reporting* | - |
| | Preparation of NFR submission | Inventory Verification/ Improvement | - aplication of QA/QC checks<br>- implementation of corrections and late data updates |
| *14 February* | *Official consideration/approval of the NFR submission to UNECE [CLRTAP]* | *Approval* | *Approval by President of APA* |
| *15 February* | *Official NFR submission to NECD [EU] and UNECE [CLRTAP]* | *Reporting* | - |
| | - Revision of CRF submission<br>- Preparation of NIR and IIR<br>- Circulation of NIR and IIR comments among FP and/or IE | Inventory Verification/ Improvement | - aplication of QA/QC checks<br>- implementation of corrections and late data updates |
| 9 March | - Deadline for NIR and IIR comments from FP and/or IE | Inventory Verification | - |
| *14 March* | *Official consideration/approaval of the CRF and NIR submission to EC (DG CLIMA) [Monitoring Mech. of GHG under EU]* | *Approval* | *Approval by President of APA* |
| *15 March* | *Submission of CRF and NIR (final versions) to the EC (DG CLIMA) [Monitoring Mech. of GHG under EU]* | *Reporting* | - |
| *15 March* | *Submission of IIR to UNECE [CLRTAP]* | *Reporting* | - |
| | - Implementation of QA/QC checks | Inventory Verification | - aplication of QA/QC checks including the NIR |
| *15 April* | *Submission of CRF and NIR (final version) to the UNFCCC [UNFCCC and Kyoto Protocol]* | *Reporting* | - |
| *8/27 May* | *Resubmission (if needed) of CRF and NIR (final version) to the EC and UNFCCC [UNFCCC and Kyoto Protocol]* | *Reporting* | - |

### 1.3.3 Calculation, data archiving and documentation system

The emissions calculations have been performed by APA. However many other institutions and agencies contributed to the inventory process, providing activity data, sectoral expert judgement, technical support and comment. 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 1.2 – 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 data processing system has been developed to answer to the various international obligations and national needs. At present, the different demands refer to: UNFCCC (CRF format); UNECE/CLRTAP (NFR format); LCP Directive (NFR format); as well national needs such as the State of Environment Reports. There is independency between emission calculations and the required structure necessary for each obligation which allows flexibility in the inventory.

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

## 1.4 Geographic and sectoral coverage

The geographical coverage of the information refers to the EMEP grid, and consequently excludes the two Autonomous Regions of Azores and Madeira Islands.

Emissions from international maritime traffic and aircraft emissions beyond the landing and take-off cycle are not included.

## 1.5 Time coverage

Emissions are estimated for each civil year from 1990 to 2015.

## 1.6 General overview of methodologies and data sources used

The inventory is compiled, to the extent as possible, in accordance with the recommended methodologies from the EMEP/CORINAIR guidebook or the IPCC Guidelines. The most recent methodological guidance –EMEP/EEA air pollutant emission inventory guidebook – 2016 and the 2006 IPCC Guidelines - have been implemented to the extent of possible for the compilation of the Portuguese inventory.

The national inventory system for air pollutants has been continuously developed and improved in order to include more pollutants and more complete and reliable estimates.

Default methods and emission factors used and the choice between Tier 1 and Tier 2 approaches, were dictated, case by case, by the availability of proper background information, from national circumstances and the availability of resources.

Table 1.2 gives an overview of the institutions and data sources providing data for the compilation of the Portuguese emission inventories.

Table 1.2 – Main data sources used in the Portuguese inventory

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

## 1.7 Key source categories

Key source analysis to the 2017 Portuguese inventory estimates was conducted using Approach 1 for both level and trend assessments, as described in the EEA Guidebook and IPCC Guidelines.

The assessment was undertaken for 2015 for all pollutants at the NFR14 code level. The pollutant-specific key categories were identified using a predetermined cumulative emissions threshold. Key categories are those which, when summed together in descending order of magnitude, cumulatively add up to 80 % of the total level.

The results of the key category analysis for each pollutant are presented in the table below, which show the contribution of the KC identified to the national total (%) and the Tier 1 identification criteria (level (L1)/trend (T1)).

The importance of combustion sources is shown by the predominance of categories identified as key under the Energy sector (categories under 1.A) for the majority of pollutants (exception for $NH_3$). $NH_3$ emissions are generated in the agriculture sector which represent almost 90% of total $NH_3$ emissions in 2015.

For NMVCOs, key categories refer in majority to the IPPU sector (2), in particularly 2.D.3.a Domestic solvent use including fungicides, 2.D.3.d Coating applications, 2.D.3.g Chemical products or 2.H.2 Food and beverages industry. Glass production (2.A.3) is responsible for the large majority of Se emissions and a significant source for other HM emissions. Iron and steel production is also an important source of HM emissions in particular, Zn emissions. The Field burning of agricultural residues (3.F) represents the bulk of PAHs emissions, and the waste sources are related to most of dioxins/furans and PCBs emissions.

Table 1.3 – Key category analysis of 2015 inventory

| NFR sectors | | | Main Pollutants (from 1990) | | | | Particulate Matter (from 2000) | | | | Other (from 1990) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NOx (as $NO_2$) | NMVOC | SOx (as $SO_2$) | $NH_3$ | $PM_{2.5}$ | $PM_{10}$ | TSP | BC | CO |
| 1A1a | Public electricity and heat production | ENERGY | 12.3% (L1, T1) | | 8.6% (L1, T1) | | 0.5% (T1) | 0.6% (T1) | 0.4% (T1) | | |
| 1A1b | Petroleum refining | ENERGY | | | 0.3% (T1) | | | | | | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | ENERGY | | | | | | | | | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | ENERGY | 3.1% (L1, T1) | | 25.9% (L1, T1) | | | | | | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | ENERGY | | | | | | | | | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | ENERGY | 10.3% (L1, T1) | 5.1% (L1, T1) | 14.2% (L1, T1) | | 10% (L1, T1) | 7.9% (L1, T1) | 13% (L1, T1) | 14.1% (L1, T1) | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | ENERGY | 3.4% (L1) | | | | | | | 5.8% (L1) | |
| 1A3ai(i) | International aviation LTO (civil) | ENERGY | | | | | 2.2% (T1) | | | 10.4% (L1, T1) | |
| 1A3bi | Road transport: Passenger cars | ENERGY | 14.1% (L1, T1) | 3.1% (L1, T1) | | 1.6% (T1) | | 3.1% (L1, T1) | | 14.9% (L1, T1) | 11.7% (L1, T1) |
| 1A3bii | Road transport: Light duty vehicles | ENERGY | 5.4% (L1) | | | | 1.2% (T1) | 1.2% (T1) | | 6.4% (L1, T1) | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | ENERGY | 20.6% (L1, T1) | | | | | | | 11.5% (L1, T1) | |
| 1A3biv | Road transport: Mopeds & motorcycles | ENERGY | | 3.7% (L1, T1) | | | | | | | 8.8% (L1, T1) |
| 1A3dii | National navigation (shipping) | ENERGY | | | 4.6% (L1) | | | | | | |
| 1A4bi | Residential: Stationary | ENERGY | | 7.5% (L1) | | | 35.3% (L1, T1) | 28.4% (L1, T1) | 14.1% (L1, T1) | 16.5% (L1, T1) | 48.6% (L1, T1) |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | ENERGY | 8.6% (L1) | | | | | | | 5.4% (L1) | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | ENERGY | 2.3% (T1) | | | | | | | | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | ENERGY | | 8.4% (L1, T1) | 17.8% (L1, T1) | | 1.9% (T1) | 1.5% (T1) | | | |
| 1B2av | Distribution of oil products | ENERGY | | 2.6% (L1) | | | | | | | |
| 1B2d | Other fugitive emissions from energy production | ENERGY | | | | | | | | | |
| 2A3 | Glass production | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | | | | 3% (L1, T1) | 2.5% (T1) | 1.2% (T1) | | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | | | 4.1% (L1, T1) | 7.4% (L1, T1) | 5.9% (L1) | 7.8% (L1, T1) | | 3.1% (L1, T1) |
| 2C1 | Iron and steel production | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | | | | | | | | |
| 2D3a | Domestic solvent use including fungicides | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | 15.1% (L1, T1) | | | | | | | |
| 2D3b | Road paving with asphalt | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | | | | 3.5% (L1) | 17.2% (L1, T1) | 45.5% (L1, T1) | | |
| 2D3d | Coating applications | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | 9.5% (L1) | | | | | | | |
| 2D3g | Chemical products | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | 11.8% (L1, T1) | | | | | | | |
| 2D3i | Other solvent use (please specify in the IIR) | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | 3.9% (L1) | | | | | | | |
| 2H1 | Pulp and paper industry | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | 2.9% (L1, T1) | 4% (L1, T1) | 11.6% (L1, T1) | | 14.5% (L1, T1) | 13.9% (L1, T1) | 7.4% (T1) | | |
| 2H2 | Food and beverages industry | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | 7.2% (L1, T1) | | | | | | | |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | | | | 3.7% (L1) | 2.9% (L1) | | | |
| 3B1a | Manure management - Dairy cattle | AGRICULTURE | | | | 7.7% (L1) | | | | | |
| 3B3 | Manure management - Swine | AGRICULTURE | | | | 12.9% (L1, T1) | | | | | |
| 3B4gi | Manure mangement - Laying hens | AGRICULTURE | | | | 5.8% (L1, T1) | | | | | |
| 3B4gii | Manure mangement - Broilers | AGRICULTURE | | | | 5.4% (L1, T1) | | | | | |
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | AGRICULTURE | | | | 20.6% (L1, T1) | | | | | |
| 3Da2a | Animal manure applied to soils | AGRICULTURE | | | | 17.4% (L1, T1) | | | | | |
| 3Da3 | Urine and dung deposited by grazing animals | AGRICULTURE | | | | 8.7% (L1, T1) | | | | | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | AGRICULTURE | | | | | | 1% (T1) | | | |
| 3F | Field burning of agricultural residues | | | | | | 3.5% (L1) | 2.9% (L1) | | | 9.6% (L1, T1) |
| 5A | Biological treatment of waste - Solid waste disposal on land | WASTE | | | | 2.8% (T1) | | | | | |
| 5C1bi | Industrial waste incineration | WASTE | | | | | | | | | |
| 5C1biii | Clinical waste incineration | WASTE | | | | | | | | | |
| | TOTAL | (%) | 80.8 | 81.9 | 82.7 | 82.7 | 81.0 | 82.1 | 80.4 | 85.1 | 81.8 |

| NFR sectors | | | Priority Heavy Metals (from 1990) | | | Additional Heavy Metals (from 1990, voluntary reporting) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pb | Cd | Hg | As | Cr | Cu | Ni | Se | Zn |
| 1A1a | Public electricity and heat production | ENERGY | 8.6% (L1) | 1.8% (T1) | 47% (L1, T1) | 55.4% (L1) | 6.4% (L1, T1) | 4.1% (T1) | 8.7% (L1, T1) | 0.4% (T1) | |
| 1A1b | Petroleum refining | | | | | | | | 1.9% (T1) | | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | | | | | 0.7% (T1) | | | | | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | | | | 25.7% (L1, T1) | | | | 11% (L1) | | 8.7% (L1) |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | | | | | 1.7% (T1) | | | 6.8% (L1) | | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | | | 63.6% (L1, T1) | | 19.9% (L1, T1) | 30.3% (L1, T1) | 6.8% (L1, T1) | 28.3% (L1, T1) | 1.7% (T1) | 1.4% (T1) |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | | | 0.7% (T1) | 2% (T1) | 1.7% (T1) | 0.7% (T1) | | 3.6% (T1) | | |
| 1A3ai(i) | International aviation LTO (civil) | | | | | | | | | | |
| 1A3bi | Road transport: Passenger cars | | 12.5% (L1, T1) | | | | 5.4% (T1) | 47.7% (L1, T1) | | | 6.8% (L1, T1) |
| 1A3bii | Road transport: Light duty vehicles | | | | | | | 13% (L1, T1) | | | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | | | | | | | 15.9% (L1) | | | |
| 1A3biv | Road transport: Mopeds & motorcycles | | | | | | | 2.6% (T1) | | | |
| 1A3dii | National navigation (shipping) | | | | | | | | | | |
| 1A4bi | Residential: Stationary | | | 9.9% (L1) | | | 7.1% (L1) | | | | 17.5% (L1, T1) |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | | | | | | | | | | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | | | | | | | | | | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | | | | | | | | | | |
| 1B2av | Distribution of oil products | | | | | | | | | | |
| 1B2d | Other fugitive emissions from energy production | | | | 4.8% (L1, T1) | | | | | | |
| 2A3 | Glass production | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | 56.8% (L1, T1) | 6% (T1) | 5.1% (L1, T1) | 12.3% (L1, T1) | 39.1% (L1, T1) | 3.5% (T1) | 20.5% (L1, T1) | 97.1% (L1, T1) | 19.9% (L1, T1) |
| 2B10a | Chemical industry: Other (please specify in the IIR) | | | | | | | | | | |
| 2C1 | Iron and steel production | | 10.6% (L1, T1) | 6.9% (L1, T1) | 4.2% (T1) | 3.5% (T1) | | | 6.6% (L1) | | 30.4% (L1, T1) |
| 2D3a | Domestic solvent use including fungicides | | | | | | | | | | |
| 2D3b | Road paving with asphalt | | | | | | | | | | |
| 2D3d | Coating applications | | | | | | | | | | |
| 2D3g | Chemical products | | | | | | | | | | |
| 2D3i | Other solvent use (please specify in the IIR) | | | | | | | | | | |
| 2H1 | Pulp and paper industry | | | | | | | | | | |
| 2H2 | Food and beverages industry | | | | | | | | | | |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | | | | | | | | | | |
| 3B1a | Manure management - Dairy cattle | AGRICULTURE | | | | | | | | | |
| 3B3 | Manure management - Swine | | | | | | | | | | |
| 3B4gi | Manure mangement - Laying hens | | | | | | | | | | |
| 3B4gii | Manure mangement - Broilers | | | | | | | | | | |
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | | | | | | | | | | |
| 3Da2a | Animal manure applied to soils | | | | | | | | | | |
| 3Da3 | Urine and dung deposited by grazing animals | | | | | | | | | | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | | | | | | | | | | |
| 3F | Field burning of agricultural residues | | | | | | | | | | |
| 5A | Biological treatment of waste - Solid waste disposal on land | WASTE | | | | | | | | | |
| 5C1bi | Industrial waste incineration | | | | | | | | | | |
| 5C1biii | Clinical waste incineration | | | | 0.1% (T1) | | | | | | |
| | **TOTAL** | (%) | **88.5** | **80.4** | **82.6** | **87.6** | **82.9** | **83.6** | **81.9** | **97.1** | **83.4** |

| NFR sectors | | | POPs (1) (from 1990) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | PCDD/ PCDF (dioxins/ furans) | PAHs | | | | | HCB | PCBs |
| | | | | benzo(a) pyrene | benzo(b) fluoranthene | benzo(k) fluoranthene | Indeno (1,2,3-cd) pyrene | Total 1-4 | | |
| 1A1a | Public electricity and heat production | ENERGY | | | | | | | 81.6% (L1, T1) | |
| 1A1b | Petroleum refining | | | | | | | | | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | | | | | | | | | 0% (T1) |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | | | | | | | | | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | | | | | | | | | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | | | | | | | | | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | | | | | | | | | |
| 1A3ai(i) | International aviation LTO (civil) | | | | | | | | | |
| 1A3bi | Road transport: Passenger cars | | | | | | | | | |
| 1A3bii | Road transport: Light duty vehicles | | | | | | | | | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | | | | | | | | | |
| 1A3biv | Road transport: Mopeds & motorcycles | | | | | | | | | |
| 1A3dii | National navigation (shipping) | | | | | | | | | |
| 1A4bi | Residential: Stationary | | 18% (L1, T1) | | | | | 9.8% (T1) | | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | | | | | | | | | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | | | | | | | | | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | | | | | | | | | |
| 1B2av | Distribution of oil products | | | | | | | | | |
| 1B2d | Other fugitive emissions from energy production | | | | | | | | | |
| 2A3 | Glass production | INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) | | | | | | | | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | | | | | | | | | |
| 2C1 | Iron and steel production | | | | | | | 0.5% (T1) | 0.4% (T1) | |
| 2D3a | Domestic solvent use including fungicides | | | | | | | | | |
| 2D3b | Road paving with asphalt | | | | | | | | | |
| 2D3d | Coating applications | | | | | | | | | |
| 2D3g | Chemical products | | | | | | | | | |
| 2D3i | Other solvent use (please specify in the IIR) | | | | | | | | | |
| 2H1 | Pulp and paper industry | | | | | | | | | |
| 2H2 | Food and beverages industry | | | | | | | | | |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | | | | | | | | | |
| 3B1a | Manure management - Dairy cattle | AGRICULTURE | | | | | | | | |
| 3B3 | Manure management - Swine | | | | | | | | | |
| 3B4gi | Manure mangement - Laying hens | | | | | | | | | |
| 3B4gii | Manure mangement - Broilers | | | | | | | | | |
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | | | | | | | | | |
| 3Da2a | Animal manure applied to soils | | | | | | | | | |
| 3Da3 | Urine and dung deposited by grazing animals | | | | | | | | | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | | | | | | | | | |
| 3F | Field burning of agricultural residues | | | | | | | 88.1% (L1, T1) | | |
| 5A | Biological treatment of waste - Solid waste disposal on land | WASTE | | | | | | | | |
| 5C1bi | Industrial waste incineration | | 10.2% (L1, T1) | | | | | | | 99.8% (L1, T1) |
| 5C1biii | Clinical waste incineration | | 59.5% (L1, T1) | | | | | | 9.7% (T1) | 0% (T1) |
| | **TOTAL** | **(%)** | **87.7** | | | | | **88.1** | **81.6** | **99.8** |

## 1.8 Information on QA/QC

APA is the national entity responsible for the Quality Assurance and Quality Control (QA\QC) System of the inventory (Figure 1.1).

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

Each Involved Entity (IE) within SNIERPA contributing with data to the inventory is responsible for the quality of their own data. A request for information on the specific QC or QA procedures is to be sent to IEs in order to document such procedures, its results and also the uncertainty calculations.

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

The 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 2006) and adapted to the 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 NFR 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, and comparison of results among different approaches.

## 1.9 General uncertainty assessment

At present, the uncertainty analysis is performed only for the direct GHG. It was not possible until now to extend the assessment to other emission estimates. It is foreseen to be implemented in the future.

## 1.10 Overview of the completeness

The national inventory comprehends emissions occurring in the whole Portuguese territory, i.e., mainland Portugal and the two autonomous regions of Madeira and Azores Islands. Emissions from air traffic and navigation realized between places in territorial Portugal, including movements between mainland and islands, are also include in national emission total.

As the EMEP scope excludes the islands, reporting under CLRTAP refers to the Mainland Portugal.

The inventory covers several gaseous air pollutants: GHGs emissions not covered in this report, carbon monoxide (CO), nitrogen oxides ($NO_x$), sulphur oxides ($SO_x$), non-methane volatile organic compounds (NMVOC), ammonia ($NH_3$), Particulate Matter, Heavy Metals and POPs.

An effort has been done in the late years in order to extend the scope of the inventory in terms of substances and the source categories covered. The situation has been continuously improved, however some pollutants/categories are still not quantified.

Table 1 included in ANNEX A: COMPLETENESS AND KEY CATEGORIES, indicates the source categories/pollutants emissions reported as “NE” (Not Estimated). These situations result, in some cases, from a lack of methodological guidance (e.g. non-availability of EF). In other cases, they correspond to areas where further work is needed at national level, and consequently they have or will be considered in the methodological development programme (PDM) for future inventory improvement.

# 2 EMISSION TRENDS

$SO_x$ emissions are generated in majority in the energy sector (~85% of total emissions in 2015) which is a major consumer of fossil fuels. Within this sector, the combustion in manufacturing industries, with approximately 46% of total emissions in 2015, and fugitive emissions from refining (~18% of total emissions in 2015) represent the major sources,

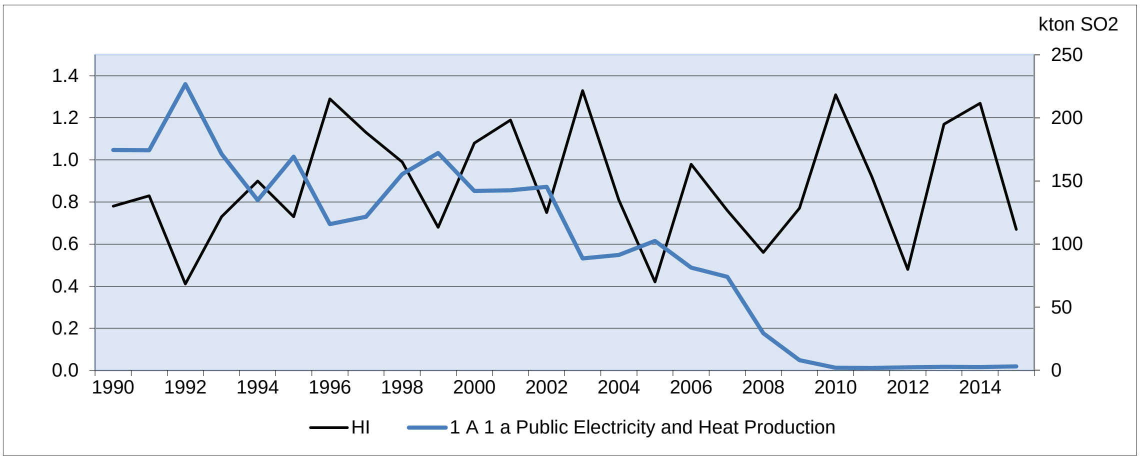
The variation of SOx emissions in the period 1990-2015 registered an overall trend variation of -88.3% for the same period, that resulted from the significant decrease of most of sub-categories: energy industries –98.3%, manufacturing industries –79.1%, transport -86.8% and combustion of other sectors -76.2%.

These tendencies reflect the implementation of important measures that had a positive effect in the emissions levels, such as the introduction of natural gas (1997), the installation of new combined cycle thermoelectric plants using natural gas (1999), the progressive installation of co-generation units, the amelioration of energetic and technologic efficiency of industrial processes, or the introduction of stricter laws regulating the quality of fuels, e.g. for residual fuel oil (Decree-Law 281/2000 of 10th November).

$SO_x$ emissions presented until the early 2000s a significant inter-annual variation which was related to the pronounced fluctuations of hydroelectric power generation that is highly dependent on annual variations in precipitation (see Figure below). This relation was broken particularly in the late years, after the implementation of new desulfurization systems in two Large Point Source Energy Plants in Mainland Portugal. As a consequence, $SO_x$ emissions from the energy industries registered a strong reduction since 2007 (approx. -190% in 2015 as compared to 2007).

The 2015 year was characterized by a decrease of the hydropower production in 2015 (order of -24%) due to an unfavorable year in terms of water availability (HPI = 0.67), contributing to a greater use of coal and NG in the electro producer.

Figure 2.1 – Hydraulic index and $SO_2$ emissions from Public Electricity and Heat Production




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

Energy is also the major responsible sector for emissions of $NO_x$, and CO, representing, respectively, approx. 93% and 86.8% of 2015 total emissions. Its contribution for NMVOC emissions is also significant, together with Industrial Processes and Products Use. Within energy, transportation is responsible for the major share of $NO_x$, CO and NMVOC emissions: approx. 45% for $NO_x$, 26% for CO and 8% for NMVOC of 2015 totals. Despite the fast growing trends of the transport sector (mainly road) since the 90s, the introduction of new petrol-engine passenger cars with catalysts converters and stricter regulations on diesel vehicles emissions, limited the growth of these emissions or even its decrease. In fact, the situation started to change in the last years, as transport emissions growth has first stabilised and even started to decline in the most recent years. The emissions variation registered in the transport road sector in the period 1990-2015 for NMVOC, CO and NOx emissions are, respectively, -86%, -85% and -9%.

Other sectors (commercial/institutional, residential and agriculture/ forestry) within energy, also amount for a significant share of CO: approx. 51% of 2015 totals.

$NH_3$ is primarily generated in biological systems, such as agriculture soil (47% of 2015 totals), manure management systems (41% of 2015 totals), chemical industry and decomposition of municipal wastes. Road transport represents a smaller amount of emissions with 1.7% of 2015 total, but has grown significantly since 1990 (~1100%). The overall evolution of ammonia in the period analysed is downwards with a -35.6% variation between 1990 and 2015.

A significant share of particulate matter is generated in other sectors (residential) which represents approximately 37% of 2015 total PM2.5 emissions and in combustion in manufacturing industry (~14%), and the estimates show an over whole negative trend since 1990 for TSP (-6%), and a negative trend for BC, (-30%), PM2.5 (-19%) and PM10 (-19%).

Figure 2.2 – Main pollutants and particulate matter total emissions

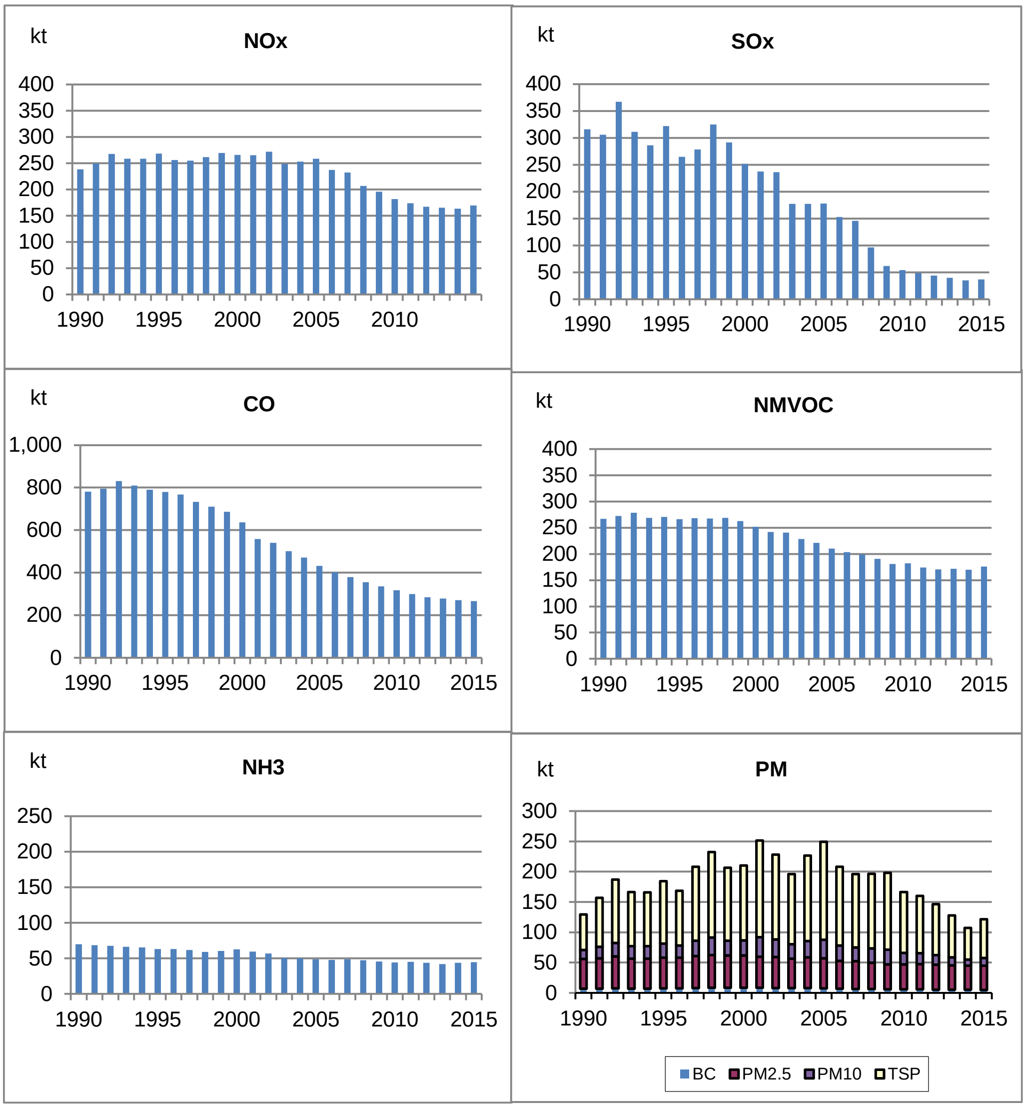


Figure 2.3 – Percentage variation of main pollutant emissions: 1990-2015 period

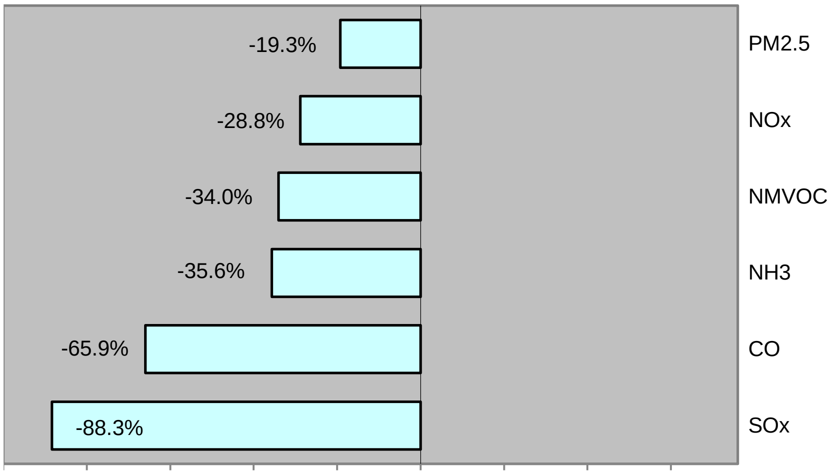
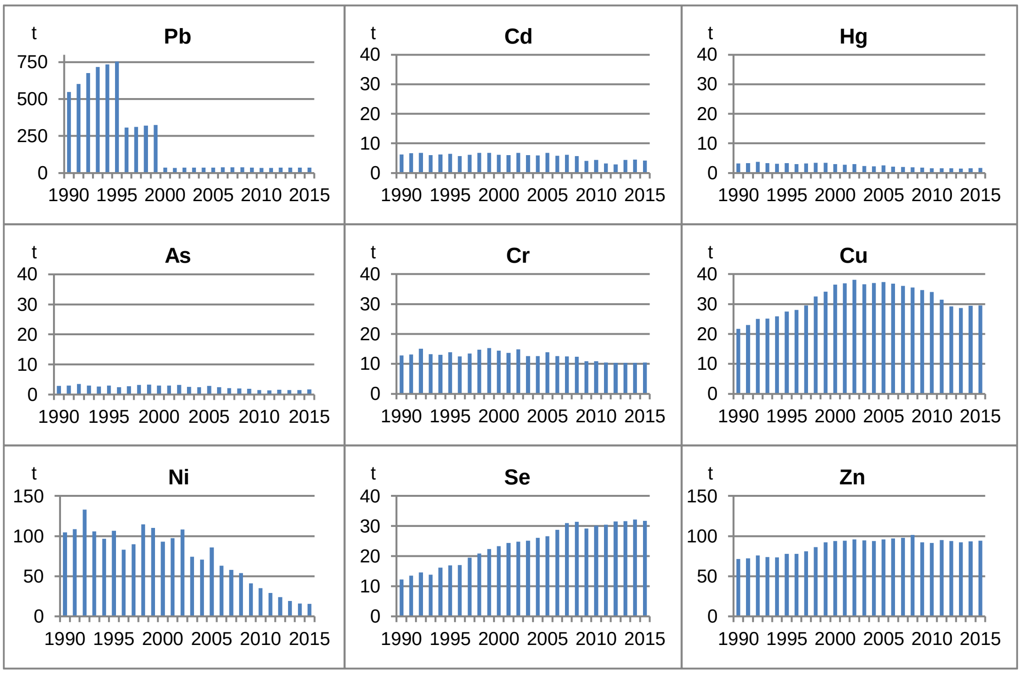



Table 2.1 – Main pollutants and particulate matter total emissions

| | NOx kt | NMVOC kt | SOx kt | NH3 kt | PM2.5 kt | PM10 kt | TSP kt | BC kt | CO kt |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 238.3 | 266.9 | 315.7 | 69.8 | 55.9 | 70.9 | 129.5 | 6.7 | 781.1 |
| 1991 | 249.5 | 272.6 | 306.0 | 68.4 | 57.1 | 75.8 | 157.0 | 7.0 | 794.2 |
| 1992 | 267.7 | 278.3 | 367.1 | 67.7 | 60.2 | 82.5 | 186.9 | 7.3 | 831.0 |
| 1993 | 258.8 | 268.8 | 311.0 | 66.3 | 56.5 | 76.8 | 166.1 | 7.0 | 810.5 |
| 1994 | 258.3 | 270.7 | 286.3 | 65.2 | 56.7 | 77.0 | 166.0 | 7.0 | 790.8 |
| 1995 | 268.3 | 266.0 | 321.9 | 63.0 | 58.2 | 81.1 | 184.0 | 7.1 | 780.1 |
| 1996 | 256.0 | 268.4 | 264.4 | 63.3 | 58.2 | 78.2 | 168.4 | 7.3 | 766.9 |
| 1997 | 254.7 | 267.2 | 278.5 | 61.6 | 60.9 | 86.1 | 208.2 | 7.8 | 733.4 |
| 1998 | 261.5 | 268.9 | 324.7 | 59.0 | 62.5 | 91.2 | 232.2 | 8.3 | 710.6 |
| 1999 | 269.4 | 262.5 | 291.3 | 60.4 | 61.7 | 86.1 | 206.6 | 8.3 | 686.0 |
| 2000 | 265.8 | 251.3 | 251.5 | 62.7 | 61.8 | 86.4 | 210.3 | 8.5 | 636.9 |
| 2001 | 265.3 | 242.0 | 237.4 | 59.5 | 59.7 | 91.9 | 251.4 | 8.2 | 557.9 |
| 2002 | 272.0 | 240.9 | 236.1 | 57.1 | 59.1 | 87.9 | 228.3 | 8.0 | 540.3 |
| 2003 | 248.6 | 228.2 | 177.5 | 50.7 | 56.6 | 80.3 | 196.0 | 7.7 | 501.7 |
| 2004 | 253.3 | 221.4 | 177.1 | 50.0 | 58.5 | 85.7 | 226.6 | 7.7 | 470.6 |
| 2005 | 258.6 | 209.8 | 177.7 | 48.8 | 56.9 | 87.7 | 249.2 | 7.2 | 432.6 |
| 2006 | 237.3 | 203.4 | 152.8 | 47.7 | 52.6 | 78.0 | 208.1 | 6.7 | 402.2 |
| 2007 | 232.3 | 199.4 | 145.4 | 48.7 | 52.0 | 75.2 | 196.0 | 6.5 | 379.0 |
| 2008 | 206.9 | 190.5 | 96.5 | 47.3 | 49.8 | 73.2 | 196.7 | 6.2 | 354.6 |
| 2009 | 195.7 | 181.1 | 61.7 | 45.6 | 47.2 | 71.4 | 197.9 | 6.0 | 335.1 |
| 2010 | 181.4 | 182.0 | 53.8 | 44.4 | 46.8 | 66.2 | 166.2 | 5.8 | 318.1 |
| 2011 | 173.6 | 174.3 | 48.9 | 45.3 | 47.4 | 65.5 | 160.1 | 5.8 | 299.6 |
| 2012 | 167.2 | 170.2 | 43.8 | 43.8 | 46.5 | 62.4 | 146.1 | 5.3 | 284.5 |
| 2013 | 165.1 | 171.4 | 39.8 | 42.1 | 45.3 | 58.5 | 127.6 | 5.1 | 278.5 |
| 2014 | 163.2 | 169.8 | 35.1 | 43.8 | 44.7 | 55.0 | 107.4 | 5.0 | 271.6 |
| 2015 | 169.7 | 176.1 | 36.8 | 44.9 | 45.1 | 57.4 | 121.3 | 4.7 | 266.2 |

Figure 2.4 – Heavy metals total emissions




Emissions of heavy metals refer in majority to energy-related sources and associated with fuel combustion. They are directly related to the type of fuel used (and its HM content) in power and heat generating facilities and in industrial facilities.

The upwards or downwards tendencies regarding heavy metals emissions differ from pollutant to pollutant. The lead emissions registered from 1990 to 2015 a decreasing trend, with a reduction of approx. 93% which are mainly related with the reductions of emissions in road transport emissions which are explained by the phased out of use of leaded petrol within the EU context.

Nickel and mercury registered significant reductions which are related to the amelioration of the fuels used and the fuel mix used in public power and heat generating facilities and in industrial facilities.

Other pollutants present increasing trends in the period 1990-2015. The growth of copper emissions is associated with road transportation, which represents around 79% of total copper emissions in 2015. Selenium emissions are mostly related to the evolution of glass production sector (2.A.3), and zinc emissions (31%) related to category 2.C.1 Iron and Steel Production and glass production (accounted in category 1.A.2.f) and the remaining part related to energy categories, in particular 1.A.4.b.i (residential combustion).

Figure 2.5 – Percentage variation of HM emissions: 1990-2015 period

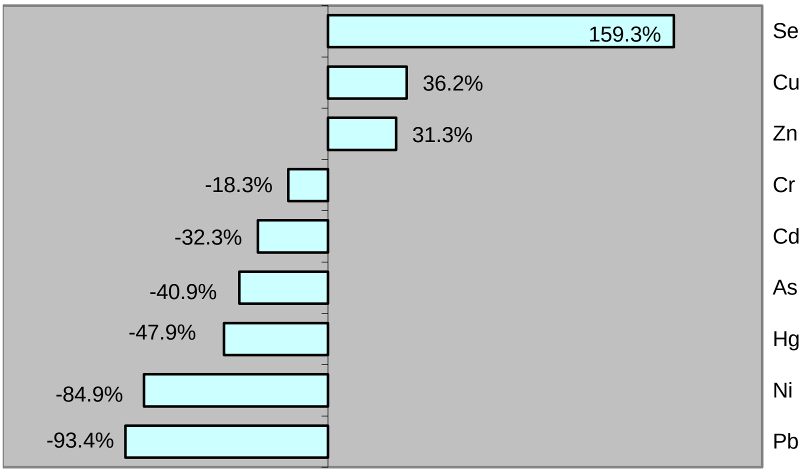



Table 2.2 – Heavy metals total emissions

| | Pb<br>t | Cd<br>t | Hg<br>t | As<br>t | Cr<br>t | Cu<br>t | Ni<br>t | Se<br>t | Zn<br>t |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 548.0 | 6.2 | 3.2 | 2.8 | 12.8 | 21.7 | 104.7 | 12.2 | 71.7 |
| 1991 | 601.7 | 6.7 | 3.3 | 3.0 | 13.2 | 23.0 | 108.8 | 13.5 | 72.2 |
| 1992 | 676.3 | 6.8 | 3.8 | 3.5 | 15.1 | 25.0 | 132.9 | 14.6 | 76.0 |
| 1993 | 717.5 | 6.0 | 3.3 | 3.0 | 13.2 | 25.1 | 105.8 | 13.9 | 74.0 |
| 1994 | 734.2 | 6.3 | 3.1 | 2.7 | 13.1 | 25.9 | 96.7 | 16.2 | 73.7 |
| 1995 | 752.7 | 6.5 | 3.3 | 3.0 | 13.9 | 27.5 | 106.4 | 17.0 | 78.0 |
| 1996 | 307.6 | 5.7 | 3.0 | 2.5 | 12.5 | 28.0 | 82.9 | 17.0 | 77.7 |
| 1997 | 310.4 | 6.1 | 3.2 | 2.7 | 13.4 | 29.5 | 89.9 | 19.5 | 81.2 |
| 1998 | 320.5 | 6.8 | 3.4 | 3.1 | 14.8 | 32.6 | 114.4 | 20.8 | 86.1 |
| 1999 | 324.3 | 6.8 | 3.4 | 3.2 | 15.3 | 34.1 | 110.4 | 22.3 | 92.1 |
| 2000 | 36.3 | 6.2 | 3.0 | 2.9 | 14.5 | 36.5 | 93.1 | 23.3 | 93.6 |
| 2001 | 35.0 | 6.1 | 2.8 | 2.9 | 13.7 | 37.0 | 97.4 | 24.4 | 94.2 |
| 2002 | 36.9 | 6.8 | 3.0 | 3.2 | 14.8 | 38.1 | 108.3 | 24.9 | 95.8 |
| 2003 | 35.6 | 6.0 | 2.3 | 2.5 | 12.6 | 36.6 | 74.4 | 25.2 | 94.5 |
| 2004 | 36.6 | 5.9 | 2.3 | 2.5 | 12.6 | 37.0 | 70.6 | 26.0 | 93.9 |
| 2005 | 37.1 | 6.8 | 2.5 | 2.8 | 13.8 | 37.3 | 85.8 | 26.6 | 96.0 |
| 2006 | 37.6 | 5.9 | 2.1 | 2.4 | 12.6 | 36.8 | 63.1 | 28.7 | 97.1 |
| 2007 | 38.1 | 6.1 | 2.0 | 2.2 | 12.5 | 36.1 | 57.8 | 31.0 | 97.7 |
| 2008 | 37.6 | 5.7 | 1.9 | 2.0 | 12.3 | 35.5 | 53.8 | 31.4 | 101.3 |
| 2009 | 35.3 | 4.1 | 1.9 | 1.9 | 10.9 | 34.7 | 41.3 | 29.2 | 92.4 |
| 2010 | 34.1 | 4.4 | 1.6 | 1.5 | 10.9 | 34.1 | 35.4 | 30.1 | 91.5 |
| 2011 | 34.9 | 3.2 | 1.6 | 1.4 | 10.4 | 31.5 | 29.0 | 30.4 | 94.9 |
| 2012 | 35.6 | 2.8 | 1.6 | 1.6 | 10.3 | 29.2 | 24.0 | 31.5 | 93.8 |
| 2013 | 35.5 | 4.4 | 1.5 | 1.5 | 10.3 | 28.7 | 19.4 | 31.6 | 92.4 |
| 2014 | 35.9 | 4.5 | 1.6 | 1.5 | 10.4 | 29.4 | 16.0 | 32.1 | 93.5 |
| 2015 | 35.9 | 4.2 | 1.7 | 1.7 | 10.5 | 29.5 | 15.8 | 31.7 | 94.1 |

Main sources of dioxines emissions refer to the incineration of industrial waste (70% of 2015 total emissions) and the combustion in the residential sector (18% of 2015 total emissions). These emissions registered a decrease of -86%) in the period 1990-2015. Polycyclic aromatic hydrocarbons (PAH) emissions are related in majority to category 3.F Field burning of agricultural wastes and the combustion in the residential sector. HCBs emissions occur in majority in energy industries (1.A.1) and waste incineration sources (5.C) and. Polychlorobiphenyls (PCB) estimated emissions are related to incineration of industrial waste.

Figure 2.6 – Persistent organic pollutant total emissions

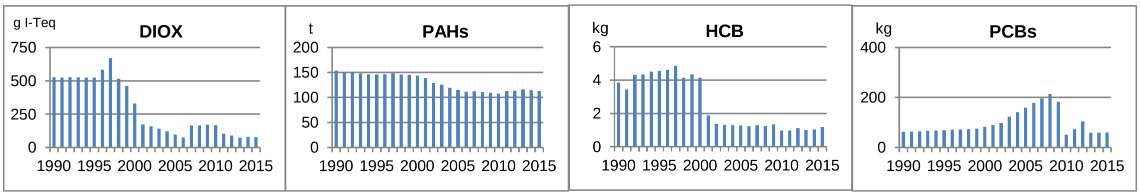



Figure 2.7 – Percentage variation of POP emissions: 1990-2015 period

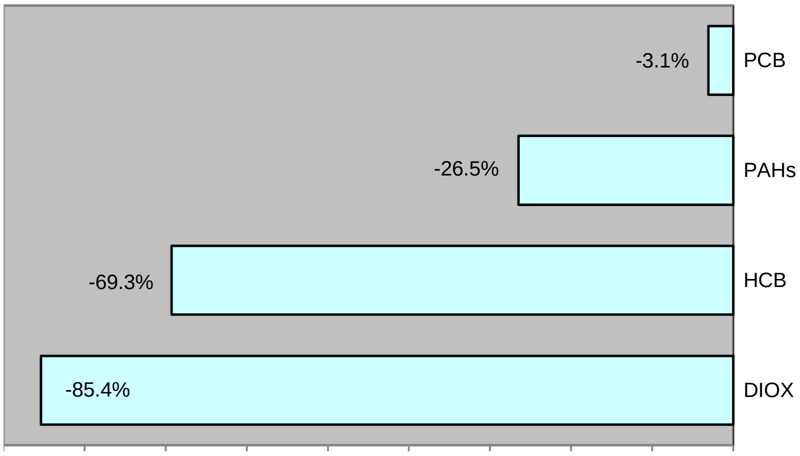


Table 2.3 – Persistent organic pollutant total emissions

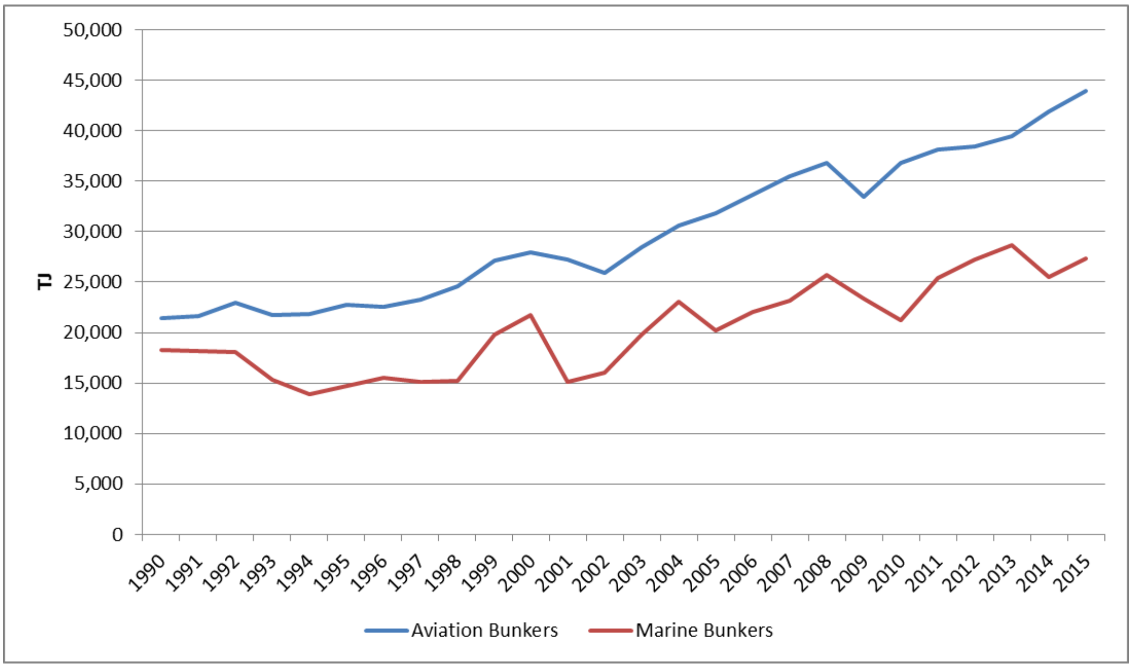
| | DIOX g I-TEQ | PAHs t | HCB kg | PCB kg |
|---|---|---|---|---|
| 1990 | 526.2 | 153.9 | 3.9 | 62.8 |
| 1991 | 525.4 | 150.6 | 3.4 | 64.0 |
| 1992 | 526.4 | 151.0 | 4.3 | 65.2 |
| 1993 | 527.4 | 147.9 | 4.3 | 66.5 |
| 1994 | 524.4 | 146.3 | 4.5 | 67.8 |
| 1995 | 525.1 | 146.0 | 4.6 | 69.2 |
| 1996 | 582.3 | 146.1 | 4.6 | 70.6 |
| 1997 | 670.5 | 148.2 | 4.9 | 72.0 |
| 1998 | 515.8 | 145.9 | 4.1 | 73.4 |
| 1999 | 461.6 | 145.1 | 4.3 | 74.8 |
| 2000 | 329.4 | 143.7 | 4.1 | 82.7 |
| 2001 | 173.9 | 138.9 | 1.9 | 90.0 |
| 2002 | 158.7 | 129.0 | 1.4 | 97.6 |
| 2003 | 141.7 | 125.8 | 1.3 | 123.1 |
| 2004 | 121.3 | 119.2 | 1.3 | 141.3 |
| 2005 | 98.0 | 115.0 | 1.3 | 159.5 |
| 2006 | 76.0 | 111.5 | 1.2 | 177.7 |
| 2007 | 164.4 | 112.3 | 1.3 | 196.0 |
| 2008 | 165.3 | 110.8 | 1.2 | 214.2 |
| 2009 | 170.7 | 109.2 | 1.3 | 182.0 |
| 2010 | 167.5 | 107.9 | 1.0 | 51.0 |
| 2011 | 102.8 | 112.7 | 1.0 | 73.6 |
| 2012 | 90.4 | 113.6 | 1.1 | 103.5 |
| 2013 | 73.3 | 116.0 | 1.0 | 59.4 |
| 2014 | 79.7 | 114.7 | 1.0 | 59.9 |
| 2015 | 77.0 | 113.1 | 1.2 | 60.8 |

# 3 ENERGY (NFR 1)

## 3.1 International Bunker Fuels

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

Figure 3.1 – International navigation and aviation bunkers

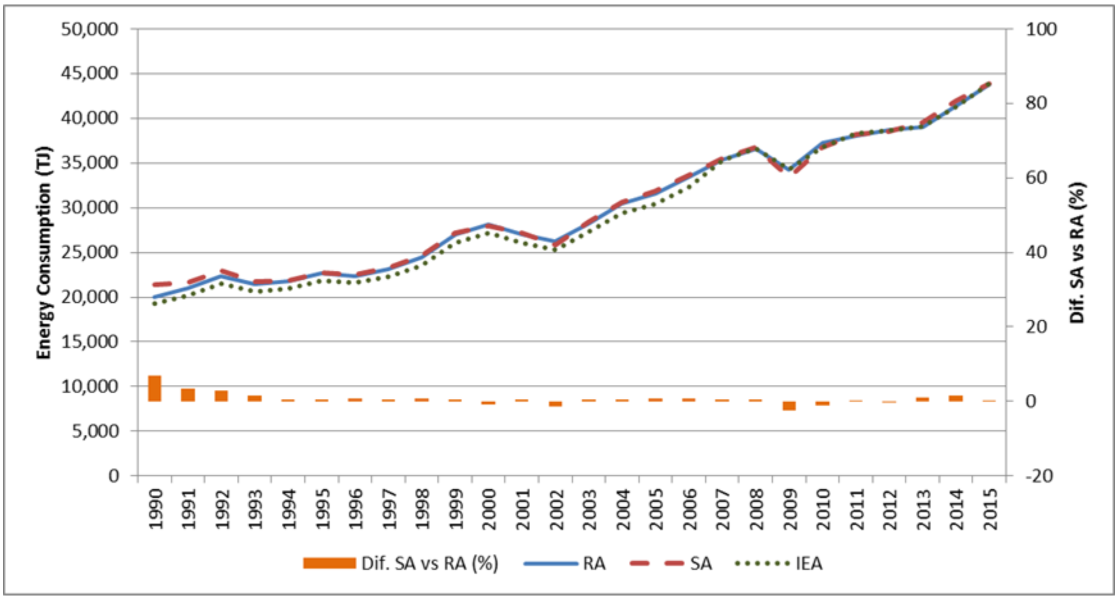



### 3.1.1 International aviation bunkers

The majority of jet fuel is used for international aviation. In 2015 the quantity of jet fuel for international aviation was about 90% of total jet fuel. This percentage was estimated according with the origin and destiny of the flight as recommended by 2006 IPCC guidelines.

Until 2006, the classification for international fuel used by the national fuel authority (DGEG) was different from the one used in national inventory. DGEG split was based in the flag of the aircraft rather than in the origin and destiny of the flight. Some efforts were made in the fuel balance to use the IPCC criteria and since 2007 the difference between the reference approach (RA) and the sectoral approach (SA) has decreased as presented in the figure below.

Figure 3.2 – International aviation bunkers



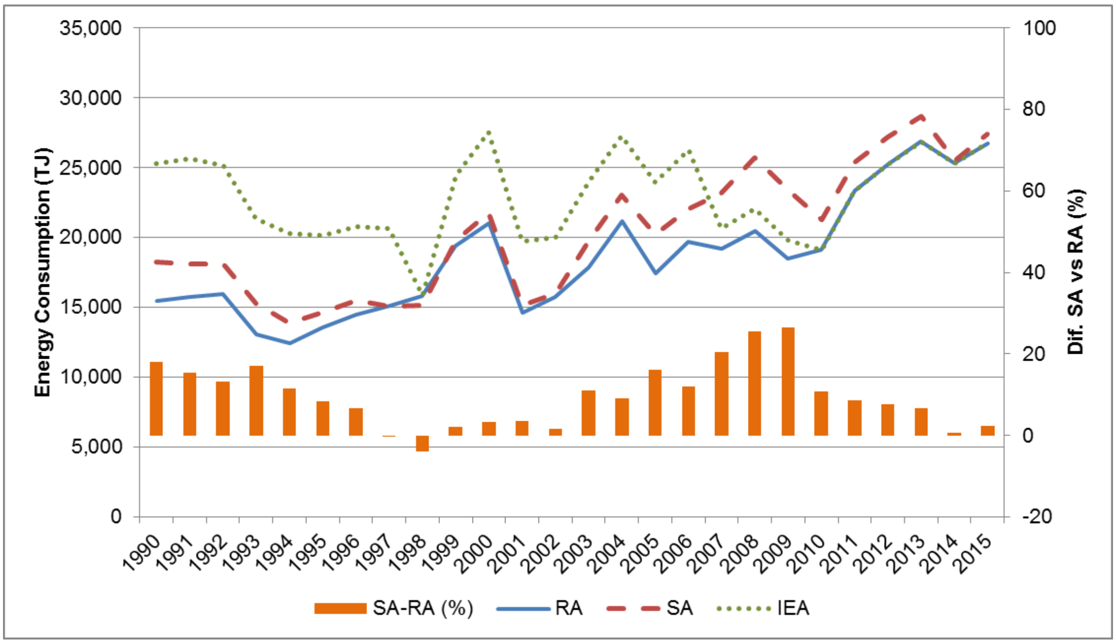

### 3.1.2 International marine bunkers

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

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

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

Figure 3.3 – International marine bunkers




## 3.2 Category Sources

### 3.2.1 Energy Industries (NFR 1.A.1)

#### 3.2.1.1 *Public Electricity and Heat Production (NFR 1.A.1.a)*

##### 3.2.1.1.1 Overview

Until 1950 electric energy production in Portugal was based in small power plant units using coal as energy source. In the 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[1] unit, build near the old unit in *Carregado entered its final testing period at the end of 2003*). In the islands of Azores and Madeira, the discontinuity in territory caused the prevalence of smaller units, basically one per island, working on fuel-oil or diesel-oil.

Apart from the dedicated electric power plants, auto-producers generate electric energy for own consumption and to sales to the public system. However not all combustion from these sources are included here because, according to the Revised 2006 IPCC Guidelines, emissions from auto-producers are to be reported under the industrial or commercial branch in which their main

[1] TER – Termoeléctrica do Carregado

economic activity occurs. The present source sector includes only emissions resulting from main power producers[2].

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.

###### *3.2.1.1.1.1 Large Point Source Energy Plants in Mainland Portugal*

The number of Large Point Source Energy Plants (LPS-EP) in continental Portugal has increased from 6 units in 1990 to 19 units at present. Power plants and installed power are listed in Table 3.1 together with their main relevant characteristics.

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

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

| Power Plant | Location | Start | Situation | Fuel*** | Power | Technology | Treatment of Gas Effluents**** | Stack Height (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Tapada do Outeiro | Gondomar | 1959 | Deactivated (2003) | LIG + FO | 150/100/47* MWe | Boiler + Steam Turbine. | ESP | 60 (x3) | Lignite use stopped in 1997 |
| Portgen (new Tapada do Outeiro) | Gondomar | 1998 | Working | NG + GO + LPG | 990 (3x330) MWe | Combined Cycle. | DLE (only for one group) | 60 (x3) | - |
| Soporgen | Lavos | 2001 | Working | NG | 67 (44+23) MWe | Co-generation. Combined Cycle | DLE | 50 (x2) | - |
| Energin | Alhamdra | 2002 | Deactivated (2014) | NG | 43.7 MWe | Co-generation. Combined Cycle | - | 31 (x1) | - |
| Mortágua | Mortágua | 1999 | Working | WW + NG + GO | 30 MWe | Boiler + Steam Turbine. | ESP | - | - |
| Pêgo | Abrantes | 1993 | Working | HC + FO + GO + LPG | 628 MWe | Boiler + Steam Turbine. | ESP + LNOX + WFGD + SCR | 225 (x1) | WFGD after 2008 SCR after 2008 |
| Pêgo (Elecgás) | Abrantes | 2010 | Working | NG + GO | 800 MWe | Combined Cycle | DLE | 80 (x2) | |
| Carregado | Alenquer | 1968 | Deactivated (2011) | FO + NG + GO + LPG | 750 (6x125) MWe | Boiler + Steam Turbine. | ESP | 100 (x3) | Natural gas introduced in 1997 |
| TER | Alenquer | 2004 | Working | NG + GO | 1170 MWe | Combined Cycle. | - | 75 (x3) | - |
| Carriço | Sines | 2006 | Working | NG + GO | 487 MWe | Co-generation. | - | 30 (x1) | - |
| Alto do Mira | Amadora | 1975 | Deactivated (2003) | GO | 132 MWe | Gas Turbine. | - | 13.5 (x1) | - |
| Barreiro | Barreiro | 1978 | Deactivated (2010) | FO + LPG | 65 (32+33) MWe | Co-generation. | - | 104 (x1) | - |
| Fisigen | Barreiro | 2009 | Working | NG | 121 MWt | Co-generation. | - | - | - |

| Power Plant | Location | Start | Situation | Fuel*** | Power | Technology | Treatment of Gas Effluents**** | Stack Height (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Setúbal | Setúbal | 1979 | Deactivated (2013) | FO + GO + LPG | 1000 (4x250) MWe | Boiler + Steam Turbine. | ESP | 201 (x2) | - |
| Sines | Sines | 1985 | Working | HC + FO | 1256 (4X314) MWe | Boiler + Steam Turbine. | ESP + LNOX + WFGD + SCR | 225 (x2) | WFGD after 2008 SCR after 2011 |
| Tunes | Silves | 1973 | Deactivated (2013) | GO | 199.2 (2x16.3 + 2x83.3) MWe | Gas turbine. | - | 13.5 | Groups 1 and 2 deactivated in 2007. |
| Lares | Figueira da Foz | 2009 | Working | NG + GO | 1428 MWt | Combined Cycle. | - | - | - |
| Constância | Constância | 2009 | Working | WW + FO + LPG | 39.2 MWt | Boiler + Steam Turbine. | - | - | - |
| Figueira da Foz | Figueira da Foz | 2009 | Working | WW + NG | 31.2 MWt | Boiler + Steam Turbine. | DLE + ESP | 80 | - |
| Cacia | Cacia | 2009 | Working | WW + NG + GO | 49.75 MWt | Boiler + Steam Turbine. | - | - | - |
| CB Setúbal | Setúbal | 2009 | Working | WW + NG + GO | 49.75 MWt | Boiler + Steam Turbine. | - | - | - |
| Rodão | Vila Velha do Rodão | 2008 | Working | WW + FO + LPG + GO | 39.1 MWt | Boiler + Steam Turbine. | - | - | - |
| Artelia | Sines | 2011 | Working | NG + BG | 269.7 (135.9 + 33.8 + 100) MWt | Combined Cycle. | LNOX | 45 | - |

* 250 MW in 2 groups using fuel oil and natural gas.
** The smaller power value refers to situation after 2 of the 3 initial groups where closed. The intermediate value refers to the situation when 2 groups where operating.
*** HC - hard-coal; LIG - Lignite; FO - fuel-oil; GO - Diesel oil; NG - Natural Gas; WW – Wood Waste; BG - Biogas
**** WFGD – Wet Flue Gas Desulfurization; DLE – Dry Low Emissions; ESP – Electrostatic Precipitators; LNOx – Low Nox Burners; SCR - Selective Catalytic Reduction

There are two small gas turbine power plants included in the public service: one near Lisbon to sustain peak power demands and another in Tunes, in the southern province of Algarve, which is used to support the increase of demand during touristy seasonal peak demands. The unit near Lisbon (Alto do Mira) has interrupted its activity in 2003.

There has also been a change in the production structure along the 1990-2005 period, with a reduction in the importance of the use of petroleum products (fuel-oil) and an increase in the use of imported coal - in first place - and then natural gas. The only other energy source used in these units was Orimolsion, that was used as fuel in *Setúbal* power plant but only in 1994 and its use had no continuation.

- In 1990 three units (*Carregado*, *Setúbal* and *Barreiro*) were using fuel-oil, one unit (*Sines*) was consuming imported hard coal and another unit (*Tapada do Outeiro*) was using lignite coal and fuel-oil;
- A new build coal unit (*Pêgo*) using hard coal, started producing electricity in 1993 and doubled its production capacity in 1995;
- The old unit in northern Portugal (*Tapada do Outeiro*) that was burning low heating value lignite coal, partly mined in Portugal, stopped using this fuel in 1997 but was kept producing electricity with a small consumption of fuel-oil since;
- Between 1995 and 1997 *Carregado* power plant shifted part of its production groups from residual fuel-oil to natural gas;
- A new unit (*Portgen*) consuming natural gas was build in northern Portugal near the old unit of *Tapada do Outeiro* and started producing in 1998;
- A new unit (*TER*) also using natural gas was installed, and started activity in the end of 2003, near the old unit of *Carregado*;
- The *Mortágua* unit in central Portugal initiated production in 1999 using a combination of natural gas and wood wastes;
- Soporgen and Energin, in central Portugal and Carriço (in the south) start production (Soporgen in 2001, Energin in 2002 and Carriço in 2006) using natural gas. They exist in close connection, respectively, with an industrial paper pulp plant, a chemical industry plant and a crude oil refinery;
- In 2009 a new power plant was built in Lavradio – Fisigen. This new plant replaced the Barreiro plant in 2010. Also in 2009 a new power plant was built in Figueira da Foz – Lares, which burn NG as fuel;
- In later years (2008 and 2009) new small power plants were built that burn wood waste;
- In 2010 a new combined cycle plant was inaugurated in Abrantes;
- Artelia new combined cycle plant begin its operation in 2011.

#### 3.2.1.1.1.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal

Even though this source produces $CO_2$ emissions it also implies a $SO_2$ emission reduction. Because of this the inclusion of a chapter describing the methodology used for determining emission from desulfurization was considered relevant in this report.

From the information gathered only two plants in Portugal implement this king of abatement system: Pêgo and Sines. Both plants use hard coal and fuel oil in the combustion processes. The abatement equipments operate since 2008 (for both plants).

In a wet flue gas desulfurization the $SO_2$ emissions are absorbed by lime, forming $CO_2$ and plaster (gypsum + $H_20$) as by-products:

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

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

Since there is no NRF category specific for desulfurization, total reduction in $SO_2$ emissions were included together with combustion emissions.

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

Electricity production in the autonomous regions of Madeira and Azores islands depends mostly on small and medium scale power plants using imported residual fuel oil and/or diesel oil, Table 3.2.

Table 3.2 – Electricity Power Plants in the Azores and Madeira

| Power Station | Location | Fuel* | Power |
|---|---|---|---|
| Porto Santo | Porto Santo | FO + GO | 51.9 MWt |
| Vitória | Funchal | FO + GO + NG | 326.4 MWt |
| Caniçal | Caniçal | FO + GO + LPG | 144 MWt |
| Santa Bárbara | Faial | FO + GO | 41.16 MWt |
| Belo Jardim | Terceira | FO + GO | 158.8 MWt |
| Caldeirão | São Miguel | FO + GO | 254.84 MWt |
| Pico | Pico | FO + GO | 26.28 MWt |
| Graciosa | Graciosa | GO | 4.26 MWe |
| São Jorge | São Jorge | GO | 7.03 MWe |
| Flores | Flores | GO | 2.31 MWe |
| Corvo | Corvo | GO | 0.56 MWe |
| Santa Maria | Santa Maria | GO | 5.68 MWe |

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

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

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

#### 3.2.1.1.2 Methodology

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

Emissions of sulphur oxides were estimated using the following mass balance equation:

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

Where

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

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

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

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

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

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

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

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

where:

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

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

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

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

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

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

and,

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

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

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

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

### *3.2.1.1.2.2 Desulfurization in Large Point Source Energy Plants in Mainland Portugal*

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

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

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

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

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

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

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

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

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

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

#### 3.2.1.1.3 Emission Factors

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

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

- IPCC Revised Guidelines (IPCC,1997; IPCC,2006);
- IPCC Good Practice Guidebook (IPCC,2000);
- EMEP/ CORINAIR Emission Factor Handbook (EEA,2002; EEA,2009);
- EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA, 2016)
- AP-42 (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c).

Emissions of Nitrogen Oxides ($NO_x$) and Particulate Material (PM) 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 from Table 3.3 to Table 3.6. For most units (*Sines*, *Pêgo*, Carregado, Barreiro, Setúbal, *Turbogas and TER*) emission factors reflect actual monitoring data under *Autocontrolo* program.

Table 3.3 – Emission Factors for energy production sector. Ozone Precursors and other pollutants

| **Fuel** | **NOx** | **NMVOC** | **CO** | **AshRet(S)** |
|---|---|---|---|---|
| | g/GJ | g/GJ | g/GJ | % |
| Lignite | 310 | 1.5 | 16 | 5 |
| Hard Coal | 62 - 537 | 1.5 | 10 | 5 |
| Fuel-oil | 180 - 300 | 3.0 | 15 | 0 |
| Orimulsion | 300 | 3.0 | 15 | 0 |
| Natural Gas | 22 - 120 | 5.0 | 13 - 19 | 0 |
| LPG | 90 | 2.5 | 17 | 0 |
| Biomass | 70 | 150 | 500 | 0 |
| Diesel (GT) | 350 | 4.0 | 15 | 0 |
| Diesel (Engine) | 1 300 | 2.0 | 15 | 0 |

Table 3.4 – Emission Factors for energy production sector. Particulate Matter

| Fuel | PM | PM10 | PM2.5 | BC |
|---|---|---|---|---|
| | g/GJ | % | % | % of PM2.5 |
| Lignite | 9.3 | 67 | 29 | - |
| Hard Coal | 1.4 – 40.1 | 67 | 29 | 2.2 |
| Fuel-oil | 0.26 – 69 [(a)] | 63 | 41 | 5.6 |
| Orimulsion | 1.03 | 63 | 63 | 5.6 |
| Natural Gas | 0.82 – 2.54 | 100 | 100 | 2.5 |
| LPG | 11.2 | 100 | 100 | 2.5 |
| Biomass | 23.2 | 74 | 65 | 3.3 |
| Diesel (GT)[1] | 30 | 100 | 100 | 33.5 |
| Diesel (Engine) | 30 | 82.2 | 77.3 | 33.5 |

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

Table 3.5 – Emission Factors for energy production sector. Heavy Metals (g/t)

| Fuel | Cd | Hg | As | Cr | Cu | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|
| 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 a) | 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 (GT) | 3.96E-02 | 1.69E-02 | 6.38E-02 | 2.61E-01 | 6.50E-01 | 6.00E-02 | 3.66E-02 | 4.33E-01 |
| Diesel (Engine) | 3.96E-02 | 1.69E-02 | 6.38E-02 | 2.61E-01 | 6.50E-01 | 6.00E-02 | 3.66E-02 | 4.33E-01 |
| 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 |

a) $g/km^3$

Table 3.6 – Emission Factors for energy production sector. Dioxins/Furans and PAHs

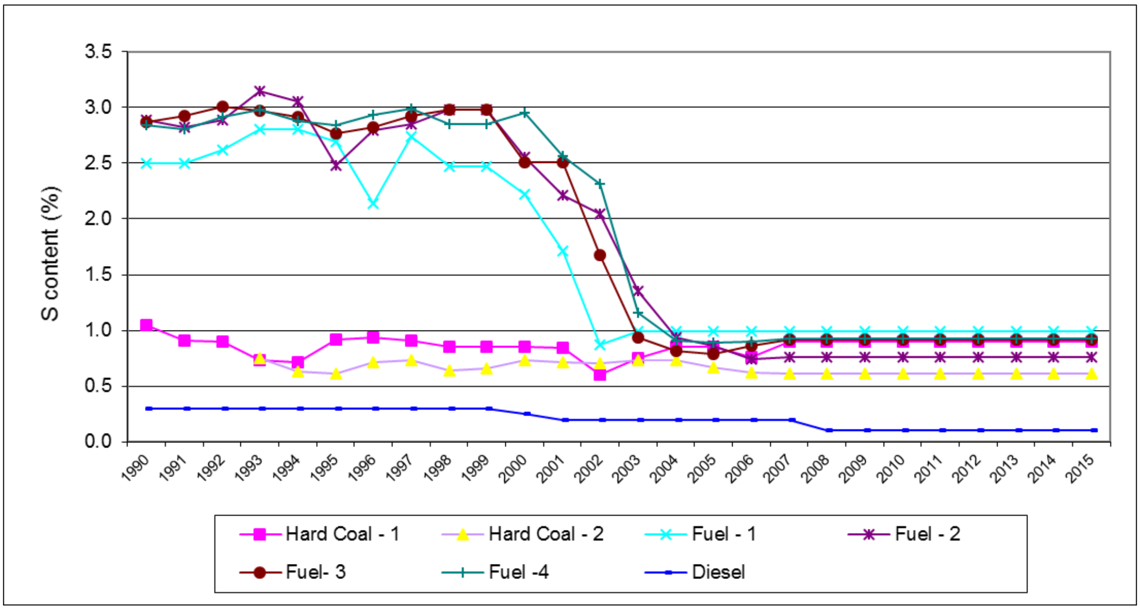
| Fuel | DioxFur | PAH | PCBs | HCB |
|---|---|---|---|---|
| | microg TEQ/TJ | µg/GJ | µg/GJ | µg/GJ |
| Lignite | 10 | 67.8 | 0.003 | 6.7 |
| Hard Coal | 10 | 69.4 | 0.003 | 6.7 |
| Fuel-oil | 3 | 15.9 | - | - |
| Orimulsion | 3 | 15.9 | - | - |
| Natural Gas | 1 | 3.1 | - | - |
| LPG | - | 3.1 | - | - |
| Biomass | 50 | 1.2 | 3.5 | 5 |
| Diesel (GT) | 1 | 6.9 | - | - |
| Diesel (Engine) | 1 | 6.9 | - | - |

Source: UNEP (2005), EEA (EMEP/CORINAIR), US-EPA AP-42
Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

[1] Mainly used in Gas Turbine plants

Average sulphur content for each fuel type has evolved along the 1990-2015 time series as shown in Figure 3.4 for the most important fuel types and power plants.

Figure 3.4 – Trends of sulphur content by fuel type[1]




### *3.2.1.1.3.2 Other Thermo-electricity Power Plants*

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

- IPCC Revised Guidelines (IPCC,1997; IPCC,2006));
- IPCC Good Practice Guidebook (IPCC,2000);
- EMEP/ CORINAIR Emission Factor Handbook (EEA,2002);
- EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA,2016)
- AP-42 (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c)

The emission factors that were used in the inventory are shown from Table 3.7 to Table 3.9 for the public power plants belonging to the public system in Azores and Madeira, and from Table 3.10 to Table 3.12 for the non public co-generation self producers[2].

[1] Power plants are denominated by number and not by name due to confidentiality constrains

[2] Power producers as main activity only.

Table 3.7 – Emission Factors for thermo-electricity production in Azores and Madeira. Ozone Precursors and other pollutants.

| Region | Fuel | $NO_x$ | NMVOC | CO |
|---|---|---|---|---|
| | | g/GJ | g/GJ | g/GJ |
| Azores | Fuel-oil | 180 | 3 | 15 |
| Azores | Diesel oil | 1 300 | 2 | 15 |
| Madeira | Fuel-oil | 180 | 3 | 15 |
| Madeira | Diesel oil | 1 300 | 2 | 15 |
| Madeira | LPG | 90 | 2.5 | 17 |

Table 3.8 – Emission Factors for thermo-electricity production in Azores and Madeira. Particulate Matter

| Region | Fuel | PM | $PM_{10}$ | $PM_{2.5}$ | BC |
|---|---|---|---|---|---|
| | | g/GJ | % | % | % $PM_{2.5}$ |
| Azores | Fuel-oil | 30 | 82.2 | 77.3 | 33.5 |
| Azores | Diesel oil | 30 | 82.2 | 77.3 | 33.5 |
| Madeira | Fuel-oil | 30 | 82.2 | 77.3 | 33.5 |
| Madeira | Diesel oil | 30 | 82.2 | 77.3 | 33.5 |
| Madeira | LPG | 11.2 | 100 | 100 | 2.5 |

Table 3.9 – 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 |
| LPG | 1.76E-05 | 4.18E-03 | 3.20E-06 | 2.24E-05 | 1.36E-05 | 3.36E-05 | 3.84E-07 | 2.00E+00 |

Table 3.10 – Emission Factors for non public co-generation self producers. Ozone Precursors gases and other pollutants

| Fuel | $NO_x$ | NMVOC | CO | S |
|---|---|---|---|---|
| | g/GJ | g/GJ | g/GJ | % |
| 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 3.11 – Emission Factors for non public co-generation self producers. Particulate Matter

| Fuel | PM | $PM_{10}$ | $PM_{2.5}$ | BC |
|---|---|---|---|---|
| | g/GJ | % | % | % $PM_{2.5}$ |
| LPG | 6.9 | 100 | 100 | 2.5 |
| Fuel –oil | 37-88 [(a)] | 71 | 52 | 5.6 |
| Diesel oil | 81.6 | 91.1 | 88.6 | 33.5 |
| Natural Gas | 0.8 | 100 | 100 | 2.5 |

(a) According to sulphur content

Table 3.12 – Emission Factors for non public co-generation self producers. Heavy Metals

| Fuel | Cd | Hg | As | Cr | Cu | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|
| | g/t | | | | | | | |
| 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 a) | 1.76E-05 | 4.18E-03 | 3.20E-06 | 2.24E-05 | 1.36E-05 | 3.36E-05 | 3.84E-07 | 4.64E-04 |

a) $g/km^3$

Table 3.13 – Emissions factors of Dioxins/Furans and PAH for for non public co-generation self producers

| Fuel | DioxFur | PAH |
|---|---|---|
| | microg TEQ/TJ | µg/GJ |
| LPG | 0 | 3.1 |
| Fuel –oil | 3 | 15.9 |
| Diesel oil | 1 | 6.9 |
| Natural Gas | 1 | 3.1 |

Source: UNEP (2005), EEA (EMEP/CORINAIR), US-EPA AP-42
Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

#### 3.2.1.1.4 Activity Data

Activity data has different origins according to specific energy plants.

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

Data on fuel consumption, by fuel type, for LPS are available from these sources:

- Large Combustion Plants (LCP) directive - which relies in direct information reported from the individual plant producer to the Environment Ministry;
- Self-control program (*Programa Autocontrolo*)[1];
- Plant activity reports from EDP;

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

- EU-ETS – European Union Emission Trading System.

For the latest years (mainly 2009 onwards) the EU-ETS completely replaced the other sources of information. Although different information sources have been used the consistency in time series is guaranteed considering that the same original source (power plant companies) is ultimately used.

As a general rule power plant units report information about consumption in t or cubic meters of gas together with the Low Heating Value[1] for that specific year from where consumption of fuels in energy units are calculated from:

Energy (GJ) = Consumption (t/year) * LHV (MJ/kg)

or

Energy (GJ) = Consumption (Nm3/year) * LHV (MJ/Nm3)

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

Table 3.14 – Low Heating Value per fuel type

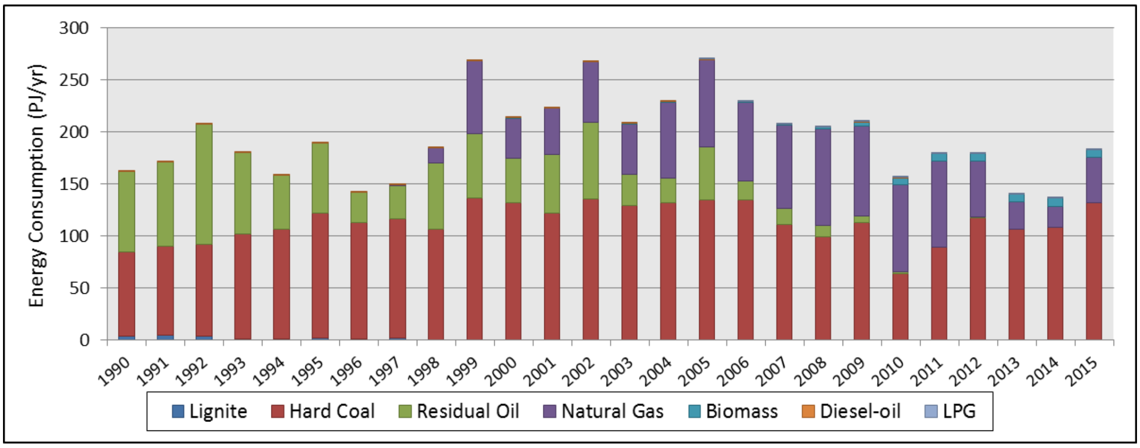
| Fuel | LHV/NCV | |
|---|---|---|
| Lignite | 16.42 (15.57 - 17.02) | MJ/kg |
| Hard Coal | 25.62 (24.45 - 27.23) | MJ/kg |
| Fuel-oil | 40.24 (39.42 - 41.61) | MJ/kg |
| Orimulsion | 28.00 | MJ/kg |
| Diesel oil | 43.30 | MJ/kg |
| Natural Gas | 38.16 (36.02 - 39.16) | MJ/kNm$^3$ |
| LPG | 47.44 (47.28 - 48.55) | MJ/kg |
| Biomass | 7.8 | MJ/kg |

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

Total consumption per fuel type in comparable energy units (PJ) may be verified in Figure 3.5.

[1] 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 3.5 – Trends of fuel consumption per fuel type




Not visible in the graph is the increase in biomass consumption (wood waste) from 1999 to 2015 (mostly in the last 5 years). The consumption of diesel-oil presents no clear trend since 1990 even though we can identify a slight decrease in the later years of the time series. LPG represents only a small franction of total fuel consumption in this sector (less than 0.001 per cent). The relevancy of residual oil has been decreasing since 2005, representing only a fraction of total consumption in 2012 due to Barreiro power plant deactivation

### *3.2.1.1.4.2 Desulfurization in Large Point Source Energy Plants n Mainland Portugal*

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

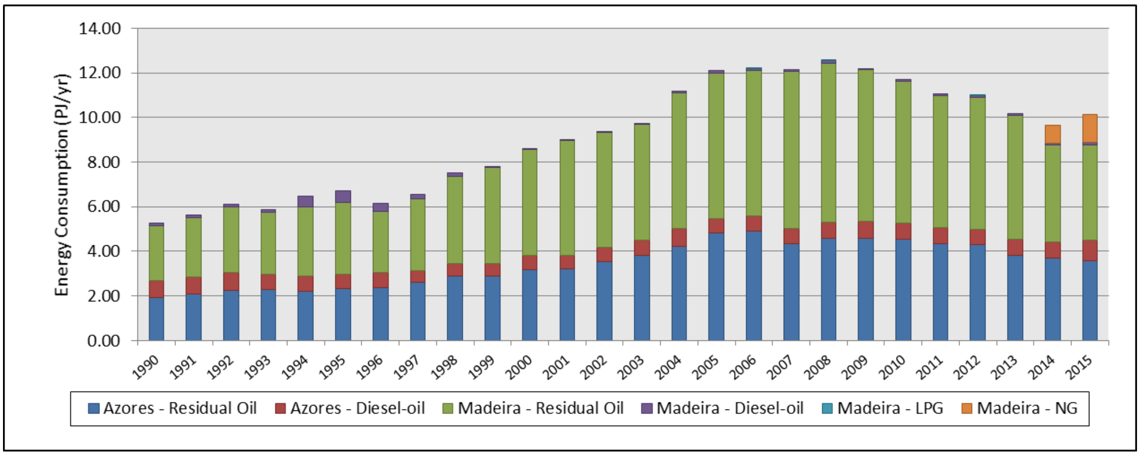
### *3.2.1.1.4.3 Energy Plants in Azores and Madeira Autonomous Regions*

The quantity of residual fuel-oil, diesel oil and GPL used in Madeira and Azores in electricity production is available from the following two ources:

- Madeira and Azores Regional Environmental entities;
- EU-ETS.

Full fuel consumption time series can be observed in the figure below:

Figure 3.6 – Trends of fuel consumption in Azores and Madeira Archipelagos




Note: Consumption of diesel oil and LPG in Madeira represent a very small quantity and is barely visible in the figure.

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

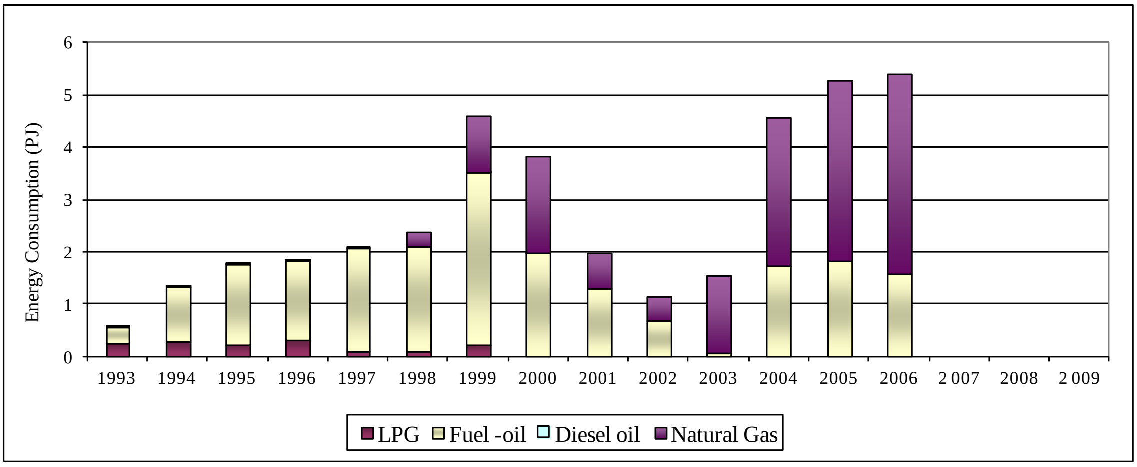
Table 3.15 – LHV per fuel type

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

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

Consumption of fuels in the auto-producers co-generation units (classified as energy producers) are reported in toe units in the Energy Balance (DGEG). These values can be observed in Figure 3.7.

Figure 3.7 – Trends in consumption of fuels in non-public co-generation plants




The growing tendency to create different companies to manage the energy production aspect of industrial co-generation plants led to the necessity, by DGEG, to shift these units from the energy-production co-generation category back to their industrial co-generation category in the Energy Balance. As a result of this shift, from 2007 onwards the energy-production co-generation category in the Energy Balance considers only two units already included, because of their size, in the LPS estimations. Because of this and to avoid double-counting fuel consumption from 2007 onwards was made 0. Since DGEG transferred fuel consumption to the industrial co-generation category, which is used for estimating combustion emissions in the industrial sector (CRF 1A2), the emission inventory maintains its completeness.

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

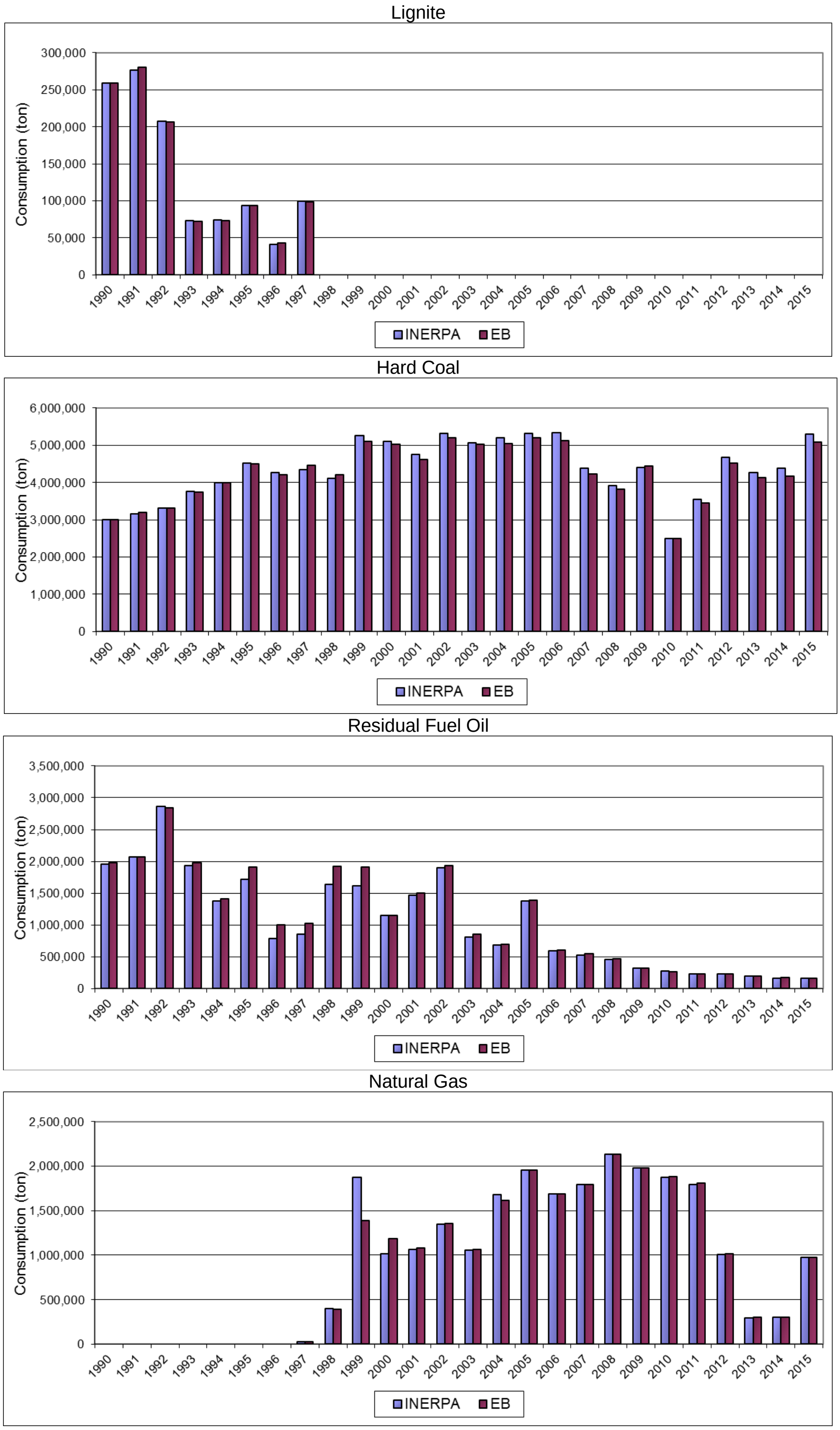
Table 3.16 – LHV per fuel type used for non-public co-generation plants estimates

| Fuel | LHV (MJkg) |
|---|---|
| LPG | 49.76 |
| Fuel -oil | 40.00 |
| Diesel oil | 42.60 |
| Natural Gas | 38.72 (MJ/Nm$^3$) |

### *3.2.1.1.4.5 Comparison of LPS data vs. National Statistics*

Consumption of fuel for electricity production in large units is also published in the Energy Balance of DGEG. Total consumption in all units was compared between the data in the inventory (INERPA) and the Energy Balance (EB) and graphs for the most important energy sources are presented in the next figure. Generally, there is an agreement between the two sources of information and, because data was acquired in an independent mode, this match gives a high degree of confidence to the results.

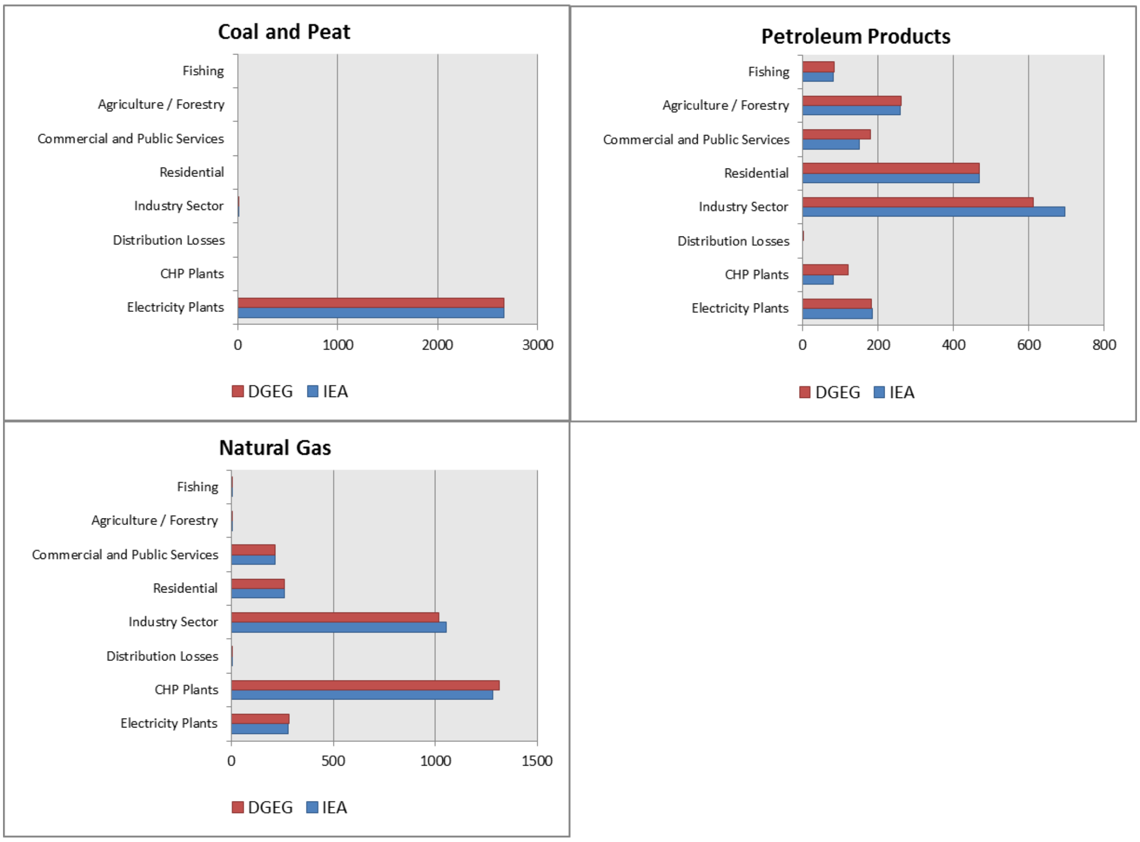
Figure 3.8 – Comparison of total fuel consumption in large power plants, between values used in the inventory (INERPA) and in the Energy Balance.



#### *3.2.1.1.4.6 Comparison of Energy Balance vs. IEA Energy Statistics*

Total energy consumption reported in DGEG energy balance was compared with IEA (International Energy Agency) energy statistics values. This comparison is included in the QA/QC procedures applied to this inventory. The energy statistic values from IEA were collect from their website. Unfortunably IEA data is only publicly available for the n-1 year (n being the latest inventory year). Following the fuel classification presented in the IEA energy statistics, three fuels types were analyzed: coal and peat, petroleum products and natural gas, connected to 8 emission sources: Electricity Plants, CHP Plants, Industry, Residential, Commercial and Public Services, Agriculture/Forestry, Fishing and Distribution Losses. The comparison between DGEG energy balance and IEA energy statistics, for 2012, is shown in the figure below.

Figure 3.9 – Comparison of fuel consumption between DGEG energy balance and IEA energy statistics




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

### 3.2.1.1.5 Recalculations

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

###### 3.2.1.1.6 Further Improvements

Even though efforts were made to increase the percentage o units treated as LPS in this year inventory, the inclusion of more LPS plants is an ongoing objective for this sector as well as for industrial combustion. These efforts are in accordance with the goals that the EC[1] has set to streamline data collection for the inventories and for the EU-ETS[2]. In the same sense on-going efforts should be maintained for the compatibilization of data acquisition by APA and DGEG in order for a better consistency of the data that is used for the Energy Balance and for the LPS data used in the inventory.

#### 3.2.1.2 *Petroleum Refining (NFR 1.A.1.b)*

##### 3.2.1.2.1 Overview

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

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

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

$SO_x$ and NMVOC emissions do also result from sulphur that is removed from intermediate or final products, mostly to respect environmental regulations, and conveyed in final flux gases. Elemental sulphur from the refining process is later recovered in both Sines and Oporto refineries but emissions from this source are considered under Emissions from Flaring and Venting (NFR 1.B.2.c).

##### 3.2.1.2.2 Methodology

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

For all pollutants except sulphur oxides ($SO_x$) the following equation was applied to estimate air emissions:

---

[1] European Commission.

[2] European CO2 trading scheme.

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

Where

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

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

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

For Heavy metals, the emission factor unit is mg/GJ and for PCDD/PCDF and PCBs the emission factor unit is ng I-TEQ/GJ, and the previous equation is adjusted to the emission factor unit. For Black Carbon (BC) the emission factor is a % of $PM_{2.5}$.

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 (t/yr);

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

#### 3.2.1.2.3 Emission Factors

The same set of emission factors was used for all three refineries and was obtained from “EMEP/EEA emission inventory guidebook”.

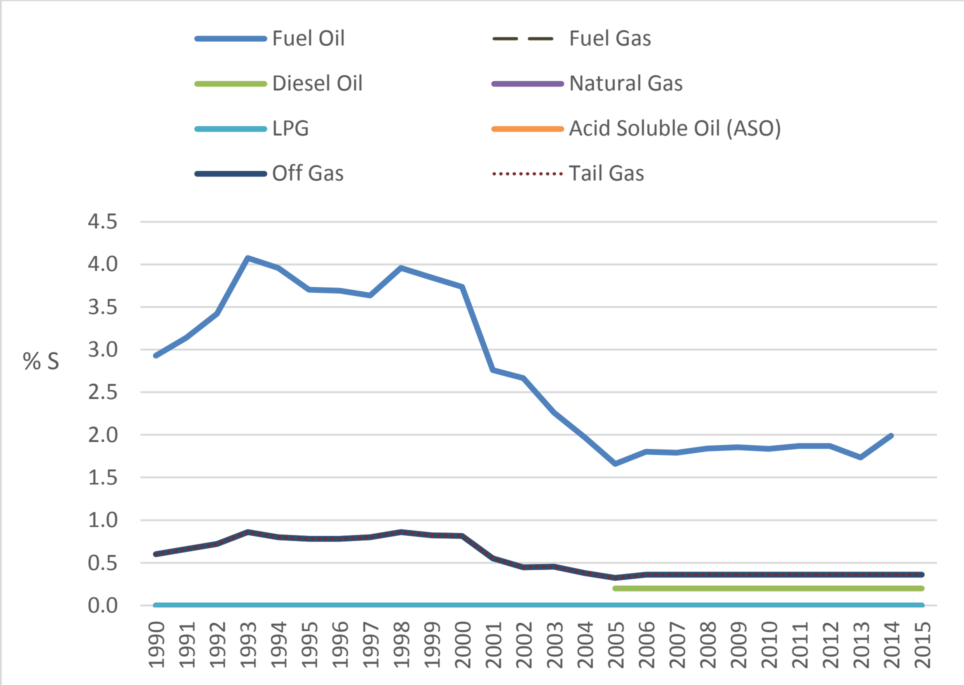
Table 3.17 – Emission Factors for combustion sources in Refining of Petroleum Products.

| Pollutant | Unit | Fuel Oil[(a)] | Refinery Gas[(b)] | Liquified Petroleum Gases[(c)] | Gas Oil[(d)] | Natural Gas[(c)] | Refinery Feedstock[(a)] |
|---|---|---|---|---|---|---|---|
| NOx | g/GJ | 142 | 63 | 89 | 942 | 89 | 142 |
| NMVOC | g/GJ | 2.3 | 2.58 | 2.6 | 37.1 | 2.6 | 2.3 |
| NH3 | g/GJ | NE | NE | NE | NE | NE | NE |
| PM2.5 | g/GJ | 9 | 0.89 | 0.89 | 21.7 | 0.89 | 9 |
| PM10 | g/GJ | 15 | 0.89 | 0.89 | 22.4 | 0.89 | 15 |
| TSP | g/GJ | 20 | 0.89 | 0.89 | 28.1 | 0.89 | 20 |
| BC | %PM2.5 | 5.6 | 18.4 | 2.5 | 78 | 2.5 | 5.6 |
| CO | g/GJ | 15 | 39.3 | 39 | 130 | 39 | 15 |
| Pb | mg/GJ | 4.6 | 1.79 | 0.0015 | 4.07 | 0.0015 | 4.6 |
| Cd | mg/GJ | 1.2 | 0.712 | 0.00025 | 1.36 | 0.00025 | 1.2 |
| Hg | mg/GJ | 0.3 | 0.086 | 0.1 | 1.36 | 0.1 | 0.3 |
| As | mg/GJ | 3.98 | 0.343 | 0.12 | 1.81 | 0.12 | 3.98 |
| Cr | mg/GJ | 14.8 | 2.74 | 0.00076 | 1.36 | 0.00076 | 14.8 |
| Cu | mg/GJ | 11.9 | 2.22 | 0.000076 | 2.72 | 0.000076 | 11.9 |
| Ni | mg/GJ | 1030 | 3.6 | 0.00051 | 1.36 | 0.00051 | 1030 |
| Se | mg/GJ | 2.1 | 0.42 | 0.0112 | 6.79 | 0.0112 | 2.1 |
| Zn | mg/GJ | 49.3 | 25.5 | 0.0015 | 1.81 | 0.0015 | 49.3 |
| PCDD/PCDF | ng I-TEQ/GJ | 2.5 | NE | 0.5 | 0.99 | 0.5 | 2.5 |
| Benzo(a)pyrene | µg/GJ | NE | 0.669 | 0.56 | 0.116 | 0.56 | NE |
| Benzo(b)fluoranthene | µg/GJ | 3.7 | 1.14 | 0.84 | 0.502 | 0.84 | 3.7 |
| Benzo(k)fluoranthene | µg/GJ | NE | 0.631 | 0.84 | 0.0987 | 0.84 | NE |
| Indeno(1,2,3-cd)pyrene | µg/GJ | NE | 0.631 | 0.84 | 0.187 | 0.84 | NE |
| HCB | µg/GJ | NE | NE | NE | 0.22 | NE | NE |
| PCBs | ng I-TEQ/GJ | NE | NE | NE | 0.13 | NE | NE |

(a) EMEP/EEA emission inventory guidebook 2013 – Table 4-4
(b) EMEP/EEA emission inventory guidebook 2013 – Table 4-2
(c) EMEP/EEA emission inventory guidebook 2013 – Table 3-4
(d) EMEP/EEA emission inventory guidebook 2013 – Table 3-19

Composition of fuels, in what concern sulphur, was reported for each year and for each pollutant directly from refineries under the LCP directive. Weighted average values from 1990 onwards are reported in the next figure. For fuel oil there is almost a continuous decrease from 1998 to 2005 and a stabilization from 2005 onwards.

Figure 3.10 - Trends of sulphur content



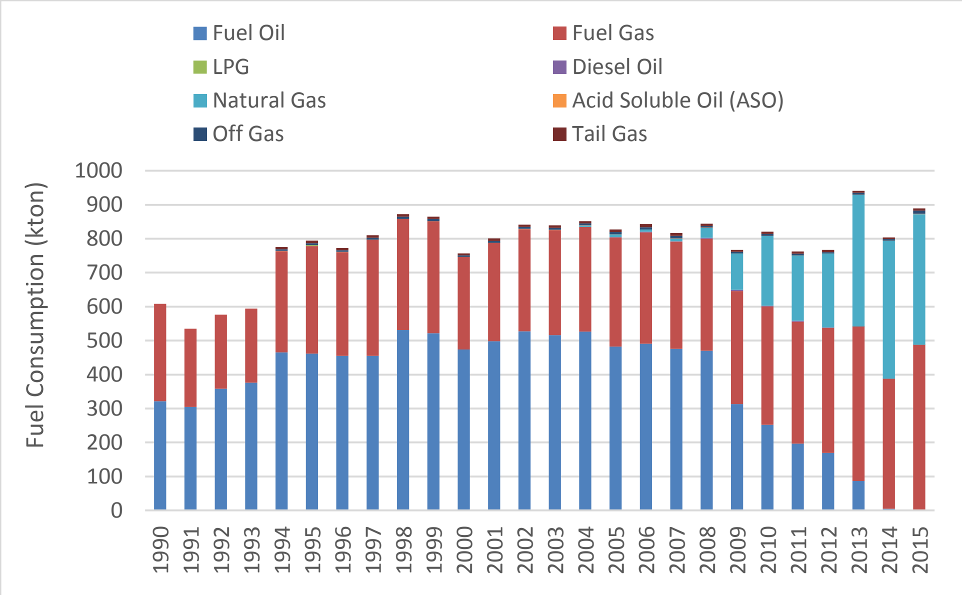

### 3.2.1.2.4 Activity Data

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

The refinery units consume self-produced residual fuel oil, fuel gas, liquefied petroleum gases (LPG), diesel oil, natural gas, acid soluble oil (ASO), tail gas and offgas.

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

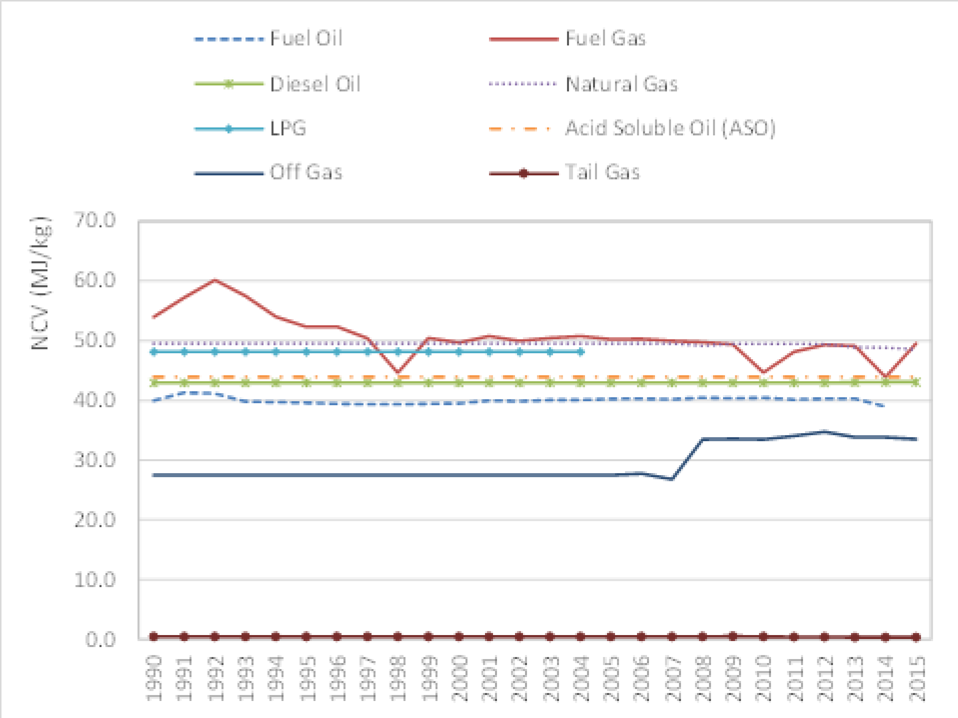
Figure 3.11 – Fuel consumption




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 (1990-2004) or EU-ETS (from 2005 onwards) and are weighted averages for all the plants.

In 2015 there is no fuel oil consumption and there is an increase in fuel gas consumption.

Figure 3.12 – Net Calorific Value (NCV) or Low Heating Value (LHV) expressed in MJ/ kg by type of equipment




#### 3.2.1.2.5 Recalculations

No recalculations were made.

### 3.2.1.3 *Other Energy Industries (NFR 1.A.1.c)*

#### 3.2.1.3.1 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.

#### 3.2.1.3.2 Methodology

Sulphur oxides emissions from combustion were estimated from fuel consumption quantities and considering its sulphur content as:

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

where

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

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

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

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

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

and,

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

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

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

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

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

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

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

where

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

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

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

#### 3.2.1.3.3 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 below.

Table 3.18 – Emission Factors used for the coquerie and city gas production

| Source | Coquerie | City Gas Production | | | Unit |
|---|---|---|---|---|---|
| Fuel | Coke Gas | FO | Naphta | NG a) | |
| $CH_4$ | 2.5 | (ii) 2.9 | (ii) 2.9 | (i) 1.4 | g/GJ |
| $N_2O$ (i) | 1.40 | 0.60 | 0.60 | 1.40 | |
| $SO_x$ | 7.05 gS/Nm³ | 2.6-2.9 | 0.1 | 0.0007 | % S |
| $NO_x$ | 120 | 160 | 160 | 100 | g/GJ |
| NMVOC | 2.5 | 3.0 | 3.0 | 5.0 | |
| CO | 17 | 15 | 15 | 13 | |
| PST | 3 | 85 | 6.5 | 0.8 | |
| $PM_{10}$ | 95.9 | 86.0 | 50.0 | 100 | % PST |
| $PM_{2.5}$ | 93.5 | 56.0 | 12.0 | 100 | |
| $PM_1$ | 77.4 | 36.0 | 8.0 | 100 | |
| Cd | NE | 6.84E-01 | 2.55E-01 | 1.76E-05 | g/t |
| 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 | |
| Cu | NE | 7.41E-01 | 1.10E+00 | 1.36E-05 | |
| Ni | NE | 2.69E+01 | 2.85E-01 | 3.36E-05 | |
| Se | NE | 6.84E-02 | 3.00E-02 | 3.84E-07 | |

(i) IPCC (1997); (ii) EEA (2002); (iii) from plant information; a) Heavy Metais - g/km³

### 3.2.1.3.4 Activity Data

#### *3.2.1.3.4.1 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 DGEG. Therefore, except for 1991 to 1994, annual consumption of coke in the integrated iron and steel plant was estimated from:

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

where

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

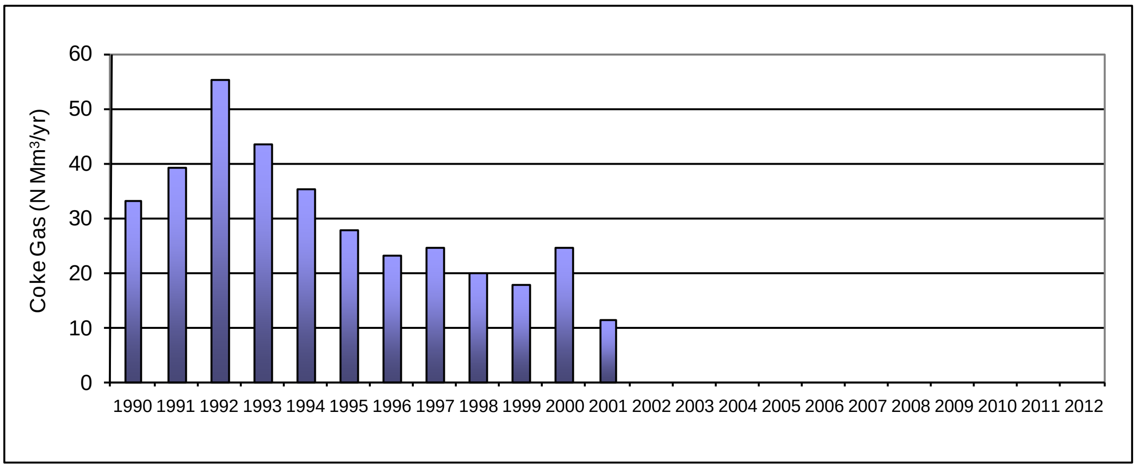
$Coquerie_{CONS\ (91-94)}$ - consumption of coke gas in the coquerie from 1990 till 1994;

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

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

The coquerie has interrupted operations in 2001 and was later dismantled. The complete time series may be seen in Figure 3.13. Conversion in energy units was calculated using a LHV of 18.78 MJ/Nm3, the value that is reported under LCP directive.

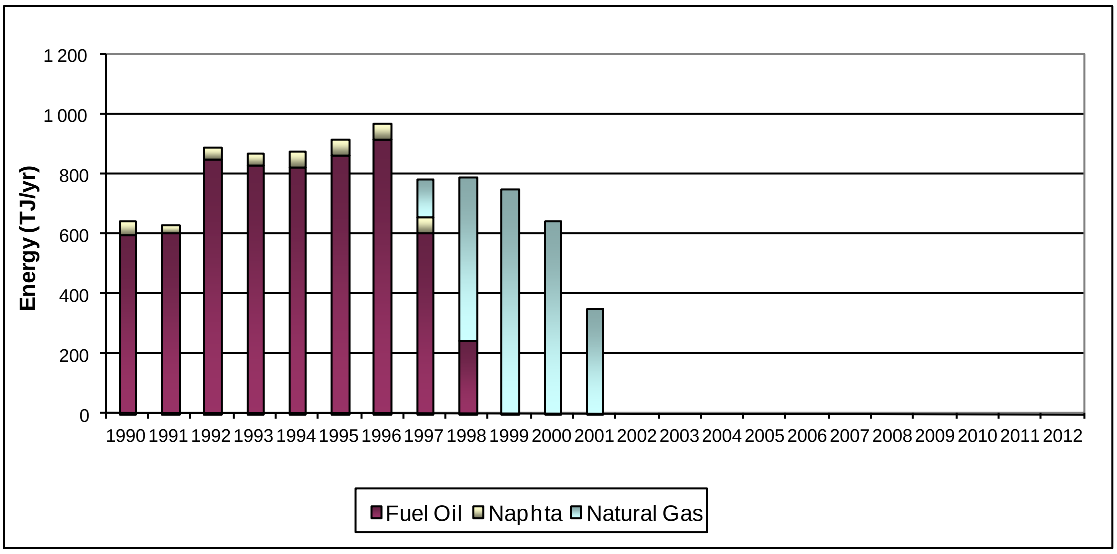
Figure 3.13 – Coke gas consumption in the coquerie




### *3.2.1.3.4.2 City Gas Production*

According to the energy balances from DGEG, this activity has used fuel oil, naphtha and, more recently, natural gas as energy sources under co-generation process, from 1990 till 2001[1]. The available time series is presented in Figure 3.14.

Figure 3.14 – Consumption of fuels in co-generation in city gas production




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

[1] 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 3.19 – NCV/LHV per fuel type for city gas production

| Fuel | NCV (MJ/kg) |
|---|---|
| Fuel-oil | 40.0 |
| Naphta | 44.0 |
| Natural Gas | 46.0 |

#### 3.2.1.3.5 Recalculations

No major recalculations were made to this sector.

## 3.2.2 Manufacturing Industries and Construction (NFR 1.A.2)

Emissions covered in this source category are those resulting from combustion activities in manufacturing industry and building and construction industry. Excluded are the process emissions from decarbonising in the cement and glass industries, 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 comprehend the sum of different industrial activities, using diverse fuels and combustion technologies and refer to the full combustion emissions of the industry sector: boilers, process dedicated fuel combustion in furnaces and kilns and all emissions originated in co-generation units[1].

### 3.2.2.1 *Methodology*

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

Emissions of $SO_x$ are directly related to the sulphur content of the fuel[2]. Estimates for $SO_x$ were calculated assuming that there were no abatement technologies. The following equation applies:

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

where:

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

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

[1] 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).

[2] For some activities SOx emissions may also be estimated using the production approach, as presented below.

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

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

For the other pollutants either the energy approach or the production approach may be used.

When the energy consumption approach is used the equation is:

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

where:

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

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

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

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

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

where:

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

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

Production – Production activity rate (t/yr).

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 (t);

$Fuel_{Cons(f,y)}$ - 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/t);

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

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

It´s important to point out that following a meeting with the energy balance team from DGEG new procedures were established to include biodiesel in the INERPA estimates. Hence all estimated derived from the energy balance now have biodiesel. This new approach for obtaining biodiesel results from the fact that from 2006 forward the gas oil reported in the energy balance contained a percentage of biodiesel. The methodology for obtaining the total pure biodiesel and pure gas oil consumed in each industrial sector follows these steps[1]:

- Total pure gas oil consumed was obtained by subtracting the total biodiesel produced (that is going to be incorporated in gas oil) to the gas oil reported in the energy balance;
- With the pure gas oil and the pure biodiesel values an incorporation rate was derived;
- For each industrial sector this incorporation rate was applied to obtain value for total gas oil and total biodiesel consumed;
- Not all the gas oil reported has biodiesel. Because of this, before applying the incorporation rate the total gas oil for heating was subtracted;
- In the end we have, for which industrial sector, the total gas oil consumed (heating gas oil + gas oil with biodiesel removed) and the total biodiesel consumed (biodiesel from gas oil +pure biodiesel purchased directly by the industrial unit).

The table below represents the incorporation rate derived for the period 2006-2015.

Table 3.20 – Incorporation rate of biodiesel (% toe/toe)

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

Emissions from the following industries were estimated based only on fuel consumption as activity data (energy approach): metallurgy; chemical and plastic industry; food, beverages and tobacco, textile industry; clothing, shoes and leather manufacturing; wood industry; rubber manufacturing; machines manufacturing industry and other metal equipment industry; extractive industry; building and construction and all other unspecified industry. Following the recommendation made by the review team, since the 2011 inventory all emissions from lime production are reported in 2.A.2. For the following industrial sectors specific estimation procedures were taken.

[1] Note: This procedure does not apply to gas oil reporter under co-generation in the energy balance. The DGEG has no documentation to differentiate this fuel as heating gas oil or as gas oil with biodiesel.

#### 3.2.2.1.1 Paper and Pulp Production

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

#### 3.2.2.1.2 Clinker Production

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

#### 3.2.2.1.3 Lime Production

Emissions of $SO_x$, $NO_x$ and CO from combustion processes in furnaces in the Lime 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.

Both this activity and Clinker production are included in the energy balance Cement sector.

#### 3.2.2.1.4 Ceramic Industry

Emissions of $SO_x$, $NO_x$, NMVOC and $CH_4$ from combustion processes in furnaces in the ceramic industry are estimated using the production approach. Emissions estimates from combustion in other equipment, boilers and engines, and emission estimates for the other pollutants, also for furnaces, are based on the energy approach

#### 3.2.2.1.5 Glass Production

Similarly to ceramic industry, emission of $SO_x$, $NO_x$, $CH_4$ and CO are estimated using production information as activity data (production approach). Emissions for the remaining pollutants, $CO_2$ and $N_2O$ from furnaces and for all pollutants from other combustion equipments are estimated using energy consumption as activity data indicator. Carbon dioxide emissions from glass production comprehend both oxidation of carbon, that are estimated using the general emission factors based on energy consumption, and decarbonizing or materials, which are included in production process and reported in “Industrial Processes: Glass Production (NFR 2.A.3)”.

#### 3.2.2.1.6 Iron and Steel Production

Air emissions from sintering ($SO_x$, $NO_x$, NMVOC and CO) and production of lime ($SO_x$, $NO_x$, CO and $CO_2$) integrated in the iron and steel production sector are estimated using production as activity data (production approach). The remaining pollutants resulting from the iron and steel industry were estimated using the energy approach. For simplicity, activity data and emission factors for this source are discussed in chapter 4.3.3.1 – Industrial Processes: Iron and Steel Production.

### 3.2.2.2 *Activity data*

Activity data comprehends consumption of fuels and industrial production rates. The subsequent chapters will follow this division.

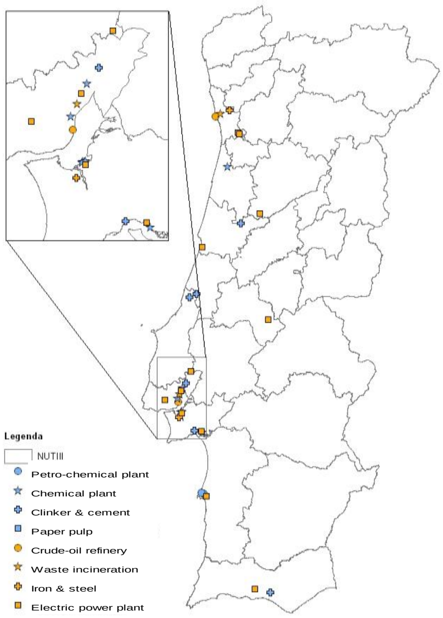
#### 3.2.2.2.1 Combustion Data

Data on fuel consumption for the Larger Point Sources (LPS) were obtained from several sources:

- directly from Large Combustion Plants (LCP) submitted to APA under the provisions of the LCP Directive;
- information received by APA from special surveys;
- from EPER/PRTR inventory;
- from self-control program (Programa Autocontrolo);
- from direct request to the LCP operators;
- since the 2009 inventory from EU-ETS.

Presently LPS comprehend one iron and steel industry, one petrochemical unit, one carbon black industrial plant, eight paper pulp plants (in most cases divided in differente fiscal entities) and six cement plants (covering all clinker producing units).

Figure 3.15 – Distribution of Large Point Sources in continental Portugal[1]




The remaining national energy consumption for each sector was estimated subtracting LPS consumption data from the figures reported in the energy balance compiled annually by DGEG

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

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:

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

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

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

Where,

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

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

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

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

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

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

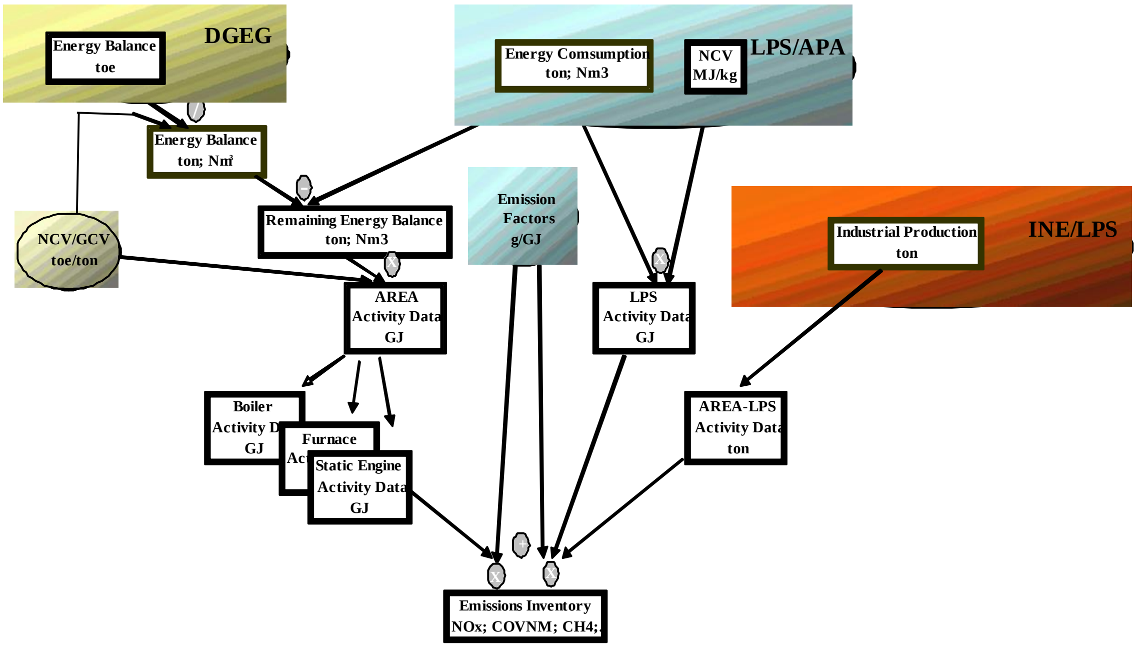
$LHV_{LPS(u,f,e)}$ – Low Heating Value/ Net Calorific Value, reported by LPS unit u, for fuel f in combustion equipment e (MJ/kg or MJ/Nm3);

$LHV_{EB(f,s)}$ – Low Heating Value/ Net Calorific Value used by DGEG in the compilation of the Energy Balance for fuel f in activity sector s (toe/t or toe/Nkm3);

$LHV_{AREA(f,s,e)}$ - 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/Nm3)[1].

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

Figure 3.16 – General procedure for emissions estimate




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

### *3.2.2.2.1.1 The Energy Balance*

The Portuguese Energy Balance (EB) is published annually by DGEG covering all national territory and without any disaggregation at regional level. The structure of the report table is summarized in the next tables. The Energy Balance for 2012 is presented in annex to the IIR.

Table 3.21 – Structure of the Portuguese Energy Balance. Sectoral categories

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

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

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

Table 3.22 – Structure of the Portuguese Energy Balance. Fuel categories

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

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

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

Table 3.23 – Definition of Sectors in accordance with Economic Activity Classes

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

###### *3.2.2.2.1.2 Tables of consumption per activity*

For confidential reasons, LPS data on fuel consumption for the iron and steel industry, the petrochemical and carbon black units are presented lumped together with data in energy balances, with no separation from the other non-LPS sources within the respective sector. Data on paper pulp plants are presented for the eight LCP units summed together with non-LPS sources (like paper production). In the cement industry since only two companies represent the six factories that exist in Portugal, for confidential reasons no activity data can be presented in this report.

*3.2.2.2.1.2.1 Iron and Steel Industry*

Table 3.24 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Iron and Steel Industry

| Steam Coal | Coke | LPG | Kerosene | Gas Oil | Residual Fuel Oil | Natural Gas |
|---|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 |
| 30.95 | 29.40 | 46.0 | 43.8 | 42.6 | 40.0 | 38.7 |

| Coke Oven Gas | Blast Furnace Gas | Tar | Gasoline | Biodiesel | Other |
|---|---|---|---|---|---|
| MJ/Nm3 | MJ/Nm3 | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 17.6 | 3.8 | 40.1 | 44.0 | 37.0 | 34.7 |

Table 3.25 – Fuel consumption in the Iron and Steel Industry in boilers and furnaces (GJ) (1/2)

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

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

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

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

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

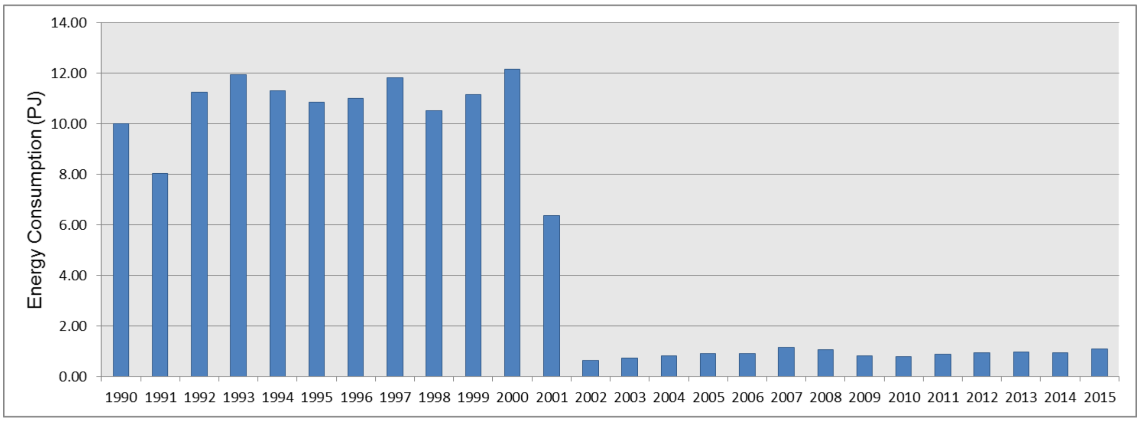
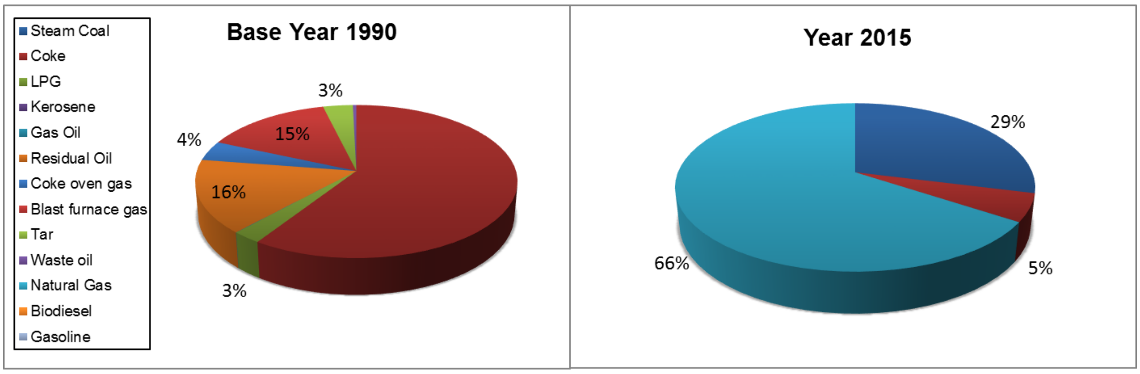



Figure 3.18 – Fuel Consumption per fuel type in Iron and Steel Industry in 1990 and 2015




There is also Coke gas consumption associated with the Iron and Steel Sector, that consumption is realized in a coquerie unit that existed within the only integrated iron and steel plant in Portugal. That activity data is presented in sub-chapter 1.2.1.3 - Other Energy Industries.

#### *3.2.2.2.1.2.2 Metallurgy Industry*

Table 3.27 – Low Heating Values/ Net Calorific Value (LHV/NCV) in Metallurgy Industry

| Steam Coal | Coal Coke | LPG | Kerosene | Gas Oil | Residual Oil |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 31.0 | 29.4 | 46.0 | 43.8 | 42.6 | 40.0 |

| Natural Gas | Wood | Gasoline | Biodiesel |
|---|---|---|---|
| MJ/Nm3 | MJ/kg | MJ/kg | MJ/kg |
| 38.7 | 12.6 | 44.0 | 37.0 |

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

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

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

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

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

Since 2007 the fuel consumption has been decreasing, explained with the abandonment of residual fuel oil and LPG and their substitution by natural gas in more recent years. The drop in total energy consumption in 2011 it's due to the significant reduction on wood fuel consumption.

Figure 3.19 – Total Energy Consumption in the Metallurgy Industry

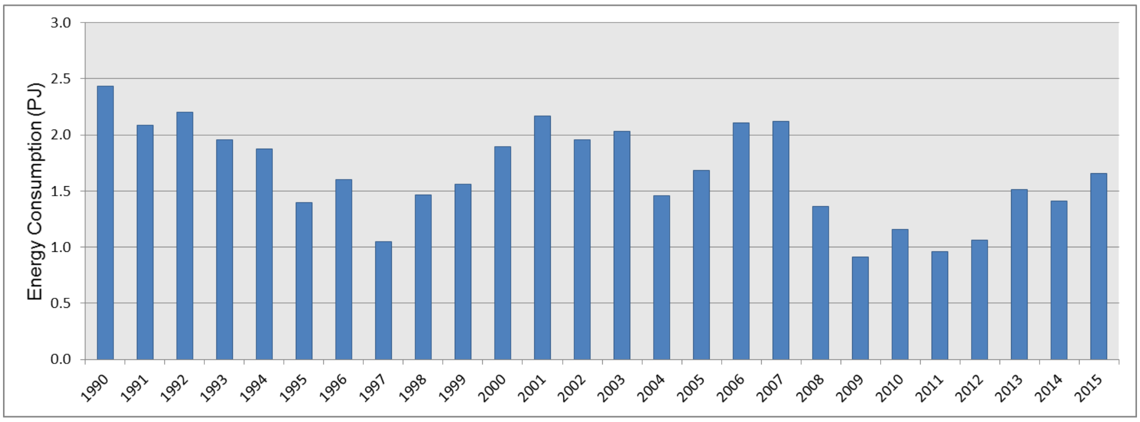
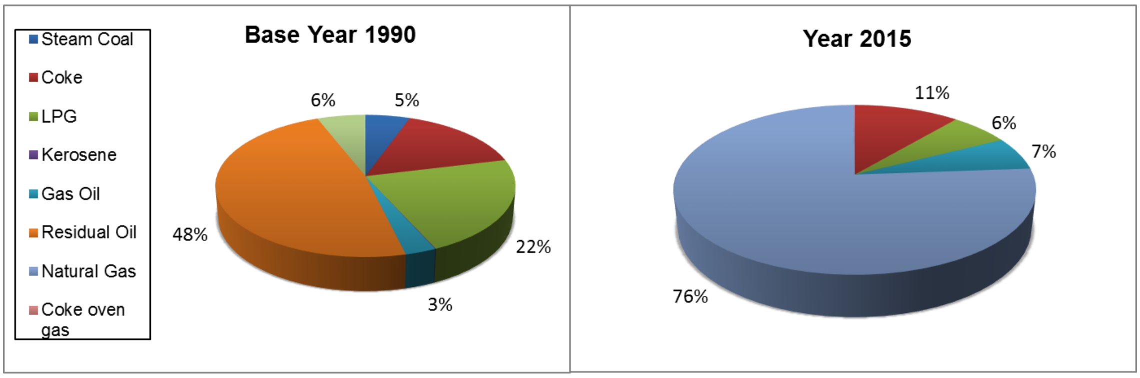



Figure 3.20 – Fuel Consumption per fuel type in Metallurgy Industries in 1990 and 2015




### *3.2.2.2.1.2.3 Chemical and Plastics Industry*

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

| Steam Coal | Coal Coke | LPG | Kerosene | Gas Oil | Residual Fuel Oil* |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 31.0 | 29.4 | 46 | 43.8 | 42.6 | 39.61 – 40.0 |

| Natural Gas | Wood | Fuel Gas[1] | Gasoline | Flare Gas[2] | Biodiesel |
|---|---|---|---|---|---|
| MJ/Nm3 | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 38.4 – 37.9 | 12.6 | 46.8 – 53.7 | 44.0 | 46.8 – 53.7 | 37.0 |

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

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

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

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

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

Table 3.33 – Fuel consumption in Chemical and Plastics Industry – Flares (GJ)

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

Two industrial plants in this sector were treated as Large Point Sources, representing a substantial component of total energy consumption, but for confidentiality constrains plant specific information cannot be published individually. In the beginning of the period under analysis, fuel consumption[1] was based on residual fuel oil, traded or by-product of the unit, and residual gases, also obtained as a by-product from the production processes. More recently, natural gas has gained a relevant importance as the third energy source. An increasing trend in total energy consumption - is verifiable in Figure 3.21. The consumption of coke time series presents an anomalous value in 2000. When questioned about this, the energy balance team at DGEG could not justify the inconsistent value.

[1] Not considering feedstocks. Emissions from feedstock use are only included when by products (pyrolysis fuel or and fuel gas) are generated and reported explicitly in the industrial plant as fuels.

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

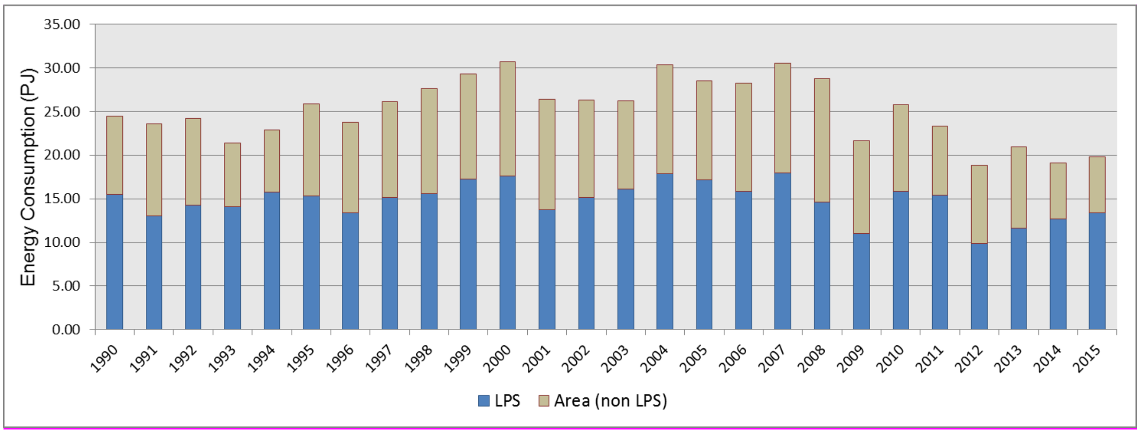
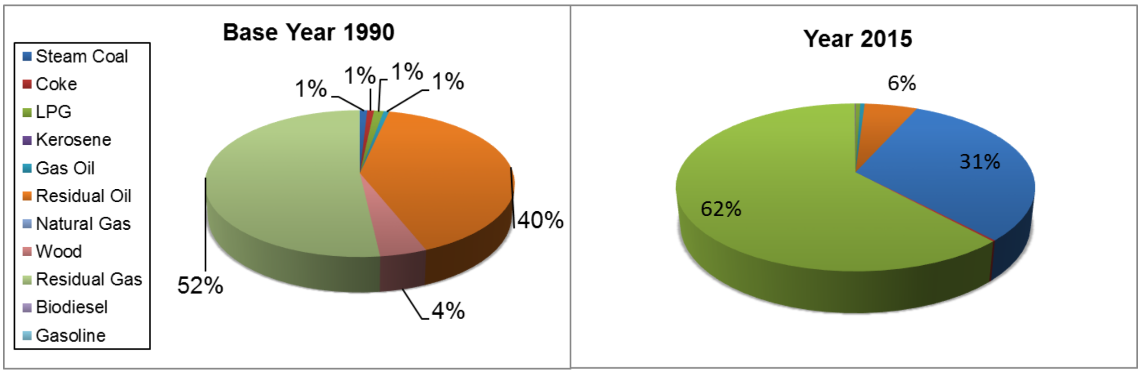



Figure 3.22 – Fuel consumption per fuel type in Chemical and Plastics Industry in 1990 and 2015




### *3.2.2.2.1.2.4 Paper and Paper Pulp Industry*

Table 3.34 – Low Heating Values / Net Calorific Values (LHV/NCV) in the Paper and Paper Pulp Industry

| Steam Coal | LPG | Kerosene | Gas Oil | Residual Fuel Oil | Natural Gas |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 |
| 31.0 | 46 - 52.7 | 43.8 | 42.6 - 43.3 | 37.9 - 41.8 | 37.9 - 39.1 |

| Gasoline | Biodiesel | Biogas | Wood | Black Liquor | Bisulphite Liquor |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 44.0 | 37.0 | 34.7 | 6.3 - 20.5 | 7.4 - 16.7 | 7.2 - 15.8 |

| Gasified Biomass | Methanol | NCG | Tall-oil |
|---|---|---|---|
| MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 14.7 - 14.7 | 17 - 19.5 | 0.0069 - 0.0074 | 34 - 35.7 |

Table 3.35 – Fuel consumption in the Paper and Paper Pulp Industry – Boilers and Furnaces (GJ)

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

(i) Wood waste includes methanol, NCG, tall-oil, biogas and gasified biomass.

Emissions report in this sub sector include all the eight paper pulp plants that existed in Portugal from 1990 to 2015 (six Kraft plants and two bisulphite smaller plants), but also smaller units dedicated to paper production. The increasing trend in total fuel consumption is evident and was almost continuous in the period. The lower temporary value in 2003 reflects a re-qualification period for one unit. Considering the share of energy sources, there is a dominance of liquor, followed by residual fuel oil, wood waste and natural gas - this last only recently - as auxiliary primary energy sources.

Table 3.36 – Fuel consumption in the Paper and Paper Pulp Industry – Static Engines (GJ)

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

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

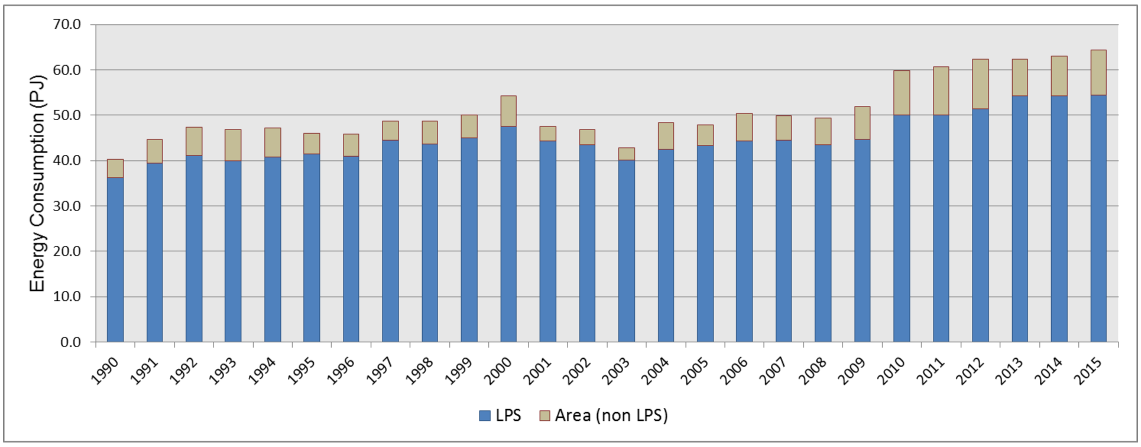
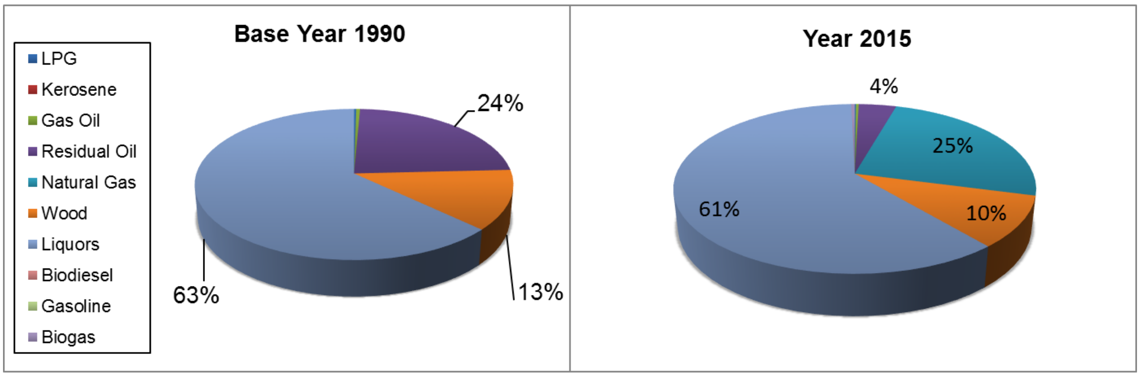



Figure 3.24 – Fuel consumption per fuel type in the Paper and Paper Pulp Industry in 1990 and 2015




### *3.2.2.2.1.2.5 Food Processing, Beverages and Tobacco Industries*

Table 3.37 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Food Processing, Beverages and Tobacco Industries

| Steam Coal | LPG | Kerosene | Gas Oil | Residual Fuel Oil | Natural Gas |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 |
| 31.0 | 46.0 | 43.8 | 42.6 | 40.0 | 38.7 |

| Wood | Gasoline | Biodiesel | Biogas |
|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 12.6 | 44.0 | 37.0 | 34.7 |

Table 3.38 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Boilers and Furnaces (GJ)

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

Table 3.39 – Fuel consumption in Food Processing, Beverages and Tobacco Industries – Static Engines (GJ)

| Year | Gasoline | Gas Oil | Biogas | Biodiesel |
|---|---|---|---|---|
| **1990** | 17,588 | 545,639 | 0 | 0 |
| **1995** | 109,277 | 735,940 | 0 | 0 |
| **2000** | 117,945 | 669,262 | 0 | 0 |
| **2005** | 68,883 | 753,087 | 0 | 0 |
| **2010** | 22,023 | 487,347 | 61 | 29,569 |
| **2013** | 0 | 449,216 | 19,929 | 28,429 |
| **2014** | 0 | 514,388 | 34,301 | 31,731 |
| **2015** | 0 | 619,924 | 38,631 | 44,848 |

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

Figure 3.25 – Total Energy Consumption in the Food Processing, Beverages and Tobacco Industries

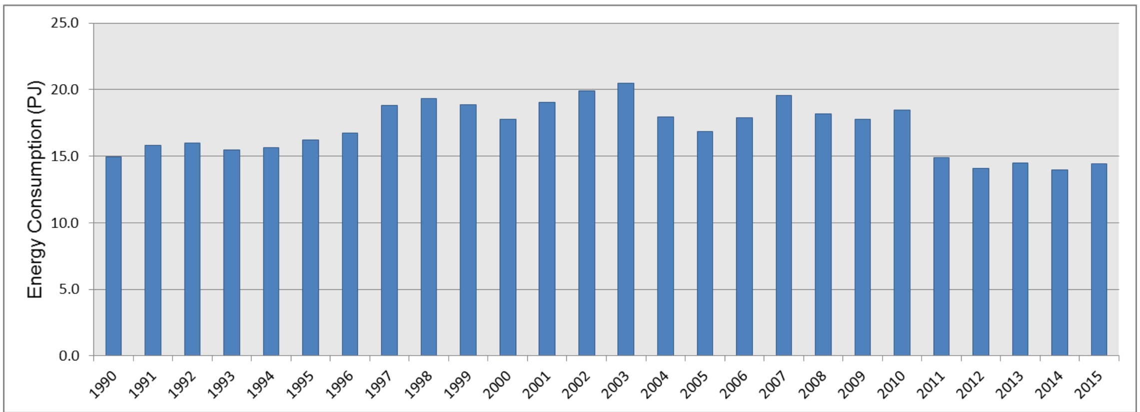
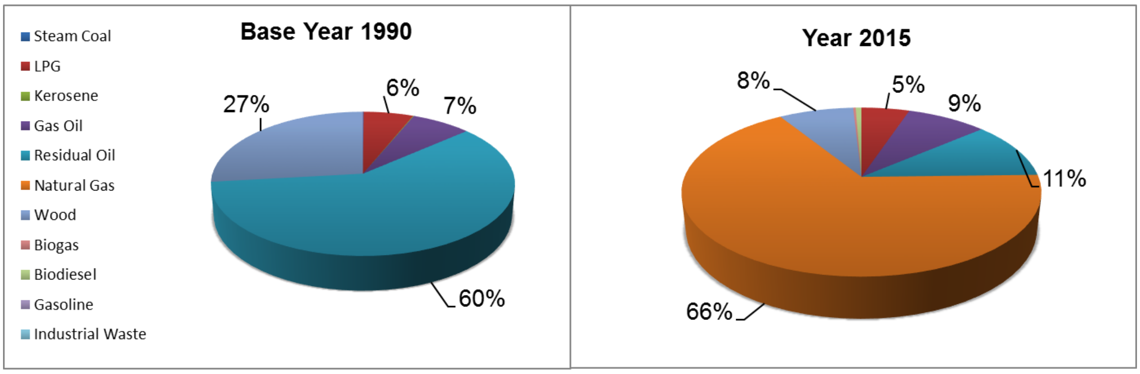


Figure 3.26 – Fuel consumption per fuel type in the Food Processing, Beverages and Tobacco Industries in 1990 and 2015




### 3.2.2.2.1.2.6 *Textile Industry*

Table 3.40 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Textile Industry

| LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 46.0 | 43.8 | 42.6 | 40.0 | 38.7 | 12.6 |

| Gasoline | Biodiesel |
|---|---|
| MJ/kg | MJ/kg |
| 44.0 | 37.0 |

Table 3.41 – Fuel consumption per fuel type in Textile Industry – Boilers and Furnaces (GJ)

| Year | LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood | Biodiesel |
|---|---|---|---|---|---|---|---|
| **1990** | 211,214 | 125 | 27,579 | 10,404,993 | 0 | 1,136,569 | 0 |
| **1995** | 375,912 | 4 | 37,333 | 8,878,803 | 0 | 1,077,866 | 0 |
| **2000** | 508,000 | 0 | 75,347 | 11,337,089 | 4,196,215 | 2,059,507 | 0 |
| **2005** | 362,613 | 4 | 108,672 | 7,295,236 | 7,979,600 | 2,225,989 | 0 |
| **2010** | 134,730 | 42 | 19,604 | 3,921,248 | 7,845,017 | 2,328,954 | 597 |
| **2013** | 115,806 | 0 | 6,721 | 344,568 | 9,892,655 | 72,845 | 334 |
| **2014** | 104,878 | 0 | 7,968 | 174,293 | 9,570,522 | 72,845 | 405 |
| **2015** | 115,178 | 0 | 34,512 | 88,926 | 9,786,478 | 87,824 | 2,457 |

Table 3.42 – Fuel consumption in Textile Industry – Static Engines (GJ)

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

Figure 3.27 – Total Energy Consumption in the Textile Industry

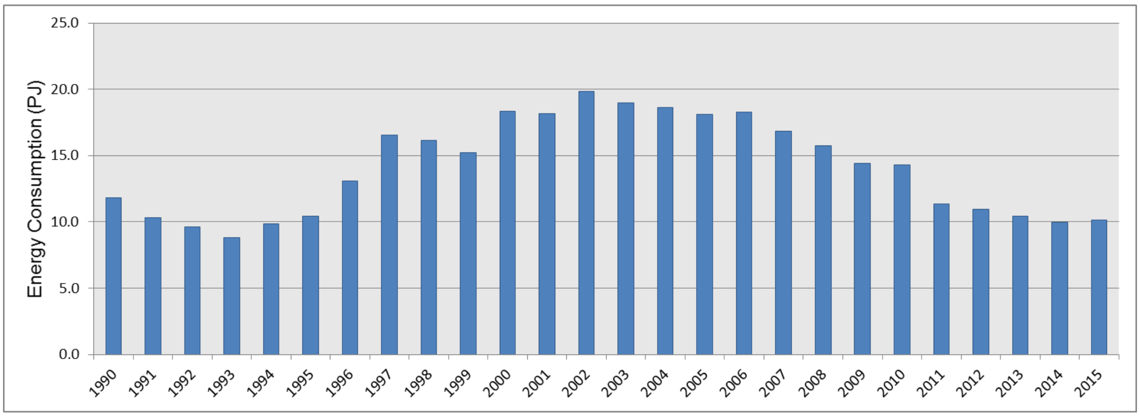
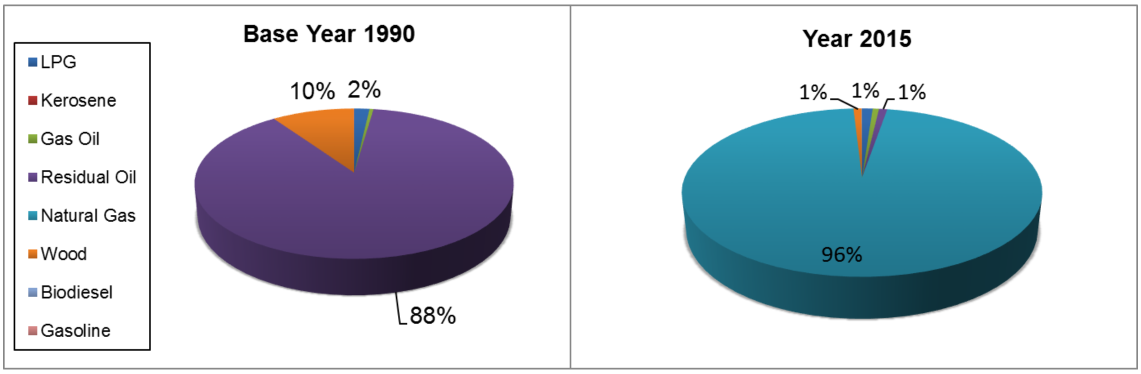



Figure 3.28 – Fuel consumption per fuel type in Textile Industry in 1990 and 2015



*3.2.2.2.1.2.7 Ceramic Industry*

Table 3.43 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Ceramic Industry

| Steam Coal | Pet Coke | LPG | Kerosene | Gas Oil | Residual Oil |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 31.0 | 32.0 | 46.0 | 43.8 | 42.6 | 40.0 |

| Natural Gas | Wood | Gasoline | Biodiesel |
|---|---|---|---|
| MJ/Nm3 | MJ/kg | MJ/kg | MJ/kg |
| 38.7 | 12.6 | 44.0 | 37.0 |

Table 3.44 – Fuel consumption in the Ceramic Industry – Boilers and Furnaces (GJ)

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

Table 3.45 – Fuel consumption in the Ceramic Industry – Static Engines (GJ)

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

The figure below shows two periods: the first goes from 1990 to 2001 and characterizes a steady increase in fuel consumption, after that total energy consumption has declined until 2011 (except for 2007 and 2008). The pattern of fuel consumption has also changed, with the abandonment of residual fuel oil and LPG and their substitution by natural gas in more recent years. This sector, together with the glass industry, is in fact one in which the substitution was more visible. The decrease in use of biomass is only apparent in per cent, because values of consumption of these fuels did in fact increased slightly. Since 2004 the gasoline consumption has been dropping significantly. In the last four years (2011-2015) a significant decrease in wood consumption was reported in the energy balance.

Figure 3.29 – Total Energy Consumption in the Ceramic Industry

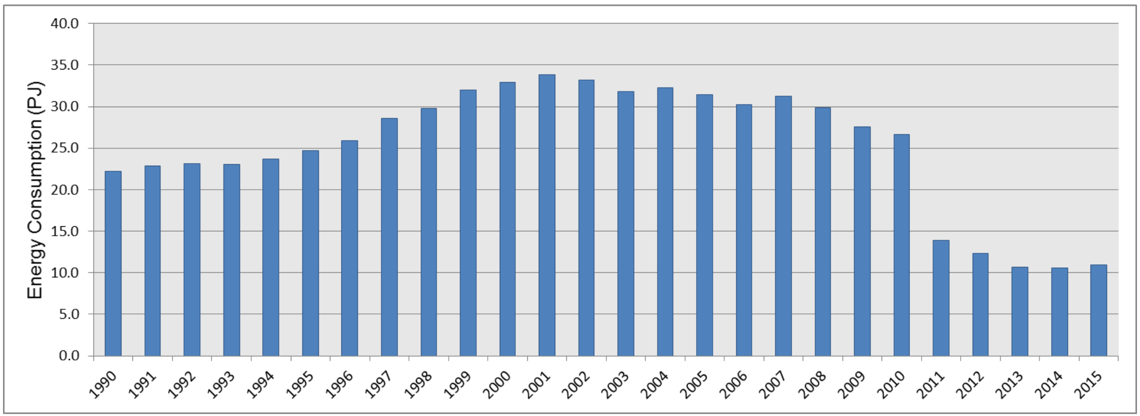
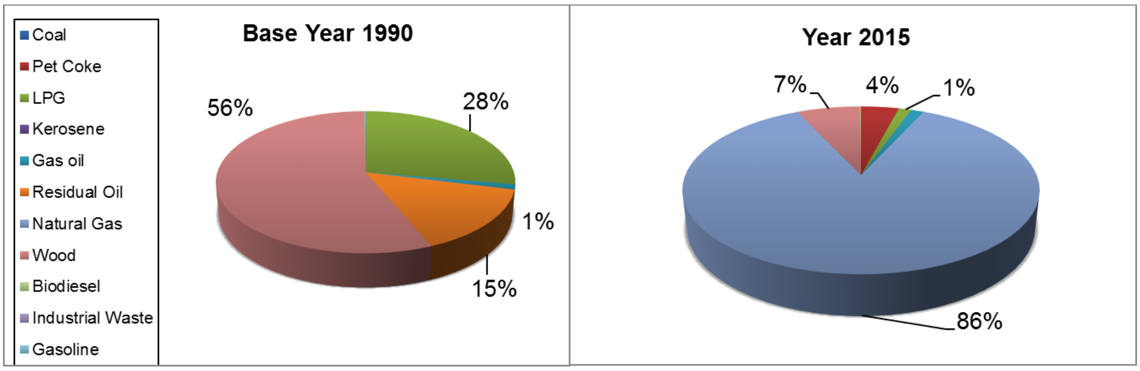



Figure 3.30 – Fuel consumption per fuel type in Ceramic Industry in 1990 and 2015




### *3.2.2.2.1.2.8 Glass Industry*

Table 3.46 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Glass Industry

| Coal | Pet Coke | LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas |
|---|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 |
| 30.95 | 32.0 | 46.0 | 43.8 | 42.6 | 40.0 | 38.7 |

| Wood | Gasoline | Biodiesel |
|---|---|---|
| MJ/kg | MJ/kg | MJ/kg |
| 12.6 | 44.0 | 37.0 |

Table 3.47 – Fuel consumption in the Glass Industry – Boilers and Furnaces (GJ)

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

Table 3.48 – Fuel consumption in the Glass Industry – Static Engines (GJ)

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

In this sector 9 plants are treated as LPS, convering flat, container and crystal glass production. The fuel consumption contribution of these 9 plants has increased from 1990 to 2012, covering in this year more than 97 per cent of the total fuel consumption in this sector.

The consumption of energy in this sector has suffered stagnation in the most recent years after 1999, showing a slight increase in 2007 and a decrease thereafter. The introduction of natural gas has almost fully replaced the consumption of LPG and most of the consumption of residual fuel oil that was in dominance in 1990. The decrese in residual oil consumption in 2012 results from fact that the only cogeneration plant from this sector did not work that year.

Figure 3.31 – Total Energy Consumption in the Glass Industry

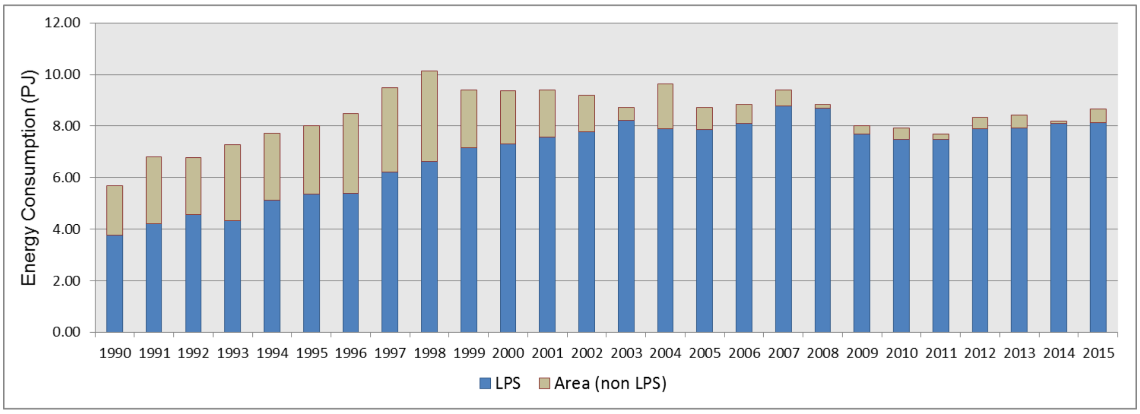
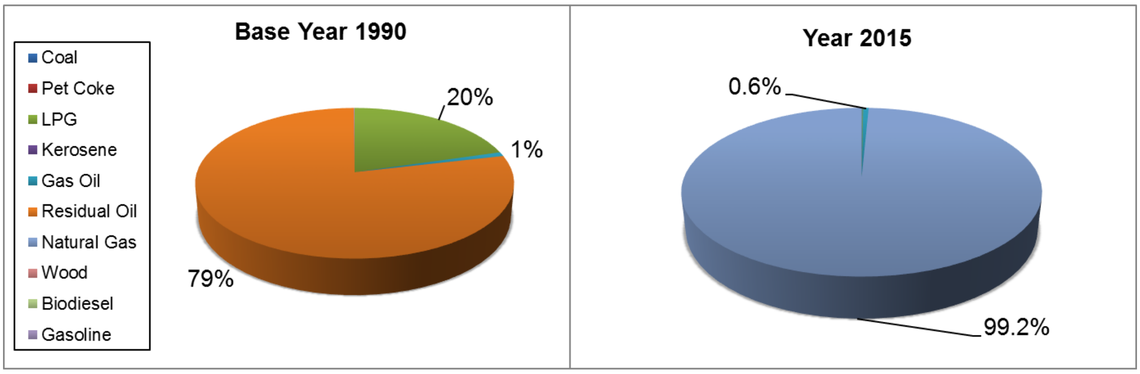



Figure 3.32 – Fuel consumption per fuel type in Glass Industry in 1990 and 2015




### *3.2.2.2.1.2.9 Cement Industry*

In the 2009 inventory new data concerning fuel consumption in Clinker Production was obtained through the LCP operator. In this new data batch, previously unreported fuels were accounted. These fuels were:

- Industrial waste – Fluff (fiber residue) and RDF (unrecycled cardboard and plastics)
- Hazardous industrial waste – composition unknown;
- Animal and wood waste – animal carcass and general wood waste;

Other changes were made to this sector in the 2012 inventory. These changes concern the inclusion of Lime Production activities as LPS in the inventory. This improvement resulted from the ongoing integration of EU-ETS data in the inventory.

Table 3.49 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Cement Industry

| Steam Coal | Petcoke | LPG | Gasoline | Kerosene | Gas Oil | Residual Oil |
|---|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 18.7 - 31 | 30.9 - 34.6 | 46.0 | 44.0 | 43.8 | 42.6 | 39.8 - 40.4 |

| Natural Gas (MJ/Nm3) | Biodiesel | Tires | Industrial Waste | Hazardous Industrial Waste | Animal + Wood Waste |
|---|---|---|---|---|---|
| MJ/Nm3 | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 38.7 | 37.0 | 23.8 - 31.4 | 10.7 - 32.3 | 12.3 - 23.5 | 9.8 - 21.0 |

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

Currently there are 7 dedicated lime production plants in operation in Portugal which use natural gas as main fuel since 2000 (prior to that was residual oil). In this sector there is also comsumption of petcoke and biomass, and small amounts of LPG and gas oil.

Even though fuel consumption in this sector includes at least 9 companies we consider this data to be confidential, because there are only two companies (associated with clinker production) for most fuels, and both represent more than 90 per cent of consumption for all other fuels. Because of this no table will be included in this report with energy consumption data desegregated by fuel type.

Figure 3.33 – Total Energy Consumption in the Cement Industry

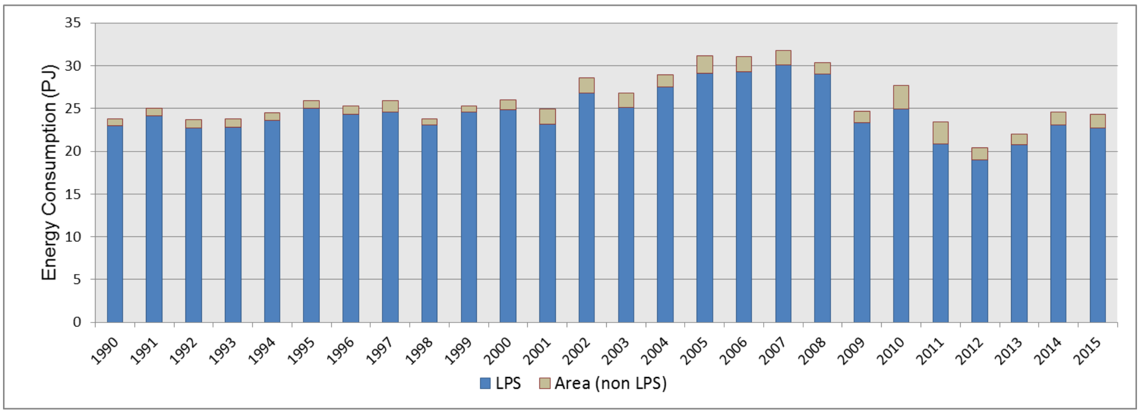
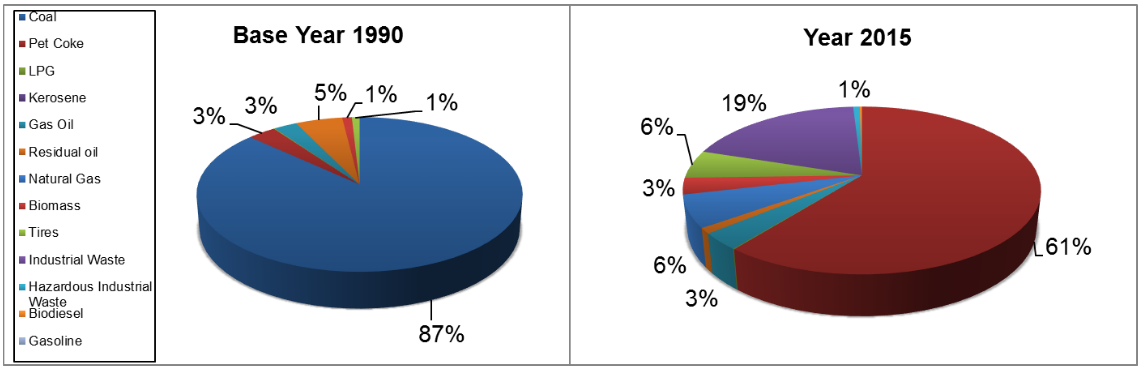


Figure 3.34 – Fuel consumption per fuel type in the Cement Industry in 1990 and 2015




*3.2.2.2.1.2.10 Clothing, Shoes and Leather Industries*

Table 3.50 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Clothing, Shoes and Leather Industries

| LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 46.0 | 43.8 | 42.6 | 40.0 | 38.7 | 12.6 |

| Gasoline | Biodiesel |
|---|---|
| MJ/kg | MJ/kg |
| 44.0 | 37.0 |

Table 3.51 – Fuel consumption in the Clothing, Shoes and Leather Industries – Boilers and Furnaces (GJ)

| Year | LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood | Biodiesel |
|---|---|---|---|---|---|---|---|
| **1990** | 56,737 | 28 | 27,665 | 766,086 | 0 | 279,958 | 0 |
| **1995** | 239,172 | 0 | 22,330 | 704,818 | 0 | 265,481 | 0 |
| **2000** | 226,044 | 0 | 15,078 | 350,076 | 148,572 | 282,636 | 0 |
| **2005** | 231,177 | 8 | 11,608 | 241,561 | 471,671 | 0 | 0 |
| **2010** | 155,078 | 0 | 7,382 | 373,331 | 767,189 | 0 | 384 |
| **2013** | 116,308 | 0 | 35,644 | 45,510 | 842,635 | 41,297 | 2,288 |
| **2014** | 115,345 | 0 | 39,739 | 47,352 | 843,682 | 41,297 | 2,484 |
| **2015** | 125,519 | 42 | 66,899 | 85,828 | 885,006 | 78,243 | 4,841 |

Table 3.52 – Fuel consumption in the Clothing, Shoes and Leather Industries – Static Engines (GJ)

| Year | Gasoline | Gas Oil | Biodiesel |
|---|---|---|---|
| **1990** | 1,962 | 27,665 | 0 |
| **1995** | 8,668 | 22,330 | 0 |
| **2000** | 3,836 | 15,078 | 0 |
| **2005** | 465 | 11,608 | 0 |
| **2010** | 0 | 7,382 | 384 |
| **2013** | 0 | 35,644 | 2,288 |
| **2014** | 0 | 39,739 | 2,484 |
| **2015** | 0 | 66,899 | 4,841 |

Figure 3.35 – Total Energy Consumption in the Clothing, Shoes and Leather Industries

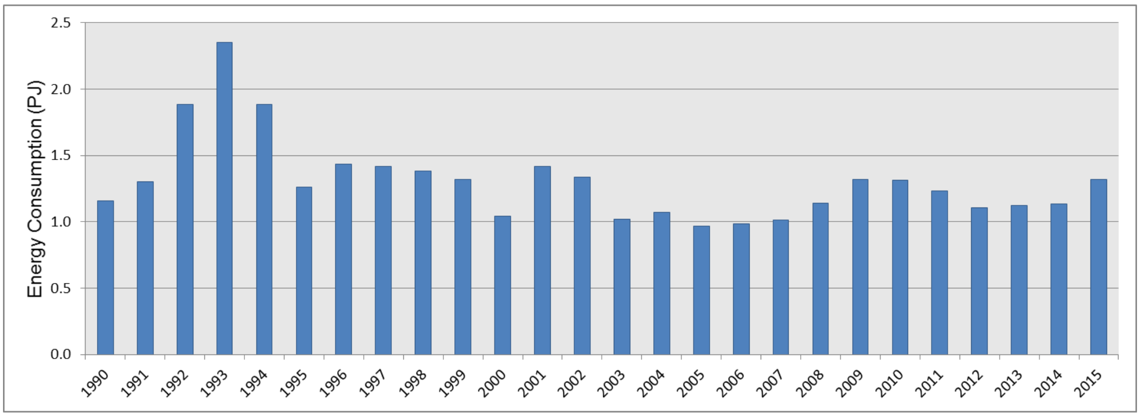
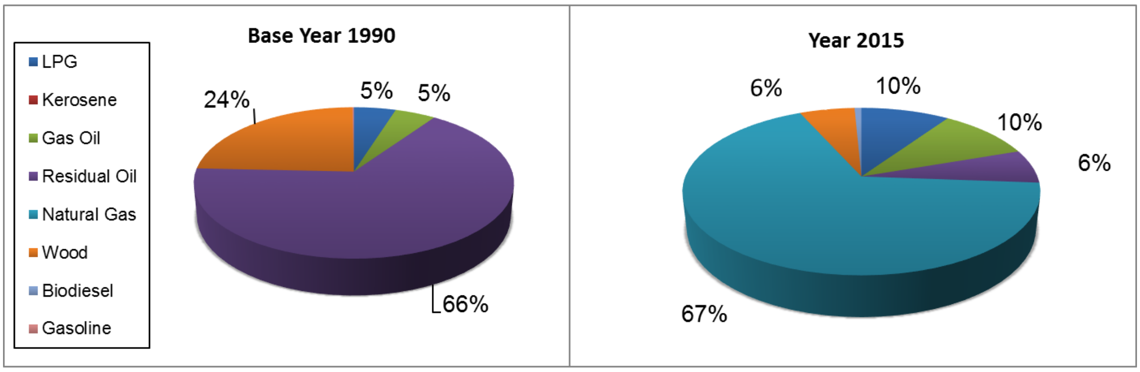



Figure 3.36 - Fuel consumption per fuel type in the Clothing, Shoes and Leather Industries in 1990 and 2015



*3.2.2.2.1.2.11 Wood Industry*

Table 3.53 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Wood Industry

| LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 46.0 | 43.8 | 42.6 | 40.0 | 38.7 | 12.6 |

| Gasoline | Biodiesel |
|---|---|
| MJ/kg | MJ/kg |
| 44.0 | 37.0 |

Table 3.54 – Fuel consumption in the Wood Industry – Boilers and Furnaces (GJ)

| Year | LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood | Biodiesel |
|---|---|---|---|---|---|---|---|
| **1990** | 85,312 | 69 | 250,404 | 1,346,386 | 0 | 1,309,205 | 0 |
| **1995** | 115,297 | 0 | 192,250 | 3,036,372 | 0 | 1,241,590 | 0 |
| **2000** | 467,887 | 85 | 206,253 | 2,939,646 | 237,201 | 907,236 | 0 |
| **2005** | 260,611 | 1,127 | 215,627 | 1,998,707 | 524,175 | 1,632,259 | 0 |
| **2010** | 59,326 | 0 | 122,508 | 1,667,574 | 335,823 | 1,706,234 | 7,553 |
| **2013** | 58,908 | 0 | 92,777 | 413,272 | 460,255 | 1,801,213 | 5,612 |
| **2014** | 50,241 | 0 | 117,162 | 430,772 | 379,240 | 1,908,954 | 7,101 |
| **2015** | 70,212 | 0 | 138,456 | 551,350 | 327,994 | 2,022,887 | 10,048 |

Table 3.55 – Fuel consumption in the Wood Industry – Static Engines (GJ)

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

Although total consumption of energy from combustion has decreased from 1990 to 2015, there is not a constant trend along periods, but instead oscillations along the period.

Figure 3.37 – Total Energy Consumption in the Wood Industry

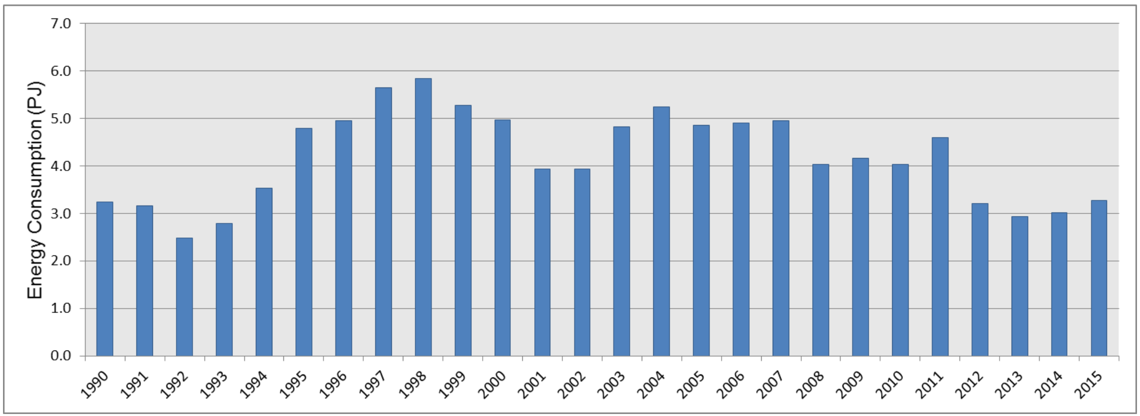
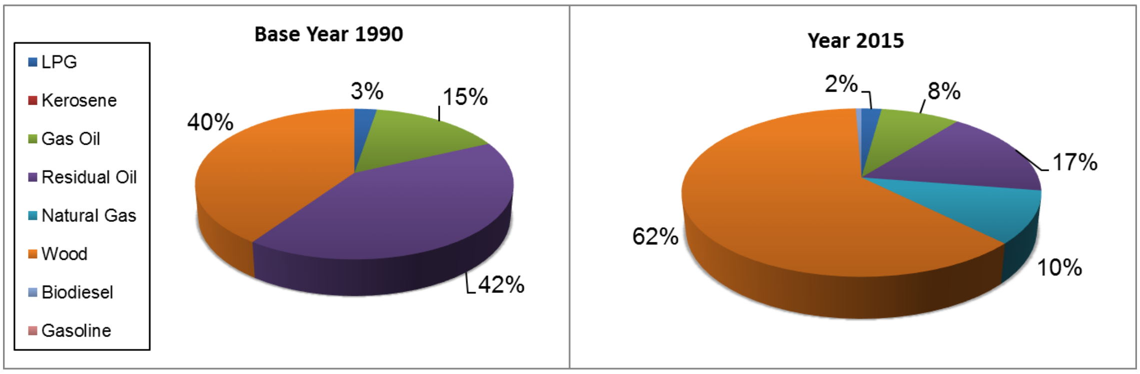



Figure 3.38 – Fuel consumption per fuel type in the Wood Industry in 1990 and 2015




### *3.2.2.2.1.2.12 Rubber Industry*

Table 3.56 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Rubber Industry

| LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 46.0 | 43.8 | 42.6 | 40.0 | 38.7 | 12.6 |

| Gasoline | Biodiesel |
|---|---|
| MJ/kg | MJ/kg |
| 44.0 | 37.0 |

Table 3.57 – Fuel consumption in the Rubber Industry – Boilers and Furnaces (GJ)

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

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

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

The sharp increase in natural gas consumption from 2007 to 2008 results from a reclassification of a co-generation plant in the energy balance (previously accounted in another sector).

Figure 3.39 – Total Energy Consumption in the Rubber Industry

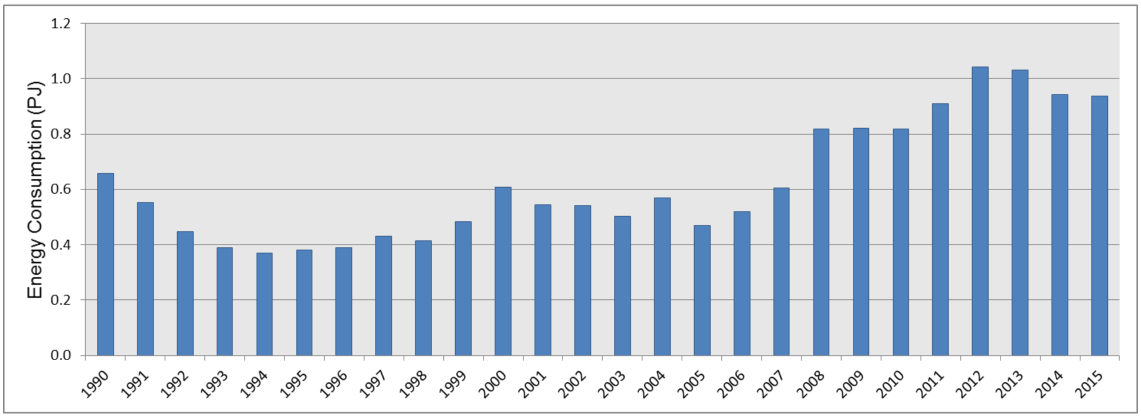
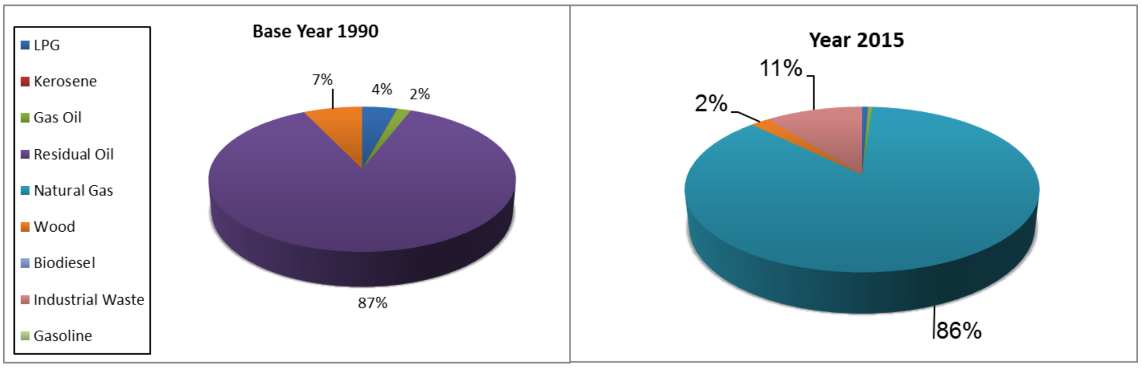


Figure 3.40 – Fuel consumption per fuel type in the Rubber Industry in 1990 and 2015




### 3.2.2.2.1.2.13 *Manufacturing of Machines and Metallic Equipments Industry*

Table 3.59 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Manufacturing of Machines and Metallic Equipments Industry

| LPG | Kerosene | Gas Oil | Residual Oil | Natural Gas | Wood |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 46.0 | 43.8 | 42.6 | 40.0 | 38.7 | 12.6 |

| Gasoline | Biodiesel |
|---|---|
| MJ/kg | MJ/kg |
| 44.0 | 37.0 |

Table 3.60 – Fuel consumption in the Manufacturing of Machines and Metallic Equipments Industry – Boilers and Furnaces (GJ)

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

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

| Year | Gasoline | Gas Oil | Biodiesel |
|---|---|---|---|
| **1990** | 43,723 | 166,018 | 0 |
| **1995** | 101,341 | 210,899 | 0 |
| **2000** | 45,687 | 117,664 | 0 |
| **2005** | 10,951 | 142,488 | 0 |
| **2010** | 90,353 | 106,258 | 6,031 |
| **2013** | 1,298 | 99,350 | 6,302 |
| **2014** | 754 | 108,424 | 6,733 |
| **2015** | 1,130 | 157,190 | 11,326 |

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

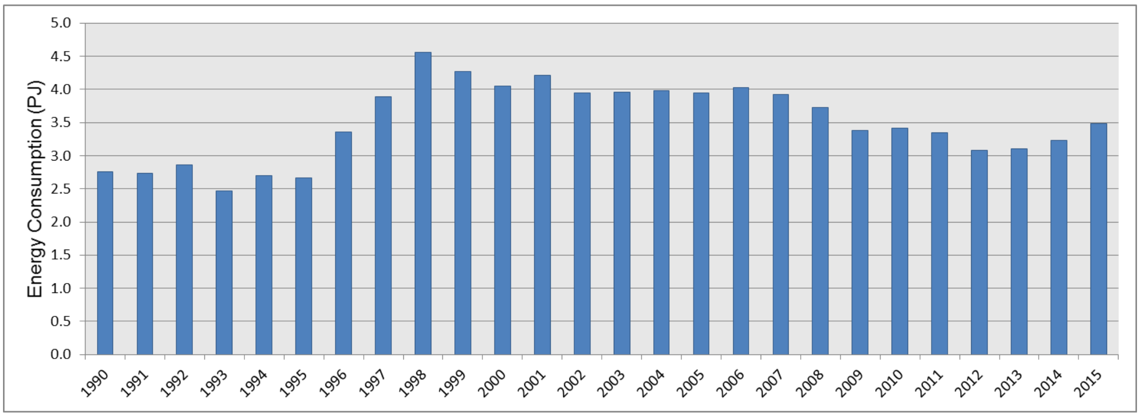
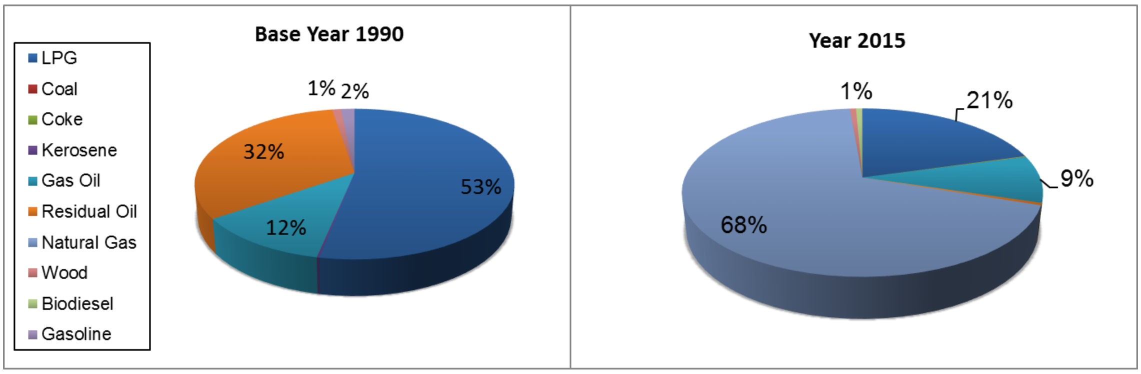



Figure 3.42 – Fuel consumption per fuel type in the Manufacturing of Machines and Metallic Equipments Industry in 1990 and 2015



#### 3.2.2.2.1.2.14 *Other Transformation Industry*

Table 3.62 – Low Heating Values/ Net Calorific Values (LHV/NCV) in Other Transformation Industry

| Lignite | LPG | Kerosene | Gas Oil | Residual Oil | City Gas |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 17.2 | 46.0 | 43.8 | 42.6 | 40.0 | 15.7 |

| Natural Gas | Wood | Gasoline | Biodiesel | Biogas |
|---|---|---|---|---|
| MJ/Nm3 | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 38.7 | 12.6 | 44.0 | 37.0 | 34.7 |

Table 3.63 – Fuel consumption in Other Transformation Industry – Boilers and Furnaces (GJ)

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

Table 3.64 – Fuel consumption in Other Transformation Industry – Static Engines (GJ)

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

An increase in fuel consumption is noticeable from 2008 to 2009. This is mainly due to gas oil and natural gas fuel consumption.

Figure 3.43 – Total Energy Consumption in Other Transformation Industry

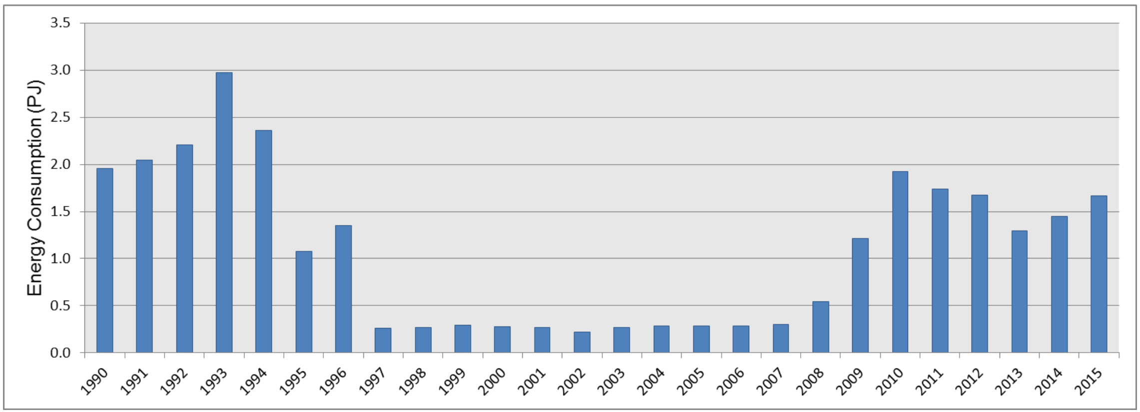
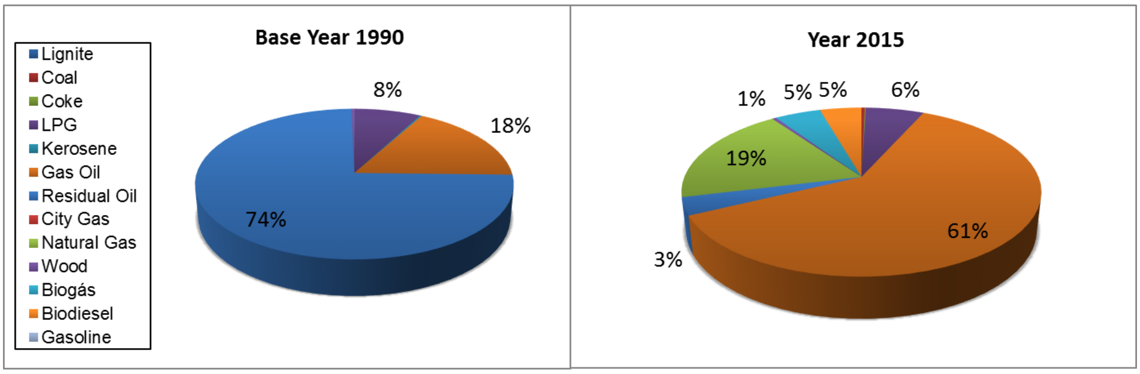



Figure 3.44 – Fuel consumption per fuel type in other transformation industry in 1990 and 2015




### *3.2.2.2.1.2.15 Extractive Industry*

Table 3.65 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Extractive Industry

| Lignite | LPG | Gasoline | Kerosene | Gas Oil | Residual Oil |
|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg |
| 17.2 | 46.0 | 44.0 | 43.8 | 42.6 | 40.0 |

| Natural Gas | Biodiesel |
|---|---|
| MJ/Nm3 | MJ/kg |
| 38.7 | 37.0 |

Table 3.66 – Fuel consumption in the Extractive Industry – Boilers and Furnaces

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

Table 3.67 – Fuel consumption in the Extractive Industry – Static Engines

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

Figure 3.45 – Total Energy Consumption in the Extractive Industry

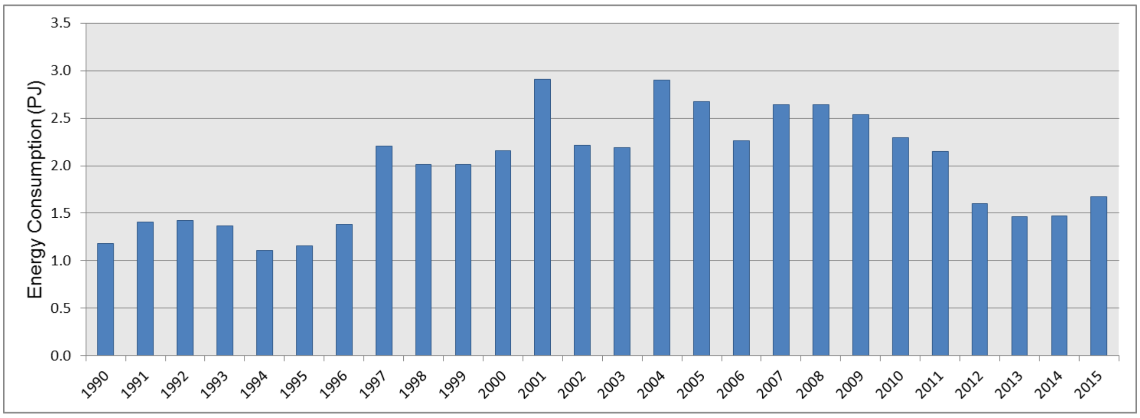
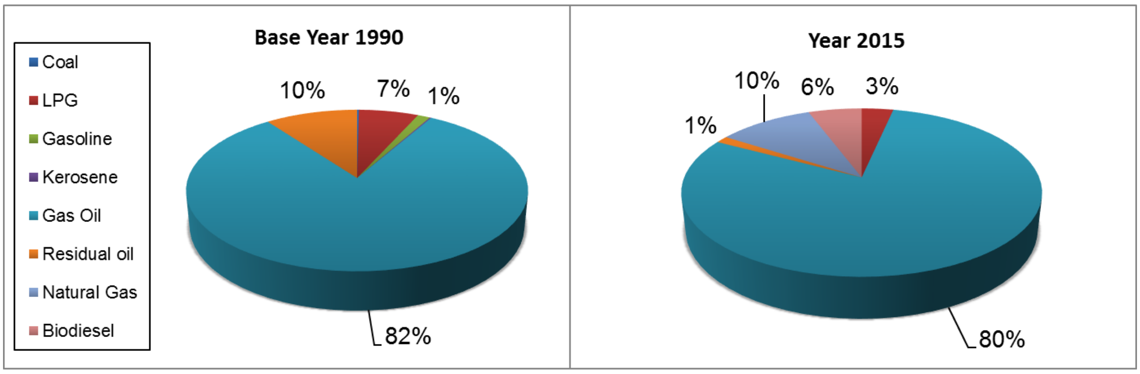


Figure 3.46 – Fuel consumption per fuel type in the Extractive Industry in 1990 and 2015




### *3.2.2.2.1.2.16 Construction and Building Industry*

Table 3.68 – Low Heating Values/ Net Calorific Values (LHV/NCV) in the Construction and Building Industry

| LPG | Gasoline | Kerosene | Gas Oil | Residual Oil | Natural Gas | Biodiesel |
|---|---|---|---|---|---|---|
| MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/kg | MJ/Nm3 | MJ/kg |
| 46.0 | 44.0 | 43.8 | 42.6 | 40.0 | 38.7 | 37.0 |

Table 3.69 – Fuel consumption in the Construction and Building Industry (GJ)

| Year | LPG | Gasoline | Kerosene | Gas Oil | Residual oil | Natural Gas | Biodiesel |
|---|---|---|---|---|---|---|---|
| **1990** | 226,695 | 27,676 | 6,859 | 5,864,312 | 668,507 | 0 | 0 |
| **1995** | 887,678 | 447,712 | 640 | 7,580,456 | 1,756,467 | 0 | 0 |
| **2000** | 545,639 | 72,532 | 130 | 7,548,443 | 1,467,006 | 8,455 | 0 |
| **2005** | 412,087 | 67,399 | 184 | 9,135,498 | 1,717,788 | 891,143 | 0 |
| **2010** | 484,791 | 91,783 | 126 | 5,583,764 | 1,072,740 | 1,202,436 | 353,676 |
| **2013** | 326,030 | 0 | 42 | 2,690,402 | 537,500 | 1,291,775 | 172,695 |
| **2014** | 317,888 | 0 | 42 | 2,682,988 | 401,792 | 1,076,367 | 165,666 |
| **2015** | 334,131 | 0 | 126 | 3,251,010 | 593,125 | 1,105,649 | 232,300 |

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

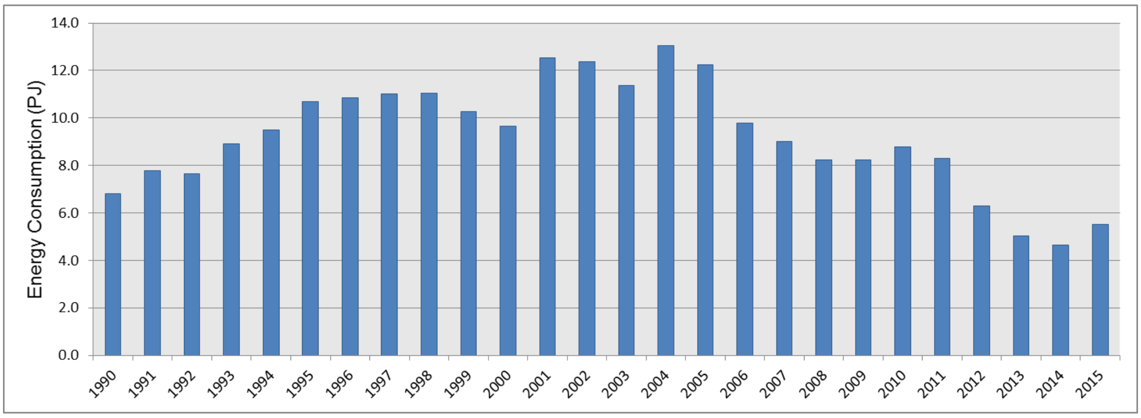
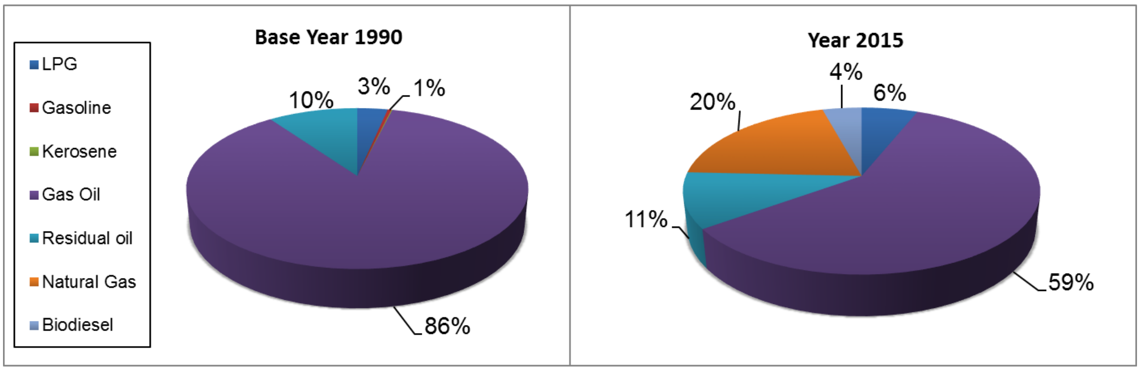



Figure 3.48 – Fuel consumption per fuel type in the Construction and Building Industry in 1990 and 2015



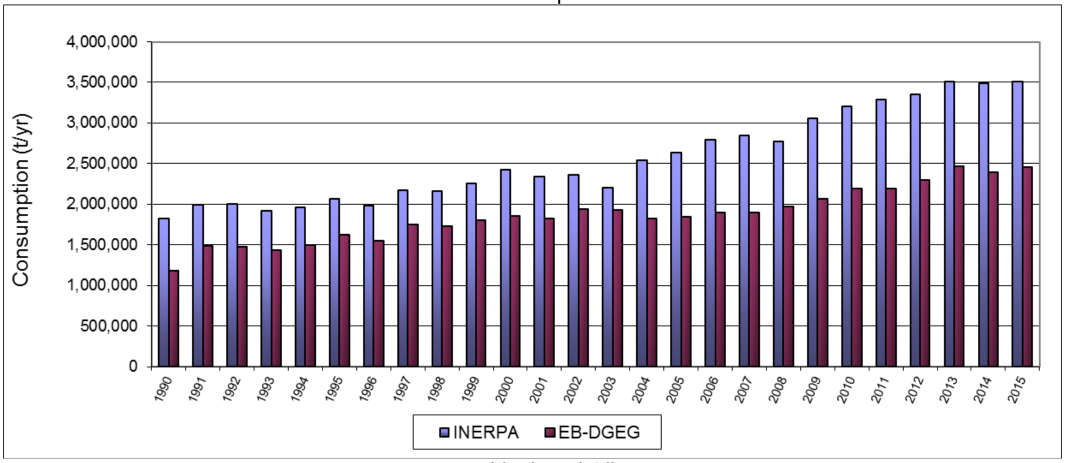

### *3.2.2.2.1.3 Comparison of LPS data vs. Energy Balance*

Total consumption in LPS per sector was compared with the correspondent value in the Energy Balance for the most important fuels, in order to verify the applicability of the methodology in use, which mixes a top-down approach (EB) with a bottom-up approach (LPS data). The following figures present the comparison done for sectors: (1) Paper Pulp; (2) Chemical Manufacturing; (3) Cement Industry and (4) Iron and Steel Plants.

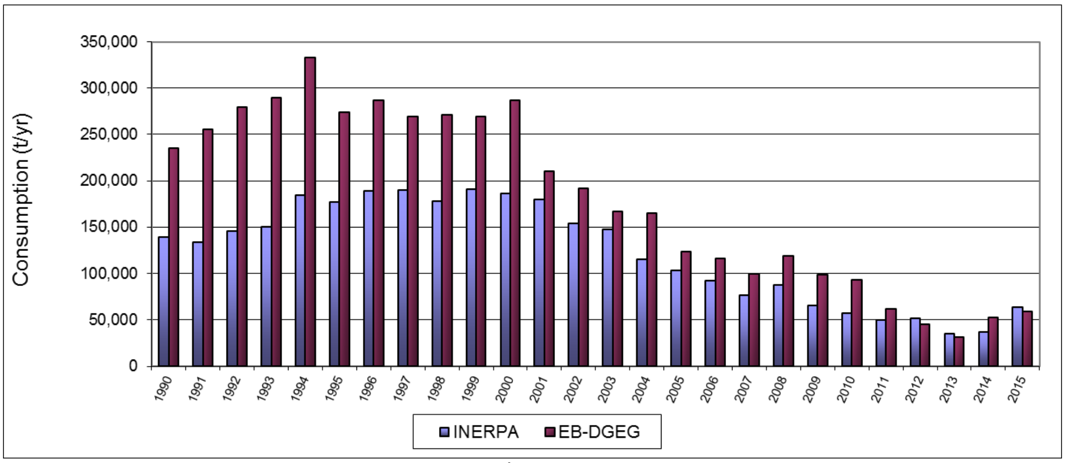
Before hand, it must be realized that to conclude for consistency between both distinct datasets, the comparison should result in higher or equal consumption in the EB than in the inventory, because apart from specific fuels (black liquor in the paper and pulp industry, coke oven gas and blast furnace gas in the iron industry, and coal, coke and tires in the cement industry) the universe considered by the Energy Balance covers more units than the set of LPS (E.g. the paper and paper pulp sector also includes consumption in the manufacturing of paper, for which there are several small units).

Figure 3.49 – Comparison of total LPS consumption in Paper Pulp units with the reported consumption in the EB for the sector "Paper pulp and paper production"

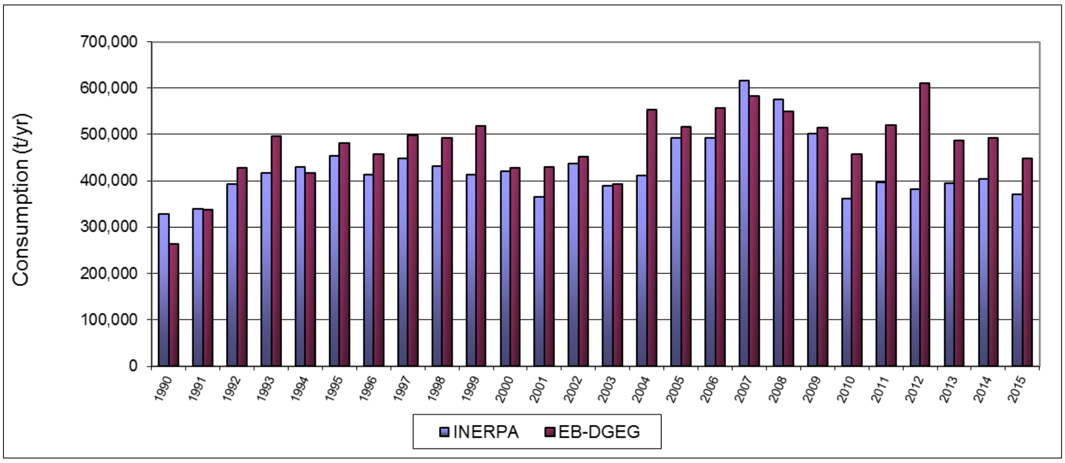
Black Liquor

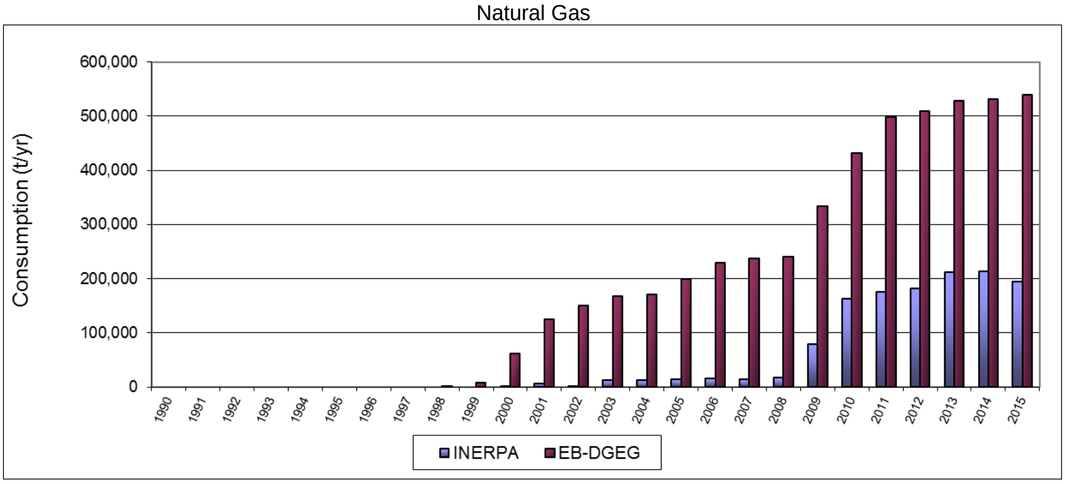



Residual Fuel Oil



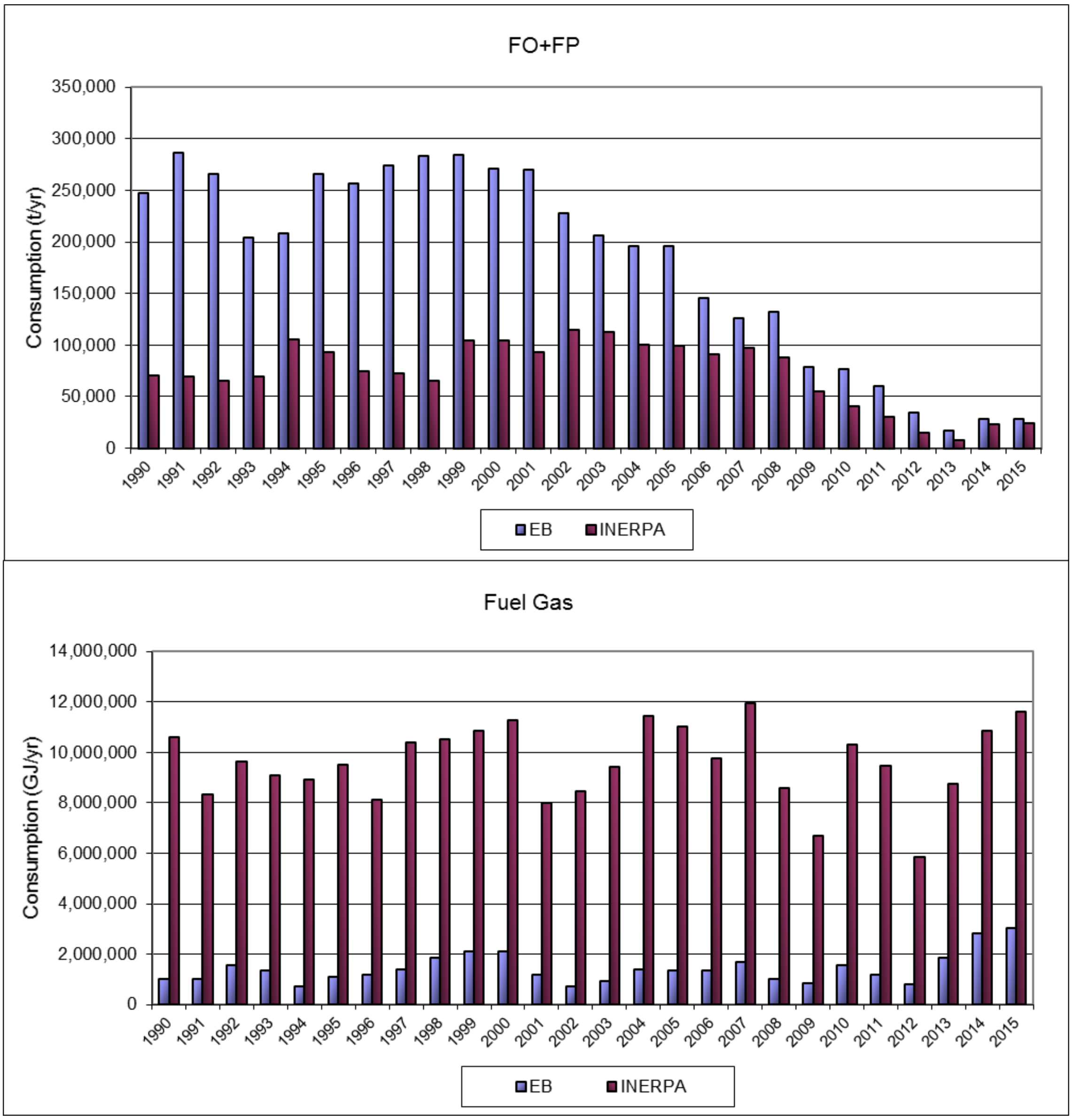

Biomass






The comparison made for the paper and pulp industry shows that differences occur, but are not substantial for the major fuels: black liquor and biomass. Part of the differences were analysed before (DGEG,2003) and could be explained by the use of different LHV in the Energy Balance, which occurs commonly for biomass fuels, given the variability in water content. It´s important to point out that in 2007 and 2008 the total Biomass considered in INERPA is slight superior to that reported in the EB. Careful estimations were made not double count the emissions.

Figure 3.50 – Comparison of total LPS consumption in Petrochemical units with the reported consumption in the EB for the sector “Chemical and Plastics”[1]



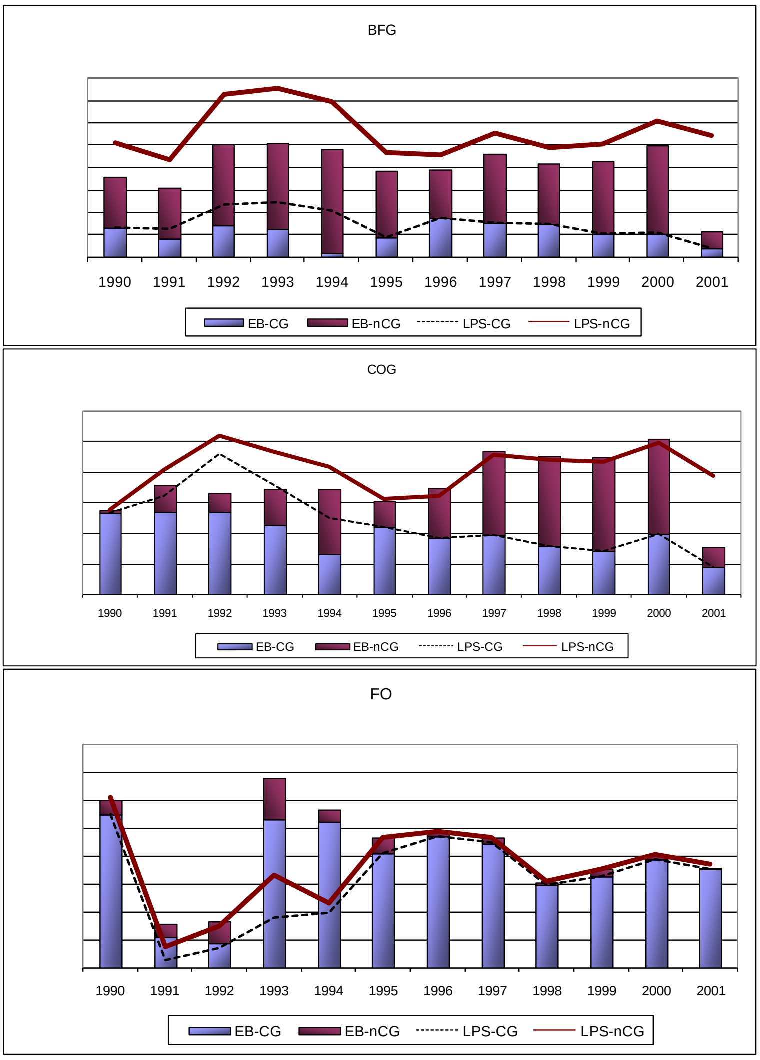

For the Petrochemical industry the comparison shows that the share of LPS in the consumption of residual fuel oil[2] is about 50 per cent until 2005. The two values show a tendency to converge in the later years. Also importante to note that in 2012 LPS values surpasse energy balance data by 8 %. Consumption of fuel gas as reported from the LPS data shows much higher values than in the EB. After consultation with DGEG it was realized that the EB does not covers consumption of fuel gas that is not traded or used in co-generation.

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

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

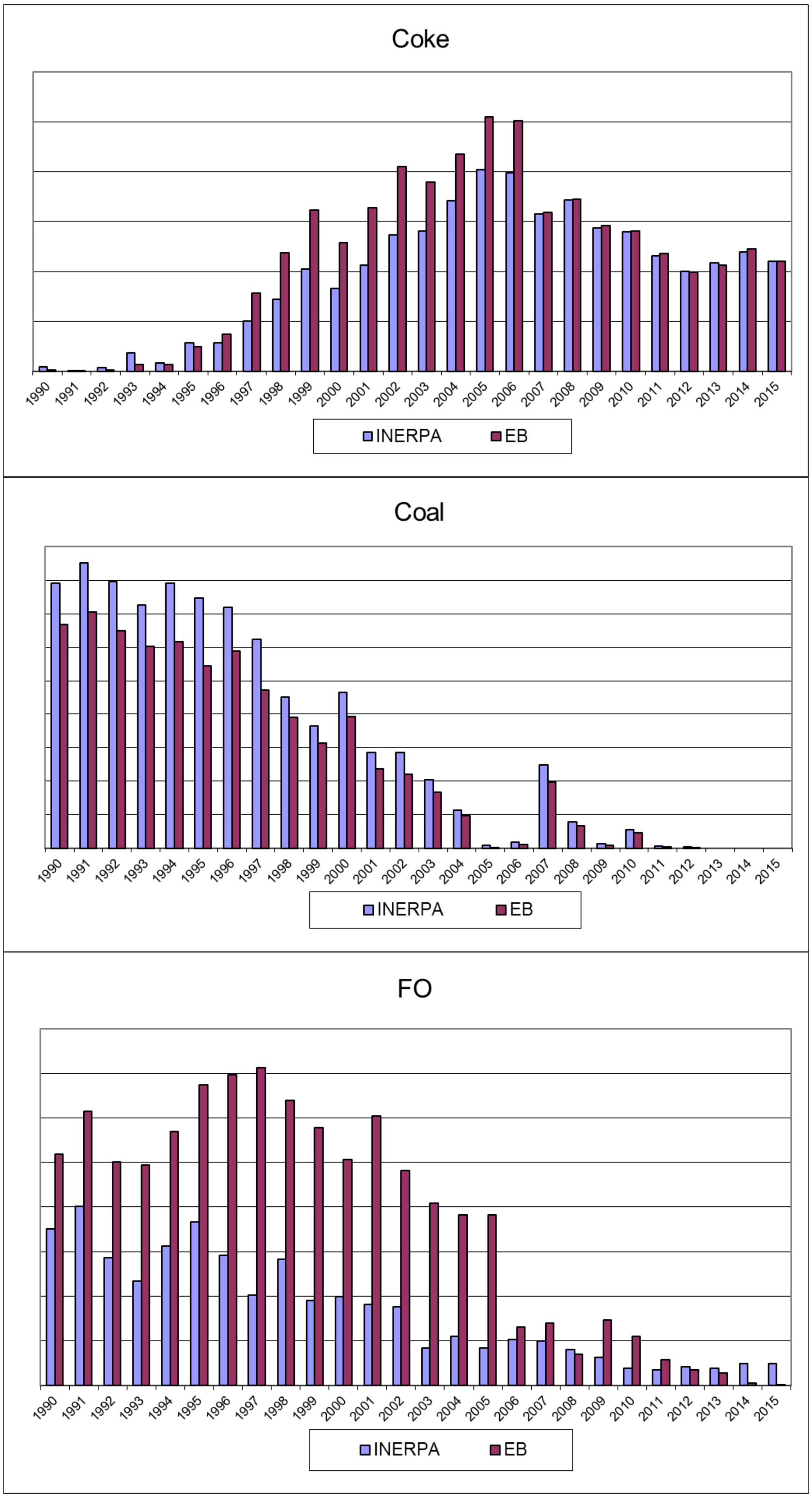
The match for the iron and steel industry show a good consistency, except for intermediate years, and for the slightly higher consumption of Blast Furnace Gas. This last difference may result from the use of different LHV values.

Figure 3.51 – Comparison of total LPS consumption in the only Integrated Iron and Steel Plant with the reported consumption in the EB for the sector “Iron and Steel”[1] (1990-2001)




[1] Units in the vertical axis are not indicated due to confidenciality issues.

Figure 3.52 – Comparison of total LPS consumption in Cement Plant with the reported consumption in the EB for the sector “Cement and Lime” (Due to confidentiality issues y axis values are not shown)



Concerning the cement industry, an acceptable coherence exists between both information sources, except for fuel oil consumption which can be explained by the inclusion of lime production in this energy balance category.

In conclusion, the analysis indicates that albeit certain differences, there is an acceptable agreement between both data sets. Nevertheless, efforts should be maintained in order for the streamlining of data between the inventory and the energy balance, and for the inclusion of all fuels, either traded or not, in the energy balance.

##### 3.2.2.2.2 Production Data

The production activity rates that were used to estimate of air emissions (production approach) are present in next tables. Although for some activities, such as cement production, emissions were estimated at plant level with plant specific emission factors. This information was considered confidential and may not be published in IIR.

Total production of paper pulp is reported in Table 3.71. Production data for Kraft paper pulp was obtained fro the following data sources:

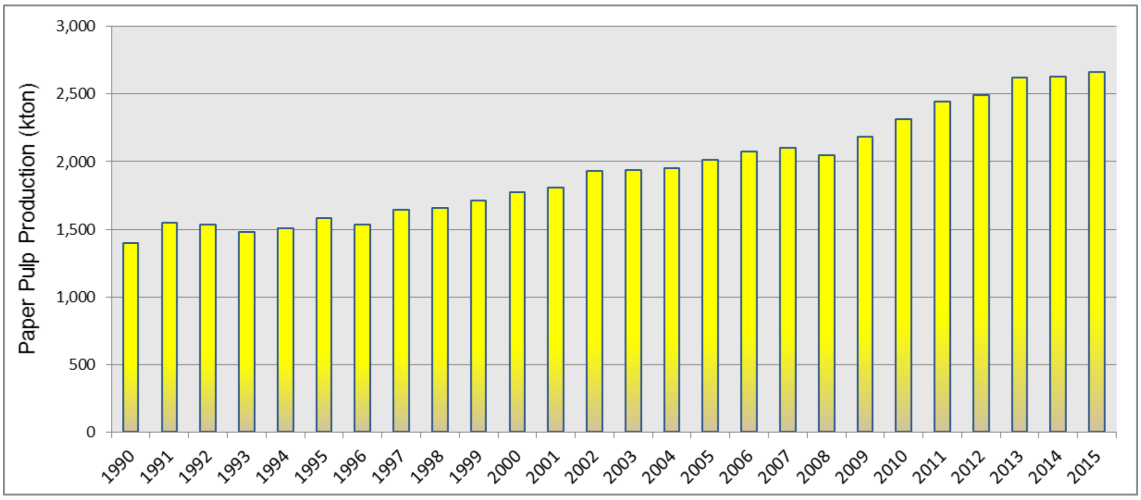
- LCP Directive – 1990 to 2000;
- CELPA – 2003 to 2009 (Kraft paper pulp);
- INE industrial production data – 2003 to 2009 ( Acid sulphite paper pulp);
- EU-ETS – 2010 onwards.

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

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

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

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



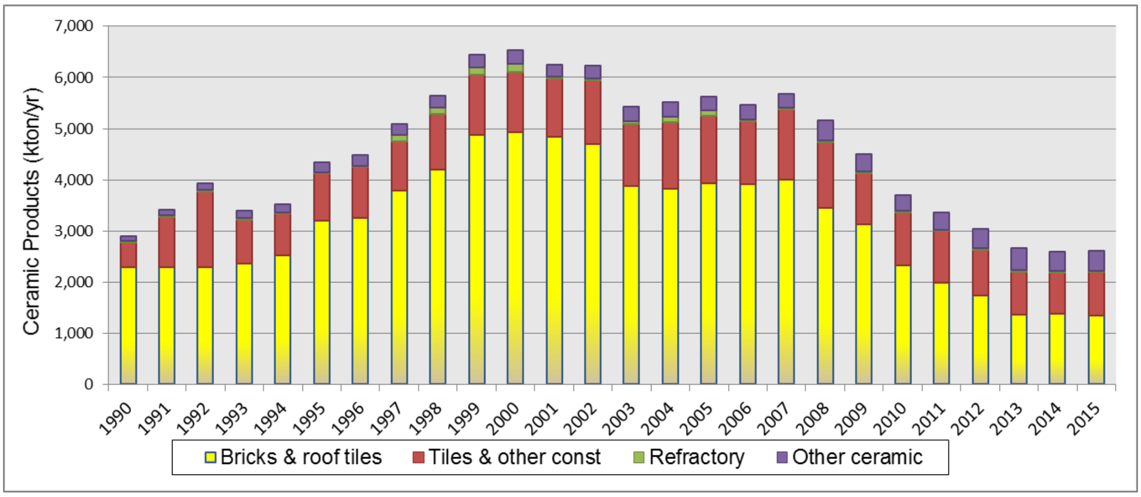
Clinker production values cannot be shown in this reported because of confidentiality issues.

Data on annual manufacturing of ceramic products is available from 1990 to 2015 from INE statistical database. The time series for total production is shown in Table 3.72 and Figure 3.54, according to type of ceramic.

Table 3.71 – Ceramic Production according to type of ceramic (kt)

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

Figure 3.54 – Ceramic Production according to type of ceramic




The production values for container glass and lead crystal glass are presented in Figure 3.55 and in Table 3.73, and they were established from the INE statistical databases and information received from Technology Centre for Ceramics and Glass (CTCV). More detailed discussion of the origins of data sources should be consulted in chapter 4.2.A.5. Because of confidentiality concerns the production of flat glass may not be published in IIR.

Figure 3.55 – Glass production by glass type (excluding flat glass production)

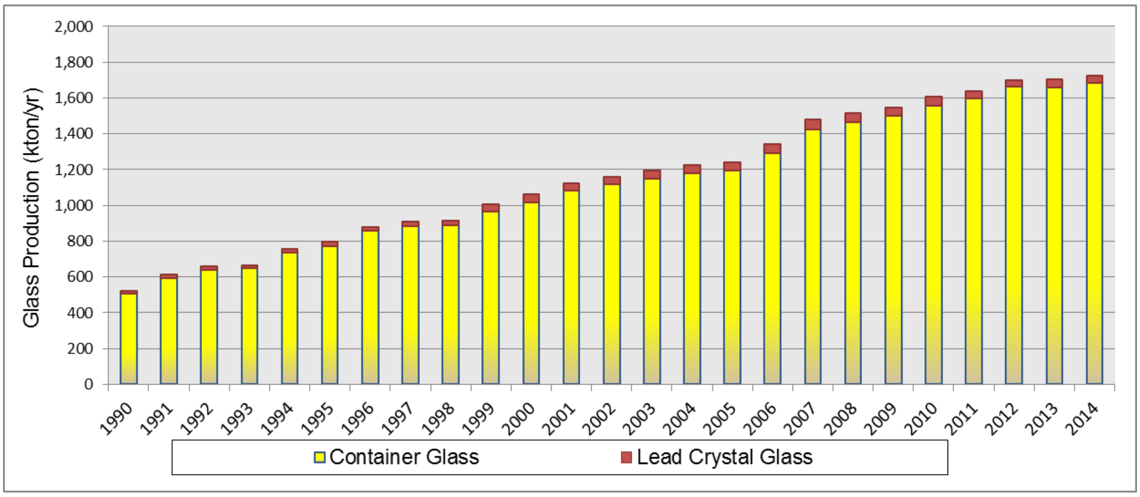



Table 3.72 – Glass production by glass type (kt/yr) excluding flat glass production

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

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

### 3.2.2.3 *Emission Factors*

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

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

- EMEP/CORINAIR Emission Inventory Guidebook - 3rd edition (EEA,2002);
- EMEP/EEA Air Pollutant Emission Inventory Guidebook – 2009 (EEA, 2009);
- EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA,2013)
- EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA,2016)
- IPCC Guidelines (IPCC,1997; IPCC, 2006);
- US EPA AP-42 and EIIP (USEPA,1996; USEPA,1996b; USEPA,1998; USEPA, 1998b; USEPA,1998c);
- Stockholm Convention Toolkit (UNEP) for Dioxins/Furans and PAH.

Also, some EF for Total Particulate Matter were established from monitoring data collected in industrial plants in Portugal.

The set of following tables present the emission factors that were used as default national emission factors in all cases where no specific emission factors may be used, either because there are 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 3.73 – Default emissions factors of ozone precursor gases for combustion equipments in the Manufacturing Industry

| Equipment | Fuel | | Code | $NO_x$ (g/GJ) | NMVOC (g/GJ) | CO (g/GJ) |
|---|---|---|---|---|---|---|
| Boilers | Steam Coal | S | 102 | 180 | 20 | 200 |
| | Brown Coal/Lignite | S | 105 | 180 | 20 | 200 |
| | Coke from Coal | S | 107 | 180 | 20 | 200 |
| | LPG | L | 303 | 74 | 23 | 29 |
| | Gasoline | L | 208 | 83 | 0.18 | 2.6 |
| | City Gas | G | 308 | 74 | 23 | 29 |
| | Coke Oven Gas | S | 304 | 74 | 23 | 29 |
| | Blast Furnace Gas | S | 305 | 74 | 23 | 29 |
| | Fuel Gas, Hydrogen | G | 399 | 74 | 23 | 29 |
| | Biomass Wood | B | 111 | 91 | 156 | 435 |
| | Kerosene | L | 206 | 83 | 0.18 | 2.6 |
| | Diesel Oil | L | 204 | 83 | 0.18 | 2.6 |
| | Residual Fuel Oil | L | 203 | 100 | 15 | 40 |
| | Natural Gas | G | 301 | 73 | 0.36 | 24 |
| | Biodiesel | B | 223 | 83 | 0.18 | 2.6 |
| Static Engines | Gasoline | L | 208 | 942 | 50 | 130 |
| | Gas Oil | L | 204 | 942 | 50 | 130 |
| | Biogas | B | 204 | 135 | 89 | 56 |
| | Biodiesel | B | 223 | 942 | 50 | 130 |

Table 3.74 – Default sulphur content of fuels for combustion equipments in the Manufacturing Industry

| Fuel | | NAPFUE | Unit | 1990 | 1995 | 2000 | 2001 | 2005 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| Steam Coal | S | 102 | % | 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 |
| Coke from Coal | S | 107 | % | 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 |
| Gasoline | L | 208 | % | 0.100 | 0.100 | 0.015 | 0.015 | 0.005 | 0.005 |
| City Gas | G | 308 | g S/Nm3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Coke Oven Gas | S | 304 | g S/Nm3 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 | 7.05 |
| Blast Furnace Gas | S | 305 | g S/Nm3 | 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 |
| Biomass Wood | B | 111 | % | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Biogas | B | 309 | % | 0.0016 | 0.0016 | 0.0016 | 0.0016 | 0.0016 | 0.0016 |
| Kerosene | L | 206 | % | 0.15 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Diesel Oil | L | 204 | % | 0.30 | 0.30 | 0.20 | 0.20 | 0.20 | 0.20 |
| Residual Fuel Oil | L | 203 | % | 2.84 | 2.26 | 2.26 | 2.26 | 1.00 | 1.00 |
| Natural Gas | G | 301 | g S/Nm3 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Biodiesel | B | 223 | % | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 3.75 – Default emissions factors of Particulate Matter for combustion equipments in the Manufacturing Industry

| Equipment | Fuel | | Code | TSP (g/GJ) | $PM_{10}$ (%TSP) | $PM_{2.5}$ (%TSP) | BC (%$PM_{2.5}$) |
|---|---|---|---|---|---|---|---|
| Boilers | Steam Coal | S | 102 | 80 | 20 | 20 | 6.4 |
| | Brown Coal/Lignite | S | 105 | 80 | 35 | 10 | 6.4 |
| | Coke from Coal | S | 107 | 80 | 20 | 20 | 6.4 |
| | LPG | L | 303 | 0.8 | 100 | 100 | 4 |
| | Gasoline | L | 208 | 9.5 | 0.0 | 0.0 | 0.0 |
| | City Gas | G | 308 | 0.8 | 100 | 100 | 4 |
| | Coke Oven Gas | S | 304 | 0.8 | 100 | 100 | 4 |
| | Blast Furnace Gas | S | 305 | 0.8 | 100 | 100 | 4 |
| | Fuel Gas, Hydrogen | G | 399 | 0.8 | 100 | 100 | 4 |
| | Biomass Wood | B | 111 | 93 | 90 | 76 | 28 |
| | Kerosene | L | 206 | 9.5 | 50 | 12 | 56 |
| | Diesel Oil | L | 204 | 9.5 | 50 | 12 | 56 |
| | Residual Fuel Oil [(a)] | L | 203 | Formula | 86 | 56 | 56 |
| | Natural Gas | G | 301 | 0.5 | 100 | 100 | 4 |
| | Biodiesel | B | 223 | 9.5 | 50 | 12 | 56 |
| Static Engines | Gasoline | L | 208 | 30 | 100 | 100 | 56 |
| | Gas Oil | L | 204 | 30 | 100 | 100 | 56 |
| | Biogas | B | 309 | 2 | 100 | 100 | 4 |
| | Biodiesel | B | 223 | 30 | 100 | 100 | 56 |

(a) Decreasing function of sulphur content (USEPA)

Table 3.76 – Default emissions factors of Heavy Metals for combustion equipments in Manufacturing Industry

| Equipment | Fuel | | NAPFUE | Cd | Hg | As | Cr | Cu | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | g/t | | | | | | | |
| Boilers | Steam Coal | S | 102 | 5.2E-02 | 1.7E-01 | 4.5E-01 | 3.6E-01 | 4.7E-01 | 7.2E-01 | 2.7E-01 | 1.3E+00 |
| | Brown Coal/Lignite | S | 105 | 4.0E-03 | 6.0E-02 | 4.0E-02 | 3.0E-02 | 2.0E-02 | 4.0E-02 | 0.0E+00 | 1.0E-01 |
| | Coke from Coal | S | 107 | 5.2E-02 | 1.7E-01 | 4.5E-01 | 3.6E-01 | 4.7E-01 | 7.2E-01 | 2.7E-01 | 1.3E+00 |
| | LPG | L | 303 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | City Gas a) | G | 308 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Coke Oven Gas a) | S | 304 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Blast Furnace Gas a) | S | 305 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Fuel Gas, Hydrogen | G | 399 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Biomass Wood | B | 111 | 1.5E-02 | 1.0E-01 | 4.3E-02 | 5.0E-04 | 1.0E-01 | 6.0E-03 | 2.3E-02 | 2.0E+00 |
| | Kerosene | L | 206 | 2.6E-01 | 0.0E+00 | 0.0E+00 | 5.0E-02 | 1.1E+00 | 2.9E-01 | 3.0E-02 | 3.0E+00 |
| | Diesel Oil | L | 204 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| | Residual Fuel Oil | L | 203 | 6.8E-01 | 5.1E-01 | 5.6E-01 | 1.7E+00 | 7.4E-01 | 2.7E+01 | 6.8E-02 | 1.9E+00 |
| | Natural Gas a) | G | 301 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Biodiesel | B | 223 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| Static Engines | Gasoline | L | 208 | 2.6E-01 | 0.0E+00 | 0.0E+00 | 5.0E-02 | 1.1E+00 | 2.9E-01 | 3.0E-02 | 3.0E+00 |
| | Gas Oil | L | 204 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| | Biogas | B | 309 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Biodiesel | B | 223 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |

a) g/km$^3$

Table 3.77 – Default emissions factors of Dioxins/Furans and PAH for combustion equipments in Manufacturing Industry

| Equipment | Fuel | | NAPFUE | DioxFur | PAH | PCB | HCB |
|---|---|---|---|---|---|---|---|
| | | | | microg TEQ/TJ | mg/GJ | µg/GJ | µg/GJ |
| Boilers | Steam Coal | S | 102 | 10.0 | 146 | 170 | 0.06 |
| | Brown Coal/Lignite | S | 105 | 10.0 | 146 | 170 | 0.06 |
| | Coke from Coal | S | 107 | 0.0 | 146 | 170 | 0.06 |
| | LPG | L | 303 | 0.0 | 5.8 | 0.0 | 0.0 |
| | City Gas | G | 308 | 0.5 | 5.8 | 0.0 | 0.0 |
| | Coke Oven Gas | S | 304 | 0.0 | 5.8 | 0.0 | 0.0 |
| | Blast Furnace Gas | S | 305 | 0.0 | 5.8 | 0.0 | 0.0 |
| | Fuel Gas, Hydrogen | G | 399 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Biomass Wood | B | 111 | 50.0 | 35 | 0.06 | 5 |
| | Kerosene | L | 206 | 0.0 | 20.1 | 0.0 | 0.0 |
| | Diesel Oil | L | 204 | 0.5 | 20.1 | 0.0 | 0.0 |
| | Residual Fuel Oil | L | 203 | 2.5 | 20.1 | 0.0 | 0.0 |
| | Natural Gas | G | 301 | 0.5 | 5.8 | 0.0 | 0.0 |
| | Biodiesel | B | 223 | 0.5 | 20.1 | 0.0 | 0.0 |
| Static Engines | Gasoline | L | 208 | 0.0 | 20.1 | 0.0 | 0.0 |
| | Gas Oil | L | 204 | 0.5 | 20.1 | 0.0 | 0.0 |
| | Biogas | B | 309 | 0.5 | 5.8 | 0.0 | 0.0 |
| | Biodiesel | B | 223 | 0.5 | 20.1 | 0.0 | 0.0 |

Source: UNEP (2005), EEA (EMEP/CORINAIR), US-EPA AP-42
Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.78 – Emission factors of Ozone precursor gases in the extractive industry

| Equipment | Fuel | | NAPFUE | $NO_x$ (g/GJ) | NMVOC (g/GJ) | CO (g/GJ) |
|---|---|---|---|---|---|---|
| Boilers | LPG | L | 303 | 65 | 2.5 | 29 |
| | Gasoline | L | 208 | 60 | 1 | 66 |
| | Kerosene | L | 206 | 60 | 1 | 66 |
| | Diesel Oil | L | 204 | 60 | 1 | 66 |
| | Residual Oil | L | 203 | 160 | 3 | 66 |
| | Natural Gas | G | 301 | 67 | 5 | 29 |
| | Lignite | S | 105 | 200 | 190 | 931 |
| | Biodiesel | B | 223 | 60 | 1 | 66 |
| Static Engines | Gasoline | L | 208 | 1300 | 100 | 66 |
| | Gas Oil | L | 204 | 1100 | 100 | 66 |
| | Biodiesel | B | 223 | 1100 | 100 | 66 |

Table 3.79 – Sulphur content in fuels used in the extractive industry (%S)

| Year | LPG | Lead Gasoline | Unlead Gasoline | Kerosene | Gas Oil | Residual Oil | Natural Gas | Lignite | Biodiesel |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 0.0016 | 0.10 | 0.100 | 0.15 | 0.30 | 2.84 | 0.0007 | 0.65 | 0 |
| 1995 | 0.0016 | 0.10 | 0.100 | 0.15 | 0.30 | 2.26 | 0.0007 | 0.65 | 0 |
| 2000 | 0.0016 | 0.10 | 0.050 | 0.15 | 0.25 | 2.26 | 0.0007 | 0.65 | 0 |
| 2005 | 0.0016 | 0.02 | 0.005 | 0.15 | 0.20 | 1.00 | 0.0007 | 0.65 | 0 |
| 2010 | 0.0016 | 0.02 | 0.005 | 0.15 | 0.10 | 1.00 | 0.0007 | 0.65 | 0 |
| 2013 | 0.0016 | 0.02 | 0.005 | 0.15 | 0.10 | 1.00 | 0.0007 | 0.65 | 0 |
| 2014 | 0.0016 | 0.02 | 0.005 | 0.15 | 0.10 | 1.00 | 0.0007 | 0.65 | 0 |
| 2015 | 0.0016 | 0.02 | 0.005 | 0.15 | 0.10 | 1.00 | 0.0007 | 0.65 | 0 |

Table 3.80 – Emission factors of Particulate Matter gases in the extractive industry

| Equipment | Fuel | | Code | TSP (g/GJ) | $PM_{10}$ (% TSP) | $PM_{2.5}$ (% TSP) | BC (% $PM_{2.5}$) |
|---|---|---|---|---|---|---|---|
| Boilers | LPG | L | 303 | 3 | 100 | 100 | 4 |
| | Gasoline | L | 208 | 43 | 100 | 100 | 56 |
| | Kerosene | L | 206 | 7 | 50 | 12 | 56 |
| | Gas Oil | L | 204 | 6.5-133.3 | 50 | 12 | 56 |
| | Residual Oil | L | 203 | 53.0-88.9 | 86 | 56 | 56 |
| | Natural Gas | G | 301 | 1 | 100 | 100 | 4 |
| | Lignite | S | 105 | 1 166 | 35 | 10 | 6.4 |
| | Biodiesel | B | 223 | 6.5-133.3 | 50 | 12 | 56 |
| Static Engines | Gasoline | L | 208 | 43 | 100 | 100 | 56 |
| | Gas Oil | L | 204 | 133 | 100 | 100 | 56 |
| | Biodiesel | B | 223 | 133 | 100 | 100 | 56 |

Table 3.81 – Emission factors of Heavy Metals in the extractive industry

| Equipment | Fuel | | Code | Cd | Hg | Ar | Cr | Cu | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | g/t | | | | | | | |
| Boilers | LPG | L | 303 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Gasoline | L | 208 | 2.6E-01 | 0.0E+00 | 0.0E+00 | 5.0E-02 | 1.1E+00 | 2.9E-01 | 3.0E-02 | 3.0E+00 |
| | Kerosene | L | 206 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| | Gas Oil | L | 204 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| | Residual Oil | L | 203 | 6.8E-01 | 5.1E-01 | 5.6E-01 | 1.7E+00 | 7.4E-01 | 2.7E+01 | 6.8E-02 | 1.9E+00 |
| | Natural Gas a) | G | 301 | 1.8E-05 | 4.2E-03 | 3.2E-06 | 2.2E-05 | 1.4E-05 | 3.4E-05 | 3.8E-07 | 4.6E-04 |
| | Lignite | S | 105 | 4.0E-03 | 6.0E-02 | 4.0E-02 | 3.0E-02 | 2.0E-02 | 4.0E-02 | 0.0E+00 | 1.0E-01 |
| | Biodiesel | B | 223 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| Static Engines | Gasoline | L | 208 | 2.6E-01 | 0.0E+00 | 0.0E+00 | 5.0E-02 | 1.1E+00 | 2.9E-01 | 3.0E-02 | 3.0E+00 |
| | Gas Oil | L | 204 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |
| | Biodiesel | B | 223 | 4.0E-02 | 1.7E-02 | 6.4E-02 | 2.6E-01 | 6.5E-01 | 6.0E-02 | 3.7E-02 | 4.3E-01 |

a) g/km$^3$

Table 3.82 – Emission factors of Dioxins/Furans and PAH in the extractive industry

| Equipment | Fuel | | Code | DioxFur | PAH | PCB | HCB |
|---|---|---|---|---|---|---|---|
| | | | | microg TEQ/TJ | mg/GJ | µg/GJ | µg/GJ |
| Boilers | LPG | L | 303 | 0.0 | 5.8 | 0.0 | 0.0 |
| | Gasoline | L | 208 | 0.0 | 20.1 | 0.0 | 0.0 |
| | Kerosene | L | 206 | 0.0 | 20.1 | 0.0 | 0.0 |
| | Gas Oil | L | 204 | 0.5 | 20.1 | 0.0 | 0.0 |
| | Residual Oil | L | 203 | 2.5 | 20.1 | 0.0 | 0.0 |
| | Natural Gas | G | 301 | 0.5 | 5.8 | 0.0 | 0.0 |
| | Lignite | S | 105 | 0.0 | 146 | 170 | 1 |
| | Biodiesel | B | 223 | 0.5 | 20.1 | 0.0 | 0.0 |
| Static Engines | Gasoline | L | 208 | 0.0 | 20.1 | 0.0 | 0.0 |
| | Gas Oil | L | 204 | 0.5 | 20.1 | 0.0 | 0.0 |
| | Biodiesel | B | 223 | 0.5 | 20.1 | 0.0 | 0.0 |

Source: UNEP (2005), EEA (EMEP/CORINAIR), US-EPA AP-42
Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.83 – Emission factors for Ozone Precursor gases in the building and construction industry

| Fuel | | NAPFUE | $NO_x$ | NMVOC | CO |
|---|---|---|---|---|---|
| | | | g/GJ | g/GJ | g/GJ |
| Residual Oil | L | 203 | 513 | 25 | 66 |
| Gas Oil | L | 204 | 513 | 25 | 66 |
| Kerosene | L | 206 | 513 | 25 | 66 |
| Motor Gasoline | L | 208 | 513 | 25 | 66 |
| LPG | L | 303 | 513 | 25 | 66 |
| Natural Gas | G | 301 | 74 | 23 | 29 |
| Biodiesel | B | 223 | 513 | 25 | 66 |

Table 3.84 – Sulphur content in the fuels used in the building and construction industry (%S)

| Year | LPG | Motor Gasoline | Kerosene | Gas Oil | Residual Oil | Natural Gas | Biodiesel |
|---|---|---|---|---|---|---|---|
| 1990 | 0.0016 | 0.10 | 0.15 | 0.30 | 2.84 | 0.0007 | 0.0 |
| 1991 | 0.0016 | 0.10 | 0.15 | 0.30 | 2.60 | 0.0007 | 0.0 |
| 1992 | 0.0016 | 0.10 | 0.15 | 0.30 | 2.60 | 0.0007 | 0.0 |
| 1993 | 0.0016 | 0.10 | 0.15 | 0.30 | 2.60 | 0.0007 | 0.0 |
| 1994 | 0.0016 | 0.10 | 0.15 | 0.30 | 2.60 | 0.0007 | 0.0 |
| 1995 | 0.0016 | 0.10 | 0.15 | 0.20 | 2.60 | 0.0007 | 0.0 |
| 1996 | 0.0016 | 0.10 | 0.15 | 0.05 | 2.60 | 0.0007 | 0.0 |
| 1997 | 0.0016 | 0.10 | 0.15 | 0.05 | 2.60 | 0.0007 | 0.0 |
| 1998 | 0.0016 | 0.10 | 0.15 | 0.05 | 2.60 | 0.0007 | 0.0 |
| 1999 | 0.0016 | 0.10 | 0.15 | 0.05 | 2.60 | 0.0007 | 0.0 |
| 2000 | 0.0016 | 0.10 | 0.15 | 0.05 | 2.60 | 0.0007 | 0.0 |
| 2001 | 0.0016 | 0.02 | 0.15 | 0.05 | 2.60 | 0.0007 | 0.0 |
| 2002 | 0.0016 | 0.02 | 0.15 | 0.04 | 2.60 | 0.0007 | 0.0 |
| 2003 | 0.0016 | 0.02 | 0.15 | 0.04 | 1.00 | 0.0007 | 0.0 |
| 2004 | 0.0016 | 0.02 | 0.15 | 0.04 | 1.00 | 0.0007 | 0.0 |
| 2005 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2006 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2007 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2008 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2009 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2010 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2011 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2012 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |
| 2013 | 0.0016 | 0.02 | 0.15 | 0.01 | 1.00 | 0.0007 | 0.0 |

Table 3.85 – Emission factors for Particulate Matter in the building and construction industry

| Fuel | | NAPFUE | TSP | $PM_{10}$ | $PM_{2.5}$ | BC |
|---|---|---|---|---|---|---|
| | | | g/GJ | % TSP | % TSP | % PM2.5 |
| Residual Oil | L | 203 | 20.0 | 100 | 100 | 56 |
| Gas Oil | L | 204 | 20.0 | 100 | 100 | 56 |
| Kerosene | L | 206 | 20.0 | 100 | 100 | 56 |
| Motor Gasoline | L | 208 | 20.0 | 100 | 100 | 56 |
| LPG | L | 303 | 20.0 | 100 | 100 | 56 |
| Natural Gas | G | 301 | 0.8 | 100 | 100 | 4 |
| Biodiesel | B | 223 | 20.0 | 100 | 100 | 56 |

Table 3.86 – Emission factors for Heavy Metals in the building and construction industry

| Fuel | | NAPFUE | Pb | Cd | Hg | As | Cr | Cu | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | g/ton | g/ton | g/ton | g/ton | g/ton | g/ton | g/ton | g/ton | g/ton |
| Residual Oil | L | 203 | 0.00320 | 0.00024 | 0.00480 | 0.00120 | 0.00800 | 0.00880 | 0.00032 | 0.00440 | 1.16000 |
| Gas Oil | L | 204 | 0.00341 | 0.00026 | 0.00511 | 0.00128 | 0.00852 | 0.00937 | 0.00034 | 0.00469 | 1.23540 |
| Kerosene | L | 206 | 0.00350 | 0.00026 | 0.00525 | 0.00131 | 0.00875 | 0.00963 | 0.00035 | 0.00481 | 1.26875 |
| Motor Gasoline | L | 208 | 0.00352 | 0.00026 | 0.00528 | 0.00132 | 0.00880 | 0.00968 | 0.00035 | 0.00484 | 1.27600 |
| LPG | L | 303 | 0.00368 | 0.00028 | 0.00552 | 0.00138 | 0.00920 | 0.01012 | 0.00037 | 0.00506 | 1.33400 |
| Natural Gas | G | 301 | 0.00051 | 0.00004 | 0.02488 | 0.00461 | 0.00060 | 0.00012 | 0.00060 | 0.00267 | 0.03363 |
| Biodiesel | B | 223 | 0.00296 | 0.00022 | 0.00444 | 0.00111 | 0.00740 | 0.00814 | 0.00030 | 0.00407 | 1.07300 |

a) g/km$^3$

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

| Equipment | Fuel | | NAPFUE | $NO_x$ | %S | | NMVOC | CO |
|---|---|---|---|---|---|---|---|---|
| | | | | g/GJ | % | Units | g/GJ | g/GJ |
| Coquerie | Coke oven gas | S | 304 | 120 | 7.05 | g S/Nm3 | 2.5 | 17 |
| Sintering | Coke oven gas | S | 304 | PA | 7.05 | g S/Nm3 | PA | PA |
| Blast Furnace Cowpers | Coke oven gas | S | 304 | 120 | 7.05 | g S/Nm3 | 2.5 | 17 |
| | Blast furnace gas | S | 305 | 70 | 0.045 | g S/Nm3 | 2.5 | 17 |
| Rolling mills | Residual oil | L | 203 | 190 | 3.5 | % S | 3 | 15 |
| | Coke oven gas | S | 304 | 120 | 7.05 | g S/Nm3 | 2.5 | 17 |
| Thermo Electric Power plant | Coke oven gas | S | 304 | 120 | 7.05 | g S/Nm3 | 2.5 | 17 |
| | Blast furnace gas | S | 305 | 70 | 0.045 | g S/Nm3 | 2.5 | 17 |
| | Residual oil (3.5%) | L | 203 | 190 | 3.5 | % S | 3 | 15 |
| | Residual oil (1%) | L | 203 | 190 | 1 | % S | 3 | 15 |
| | Tar | L | 299 | 300 | 0.6 | % S | 3 | 15 |
| Heat power plant | LPG | L | 303 | 160 | 0.005 | % S | 4 | 17 |
| | Tar | L | 299 | 300 | 0.6 | % S | 3 | 15 |
| | Waste Oils | O | 115 | 190 | 0 | % S | 3 | 15 |
| Lime kiln | Residual Oil | L | 203 | PA | 3.5 | % S | 3 | PA |

Note: PA = Process Approach

Table 3.88 – Emission factors (Production Approach) for use in LPS units in the Iron and Steel Industry: Ozone Precursors from combustion

| Equipment | Fuel | | NAPFUE | $NO_x$ (kg/t) | $SO_x$ (kg/t) | NMVOC (kg/t) | CO (kg/t) |
|---|---|---|---|---|---|---|---|
| Sintering | Coke oven gas | S | 304 | 0.5 | 1.0 | 0.10 | 30 |
| Lime kiln | Residual Oil | L | 203 | 0.1 | 0.42 | - | 2 |

Table 3.89 – Emission factors (Energy Approach) for use in LPS units in the Iron and Steel Industry: Particulate Matter from combustion

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

Note: PA = Process Approach

In the 2012 inventory, for the paper and pulp industrial sector, efforts were made to improve the emission estimation by reviewing and update emission factors when possible. To this end new EF data sources were used (EEA, 2009) as well as an in depth revision of the plant specific emission factors. The EF used for this industrial sector (LPS estimation only) can be found in the next tables.

Table 3.90 – Emission factors used in LPS units in the Paper Pulp Industry: Ozone precursors from combustion – Energy Approach – International EF sources

| Equipment | Fuel | NAPFUE | | NOx | NMVOC | CO |
|---|---|---|---|---|---|---|
| | | | | EF (g/GJ) | EF (g/GJ) | EF (g/GJ) |
| Auxiliary Boilers | Residual Oil | L | 203 | 170 - 210 | 2.3 | 15.1 |
| | Natural Gas | G | 301 | 70.0 | 2.0 | 20.0 |
| Biomass Boilers | Wood Waste | B | 111 | 153.5 | 7.3 | 150 |
| | Residual Oil | L | 203 | - | 2.3 | 15.1 |
| | Natural Gas | G | 301 | - | 1.5 | - |
| | LPG | L | 303 | - | 1.5 | - |
| Recovery Boilers | Residual Oil | L | 203 | - | - | 15.1 |
| | Natural Gas | G | 301 | - | - | - |
| | Gas Oil | L | 204 | - | - | - |
| | Bisulfite Liquor | B | 215 | - | - | 150.0 |
| | Black Liquor | B | 215 | - | - | - |
| | Methanol | B | 111 | - | - | - |
| Flare | LPG | L | 303 | 90 | 3.0 | 30.0 |
| Lime Kiln | Gasified Biomass | B | 111 | - | - | - |
| | Residual Oil | L | 203 | - | - | - |
| | Natural Gas | G | 301 | - | - | - |
| | Gas Oil | L | 204 | - | - | - |
| | NCG | B | 111 | - | - | - |
| | Tall-oil | B | 111 | - | - | - |
| Static Engine | Gas Oil | L | 204 | 1 450.0 | 37.1 | 385.0 |
| Gas Turbine | Natural Gas | G | 301 | 153.0 | 1.0 | 39.2 |

Table 3.91 – Emission factors used in LPS units in the Paper Pulp Industry: Ozone precursors from combustion – Production Approach – International EF sources

| Equipment | NOx | NMVOC |
|---|---|---|
| | EF (kg/t pulp) | EF (kg/t pulp) |
| Recovery Boilers | 2.0 (i) | 0.2 - 0.75 |
| Lime Kiln | - | 0.096 |

(i) Only for Bisulfite.

Table 3.92 – Emission factors used in LPS units in the Paper Pulp Industry: Ozone precursors from combustion – Production Approach and Energy Approach – Plant specific EF

| Equipment | Approach | NOx | | CO | |
|---|---|---|---|---|---|
| | | EF | Unit | EF | Unit |
| Auxiliary Boilers | Energy | 91.2 | g/GJ | 86.7 | g/GJ |
| Biomass Boilers | Energy | 63.17 - 180.5 | g/GJ | 53.73 – 1 294.0 | g/GJ |
| Recovery Boilers | Production | 0.33 - 1.17 | kg/t pulp | 0.05 - 2.59 | kg/t pulp |
| Lime Kiln | Production | 0.12 - 0.22 | kg/t pulp | 0.01 - 0.07 | kg/t pulp |

Table 3.93 – Emission factors used in LPS units in the Paper Pulp Industry: Sulphur Oxides ($SO_x$) emissions – Mass Balance – International EF sources

| Equipment | Fuel | NAPFUE | | SOx |
|---|---|---|---|---|
| | | | | % |
| Auxiliary Boilers | Residual Oil | L | 203 | 0.9 - 3.5 |
| | Natural Gas | G | 301 | 0 |
| Biomass Boilers | Wood Waste | B | 111 | 0.03 |
| | Residual Oil | L | 203 | 0.9 - 3.5 |
| | Natural Gas | G | 301 | 0 |
| | LPG | L | 303 | 0 |
| Recovery Boilers | Residual Oil | L | 203 | - |
| | Natural Gas | G | 301 | - |
| | Gas Oil | L | 204 | - |
| | Bisulfite Liquor | B | 215 | - |
| | Black Liquor | B | 215 | - |
| | Methanol | B | 111 | - |
| Flare | LPG | L | 303 | 0 |
| Lime Kiln | Gasified Biomass | B | 111 | - |
| | Residual Oil | L | 203 | - |
| | Natural Gas | G | 301 | - |
| | Gas Oil | L | 204 | - |
| | NCG | B | 111 | - |
| | Tall-oil | B | 111 | - |
| Static Engine | Gas Oil | L | 204 | 0.3 |
| Gas Turbine | Natural Gas | G | 301 | 0 |

Table 3.94 – Emission factors used in LPS units in the Paper Pulp Industry: Sulphur Oxides (SOx) emissions – Production Approach – International EF sources

| Equipment | SOx |
|---|---|
| | EF (kg/t pulp) |
| Recovery Boilers | 3.5 - 4.5 |
| Lime Kiln | 0.15 |

Table 3.95 – Emission factors used in LPS units in the Paper Pulp Industry: Particulate Matter – Energy Approach – International EF sources

| Equipment | Fuel | NAPFUE | | TSP |
|---|---|---|---|---|
| | | | | g/GJ |
| Auxiliary Boilers | Residual Oil | L | 203 | 20.0 |
| | Natural Gas | G | 301 | 0.5 |
| Biomass Boilers | Wood Waste | B | 111 | 35.0 |
| | Residual Oil | L | 203 | - |
| | Natural Gas | G | 301 | - |
| | LPG | L | 303 | - |
| Recovery Boilers | Residual Oil | L | 203 | - |
| | Natural Gas | G | 301 | - |
| | Gas Oil | L | 204 | - |
| | Bisulfite Liquor | B | 215 | - |
| | Black Liquor | B | 215 | - |
| | Methanol | B | 111 | - |
| Flare | LPG | L | 303 | 0.5 |
| Lime Kiln | Gasified Biomass | B | 111 | - |
| | Residual Oil | L | 203 | - |
| | Natural Gas | G | 301 | - |
| | Gas Oil | L | 204 | - |
| | NCG | B | 111 | - |
| | Tall-oil | B | 111 | - |
| Static Engine | Gas Oil | L | 204 | 28.1 |
| Gas Turbine | Natural Gas | G | 301 | 0.91 |

Table 3.96 – Emission factors used in LPS units in the Paper Pulp Industry: Particulate Matter – Production Approach – International EF sources

| Equipment | NOx |
|---|---|
| | EF (kg/t pulp) |
| Recovery Boilers | 1.0 (i) |

(i) Only for Bisulfite.

Table 3.97 – Emission factors used in LPS units in the Paper Pulp Industry: Particulate Matter – Production Approach and Energy Approach – Plant specific EF

| Equipment | Approach | NOx | |
|---|---|---|---|
| | | EF | Unit |
| Biomass Boilers | Energy | 10.1 - 405.8 | g/GJ |
| Recovery Boilers | Production | 0.1 - 1.48 | kg/t pulp |
| Lime Kiln | Production | 0.01 - 0.04 | kg/t pulp |

Table 3.98 – Emission factors used in LPS units in the Paper Pulp Industry: Particulate Matter – Fraction of PM10, PM2.5 and BC – International EF sources

| Equipment | Fuel | NAPFUE | | PM10 | PM2.5 | BC |
|---|---|---|---|---|---|---|
| | | | | % | % | % PM2.5 |
| Auxiliary Boilers | Residual Oil | L | 203 | 75.0 | 45.0 | 56.0 |
| | Natural Gas | G | 301 | 100.0 | 100.0 | 4.0 |
| Biomass Boilers | Wood Waste | B | 111 | 71.4 | 34.3 | 28.0 |
| | Residual Oil | L | 203 | 75.0 | 45.0 | 56.0 |
| | Natural Gas | G | 301 | 100.0 | 100.0 | 4.0 |
| | LPG | L | 303 | 100.0 | 100.0 | 4.0 |
| Recovery Boilers | Residual Oil | L | 203 | 93.5 | 67.0 | 56.0 |
| | Natural Gas | G | 301 | 93.5 | 53.8 | 4.0 |
| | Gas Oil | L | 204 | 93.5 | 53.8 | 56.0 |
| | Bisulfite Liquor | B | 215 | 93.5 | 67.0 | 28.0 |
| | Black Liquor | B | 215 | 93.5 | 53.8 | 28.0 |
| | Methanol | B | 111 | 93.5 | 53.8 | 28.0 |
| Flare | LPG | L | 303 | 100.0 | 100.0 | 4.0 |
| Lime Kiln | Gasified Biomass | B | 111 | 98.3 | 96.0 | 28.0 |
| | Residual Oil | L | 203 | 98.3 | 96.0 | 56.0 |
| | Natural Gas | G | 301 | 98.3 | 96.0 | 4.0 |
| | Gas Oil | L | 204 | 88.5 | 83.0 | 56.0 |
| | NCG | B | 111 | 88.5 | 83.0 | 28.0 |
| | Tall-oil | B | 111 | 98.3 | 96.0 | 28.0 |
| Static Engine | Gas Oil | L | 204 | 79.7 | 77.2 | 56.0 |
| Gas Turbine | Natural Gas | G | 301 | 100.0 | 100.0 | 4.0 |

Table 3.99 – Emission factors used in LPS units in the Paper Pulp Industry: Heavy Metals – International EF sources

| Fuel | Pb | Cd | Hg | As | Cr | Cu | Ni | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|
| | g/t | | | | | | | | |
| Wood | 5.00E-02 | 1.47E-02 | 1.00E-01 | 4.27E-02 | 5.00E-04 | 1.00E-01 | 6.03E-03 | 2.30E-02 | 2.00E+00 |
| Gasified Biomass | 5.00E-02 | 1.47E-02 | 1.00E-01 | 4.27E-02 | 5.00E-04 | 1.00E-01 | 6.03E-03 | 2.30E-02 | 2.00E+00 |
| Residual Oil | 9.31E-01 | 6.84E-01 | 5.07E-01 | 5.56E-01 | 1.70E+00 | 7.41E-01 | 2.69E+01 | 6.84E-02 | 1.90E+00 |
| Natural Gas | 8.00E-03 | 1.76E-02 | 4.16E-03 | 3.20E-03 | 2.24E-02 | 1.36E-02 | 3.36E-02 | 3.84E-04 | 4.64E-01 |
| Gas Oil | 5.93E-01 | 3.96E-02 | 1.69E-02 | 6.38E-02 | 2.61E-01 | 6.50E-01 | 6.00E-02 | 3.66E-02 | 4.33E-01 |
| Bisulfite Liquor | 5.00E-02 | 1.47E-02 | 1.00E-01 | 4.27E-02 | 5.00E-04 | 1.00E-01 | 6.03E-03 | 2.30E-02 | 2.00E+00 |
| Black Liquor | 5.00E-02 | 1.47E-02 | 1.00E-01 | 4.27E-02 | 5.00E-04 | 1.00E-01 | 6.03E-03 | 2.30E-02 | 2.00E+00 |
| Methanol | 9.52E-03 | 2.09E-02 | 4.95E-03 | 3.81E-03 | 2.67E-02 | 1.62E-02 | 4.00E-02 | 4.57E-04 | 5.52E-01 |
| NCG | 8.00E-03 | 1.76E-02 | 4.16E-03 | 3.20E-03 | 2.24E-02 | 1.36E-02 | 3.36E-02 | 3.84E-04 | 4.64E-01 |
| LPG | 9.52E-03 | 2.09E-02 | 4.95E-03 | 3.81E-03 | 2.67E-02 | 1.62E-02 | 4.00E-02 | 4.57E-04 | 5.52E-01 |
| Tall-oil | 5.00E-02 | 1.47E-02 | 1.00E-01 | 4.27E-02 | 5.00E-04 | 1.00E-01 | 6.03E-03 | 2.30E-02 | 2.00E+00 |

(i) Except for Natural Gas ana NCG which is g/km3

Table 3.100 – Emission factors used in LPS units in the Paper Pulp Industry: Dioxins/Furans and PAH – International EF sources

| Equipment | Fuel | NAPFUE | | DioxFur ng TEQ/GJ | PAH mg/GJ |
|---|---|---|---|---|---|
| Auxiliary Boilers | Residual Oil | L | 203 | 2.5 | 0.007 |
| | Natural Gas | G | 301 | 2.0 | 0.003 |
| Biomass Boilers | Wood Waste | B | 111 | 50.0 | 1.53 |
| | Residual Oil | L | 203 | 2.5 | 0.007 |
| | Natural Gas | G | 301 | 0.5 | 0.003 |
| | LPG | L | 303 | 0.5 | 0.003 |
| Recovery Boilers | Residual Oil | L | 203 | 2.5 | 0.007 |
| | Natural Gas | G | 301 | 0.5 | 0.003 |
| | Gas Oil | L | 204 | 0 | 0.91 |
| | Bisulfite Liquor | B | 215 | 0 | 0 |
| | Black Liquor | B | 215 | 0 | 0 |
| | Methanol | B | 111 | 0 | 0 |
| Flare | LPG | L | 303 | 2 | 0.003 |
| Lime Kiln | Gasified Biomass | B | 111 | 50 | 1.53 |
| | Residual Oil | L | 203 | 2.5 | 0.007 |
| | Natural Gas | G | 301 | 0.5 | 0.003 |
| | Gas Oil | L | 204 | 0 | 0.91 |
| | NCG | B | 111 | 0 | 0 |
| | Tall-oil | B | 111 | 0 | 0 |
| Static Engine | Gas Oil | L | 204 | 0 | 0.90 |
| Gas Turbine | Natural Gas | G | 301 | 0.5 | 0.003 |

For the cement source, sector emissions were estimated using either activity data as energy consumption (energy approach) or either cement produced (production approach), although both represent similar emissions in cement kiln. Emission factors will not be presented in this report because of confidentiality issues (please see Activity Date chapter for more explanations).Most emission factors result from plant specific emission factors developed from monitoring at each installation.

Table 3.101 – Emission Factors for ceramic production using the Production Approach: Indirect Ozone Precursor gases and $SO_x$

| | Fuel | | NAPFUE | $NO_x$ (kg/t) | SOx (kg/t) | NMVOC (kg/t) |
|---|---|---|---|---|---|---|
| Bricks and roof tiles [(a)] | LPG | L | 303 | 0.45 | 1.50 | 0.03 |
| | Residual Oil | L | 203 | 0.45 | 1.13 | 0.03 |
| | Natural Gas | G | 301 | 0.45 | 1.50 | 0.03 |
| | Biomass Wood | B | 111 | 0.47 | 0.39 | 0.09 |
| Tiles & other construction materials [(a)] | LPG | L | 303 | 0.27 | 0.01 | 0.22 |
| | Residual Oil | L | 203 | 0.27 | 62.48 | 0.22 |
| | Natural Gas | G | 301 | 0.27 | 0.05 | 0.22 |
| | Biomass Wood | B | 111 | 0.27 | 0.14 | 0.22 |
| Refractory [(b)] | LPG | L | 303 | 0.87 | 3.80 | 0.03 |
| | Residual Oil | L | 203 | 0.87 | 3.80 | 0.03 |
| | Natural Gas | G | 301 | 0.87 | 3.80 | 0.03 |
| | Biomass Wood | B | 111 | 0.87 | 3.80 | 0.09 |
| Other Ceramic [(c)] | LPG | L | 303 | 0.27 | 0.01 | 0.22 |
| | Residual Oil | L | 203 | 0.27 | 62.48 | 0.22 |
| | Natural Gas | G | 301 | 0.27 | 0.05 | 0.22 |
| | Biomass Wood | B | 111 | 0.27 | 0.14 | 0.22 |

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

Table 3.102 – Emission Factors for ceramic production using the Production Approach: Particulate Matter

| | Fuel | | Code | TSP (kg/t) | $PM_{10}$ (% TSP) | $PM_{2.5}$ (% TSP) | BC (%$PM_{2.5}$) |
|---|---|---|---|---|---|---|---|
| Bricks and roof tiles [(a)] | LPG | L | 303 | 0.14 | 100 | 100 | 4.0 |
| | Residual Oil | L | 203 | 0.14 | 88 | 88 | 56.0 |
| | Natural Gas | G | 301 | 0.14 | 100 | 100 | 4.0 |
| | Biomass Wood | B | 111 | 0.13 | 62 | 62 | 28.0 |
| Tiles & other construction materials [(a)] | LPG | L | 303 | 11 | 27 | 27 | 4.0 |
| | Residual Oil | L | 203 | 11 | 27 | 27 | 56.0 |
| | Natural Gas | G | 301 | 11 | 27 | 27 | 4.0 |
| | Biomass Wood | B | 111 | 11 | 27 | 27 | 28.0 |
| Refractory [(b)] | LPG | L | 303 | 68 | 25 | 25 | 4.0 |
| | Residual Oil | L | 203 | 68 | 25 | 25 | 56.0 |
| | Natural Gas | G | 301 | 68 | 25 | 25 | 4.0 |
| | Biomass Wood | B | 111 | 68 | 25 | 25 | 28.0 |
| Other Ceramic [(c)] | LPG | L | 303 | 11 | 27 | 27 | 4.0 |
| | Residual Oil | L | 203 | 11 | 27 | 27 | 56.0 |
| | Natural Gas | G | 301 | 11 | 27 | 27 | 4.0 |
| | Biomass Wood | B | 111 | 11 | 27 | 27 | 28.0 |

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

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.

#### 3.2.2.4 *Recalculations*

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

#### 3.2.2.5 *Further Improvements*

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

### 3.2.3 Transport (NFR 1.A.3)

#### 3.2.3.1 *Civil Aviation (NFR 1.A.3.a)*

##### 3.2.3.1.1 Overview

Emissions from aviation come from the combustion of jet fuel and aviation gasoline. Emissions from combustion in aircraft mobile activities comprehend all air emissions associated with fuel combustion in airplanes, either realized in passenger or freight planes, and either realized during flight or in land activities: idle and taxi. Aircraft operations are divided into

- Landing/Take-off cycle and;
- Cruise.

Emissions from military aircraft are included in sector 1.A.5 Other Mobile Sources.

The method to estimate emissions from jet fuel consumption is a Tier 3 method according with EMEP/CORINAIR Guidebook. This method uses data from individual flights with information on the origin and destination, aircraft type, engines type, and date of the flight. This method provides a good accurate separation between domestic and international flights.

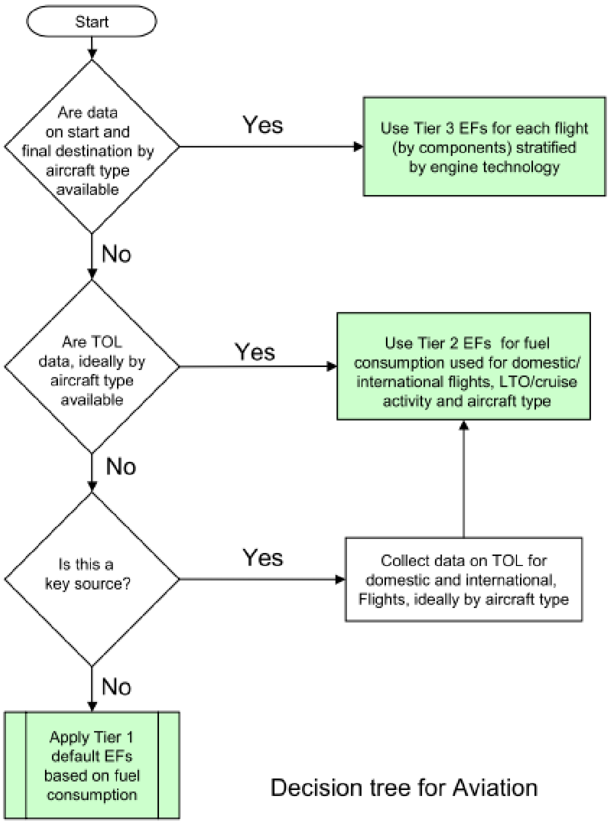



Figure 3.56 – Decision tree for emissions from aviation (EMEP/EEA, 2013)

The method to estimate emissions from aviation gasoline is a Tier 1 method which is based primarily in energy statistics.

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

The IIR covers LTO emissions from either domestic or international flights. Cruise emissions, realized above 3000 ft, although excluded from the IIR coverage are reported as memo item. The LTO emissions from Madeira and Azores islands are also excluded from the IIR coverage.

The model developed by the inventory team at the Portuguese environmental Agency, provides the necessary disaggregation to fulfill the report needs of the IIR.

### 3.2.3.1.2 Methodology

The methodology that is used in the inventory is coherent with good practices from IPCC and is equivalent to the Tier 2b for jet fuel and Tier 1 for aviation gasoline. Emissions are calculated separately for:

- Landing and Take-off emissions (LTO). Emissions from activities realized near airport in the ground and on flight under an altitude of 3000 feet (914 m): idle, taxi-in, taxi-out, take-off, climbing and descending;

- Cruise emissions. All emissions realized above 3000 feet, including ascend and descend between cruise altitude and 3000 feet
- Fuel type: jet fuel and aviation gasoline. Jet fuel is used mostly in large commercial aircraft. Aviation gasoline is used in piston engine aircrafts;
- Origin and destination of the flight;
- Movement type: arrival and departure
- Aircraft type.

###### *3.2.3.1.2.1 Landing/Take-off*

The general approach to estimate emissions during Landing/Take-off is:

$$\text{Emission}_{\text{LTO}(p,d,a,s,y)} = \text{Emission}_{\text{Arrival}(p,d,a,s,y)} + \text{Emission}_{\text{Departure}(p,d,a,s,y)}$$

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

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

where

$\text{Emission}_{\text{LTO}\ (p,d,a,s,y)}$ – Emissions of pollutant p from origin/destiny d in airport a performed by aircraft s during year y (t/yr);

$\text{Emission}_{\text{Arrival}(p,d,a,s,y)}$, $\text{Emission}_{\text{Departure}(p,d,a,s,y)}$ – Arrival and departure emissions of pollutant p from, respectively, origin and destiny d in airport a performed by aircraft s during year y (t/yr);

$N_{\text{arrival}}$, $N_{\text{departure}}$ – Number of arrival and departure movements performed in year y, by aircraft s in airport s from origin/destiny d.

$EF_{\text{Arrival}(p,s)}$ – Sum of approach and taxi-in emission factor for pollutant p and aircraft s (kg/movement);

$EF_{\text{Departure}(p,s)}$ – Sum of taxi-out, take-off and climb emission factor for pollutant p and aircraft s (kg/movement);

p – pollutant;

d – origin/destination;

a – airport;

s – aircraft;

y – year.

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

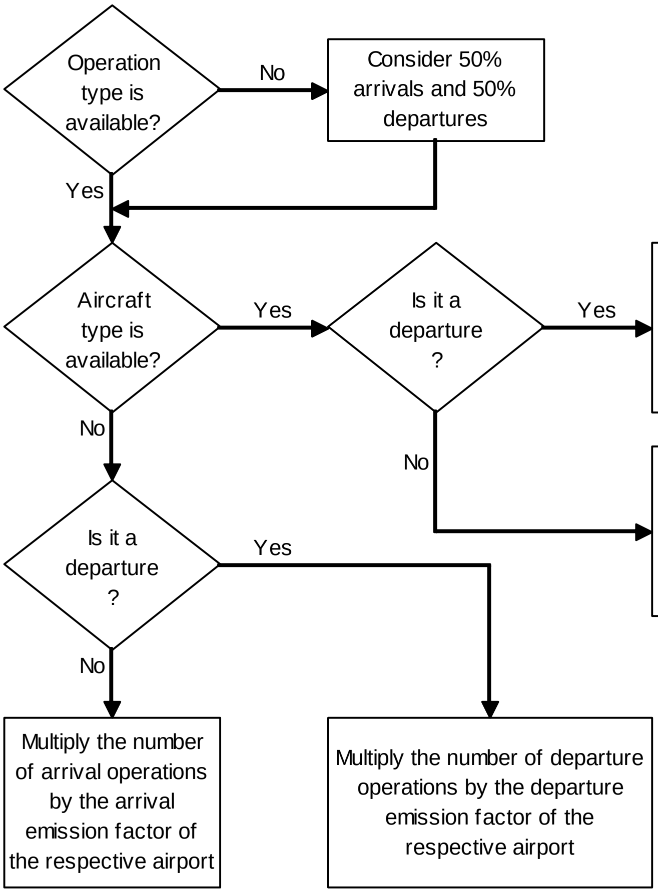
$$Emission_{LTO(p,d,a,y)} = Emission_{Arrival(p,d,s,y)} + Emission_{Departure(p,d,a,y)}$$

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

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

Figure below outlines the process whereby LTO emissions are estimated.

Figure 3.57 – Decision tree for LTO emission calculation




### *3.2.3.1.2.2 Cruise*

Domestic cruise emissions are estimated based on aircraft movement data. The approach relies on a origin and destination matrix. The distances between airports are calculated from an airport coordinates database (Partow, 2003) applied to a great circle distance algorithm (GCD) assuming the Earth as a perfect sphere. Emission factors are given for each aircraft type and for a specific flight distance. International cruise emissions are estimated from fuel consumption. The international fuel consumption is estimated by subtracting the LTO and the domestic cruise fuel from the total fuel sales.

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

where

$Emission_{cruise(p,d,a,s,y)}$ – Domestic cruise emissions of pollutant p resulting from flight with origin/destiny d in airport a performed by aircraft s during year y (t/yr);

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

$EF_{cruise(p,d,a,s,t,y)}$ – Emission factor for pollutant p specific for flight with origin/destination d taking time t performed by aircraft type s in year y (kg/LTO).

In national airports the same national flight is registered in origin airport as a departure and in destiny airport as an arrival therefore the number of national movements must be divided by two to avoid double counting.

#### 3.2.3.1.3 Emission Factors

##### *3.2.3.1.3.1 LTO*

###### *3.2.3.1.3.1.1 Aircraft Based LTO Emission Factors*

Emissions factors for LTO were set for each aircraft type according to information from ICAO Emission Factor Databank which contains emission factors for each operation condition: idle, take off, climb out and approach conditions. Emissions factors for arrival and departure were than set from the default time in mode proposed by FAEED table and from the emission factor for each operation condition where:

- Departure includes taxi-out (idle), take off and climb out modes;
- Arrival includes approach and taxi in (idle) conditions.

Table 3.103 - Emissions factors for most common aircraft movements in national airports.

| Aircraft | Take-off (kg/movement) | | | | | Land (kg/movement) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FC | HC | CO | NOx | PM | FC | HC | CO | NOx | PM |
| Airbus A318/319/320/321 | 674.7 | 1.8 | 15.6 | 26.5 | 6.3 | 273.0 | 0.7 | 6.1 | 4.7 | 3.0 |
| Airbus A320-100/200 | 674.7 | 1.8 | 15.6 | 26.5 | 6.3 | 273.0 | 0.7 | 6.1 | 4.7 | 3.0 |
| Airbus A319 | 546.4 | 0.8 | 8.7 | 15.1 | 5.1 | 224.6 | 0.3 | 3.7 | 2.9 | 2.4 |
| British Aerospace ATP | 813.2 | 1.4 | 15.5 | 27.3 | 7.6 | 354.5 | 0.6 | 6.6 | 5.7 | 3.9 |
| Boeing 737 all pax models | 685.2 | 4.4 | 16.3 | 13.4 | 6.3 | 287.4 | 1.9 | 7.8 | 2.9 | 3.1 |
| Fokker 100 | 481.0 | 1.9 | 12.4 | 9.5 | 4.4 | 202.8 | 0.8 | 5.3 | 1.7 | 2.1 |
| Shorts SD.360 | 63.9 | 8.7 | 10.0 | 0.5 | 0.6 | 34.1 | 4.0 | 4.9 | 0.2 | 0.4 |
| Embraer RJ135 / RJ140 / RJ145 | 232.5 | 0.8 | 5.3 | 4.9 | 2.2 | 105.2 | 0.4 | 2.4 | 1.2 | 1.1 |
| Airbus A321-100/200 | 674.7 | 1.8 | 15.6 | 26.5 | 6.3 | 273.0 | 0.7 | 6.1 | 4.7 | 3.0 |
| Embraer RJ145 Amazon | 232.5 | 0.8 | 5.3 | 4.9 | 2.2 | 105.2 | 0.4 | 2.4 | 1.2 | 1.1 |
| Boeing 757 all pax models | 804.2 | 1.4 | 15.5 | 27.3 | 7.5 | 328.7 | 0.6 | 6.5 | 5.2 | 3.6 |
| Boeing 737-800 (winglets) pax | 581.4 | 1.3 | 11.3 | 16.7 | 5.4 | 243.2 | 0.5 | 4.7 | 3.9 | 2.6 |
| Airbus A310-200 Freighter | 996.1 | 4.7 | 20.7 | 37.3 | 9.4 | 421.2 | 1.9 | 8.9 | 6.9 | 4.7 |
| Airbus A310 all pax models | 1136.9 | 1.3 | 9.0 | 50.1 | 10.5 | 499.0 | 0.5 | 3.8 | 8.0 | 5.4 |
| Cessna 172 Mescalero | 2.5 | 0.1 | 2.2 | 0.0 | 0.0 | 1.4 | 0.0 | 1.5 | 0.0 | 0.0 |
| Boeing 757 Mixed Configuration | 804.2 | 1.4 | 15.5 | 27.3 | 7.5 | 328.7 | 0.6 | 6.5 | 5.2 | 3.6 |
| Fairchild Dornier Do.228 | 111.3 | 5.4 | 14.7 | 2.3 | 1.0 | 54.2 | 2.4 | 7.7 | 0.6 | 0.6 |
| Boeing 737-300 Freighter | 548.5 | 1.2 | 18.4 | 11.3 | 5.1 | 235.0 | 0.5 | 7.6 | 3.1 | 2.5 |
| McDonnell Douglas MD80 | 656.6 | 2.7 | 9.3 | 16.5 | 6.1 | 281.9 | 1.5 | 4.6 | 3.8 | 3.0 |
| Beechcraft 1900/1900C/1900D | 131.6 | 16.2 | 16.2 | 1.5 | 1.2 | 60.5 | 6.8 | 8.7 | 0.4 | 0.6 |
| Boeing 737-700 (winglets) pax | 505.6 | 1.5 | 12.1 | 12.1 | 4.7 | 215.5 | 0.5 | 5.2 | 3.2 | 2.3 |
| CASA / IPTN 212 Aviocar | 378.0 | 4.2 | 14.2 | 11.0 | 3.5 | 171.1 | 1.9 | 7.0 | 2.3 | 1.9 |
| Boeing 737-500 pax | 548.5 | 1.2 | 18.4 | 11.3 | 5.1 | 235.0 | 0.5 | 7.6 | 3.1 | 2.5 |
| Beechcfrat 1900/1900C | 131.6 | 16.2 | 16.2 | 1.5 | 1.2 | 60.5 | 6.8 | 8.7 | 0.4 | 0.6 |
| Aerospatiale Fennec (AS-550) | 94.1 | 1.5 | 3.4 | 1.3 | 1.0 | 94.1 | 1.5 | 3.4 | 1.3 | 1.1 |
| Dassault (Breguet Mystere) Falcon | 42.2 | 0.4 | 2.0 | 0.9 | 0.4 | 34.1 | 0.4 | 2.4 | 0.3 | 0.3 |
| Airbus A340 all models | 1376.4 | 11.8 | 74.4 | 106.1 | 12.8 | 557.3 | 4.4 | 28.6 | 18.2 | 6.1 |
| Boeing 767 all pax models | 996.1 | 4.7 | 20.7 | 37.3 | 9.4 | 421.2 | 1.9 | 8.9 | 6.9 | 4.7 |
| Mooney M-20 | 3.0 | 0.1 | 3.1 | 0.0 | 0.0 | 2.1 | 0.0 | 2.5 | 0.0 | 0.0 |

###### *3.2.3.1.3.1.2 Airport Based LTO Emission Factors*

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

Table 3.104 – Airport based LTO emission factors (kg/movement).

| Airport | Operation | Parameter | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Lisboa (LIS) | Take-off | Fuel Consumption | 670.2 | 608.9 | 567.4 | 452.6 | 451.6 | 447.0 | 462.5 | 468.4 |
| | | VOC | 16.4 | 14.9 | 15.2 | 9.3 | 2.8 | 2.4 | 2.3 | 2.3 |
| | | CO | 37.1 | 33.7 | 35.4 | 21.5 | 13.8 | 12.2 | 12.3 | 12.8 |
| | | NOx | 26.3 | 23.9 | 23.6 | 16.2 | 15.9 | 16.1 | 16.0 | 17.1 |
| | | $PM_{10}$ | 6.2 | 5.6 | 5.2 | 4.2 | 4.2 | 4.2 | 4.3 | 4.4 |
| | Landing | Fuel Consumption | 291.0 | 264.4 | 240.2 | 204.2 | 206.6 | 201.0 | 178.6 | 223.7 |
| | | VOC | 7.0 | 6.4 | 6.0 | 4.4 | 1.5 | 1.3 | 1.3 | 1.2 |
| | | CO | 17.8 | 16.2 | 16.3 | 11.1 | 7.0 | 6.2 | 6.2 | 6.5 |
| | | NOx | 4.9 | 4.4 | 4.3 | 3.3 | 3.4 | 3.3 | 2.9 | 3.8 |
| | | $PM_{10}$ | 3.1 | 2.8 | 2.6 | 2.2 | 2.2 | 2.2 | 1.9 | 2.4 |
| Porto (OPO) | Take-off | Fuel Consumption | 530.0 | 481.5 | 401.1 | 374.4 | 427.6 | 342.9 | 423.7 | 358.1 |
| | | VOC | 8.2 | 7.5 | 6.5 | 4.1 | 3.3 | 3.0 | 2.9 | 2.6 |
| | | CO | 26.3 | 23.9 | 23.0 | 13.7 | 12.8 | 11.4 | 12.7 | 10.7 |
| | | NOx | 19.1 | 17.3 | 15.0 | 11.9 | 14.7 | 11.6 | 14.3 | 11.9 |
| | | $PM_{10}$ | 4.9 | 4.5 | 3.7 | 3.5 | 4.0 | 3.2 | 3.9 | 3.3 |
| | Landing | Fuel Consumption | 236.2 | 214.6 | 181.3 | 172.9 | 191.7 | 156.8 | 160.6 | 171.1 |
| | | VOC | 3.7 | 3.3 | 2.9 | 2.2 | 1.6 | 1.4 | 1.7 | 1.4 |
| | | CO | 12.7 | 11.5 | 11.1 | 7.2 | 6.3 | 5.7 | 6.7 | 5.8 |
| | | NOx | 3.8 | 3.5 | 3.0 | 2.6 | 3.2 | 2.5 | 2.7 | 2.8 |
| | | $PM_{10}$ | 2.5 | 2.3 | 1.9 | 1.9 | 2.1 | 1.7 | 1.7 | 1.8 |
| Faro (FAO) | Take-off | Fuel Consumption | 514.8 | 467.7 | 443.6 | 348.7 | 339.1 | 274.3 | 319.6 | 263.5 |
| | | VOC | 5.3 | 4.8 | 4.9 | 3.0 | 2.4 | 2.2 | 2.0 | 2.1 |
| | | CO | 19.2 | 17.4 | 17.2 | 12.2 | 11.0 | 9.0 | 9.3 | 8.5 |
| | | NOx | 17.4 | 15.8 | 16.0 | 11.0 | 10.0 | 8.0 | 9.6 | 7.7 |
| | | $PM_{10}$ | 4.8 | 4.3 | 4.1 | 3.2 | 3.1 | 2.5 | 3.0 | 2.4 |
| | Landing | Fuel Consumption | 231.8 | 210.6 | 198.9 | 158.2 | 161.1 | 134.9 | 117.5 | 139.3 |
| | | VOC | 2.7 | 2.5 | 2.5 | 1.7 | 1.4 | 1.4 | 1.4 | 1.4 |
| | | CO | 10.0 | 9.1 | 9.0 | 6.5 | 5.9 | 5.1 | 5.0 | 5.0 |
| | | NOx | 3.5 | 3.2 | 3.1 | 2.3 | 2.4 | 2.0 | 1.6 | 2.0 |
| | | $PM_{10}$ | 2.5 | 2.3 | 2.1 | 1.7 | 1.7 | 1.4 | 1.3 | 1.5 |
| Santa Maria (SMA) | Take-off | Fuel Consumption | 424.1 | 385.3 | 328.4 | 393.3 | 446.6 | 391.5 | 272.4 | 335.2 |
| | | VOC | 9.2 | 8.3 | 9.8 | 7.6 | 5.2 | 3.8 | 2.3 | 2.0 |
| | | CO | 23.1 | 21.0 | 22.2 | 19.1 | 17.6 | 17.8 | 9.8 | 10.2 |
| | | NOx | 16.3 | 14.8 | 12.0 | 16.0 | 20.0 | 17.7 | 8.2 | 12.4 |
| | | $PM_{10}$ | 3.9 | 3.6 | 3.0 | 3.7 | 4.2 | 3.6 | 2.5 | 3.1 |
| | Landing | Fuel Consumption | 216.1 | 196.3 | 169.9 | 196.1 | 223.3 | 179.6 | 151.9 | 178.3 |
| | | VOC | 4.6 | 4.1 | 4.9 | 3.4 | 2.6 | 2.0 | 1.8 | 1.3 |
| | | CO | 13.2 | 12.0 | 12.4 | 10.7 | 9.8 | 10.0 | 8.2 | 6.6 |
| | | NOx | 3.6 | 3.2 | 2.6 | 3.6 | 4.3 | 3.6 | 2.5 | 3.3 |
| | | $PM_{10}$ | 2.3 | 2.1 | 1.8 | 2.1 | 2.4 | 1.9 | 1.6 | 1.9 |
| Ponta Delgada (PDL) | Take-off | Fuel Consumption | 616.3 | 559.9 | 895.0 | 403.0 | 475.3 | 436.8 | 476.2 | 525.1 |
| | | VOC | 7.7 | 7.0 | 10.1 | 3.8 | 2.7 | 2.1 | 2.3 | 2.3 |
| | | CO | 19.5 | 17.7 | 24.2 | 12.4 | 12.6 | 10.6 | 11.0 | 13.7 |
| | | NOx | 20.4 | 18.6 | 31.5 | 13.0 | 15.9 | 14.1 | 15.7 | 20.3 |
| | | $PM_{10}$ | 5.7 | 5.2 | 8.3 | 3.8 | 4.4 | 4.1 | 4.4 | 4.9 |
| | Landing | Fuel Consumption | 285.0 | 258.9 | 414.5 | 175.7 | 202.8 | 200.3 | 176.5 | 243.4 |
| | | VOC | 4.4 | 4.0 | 7.6 | 1.8 | 1.3 | 1.2 | 1.0 | 1.1 |
| | | CO | 11.2 | 10.2 | 16.4 | 6.2 | 6.3 | 5.7 | 5.1 | 6.5 |
| | | NOx | 4.1 | 3.7 | 6.3 | 2.6 | 3.1 | 3.1 | 2.7 | 4.3 |
| | | $PM_{10}$ | 3.1 | 2.8 | 4.5 | 1.9 | 2.2 | 2.2 | 1.9 | 2.6 |

| Airport | Operation | Parameter | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Horta (HOR) | Take-off | Fuel Consumption | 457.9 | 416.0 | 783.6 | 287.9 | 405.3 | 295.1 | 391.5 | 263.2 |
| | | VOC | 3.8 | 3.5 | 1.8 | 4.8 | 3.6 | 2.1 | 3.0 | 1.0 |
| | | CO | 13.0 | 11.8 | 15.6 | 10.6 | 10.7 | 9.1 | 10.4 | 6.6 |
| | | NOx | 14.4 | 13.1 | 25.7 | 8.5 | 13.1 | 9.5 | 13.0 | 8.9 |
| | | $PM_{10}$ | 4.3 | 3.9 | 7.3 | 2.7 | 3.8 | 2.8 | 3.7 | 2.5 |
| | Landing | Fuel Consumption | 219.8 | 199.6 | 337.9 | 146.4 | 194.9 | 142.3 | 115.2 | 163.8 |
| | | VOC | 1.8 | 1.7 | 0.7 | 2.1 | 1.9 | 1.3 | 1.9 | 0.7 |
| | | CO | 6.8 | 6.2 | 6.7 | 5.6 | 5.7 | 5.1 | 5.2 | 4.6 |
| | | NOx | 3.2 | 2.9 | 5.3 | 2.0 | 2.9 | 2.0 | 1.7 | 2.5 |
| | | $PM_{10}$ | 2.4 | 2.2 | 3.7 | 1.6 | 2.1 | 1.5 | 1.2 | 1.8 |
| Flores (FLW) | Take-off | Fuel Consumption | 422.4 | 383.8 | 299.1 | 359.5 | 343.4 | 322.2 | 384.7 | 380.6 |
| | | VOC | 5.3 | 4.8 | 4.3 | 5.3 | 3.9 | 1.7 | 3.2 | 1.0 |
| | | CO | 14.2 | 12.9 | 9.3 | 11.8 | 9.5 | 7.8 | 9.6 | 7.4 |
| | | NOx | 13.0 | 11.8 | 8.9 | 10.8 | 10.6 | 10.6 | 12.3 | 12.2 |
| | | $PM_{10}$ | 4.0 | 3.6 | 2.8 | 3.4 | 3.2 | 3.0 | 3.6 | 3.6 |
| | Landing | Fuel Consumption | 227.7 | 206.8 | 164.9 | 170.2 | 176.2 | 122.7 | 185.2 | 210.6 |
| | | VOC | 2.2 | 2.0 | 1.9 | 2.6 | 1.9 | 1.4 | 1.6 | 0.7 |
| | | CO | 7.5 | 6.8 | 5.1 | 6.6 | 5.0 | 4.4 | 5.0 | 4.3 |
| | | NOx | 3.4 | 3.1 | 2.4 | 2.4 | 2.4 | 1.8 | 2.6 | 3.0 |
| | | $PM_{10}$ | 2.5 | 2.3 | 1.8 | 1.9 | 1.9 | 1.3 | 2.0 | 2.3 |
| Funchal (FNC) | Take-off | Fuel Consumption | 623.5 | 566.5 | 465.6 | 466.6 | 469.7 | 457.0 | 519.8 | 448.7 |
| | | VOC | 5.9 | 5.4 | 4.5 | 2.7 | 1.7 | 1.5 | 1.7 | 1.4 |
| | | CO | 20.2 | 18.3 | 15.1 | 13.0 | 12.1 | 11.0 | 12.1 | 10.6 |
| | | NOx | 19.3 | 17.6 | 14.0 | 15.2 | 14.6 | 14.6 | 16.5 | 14.0 |
| | | $PM_{10}$ | 5.8 | 5.2 | 4.3 | 4.3 | 4.4 | 4.2 | 4.8 | 4.2 |
| | Landing | Fuel Consumption | 280.8 | 255.1 | 210.8 | 206.3 | 209.3 | 204.3 | 187.4 | 205.1 |
| | | VOC | 2.9 | 2.7 | 2.2 | 1.5 | 0.9 | 0.7 | 0.9 | 0.8 |
| | | CO | 10.3 | 9.4 | 7.9 | 6.5 | 5.7 | 5.2 | 5.1 | 5.2 |
| | | NOx | 4.0 | 3.7 | 2.9 | 3.2 | 3.2 | 3.2 | 2.8 | 3.1 |
| | | $PM_{10}$ | 3.0 | 2.7 | 2.3 | 2.2 | 2.3 | 2.2 | 2.0 | 2.2 |
| Porto Santo (PXO) | Take-off | Fuel Consumption | 561.0 | 509.6 | 534.2 | 438.3 | 447.3 | 433.7 | 483.7 | 443.3 |
| | | VOC | 7.9 | 7.2 | 4.8 | 6.7 | 2.8 | 1.5 | 1.7 | 1.5 |
| | | CO | 25.0 | 22.7 | 15.8 | 19.3 | 14.1 | 10.8 | 10.7 | 12.2 |
| | | NOx | 18.6 | 16.9 | 18.4 | 16.0 | 13.9 | 13.4 | 15.6 | 13.7 |
| | | $PM_{10}$ | 5.2 | 4.7 | 4.9 | 4.1 | 4.2 | 4.0 | 4.5 | 4.1 |
| | Landing | Fuel Consumption | 277.8 | 252.4 | 238.5 | 196.3 | 207.6 | 200.8 | 215.8 | 218.0 |
| | | VOC | 3.2 | 2.9 | 2.3 | 2.8 | 1.2 | 0.7 | 0.9 | 0.7 |
| | | CO | 12.0 | 10.9 | 8.1 | 8.8 | 6.6 | 5.1 | 5.1 | 6.1 |
| | | NOx | 4.1 | 3.7 | 4.0 | 3.2 | 3.1 | 3.0 | 3.3 | 3.3 |
| | | $PM_{10}$ | 3.0 | 2.7 | 2.6 | 2.1 | 2.2 | 2.2 | 2.3 | 2.4 |
| Terceira (TER) | Take-off | Fuel Consumption | 958.6 | 870.9 | 743.3 | 847.6 | 623.2 | 642.0 | 654.0 | 702.0 |
| | | VOC | 7.4 | 6.7 | 5.7 | 8.9 | 5.5 | 3.0 | 2.0 | 2.6 |
| | | CO | 28.2 | 25.6 | 21.8 | 29.0 | 18.7 | 17.8 | 13.5 | 17.2 |
| | | NOx | 39.1 | 35.6 | 30.3 | 36.8 | 23.4 | 27.1 | 22.9 | 29.1 |
| | | $PM_{10}$ | 9.0 | 8.1 | 7.0 | 7.9 | 5.8 | 6.0 | 6.1 | 6.6 |
| | Landing | Fuel Consumption | 391.8 | 355.9 | 303.8 | 338.7 | 262.6 | 253.8 | 285.6 | 287.7 |
| | | VOC | 3.0 | 2.7 | 2.3 | 3.3 | 2.3 | 1.2 | 1.3 | 1.1 |
| | | CO | 11.8 | 10.7 | 9.1 | 11.9 | 8.5 | 7.0 | 7.4 | 7.0 |
| | | NOx | 6.9 | 6.3 | 5.4 | 6.4 | 4.6 | 4.7 | 5.1 | 5.3 |
| | | $PM_{10}$ | 4.3 | 3.9 | 3.3 | 3.7 | 2.9 | 2.8 | 3.1 | 3.1 |

### *3.2.3.1.3.2 Cruise Emissions*

#### *3.2.3.1.3.2.1 Aircraft Based Cruise Emissions*

Cruise emissions were estimated from EMEP/CORINAR detailed methodology. Cruise emissions are given for typical cruise distances (see EMEP/CORINAIR Emission Inventory Guidebook, December 2001: ppB851-22, Table 8.4; Annex 1; Annex 2). This information was used to derive emissions for specific distances according with a trend line established between discrete samples provided in the EMEP/CORINAIR Emission Inventory Guidebook.

The table below shows an example of cruise emission for Airbus and Boeing models.

Table 3.105 – Cruise emissions and fuel consumption.

| Aircraft | Distance (km) | Fuel Consumption (kg) | NOX (kg) | HC (g) | CO (g) |
|---|---|---|---|---|---|
| Airbus A310 all pax models | 0 | 0 | 0 | 0 | 0 |
| | 232 | 1 270 | 30 | 290 | 1587 |
| | 463 | 2 359 | 49 | 490 | 2651 |
| | 926 | 4 450 | 64 | 763 | 3848 |
| | 1389 | 6 541 | 89 | 1026 | 4913 |
| | 1852 | 8 632 | 113 | 1288 | 5977 |
| | 2778 | 12 992 | 166 | 1836 | 8193 |
| | 3704 | 17 441 | 214 | 2378 | 10345 |
| | 4630 | 22 159 | 273 | 2960 | 12678 |
| | 5556 | 27 135 | 340 | 3585 | 15206 |
| | 6482 | 32 223 | 408 | 4223 | 17790 |
| Airbus A318/319/320/321 | 0 | 0 | 0 | 0 | 0 |
| | 232 | 842 | 17 | 149 | 1096 |
| | 463 | 1 695 | 27 | 267 | 1742 |
| | 926 | 2 858 | 45 | 508 | 3108 |
| | 1389 | 3 903 | 56 | 684 | 3571 |
| | 1852 | 5 225 | 73 | 915 | 4688 |
| | 2778 | 7 530 | 99 | 1311 | 6166 |
| | 3704 | 10 064 | 130 | 1747 | 7849 |
| | 4630 | 12 639 | 159 | 2189 | 9532 |
| Boeing 727 all pax models | 0 | 0 | 0 | 0 | 0 |
| | 231.5 | 1303.9 | 11 | 907 | 3459 |
| | 463 | 2341.8 | 17 | 2206 | 5869 |
| | 926 | 4247.3 | 43 | 2311 | 8837 |
| | 1389 | 6080.4 | 58 | 3072 | 11842 |
| | 1852 | 8058.3 | 74 | 3746 | 14568 |
| | 2778 | 12131.4 | 108 | 5279 | 20688 |
| | 3704 | 16459.4 | 147 | 6871 | 27075 |
| | 4630 | 20825.2 | 185 | 8477 | 33515 |

Source: EMEP/CORINAIR

###### *3.2.3.1.3.2.2 Airport Based Cruise Emissions*

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

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

##### *3.2.3.1.3.3 Correspondence between aircraft type and representative aircraft*

The availability of emissions factor is limited to a certain number of engines and frames. Therefore a representative aircraft is needed when an emission factor is not available for a specific airplane.

The table 5 I ANNEX C: ENERGY (NFR 1) shows the correspondence between aircrafts and representative aircrafts for LTO and cruise emissions factors.

##### *3.2.3.1.3.4 Fuel dependent emission factors*

Fuel dependent emission factors were set for $SO_2$ and heavy metals. The LHV were obtained from the national energy authority (DGEG).

Table 3.106 – Fuel dependent emission factors.

| Pollutant | Aviation Gasoline | Jet Fuel |
|---|---|---|
| LHV (MJ/kg) | 44.0 | 43.0 |
| $SO_2$ (%) | 0.04 | 0.04 |
| Pb (g/t) | 0.45 | 0.45 |
| Cd (g/t) | 0.25 | 0.25 |
| Cr (g/t) | 0.05 | 0.05 |
| Cu (g/t) | 1.10 | 1.10 |
| Ni (g/t) | 0.28 | 0.28 |
| Se (g/t) | 0.03 | 0.03 |
| Zn (g/t) | 3.00 | 3.00 |

Source: IPCC; DGEG

#### 3.2.3.1.4 Activity Data

##### *3.2.3.1.4.1 Flight movements in Airports*

Very important activity data for this source activity is the number of arrival and departure movements. The number of movements by airport, aircraft, origin/destiny and movement type (arrival or departure) for the period between 1990 and 2015 was provided by the *Autoridade Nacional da Aviação Civil* (ANAC). This database is being improved and the coverage of it is increasing as new airports (mostly regional and local airports) are connected to the movements' database from ANAC.

Table 3.107 – LTO per airport

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

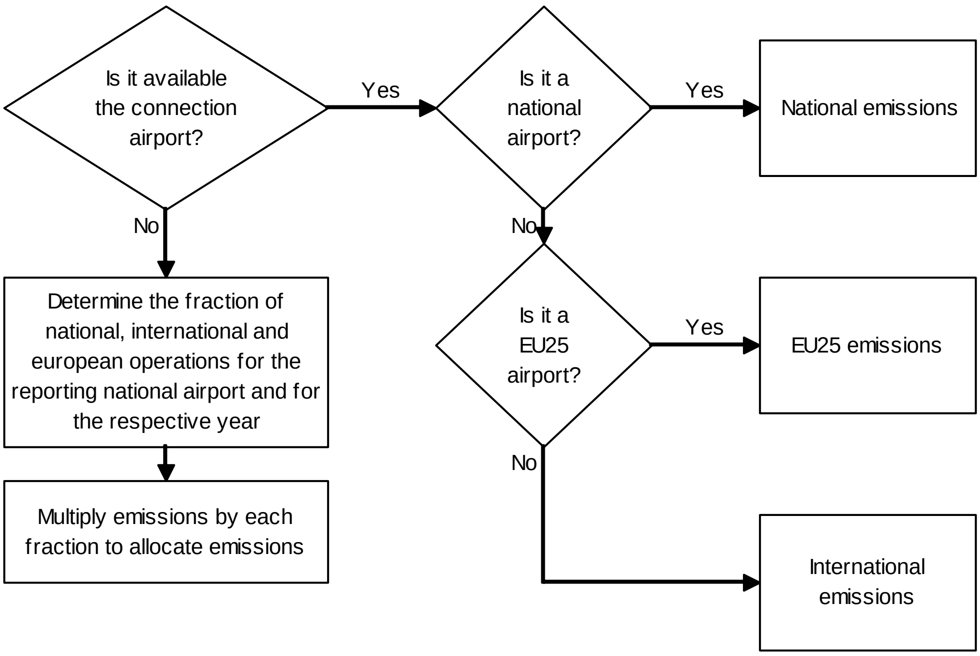
Source: ANAC

Data concerning aircraft operation characteristics, particularly, the origin/destiny, the aircraft type and the movement type was sometimes not included in the records database. The worst case refers to the period between 1990 and 1994, for this period the only information available was the number of operations, all other information was missing. There is also the period between 1995 and 1999 with missing data on aircraft type. For all these cases an alternative approach had to be set.

An alternative database was however available with information on the number of operations and the aircraft types. This data was very useful to determine the aircraft fleet profile in each airport between 1990 and 1999 whereby airport representative arrival and departure emission factors were determined.

On the other hand, for records with missing information on origin and destiny, a yearly fraction of international, domestic and European flights was derived for each airport relying on the movements which had this information. This was necessary to differentiate emissions between domestic and international.

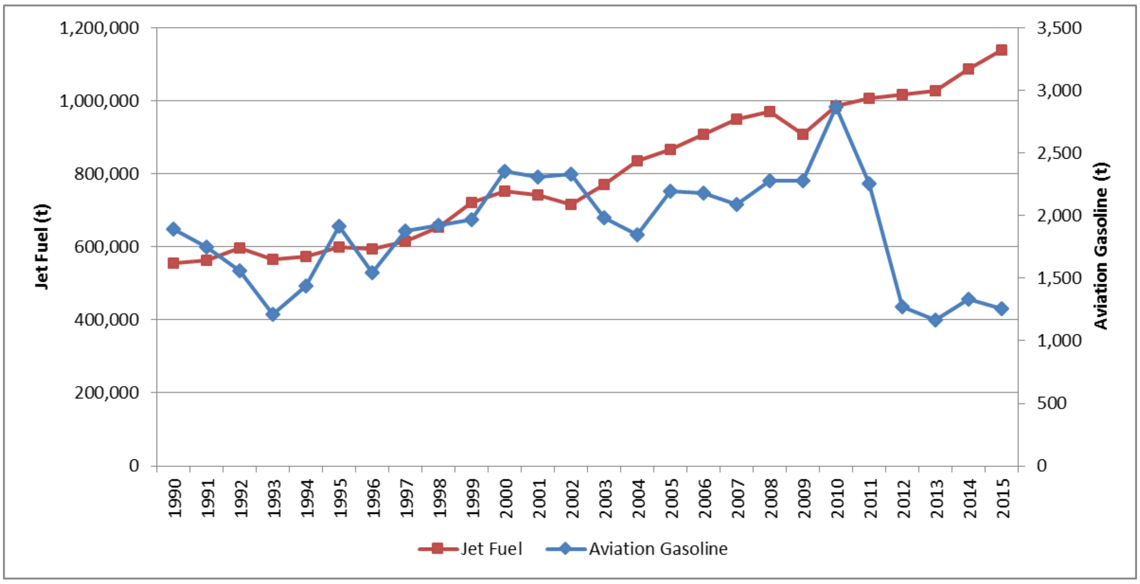
Figure 3.58 – Decision tree for distinction between domestic and international emissions.




### *3.2.3.1.4.2 Fuel Consumption*

Fuel consumption is available from fuel sales statistics from DGEG for main territory and islands and is presented in the figure bellow and ANNEX C: ENERGY (NFR 1). LTO and domestic cruise fuel consumption is estimated with a bottom-up approach. International cruise consumption is estimated as the difference to the total fuel sales. This approach guarantees that the total fuel for aviation equals the fuel sales.

Figure 3.59 – Total Fuel consumption of Aviation Gasoline and Jet Fuel




Source: DGEG

From the fraction of LTO islands/mainland, fuel consumption in islands of Madeira and Azores is subtracted from the total fuel sales since these emissions are not covered by the IIR.

#### 3.2.3.1.5 Category-specific QA/QC and verification

Energy consumption was compared with data from the energy balance reported by DGEG. No differences were found between total fuel estimated with the described methodology and total fuel reported in the energy balance.

#### 3.2.3.1.6 Recalculations

No recalculations were made.

#### 3.2.3.1.7 Further Improvements

No further improvements are planned for this sector.

### 3.2.3.2 *Road Transportation (NFR 1.A.3.b)*

#### 3.2.3.2.1 Overview

Road transportation is one of the most important emission sources of pollutants associated with trans-boundary, regional and, particularly, local air problems, comprehending sulphur oxides ($SO_x$), nitrogen oxides ($NO_x$), carbon monoxide (CO), non-volatile organic compounds (NMVOC) that are indirectly responsible for the formation of ozone ($O_3$) in the lower troposphere. Substantial emissions of ammonia, particulate matter and heavy metals result also from this sector of activity.

Table 3.108 – Main pollutants and particulate matter emissions from road transport in mainland territory

| | 1990 | | 2015 | | Var (1990 - 2015) | |
|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| $SO_2$ | 12374 | t | 97 | t | -99 | % |
| $NO_x$ | 78751 | t | 71355 | t | -9 | % |
| NMVOC | 108165 | t | 14912 | t | -86 | % |
| CO | 479048 | t | 67960 | t | -86 | % |
| $NH_3$ | 67 | t | 805 | t | 1094 | % |
| $PM_{10}$ | 6635 | t | 3858 | t | -42 | % |
| $PM_{2.5}$ | 6225 | t | 3138 | t | -50 | % |

Table 3.109 – Heavy metals emissions from road transport in mainland territory

| | 1990 | | 2015 | | Var (1990 - 2015) | |
|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| Pb | 552367 | kg | 5507 | kg | -99 | % |
| Cu | 15001 | kg | 24350 | kg | 62 | % |
| Cd | 35 | kg | 58 | kg | 63 | % |
| Cr | 603 | kg | 978 | kg | 62 | % |
| Ni | 280 | kg | 457 | kg | 63 | % |
| Se | 39 | kg | 65 | kg | 65 | % |
| Zn | 6693 | kg | 11174 | kg | 67 | % |

Table 3.110 – Persistent organic pollutant emissions from road transport in mainland territory

| | 1990 | | 2015 | | Var (1990 - 2015) | |
|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Value** | **Unit** | **Value** | **Unit** |
| DioxFur | 1.4 | g | 2.4 | g | 80 | % |

### 3.2.3.2.2 Methodology

Emissions from road transportation are estimated using the COPERT IV (version 11.4 - September 2016). An additional tool was developed by APA to calculate the vehicle fleet. This estimates annual fleet from long-time series of vehicle sales and abatements. Activity level, expressed in km/vehicle/year, was obtained from a model based on data from vehicle inspection centers. The fuel consumption is provided by the national energy authority and this information is used to correct fuel consumption using bottom-up approach in conjunction with top-down approach.

Emissions from heavy duty vehicles, buses and coaches were estimated from vehicle-kilometers obtained from national statistics. Disaggregation by vehicle technology was then obtained using the data from the vehicle inspection centers.

Estimated emissions from road transport are based in Tier 2 method for $CO_2$ emissions and Tier 3 for non-$CO_2$ emissions.

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

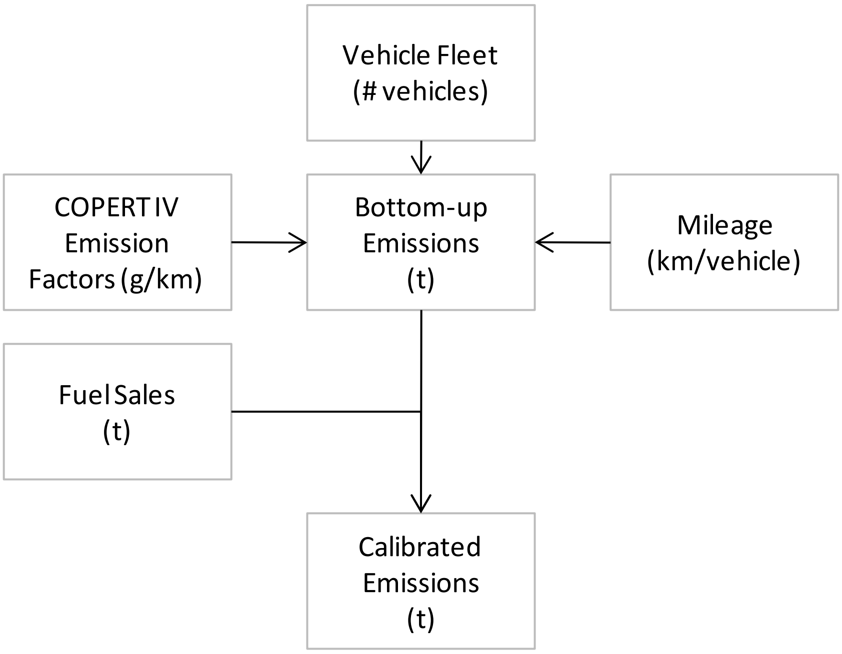
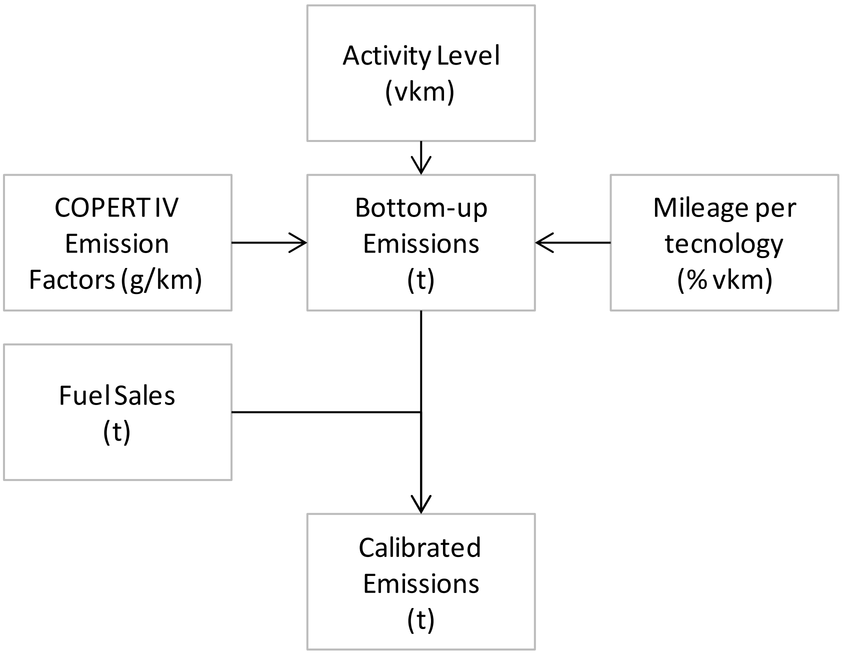



Figure 3.61 – General scheme of methodology applied for road transport emissions estimates (Heavy duty vehicles, buses and coaches)



#### 3.2.3.2.2.1 Vehicle Fleet

A function for vehicle abatement based on vehicle age was applied to vehicle sales in order to determine the active fleet per year. This function derives from *Associação Automóvel de Portugal* (ACAP) data and is valid for passenger cars, light duty vehicles and motorcycles and is summarized in the following couple equations:

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

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

Where,

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

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

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

The number of mopeds was obtained from the insurance institute as information on mopeds sales and abatements is not available.

National statistics institute provides information on the total activity level for heavy duty trucks, Buses and Coaches. The activity level is then disaggregated by technology using the information from vehicle inspection centers.

#### 3.2.3.2.2.2 Distance Travelled

Distance driven was established using a model based on data from the vehicle inspection centers.

Distance travelled by heavy duty vehicles, buses and coaches was established from national statistics. Disaggregation by vehicle technology was then obtained using the data from the vehicle inspection centers.

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

Table 3.111 – Km per year per vehicle as function of vehicle age for passenger cars and light duty vehicles.

| Vehicle Category | Sub Categories | Mileage Function | Parameters |
|---|---|---|---|
| Passenger Cars | Gasoline <1,4 l<br>Hybrid Gasoline <1,4 l | km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p) | A1 = 11059.2452<br>A2 = -2885.12141<br>x0 = 23.28806<br>p = 2.56847 |
| | Gasoline 1,4 - 2,0 l<br>Hybrid Gasoline 1,4 - 2,0 l | km/year = y0 + A * Exp(-0.5 * ((age - xc) / w) ^ 2) | y0 = 13010.25545<br>xc = 26.65915<br>w = 8.63531<br>A = -8623.92117 |
| | Gasoline >2,0 l<br>LPG<br>2-Stroke<br>Hybrid Gasoline >2,0 l | km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p) | A1 = 13354.66789<br>A2 = 737.09264<br>x0 = 19.69152<br>p = 2.4209 |
| | Diesel <2,0 l | km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p) | A1 = 19241.06557<br>A2 = 6603.86725<br>x0 = 17.45625<br>p = 2.53695 |
| | Diesel >2,0 l | km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p) | A1 = 20445.94606<br>A2 = 9728.01464<br>x0 = 14.25834<br>p = 3.25053 |
| Light Duty Vehicles | Diesel <3,5 t | km/year = A2 + (A1 - A2) / (1 + (age / x0) ^ p) | A1 = 20800.21535<br>A2 = 2597.42606<br>x0 = 15.44257<br>p = 2.32592 |

Table 3.112 – Km per year per vehicle type

| Sector | Subsector | Technology | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Passenger Cars | Gasoline <1,4 l | PRE ECE | 5,145 | 3,720 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline <1,4 l | ECE 15/00-01 | 7,731 | 5,637 | 3,989 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline <1,4 l | ECE 15/02 | 9,316 | 7,268 | 5,098 | 3,454 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline <1,4 l | ECE 15/03 | 10,457 | 9,009 | 6,941 | 4,895 | 3,454 | 0 | 0 | 0 |
| Passenger Cars | Gasoline <1,4 l | ECE 15/04 | 11,021 | 10,655 | 9,478 | 7,561 | 5,523 | 4,553 | 4,276 | 3,999 |
| Passenger Cars | Gasoline <1,4 l | Improved Conventional | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline <1,4 l | Open Loop | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline <1,4 l | PC Euro 1 - 91/441/EEC | 0 | 11,049 | 10,692 | 9,452 | 7,455 | 6,144 | 5,718 | 5,305 |
| Passenger Cars | Gasoline <1,4 l | PC Euro 2 - 94/12/EEC | 0 | 0 | 11,036 | 10,541 | 9,134 | 7,932 | 7,501 | 7,063 |
| Passenger Cars | Gasoline <1,4 l | PC Euro 3 - 98/69/EC Stage2000 | 0 | 0 | 0 | 10,982 | 10,252 | 9,368 | 9,004 | 8,615 |
| Passenger Cars | Gasoline <1,4 l | PC Euro 4 - 98/69/EC Stage2005 | 0 | 0 | 0 | 11,059 | 10,949 | 10,588 | 10,396 | 10,169 |
| Passenger Cars | Gasoline <1,4 l | PC Euro 5 (post 2005) | 0 | 0 | 0 | 0 | 11,059 | 11,032 | 11,007 | 10,954 |
| Passenger Cars | Gasoline <1,4 l | PC Euro 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,059 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PRE ECE | 6,277 | 4,721 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | ECE 15/00-01 | 9,583 | 6,875 | 4,938 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | ECE 15/02 | 11,401 | 9,112 | 6,237 | 4,544 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | ECE 15/03 | 12,332 | 10,969 | 8,515 | 5,888 | 4,544 | 0 | 0 | 0 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | ECE 15/04 | 12,877 | 12,584 | 11,621 | 9,591 | 6,917 | 5,611 | 5,273 | 4,976 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | Improved Conventional | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | Open Loop | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PC Euro 1 - 91/441/EEC | 0 | 12,898 | 12,551 | 11,477 | 9,262 | 7,546 | 6,977 | 6,438 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PC Euro 2 - 94/12/EEC | 0 | 0 | 12,880 | 12,430 | 11,172 | 9,852 | 9,326 | 8,770 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PC Euro 3 - 98/69/EC Stage2000 | 0 | 0 | 0 | 12,803 | 12,173 | 11,364 | 10,996 | 10,579 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PC Euro 4 - 98/69/EC Stage2005 | 0 | 0 | 0 | 12,937 | 12,758 | 12,422 | 12,254 | 12,052 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PC Euro 5 (post 2005) | 0 | 0 | 0 | 0 | 12,937 | 12,898 | 12,874 | 12,823 |
| Passenger Cars | Gasoline 1,4 - 2,0 l | PC Euro 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12,937 |

| Sector | Subsector | Technology | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Passenger Cars | Gasoline >2,0 l | PRE ECE | 6,686 | 5,485 | 0 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline >2,0 l | ECE 15/00-01 | 9,082 | 7,059 | 5,670 | 0 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline >2,0 l | ECE 15/02 | 10,921 | 8,664 | 6,640 | 5,272 | 0 | 0 | 0 | 0 |
| Passenger Cars | Gasoline >2,0 l | ECE 15/03 | 12,190 | 10,208 | 7,997 | 6,197 | 5,272 | 0 | 0 | 0 |
| Passenger Cars | Gasoline >2,0 l | ECE 15/04 | 13,288 | 12,723 | 11,154 | 8,992 | 7,027 | 6,184 | 5,946 | 5,714 |
| Passenger Cars | Gasoline >2,0 l | PC Euro 1 - 91/441/EEC | 0 | 13,331 | 12,735 | 11,050 | 8,816 | 7,544 | 7,156 | 6,791 |
| Passenger Cars | Gasoline >2,0 l | PC Euro 2 - 94/12/EEC | 0 | 0 | 13,312 | 12,549 | 10,726 | 9,376 | 8,925 | 8,482 |
| Passenger Cars | Gasoline >2,0 l | PC Euro 3 - 98/69/EC Stage2000 | 0 | 0 | 0 | 13,211 | 12,109 | 10,959 | 10,521 | 10,072 |
| Passenger Cars | Gasoline >2,0 l | PC Euro 4 - 98/69/EC Stage2005 | 0 | 0 | 0 | 13,355 | 13,171 | 12,638 | 12,372 | 12,069 |
| Passenger Cars | Gasoline >2,0 l | PC Euro 5 (post 2005) | 0 | 0 | 0 | 0 | 13,355 | 13,318 | 13,285 | 13,210 |
| Passenger Cars | Gasoline >2,0 l | PC Euro 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13,355 |
| Passenger Cars | Diesel <2,0 l | Conventional | 18,516 | 18,089 | 16,360 | 14,000 | 11,863 | 10,910 | 10,660 | 10,434 |
| Passenger Cars | Diesel <2,0 l | PC Euro 1 - 91/441/EEC | 0 | 19,198 | 18,445 | 16,380 | 13,803 | 12,447 | 12,051 | 11,687 |
| Passenger Cars | Diesel <2,0 l | PC Euro 2 - 94/12/EEC | 0 | 0 | 19,196 | 18,299 | 16,092 | 14,515 | 14,005 | 13,513 |
| Passenger Cars | Diesel <2,0 l | PC Euro 3 - 98/69/EC Stage2000 | 0 | 0 | 0 | 19,127 | 17,943 | 16,608 | 16,091 | 15,566 |
| Passenger Cars | Diesel <2,0 l | PC Euro 4 - 98/69/EC Stage2005 | 0 | 0 | 0 | 19,241 | 19,031 | 18,369 | 18,034 | 17,652 |
| Passenger Cars | Diesel <2,0 l | PC Euro 5 (post 2005) | 0 | 0 | 0 | 0 | 19,241 | 19,191 | 19,142 | 19,041 |
| Passenger Cars | Diesel <2,0 l | PC Euro 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19,241 |
| Passenger Cars | Diesel >2,0 l | Conventional | 18,690 | 17,521 | 15,735 | 13,871 | 12,317 | 11,661 | 11,497 | 11,351 |
| Passenger Cars | Diesel >2,0 l | PC Euro 1 - 91/441/EEC | 0 | 20,428 | 19,808 | 17,394 | 14,327 | 12,960 | 12,604 | 12,293 |
| Passenger Cars | Diesel >2,0 l | PC Euro 2 - 94/12/EEC | 0 | 0 | 20,433 | 19,762 | 17,201 | 15,267 | 14,676 | 14,132 |
| Passenger Cars | Diesel >2,0 l | PC Euro 3 - 98/69/EC Stage2000 | 0 | 0 | 0 | 20,381 | 19,230 | 17,603 | 16,955 | 16,303 |
| Passenger Cars | Diesel >2,0 l | PC Euro 4 - 98/69/EC Stage2005 | 0 | 0 | 0 | 20,446 | 20,333 | 19,770 | 19,425 | 19,001 |
| Passenger Cars | Diesel >2,0 l | PC Euro 5 (post 2005) | 0 | 0 | 0 | 0 | 20,446 | 20,426 | 20,397 | 20,331 |
| Passenger Cars | Diesel >2,0 l | PC Euro 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20,446 |

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

### *3.2.3.2.2.3 Allocation of distance travelled*

Vehicle-kilometers (vkm) were allocated to urban, rural and highway driving modes. Information on vkm driven under highways derive from the *Instituto da Mobilidade e dos Transportes (IMT)* which is the national authority for terrestrial transportation. Originally this data is communicated to IMT by the highway service providers. The remaining vkm are allocated to urban and rural driving modes according with the population living in each area.

### *3.2.3.2.2.4 Speed*

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

Table 3.113 – Assumed vehicle speeds by driving mode and vehicle type.

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

#### *3.2.3.2.2.5 Fuel consumption*

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

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

Where,

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

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

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

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

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

m=driving mode: highway, rural, urban

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

y = civil year.

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

Fuel adjustments are necessary so that the sum of estimated fuel consumption equals the total fuel sales from the *Direcção-Geral de Energia e Geologia* (DGEG). Fuel consumption estimates were corrected with the following factor for car type c, technology t, fuel f, driving mode d and year y.

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

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

#### *3.2.3.2.2.7 Emission Factors*

Emissions factors were determined using COPERT IV (version 11.4 - September 2016).

This set of equations allows the estimation of emission factors as function of driving conditions and vehicle properties:

- Vehicle class: light passenger vehicles, LDV, HDV, Mopeds with cylinder capacity under 50 cc and; Motorcycles with cilinder capacity greater than 50 cc;

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

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

Table 3.114 – 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 | 2008 |
| | Euro V ([22]) | 2009 | 2014 |
| | Euro VI ([1]) | 2014 | ... |
| Light Duty Vehicles | Conv | … | 1991 |
| | Euro I | 1992 | 1997 |
| | Euro II | 1998 | 2001 |
| | Euro III | 2002 | 2006 |
| | Euro IV | 2006 | 2009 |
| | Euro V ([1]) | 2010 | 2015 |
| | Euro VI ([1]) | 2015 | ... |
| Heavy Duty Vehicles | Conv | … | 1991 |
| | Euro I | 1992 | 1995 |
| | Euro II | 1996 | 2000 |
| | Euro III | 2001 | 2005 |
| | Euro IV | 2006 | 2008 |
| | Euro V | 2009 | … |
| Mopeds | Conv | … | 1999 |
| | Euro 1 | 2000 | 2002 |
| | Euro 2 | 2003 | 2005 |
| | Euro 3 | 2006 | … |
| Motorcycles | Conv | … | 1999 |
| | Euro 1 | 2000 | 2003 |
| | Euro 2 | 2004 | 2005 |
| | Euro 3 | 2006 | |

[22] Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information. (OJ L 171 29.6.2007, p. 1).

According with COPERT IV method, driving condition parameters, such as the average trip length, must be set in order to derive adequate emission factors.

There is no available updated data regarding ltrip for Portugal. Therefore it was decided to use an European average value of 12 km ($L_{trip}$) as proposed by COPERT IV. The European average value is closed to the value for Spain which is assumed to be adequate also for Portugal

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

Table 3.115 – Sulphur content in gasoline and diesel (%)

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

| Fuel | 1990-1994 | 1995 | 1996-1999 | 2000-2004 | 2005-2008 | 2009-2015 |
|---|---|---|---|---|---|---|
| Diesel | 0.300 | 0.200 | 0.050 | 0.035 | 0.005 | 0.001 |

Source: National Legislation (Portaria n.º125/89, Portaria n.º1489/95,Decreto-Lei nº 104/2000,Decreto-Lei nº 235/2004, Decreto-Lei nº 142/2010);

Table 3.116 – Other heavy metal content in the fuel (g/t)

| HM | Gasoline | Diesel | LPG | CNG | Biodiesel |
|---|---|---|---|---|---|
| Cd | 0.01 | 0.01 | NA | NA | NA |
| Hg | 0.00 | 0.00 | NA | NA | NA |
| As | 0.00 | 0.00 | NA | NA | NA |
| Cr | 0.05 | 0.05 | NA | NA | NA |
| Cu | 1.70 | 1.70 | NA | NA | NA |
| Ni | 0.07 | 0.07 | NA | NA | NA |
| Se | 0.01 | 0.01 | NA | NA | NA |
| Zn | 1.00 | 1.00 | NA | NA | NA |

Source: (EEA/EMEP, 2009)

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

Table 3.117 – Monthly average ambient temperatures (ºC)

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

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

Monthly values of fuel volatility (RVP - Reid Vapour Pressure) were established from Portuguese legislation (Decreto-lei n.º 104/2000; Portaria 1489/95; Portaria 125/89). RVP values considered in national legislation 104/2000 are applicable since the beginning of year 2000 although the regulatory document was valid only after May 2000.

Table 3.118 – Reid Vapour Pressure (kPa)

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

Emissions from biomass

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

Table 3.119 – Effect of biodiesel blends on diesel vehicles emissions

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

Source: (EEA/EMEP, 2009)

The effect of biodiesel may vary with the vehicle technology but the extent of the variation is difficult to estimate in the absence of detailed literature data. With regard to $NO_x$, $CO_2$ and CO, any effect of technology should be negligible, given the marginal effect of biodiesel on these pollutants in general. The effect of biodiesel on PM for different technologies is more difficult to assess (EEA/EMEP, 2009).

Considering that detailed literature data on biodiesel effects is scarce and that the actual blend used for road transportation in Portugal was about 7.83% in 2015, emission factors from biodiesel use were assumed to be the same as for diesel.

Table 3.120 – National biodiesel blends with diesel (% v/v)

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

Source: (DGEG)

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

### 3.2.3.2.3 Implied Emission Factors

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

Table 3.121 – Road transportation energy based implied emission factors (kg/GJ) for main pollutants, particulate matter and black carbon

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| SO2 (kg/GJ) | Diesel | Passenger Cars | 0.14084 | 0.09390 | 0.01643 | 0.00235 | 0.00044 | 0.00044 | 0.00044 | 0.00044 |
| | | Light Duty Vehicles | 0.14084 | 0.09390 | 0.01643 | 0.00235 | 0.00044 | 0.00044 | 0.00044 | 0.00044 |
| | | Heavy Vehicles | 0.14084 | 0.09390 | 0.01643 | 0.00235 | 0.00044 | 0.00044 | 0.00044 | 0.00044 |
| | Gasoline | Passenger Cars | 0.04546 | 0.04546 | 0.00682 | 0.00227 | 0.00045 | 0.00045 | 0.00045 | 0.00045 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.04546 | 0.04546 | 0.00682 | 0.00227 | 0.00045 | 0.00045 | 0.00045 | 0.00045 |
| | | Motorcycles | 0.04546 | 0.04546 | 0.00682 | 0.00227 | 0.00045 | 0.00045 | 0.00045 | 0.00045 |
| | CNG | Heavy Vehicles | - | - | 0.00007 | 0.00007 | 0.00007 | 0.00007 | 0.00007 | 0.00007 |
| | LPG | Passenger Cars | 0.00007 | 0.00007 | 0.00007 | 0.00007 | 0.00007 | 0.00007 | 0.00007 | 0.00007 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| NO2 (kg/GJ) | Diesel | Passenger Cars | 0.25944 | 0.26244 | 0.27319 | 0.28308 | 0.26439 | 0.25961 | 0.25831 | 0.24598 |
| | | Light Duty Vehicles | 0.42834 | 0.41407 | 0.39394 | 0.36479 | 0.32352 | 0.29994 | 0.28990 | 0.28082 |
| | | Heavy Vehicles | 0.86357 | 0.86270 | 0.84874 | 0.85122 | 0.74297 | 0.73938 | 0.73997 | 0.74363 |
| | Gasoline | Passenger Cars | 0.71488 | 0.55037 | 0.34917 | 0.21775 | 0.13101 | 0.08672 | 0.07216 | 0.05894 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.05091 | 0.05091 | 0.06528 | 0.12708 | 0.16934 | 0.18120 | 0.18325 | 0.18460 |
| | | Motorcycles | 0.14385 | 0.13577 | 0.13088 | 0.13197 | 0.11835 | 0.10341 | 0.09823 | 0.09406 |
| | CNG | Heavy Vehicles | - | - | 0.51893 | 0.52181 | 0.51529 | 0.51529 | 0.51529 | 0.51529 |
| | LPG | Passenger Cars | 0.85293 | 0.52807 | 0.36446 | 0.30220 | 0.21505 | 0.12391 | 0.09427 | 0.07523 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| NMVOC (kg/GJ) | Diesel | Passenger Cars | 0.06478 | 0.04066 | 0.02853 | 0.01836 | 0.01131 | 0.00838 | 0.00745 | 0.00657 |
| | | Light Duty Vehicles | 0.03835 | 0.03966 | 0.04035 | 0.03746 | 0.02915 | 0.02280 | 0.01976 | 0.01693 |
| | | Heavy Vehicles | 0.06640 | 0.06474 | 0.05550 | 0.04914 | 0.03769 | 0.03563 | 0.03568 | 0.03545 |
| | Gasoline | Passenger Cars | 1.07751 | 0.86653 | 0.53855 | 0.34487 | 0.22322 | 0.16271 | 0.14186 | 0.12224 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 7.59 | 7.59 | 6.90 | 4.42 | 2.65 | 2.14 | 2.04 | 1.98 |
| | | Motorcycles | 1.99 | 2.06 | 1.94 | 1.38 | 1.08 | 0.84 | 0.76 | 0.69 |
| | CNG | Heavy Vehicles | - | - | 0.00292 | 0.00306 | 0.00275 | 0.00275 | 0.00275 | 0.00275 |
| | LPG | Passenger Cars | 0.45447 | 0.39986 | 0.33079 | 0.28564 | 0.22240 | 0.14771 | 0.12089 | 0.10511 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| CO (kg/GJ) | Diesel | Passenger Cars | 0.27658 | 0.22764 | 0.17122 | 0.10282 | 0.06606 | 0.05272 | 0.04866 | 0.04508 |
| | | Light Duty Vehicles | 0.36051 | 0.31313 | 0.21708 | 0.16672 | 0.13687 | 0.10804 | 0.09416 | 0.08121 |
| | | Heavy Vehicles | 0.21663 | 0.21341 | 0.19994 | 0.19213 | 0.17306 | 0.17037 | 0.17135 | 0.17265 |
| | Gasoline | Passenger Cars | 6.80 | 5.02 | 3.07 | 1.91 | 1.21 | 0.89 | 0.78 | 0.67 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 13.36 | 13.36 | 11.89 | 7.71 | 4.12 | 2.95 | 2.71 | 2.54 |
| | | Motorcycles | 12.30 | 12.31 | 11.26 | 8.46 | 6.62 | 4.98 | 4.42 | 3.95 |
| | CNG | Heavy Vehicles | - | - | 0.06519 | 0.06642 | 0.06364 | 0.06364 | 0.06364 | 0.06364 |
| | LPG | Passenger Cars | 2.07 | 1.72 | 1.47 | 1.35 | 1.12 | 0.80 | 0.69 | 0.62 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| NH3 (kg/GJ) | Diesel | Passenger Cars | 0.00037 | 0.00038 | 0.00037 | 0.00039 | 0.00043 | 0.00049 | 0.00051 | 0.00067 |
| | | Light Duty Vehicles | 0.00028 | 0.00029 | 0.00031 | 0.00031 | 0.00032 | 0.00036 | 0.00039 | 0.00041 |
| | | Heavy Vehicles | 0.00030 | 0.00030 | 0.00026 | 0.00026 | 0.00027 | 0.00026 | 0.00026 | 0.00026 |
| | Gasoline | Passenger Cars | 0.00075 | 0.00799 | 0.01842 | 0.02468 | 0.02254 | 0.01986 | 0.01840 | 0.01664 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.00091 | 0.00091 | 0.00093 | 0.00104 | 0.00111 | 0.00113 | 0.00113 | 0.00113 |
| | | Motorcycles | 0.00116 | 0.00114 | 0.00114 | 0.00120 | 0.00125 | 0.00129 | 0.00130 | 0.00131 |
| | CNG | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | LPG | Passenger Cars | 0.00077 | 0.01632 | 0.02602 | 0.02957 | 0.02894 | 0.02305 | 0.02033 | 0.01914 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| PM10 (kg/GJ) | Diesel | Passenger Cars | 0.09683 | 0.06048 | 0.03842 | 0.02695 | 0.02197 | 0.01884 | 0.01779 | 0.01672 |
| | | Light Duty Vehicles | 0.10389 | 0.08880 | 0.06111 | 0.04125 | 0.03128 | 0.02533 | 0.02284 | 0.02060 |
| | | Heavy Vehicles | 0.03930 | 0.03898 | 0.03619 | 0.03224 | 0.02531 | 0.02488 | 0.02479 | 0.02468 |
| | Gasoline | Passenger Cars | 0.00733 | 0.00772 | 0.00791 | 0.00774 | 0.00757 | 0.00749 | 0.00747 | 0.00744 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.16900 | 0.16900 | 0.15901 | 0.09950 | 0.05091 | 0.03617 | 0.03339 | 0.03143 |
| | | Motorcycles | 0.03340 | 0.03297 | 0.03222 | 0.02759 | 0.02299 | 0.01862 | 0.01714 | 0.01591 |
| | CNG | Heavy Vehicles | - | - | 0.00382 | 0.00381 | 0.00383 | 0.00383 | 0.00383 | 0.00383 |
| | LPG | Passenger Cars | 0.00769 | 0.00785 | 0.00794 | 0.00780 | 0.00765 | 0.00750 | 0.00745 | 0.00741 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| PM2.5 (kg/GJ) | Diesel | Passenger Cars | 0.09380 | 0.05727 | 0.03523 | 0.02374 | 0.01876 | 0.01562 | 0.01457 | 0.01349 |
| | | Light Duty Vehicles | 0.10052 | 0.08534 | 0.05749 | 0.03754 | 0.02753 | 0.02157 | 0.01907 | 0.01684 |
| | | Heavy Vehicles | 0.03612 | 0.03576 | 0.03330 | 0.02929 | 0.02228 | 0.02190 | 0.02183 | 0.02172 |
| | Gasoline | Passenger Cars | 0.00435 | 0.00457 | 0.00468 | 0.00453 | 0.00439 | 0.00432 | 0.00430 | 0.00428 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.16464 | 0.16464 | 0.15455 | 0.09453 | 0.04559 | 0.03076 | 0.02796 | 0.02599 |
| | | Motorcycles | 0.03115 | 0.03068 | 0.02990 | 0.02522 | 0.02058 | 0.01614 | 0.01465 | 0.01340 |
| | CNG | Heavy Vehicles | - | - | 0.00206 | 0.00206 | 0.00207 | 0.00207 | 0.00207 | 0.00207 |
| | LPG | Passenger Cars | 0.00456 | 0.00465 | 0.00470 | 0.00461 | 0.00449 | 0.00435 | 0.00430 | 0.00427 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| BC (kg/GJ) | Diesel | Passenger Cars | 0.05346 | 0.03264 | 0.02008 | 0.01353 | 0.01004 | 0.00835 | 0.00780 | 0.00716 |
| | | Light Duty Vehicles | 0.05529 | 0.04694 | 0.03162 | 0.02065 | 0.01422 | 0.01113 | 0.00986 | 0.00862 |
| | | Heavy Vehicles | 0.01914 | 0.01895 | 0.01765 | 0.01552 | 0.01109 | 0.01089 | 0.01087 | 0.01072 |
| | Gasoline | Passenger Cars | 0.00052 | 0.00055 | 0.00056 | 0.00054 | 0.00053 | 0.00052 | 0.00052 | 0.00051 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.01811 | 0.01811 | 0.01700 | 0.01040 | 0.00501 | 0.00338 | 0.00308 | 0.00286 |
| | | Motorcycles | 0.00343 | 0.00337 | 0.00329 | 0.00277 | 0.00226 | 0.00178 | 0.00161 | 0.00147 |
| | CNG | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | LPG | Passenger Cars | - | - | - | - | - | - | - | - |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

Table 3.122 – Road transportation energy based implied emission factors (g/GJ) for heavy metals

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb (g/GJ) | Diesel | Passenger Cars | 0.00057 | 0.00057 | 0.00057 | 0.00057 | 0.00054 | 0.00054 | 0.00054 | 0.00053 |
| | | Light Duty Vehicles | 0.00057 | 0.00057 | 0.00057 | 0.00057 | 0.00054 | 0.00054 | 0.00054 | 0.00053 |
| | | Heavy Vehicles | 0.00057 | 0.00057 | 0.00057 | 0.00057 | 0.00054 | 0.00054 | 0.00054 | 0.00053 |
| | Gasoline | Passenger Cars | 9.12150 | 9.12150 | 0.11402 | 0.11402 | 0.11402 | 0.11402 | 0.11402 | 0.11402 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 9.12150 | 9.12150 | 0.11402 | 0.11402 | 0.11402 | 0.11402 | 0.11402 | 0.11402 |
| | | Motorcycles | 9.12150 | 9.12150 | 0.11402 | 0.11402 | 0.11402 | 0.11402 | 0.11402 | 0.11402 |
| | CNG | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | LPG | Passenger Cars | - | - | - | - | - | - | - | - |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Cu (g/GJ) | Diesel | Passenger Cars | 0.11218 | 0.11715 | 0.11697 | 0.11701 | 0.10956 | 0.10947 | 0.10967 | 0.10870 |
| | | Light Duty Vehicles | 0.11872 | 0.12088 | 0.12456 | 0.12655 | 0.11967 | 0.11988 | 0.12013 | 0.11913 |
| | | Heavy Vehicles | 0.12140 | 0.12207 | 0.10935 | 0.10907 | 0.10487 | 0.10230 | 0.10171 | 0.10044 |
| | Gasoline | Passenger Cars | 0.10988 | 0.11441 | 0.11659 | 0.11562 | 0.11462 | 0.11421 | 0.11409 | 0.11387 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.15104 | 0.15104 | 0.15363 | 0.16667 | 0.17563 | 0.17811 | 0.17854 | 0.17883 |
| | | Motorcycles | 0.09431 | 0.09577 | 0.09668 | 0.09766 | 0.09859 | 0.09995 | 0.10040 | 0.10075 |
| | CNG | Heavy Vehicles | - | - | 0.05064 | 0.05052 | 0.05078 | 0.05078 | 0.05078 | 0.05078 |
| | LPG | Passenger Cars | 0.07470 | 0.07705 | 0.07827 | 0.07643 | 0.07535 | 0.07512 | 0.07504 | 0.07497 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Cd (g/GJ) | Diesel | Passenger Cars | 0.00028 | 0.00028 | 0.00028 | 0.00028 | 0.00026 | 0.00026 | 0.00026 | 0.00026 |
| | | Light Duty Vehicles | 0.00028 | 0.00028 | 0.00028 | 0.00029 | 0.00027 | 0.00027 | 0.00027 | 0.00027 |
| | | Heavy Vehicles | 0.00028 | 0.00028 | 0.00027 | 0.00027 | 0.00026 | 0.00026 | 0.00026 | 0.00026 |
| | Gasoline | Passenger Cars | 0.00027 | 0.00027 | 0.00027 | 0.00027 | 0.00027 | 0.00027 | 0.00027 | 0.00027 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.00029 | 0.00029 | 0.00029 | 0.00030 | 0.00030 | 0.00030 | 0.00030 | 0.00030 |
| | | Motorcycles | 0.00026 | 0.00026 | 0.00026 | 0.00026 | 0.00026 | 0.00026 | 0.00026 | 0.00026 |
| | CNG | Heavy Vehicles | - | - | 0.00003 | 0.00002 | 0.00003 | 0.00003 | 0.00003 | 0.00003 |
| | LPG | Passenger Cars | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Cr (g/GJ) | Diesel | Passenger Cars | 0.00448 | 0.00470 | 0.00469 | 0.00469 | 0.00440 | 0.00439 | 0.00440 | 0.00436 |
| | | Light Duty Vehicles | 0.00478 | 0.00488 | 0.00504 | 0.00513 | 0.00486 | 0.00487 | 0.00488 | 0.00484 |
| | | Heavy Vehicles | 0.00489 | 0.00492 | 0.00435 | 0.00433 | 0.00418 | 0.00407 | 0.00404 | 0.00399 |
| | Gasoline | Passenger Cars | 0.00439 | 0.00460 | 0.00470 | 0.00465 | 0.00461 | 0.00459 | 0.00458 | 0.00457 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.00626 | 0.00626 | 0.00638 | 0.00697 | 0.00738 | 0.00749 | 0.00751 | 0.00752 |
| | | Motorcycles | 0.00368 | 0.00374 | 0.00378 | 0.00383 | 0.00387 | 0.00393 | 0.00395 | 0.00397 |
| | CNG | Heavy Vehicles | - | - | 0.00230 | 0.00229 | 0.00231 | 0.00231 | 0.00231 | 0.00231 |
| | LPG | Passenger Cars | 0.00341 | 0.00352 | 0.00357 | 0.00349 | 0.00344 | 0.00343 | 0.00343 | 0.00342 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ni (g/GJ) | Diesel | Passenger Cars | 0.0022 | 0.0022 | 0.0022 | 0.0022 | 0.0021 | 0.0021 | 0.0021 | 0.0020 |
| | | Light Duty Vehicles | 0.0022 | 0.0022 | 0.0023 | 0.0023 | 0.0021 | 0.0021 | 0.0021 | 0.0021 |
| | | Heavy Vehicles | 0.0022 | 0.0022 | 0.0021 | 0.0021 | 0.0020 | 0.0020 | 0.0020 | 0.0020 |
| | Gasoline | Passenger Cars | 0.0021 | 0.0021 | 0.0022 | 0.0021 | 0.0021 | 0.0021 | 0.0021 | 0.0021 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.0024 | 0.0024 | 0.0024 | 0.0025 | 0.0026 | 0.0026 | 0.0026 | 0.0026 |
| | | Motorcycles | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 | 0.0020 |
| | CNG | Heavy Vehicles | - | - | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | LPG | Passenger Cars | 0.0005 | 0.0006 | 0.0006 | 0.0006 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Se (g/GJ) | Diesel | Passenger Cars | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Light Duty Vehicles | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Heavy Vehicles | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | Gasoline | Passenger Cars | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Motorcycles | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | CNG | Heavy Vehicles | - | - | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | LPG | Passenger Cars | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Zn (g/GJ) | Diesel | Passenger Cars | 0.0513 | 0.0528 | 0.0525 | 0.0529 | 0.0498 | 0.0498 | 0.0499 | 0.0495 |
| | | Light Duty Vehicles | 0.0550 | 0.0559 | 0.0574 | 0.0582 | 0.0550 | 0.0550 | 0.0552 | 0.0547 |
| | | Heavy Vehicles | 0.0509 | 0.0513 | 0.0499 | 0.0510 | 0.0483 | 0.0483 | 0.0483 | 0.0481 |
| | Gasoline | Passenger Cars | 0.0502 | 0.0515 | 0.0521 | 0.0521 | 0.0520 | 0.0519 | 0.0519 | 0.0518 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.0599 | 0.0599 | 0.0607 | 0.0651 | 0.0680 | 0.0688 | 0.0690 | 0.0691 |
| | | Motorcycles | 0.0426 | 0.0429 | 0.0431 | 0.0437 | 0.0442 | 0.0447 | 0.0449 | 0.0450 |
| | CNG | Heavy Vehicles | - | - | 0.0131 | 0.0131 | 0.0131 | 0.0131 | 0.0131 | 0.0131 |
| | LPG | Passenger Cars | 0.0288 | 0.0292 | 0.0295 | 0.0292 | 0.0290 | 0.0290 | 0.0290 | 0.0290 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

Table 3.123 – Road transportation energy based implied emission factors (g/GJ) for persistent organic pollutant

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dioxins and Furans (g/GJ) | Diesel | Passenger Cars | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01287 | 0.01252 | 0.01122 | 0.01018 |
| | | Light Duty Vehicles | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01287 | 0.01252 | 0.01122 | 0.01018 |
| | | Heavy Vehicles | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01287 | 0.01252 | 0.01122 | 0.01018 |
| | Gasoline | Passenger Cars | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01371 | 0.01335 | 0.01195 | 0.01093 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01371 | 0.01335 | 0.01195 | 0.01093 |
| | | Motorcycles | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01371 | 0.01335 | 0.01195 | 0.01093 |
| | CNG | Heavy Vehicles | - | - | 0.01201 | 0.01333 | 0.01371 | 0.01335 | 0.01195 | 0.01093 |
| | LPG | Passenger Cars | 0.01050 | 0.01200 | 0.01201 | 0.01333 | 0.01371 | 0.01335 | 0.01195 | 0.01093 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

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

Table 3.124 – Road transportation distance based implied emission factor (g/km) for main pollutants, particulate matter and black carbon

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| SO2 (g/km) | Diesel | Passenger Cars | 0.37879 | 0.24678 | 0.04412 | 0.00606 | 0.00112 | 0.00111 | 0.00111 | 0.00110 |
| | | Light Duty Vehicles | 0.49550 | 0.32152 | 0.05382 | 0.00751 | 0.00140 | 0.00139 | 0.00139 | 0.00138 |
| | | Heavy Vehicles | 1.40746 | 0.92623 | 0.19100 | 0.02724 | 0.00495 | 0.00511 | 0.00519 | 0.00516 |
| | Gasoline | Passenger Cars | 0.12403 | 0.12178 | 0.01810 | 0.00587 | 0.00116 | 0.00116 | 0.00116 | 0.00116 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.05000 | 0.05000 | 0.00733 | 0.00219 | 0.00041 | 0.00040 | 0.00040 | 0.00040 |
| | | Motorcycles | 0.07825 | 0.07964 | 0.01198 | 0.00378 | 0.00073 | 0.00071 | 0.00070 | 0.00069 |
| | CNG | Heavy Vehicles | - | - | 0.00150 | 0.00151 | 0.00150 | 0.00150 | 0.00150 | 0.00150 |
| | LPG | Passenger Cars | 0.00018 | 0.00018 | 0.00018 | 0.00018 | 0.00018 | 0.00018 | 0.00018 | 0.00018 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| NO2 (g/km) | Diesel | Passenger Cars | 0.69776 | 0.68976 | 0.73348 | 0.73051 | 0.66939 | 0.65356 | 0.64871 | 0.61683 |
| | | Light Duty Vehicles | 1.50693 | 1.41789 | 1.29035 | 1.16745 | 1.02454 | 0.94641 | 0.91386 | 0.88465 |
| | | Heavy Vehicles | 8.62977 | 8.51011 | 9.86553 | 9.87857 | 8.34964 | 8.58380 | 8.70327 | 8.77522 |
| | Gasoline | Passenger Cars | 1.95063 | 1.47450 | 0.92689 | 0.56279 | 0.33524 | 0.22182 | 0.18452 | 0.15091 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.05600 | 0.05600 | 0.07019 | 0.12272 | 0.15283 | 0.16063 | 0.16194 | 0.16280 |
| | | Motorcycles | 0.24765 | 0.23787 | 0.23002 | 0.21932 | 0.18920 | 0.16073 | 0.15130 | 0.14382 |
| | CNG | Heavy Vehicles | - | - | 11.19552 | 11.28304 | 11.08601 | 11.08601 | 11.08601 | 11.08601 |
| | LPG | Passenger Cars | 2.21960 | 1.39134 | 0.96345 | 0.78664 | 0.55484 | 0.31885 | 0.24239 | 0.19332 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| NMVOC (g/km) | Diesel | Passenger Cars | 0.17422 | 0.10688 | 0.07659 | 0.04739 | 0.02864 | 0.02109 | 0.01871 | 0.01647 |
| | | Light Duty Vehicles | 0.13490 | 0.13580 | 0.13216 | 0.11988 | 0.09230 | 0.07193 | 0.06229 | 0.05332 |
| | | Heavy Vehicles | 0.66351 | 0.63863 | 0.64510 | 0.57032 | 0.42354 | 0.41365 | 0.41971 | 0.41832 |
| | Gasoline | Passenger Cars | 2.94007 | 2.32152 | 1.42961 | 0.89135 | 0.57117 | 0.41620 | 0.36279 | 0.31299 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 8.35 | 8.35 | 7.41 | 4.27 | 2.39 | 1.90 | 1.81 | 1.74 |
| | | Motorcycles | 3.42 | 3.61 | 3.41 | 2.29 | 1.73 | 1.31 | 1.17 | 1.05 |
| | CNG | Heavy Vehicles | - | - | 0.06304 | 0.06619 | 0.05910 | 0.05910 | 0.05910 | 0.05910 |
| | LPG | Passenger Cars | 1.18268 | 1.05353 | 0.87444 | 0.74355 | 0.57381 | 0.38011 | 0.31085 | 0.27008 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| CO (g/km) | Diesel | Passenger Cars | 0.74385 | 0.59831 | 0.45969 | 0.26534 | 0.16726 | 0.13272 | 0.12221 | 0.11303 |
| | | Light Duty Vehicles | 1.26832 | 1.07224 | 0.71104 | 0.53355 | 0.43345 | 0.34091 | 0.29682 | 0.25583 |
| | | Heavy Vehicles | 2.16478 | 2.10514 | 2.32409 | 2.22967 | 1.94491 | 1.97789 | 2.01541 | 2.03733 |
| | Gasoline | Passenger Cars | 18.55 | 13.44 | 8.14 | 4.95 | 3.11 | 2.27 | 1.99 | 1.72 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 14.70 | 14.70 | 12.79 | 7.45 | 3.71 | 2.62 | 2.40 | 2.24 |
| | | Motorcycles | 21.18 | 21.56 | 19.78 | 14.06 | 10.58 | 7.73 | 6.81 | 6.04 |
| | CNG | Heavy Vehicles | - | - | 1.40648 | 1.43623 | 1.36924 | 1.36924 | 1.36924 | 1.36924 |
| | LPG | Passenger Cars | 5.391 | 4.541 | 3.884 | 3.518 | 2.886 | 2.070 | 1.772 | 1.603 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| NH3 (g/km) | Diesel | Passenger Cars | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00108 | 0.00123 | 0.00129 | 0.00169 |
| | | Light Duty Vehicles | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00114 | 0.00122 | 0.00131 |
| | | Heavy Vehicles | 0.00300 | 0.00300 | 0.00300 | 0.00300 | 0.00306 | 0.00307 | 0.00306 | 0.00303 |
| | Gasoline | Passenger Cars | 0.00204 | 0.02142 | 0.04890 | 0.06377 | 0.05768 | 0.05081 | 0.04705 | 0.04262 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00100 | 0.00100 |
| | | Motorcycles | 0.00200 | 0.00200 | 0.00200 | 0.00200 | 0.00200 | 0.00200 | 0.00200 | 0.00200 |
| | CNG | Heavy Vehicles | - | - | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | LPG | Passenger Cars | 0.00200 | 0.04300 | 0.06877 | 0.07698 | 0.07466 | 0.05931 | 0.05227 | 0.04918 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| PM10 (g/km) | Diesel | Passenger Cars | 0.26041 | 0.15896 | 0.10316 | 0.06956 | 0.05564 | 0.04744 | 0.04469 | 0.04192 |
| | | Light Duty Vehicles | 0.36550 | 0.30409 | 0.20017 | 0.13201 | 0.09905 | 0.07993 | 0.07200 | 0.06491 |
| | | Heavy Vehicles | 0.39276 | 0.38451 | 0.42066 | 0.37411 | 0.28440 | 0.28888 | 0.29155 | 0.29128 |
| | Gasoline | Passenger Cars | 0.02001 | 0.02068 | 0.02099 | 0.02001 | 0.01938 | 0.01917 | 0.01910 | 0.01904 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.18589 | 0.18589 | 0.17097 | 0.09609 | 0.04594 | 0.03207 | 0.02950 | 0.02772 |
| | | Motorcycles | 0.05749 | 0.05776 | 0.05663 | 0.04586 | 0.03676 | 0.02894 | 0.02641 | 0.02433 |
| | CNG | Heavy Vehicles | - | - | 0.08233 | 0.08233 | 0.08233 | 0.08233 | 0.08233 | 0.08233 |
| | LPG | Passenger Cars | 0.02001 | 0.02069 | 0.02099 | 0.02030 | 0.01974 | 0.01930 | 0.01914 | 0.01905 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| PM2.5 (g/km) | Diesel | Passenger Cars | 0.25227 | 0.15052 | 0.09459 | 0.06126 | 0.04749 | 0.03933 | 0.03659 | 0.03384 |
| | | Light Duty Vehicles | 0.35364 | 0.29222 | 0.18830 | 0.12015 | 0.08719 | 0.06806 | 0.06013 | 0.05304 |
| | | Heavy Vehicles | 0.36091 | 0.35272 | 0.38707 | 0.33986 | 0.25037 | 0.25428 | 0.25677 | 0.25631 |
| | Gasoline | Passenger Cars | 0.01186 | 0.01224 | 0.01242 | 0.01171 | 0.01123 | 0.01106 | 0.01100 | 0.01095 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.18110 | 0.18110 | 0.16618 | 0.09129 | 0.04115 | 0.02727 | 0.02471 | 0.02292 |
| | | Motorcycles | 0.05363 | 0.05375 | 0.05255 | 0.04192 | 0.03290 | 0.02509 | 0.02257 | 0.02049 |
| | CNG | Heavy Vehicles | - | - | 0.04445 | 0.04445 | 0.04445 | 0.04445 | 0.04445 | 0.04445 |
| | LPG | Passenger Cars | 0.01187 | 0.01225 | 0.01242 | 0.01200 | 0.01159 | 0.01120 | 0.01105 | 0.01096 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| BC (g/km) | Diesel | Passenger Cars | 0.14379 | 0.08580 | 0.05392 | 0.03492 | 0.02541 | 0.02103 | 0.01959 | 0.01796 |
| | | Light Duty Vehicles | 0.19450 | 0.16072 | 0.10357 | 0.06608 | 0.04502 | 0.03512 | 0.03107 | 0.02717 |
| | | Heavy Vehicles | 0.19128 | 0.18694 | 0.20515 | 0.18013 | 0.12458 | 0.12642 | 0.12785 | 0.12650 |
| | Gasoline | Passenger Cars | 0.00142 | 0.00147 | 0.00149 | 0.00141 | 0.00135 | 0.00133 | 0.00132 | 0.00131 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.01992 | 0.01992 | 0.01828 | 0.01004 | 0.00453 | 0.00300 | 0.00272 | 0.00252 |
| | | Motorcycles | 0.00590 | 0.00591 | 0.00578 | 0.00461 | 0.00362 | 0.00276 | 0.00248 | 0.00225 |
| | CNG | Heavy Vehicles | - | - | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | LPG | Passenger Cars | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

Table 3.125 – Road transportation distance based implied emission factor (g/km) for heavy metals

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pb (g/km) | Diesel | Passenger Cars | 0.0000015 | 0.0000015 | 0.0000015 | 0.0000015 | 0.0000014 | 0.0000014 | 0.0000013 | 0.0000013 |
| | | Light Duty Vehicles | 0.0000020 | 0.0000020 | 0.0000019 | 0.0000018 | 0.0000017 | 0.0000017 | 0.0000017 | 0.0000017 |
| | | Heavy Vehicles | 0.0000057 | 0.0000056 | 0.0000067 | 0.0000066 | 0.0000060 | 0.0000062 | 0.0000063 | 0.0000063 |
| | Gasoline | Passenger Cars | 0.0248888 | 0.0244375 | 0.0003027 | 0.0002947 | 0.0002918 | 0.0002916 | 0.0002916 | 0.0002919 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.0100334 | 0.0100334 | 0.0001226 | 0.0001101 | 0.0001029 | 0.0001011 | 0.0001008 | 0.0001006 |
| | | Motorcycles | 0.0157027 | 0.0159806 | 0.0002004 | 0.0001895 | 0.0001823 | 0.0001772 | 0.0001756 | 0.0001743 |
| | CNG | Heavy Vehicles | - | - | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | LPG | Passenger Cars | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Cu (g/km) | Diesel | Passenger Cars | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Light Duty Vehicles | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 |
| | | Heavy Vehicles | 0.0012 | 0.0012 | 0.0013 | 0.0013 | 0.0012 | 0.0012 | 0.0012 | 0.0012 |
| | Gasoline | Passenger Cars | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| | | Motorcycles | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| | CNG | Heavy Vehicles | - | - | 0.0011 | 0.0011 | 0.0011 | 0.0011 | 0.0011 | 0.0011 |
| | LPG | Passenger Cars | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Cd (g/km) | Diesel | Passenger Cars | 7.42641E-07 | 7.32478E-07 | 7.47664E-07 | 7.19304E-07 | 6.62518E-07 | 6.58279E-07 | 6.57747E-07 | 6.51028E-07 |
| | | Light Duty Vehicles | 9.87328E-07 | 9.65302E-07 | 9.30381E-07 | 9.12737E-07 | 8.49555E-07 | 8.46311E-07 | 8.46898E-07 | 8.39032E-07 |
| | | Heavy Vehicles | 2.78728E-06 | 2.75601E-06 | 3.1882E-06 | 3.19052E-06 | 2.91282E-06 | 2.99753E-06 | 3.03747E-06 | 3.02107E-06 |
| | Gasoline | Passenger Cars | 7.31463E-07 | 7.24418E-07 | 7.20738E-07 | 7.00961E-07 | 6.92897E-07 | 6.92137E-07 | 6.91828E-07 | 6.92409E-07 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 3.16602E-07 | 3.16602E-07 | 3.10972E-07 | 2.86081E-07 | 2.71721E-07 | 2.68069E-07 | 2.67449E-07 | 2.67043E-07 |
| | | Motorcycles | 4.44491E-07 | 4.53461E-07 | 4.55642E-07 | 4.3203E-07 | 4.16587E-07 | 4.06238E-07 | 4.02967E-07 | 4.00311E-07 |
| | CNG | Heavy Vehicles | - | - | 5.39414E-07 | 5.39414E-07 | 5.39414E-07 | 5.39414E-07 | 5.39414E-07 | 5.39414E-07 |
| | LPG | Passenger Cars | 1.11316E-07 | 1.15518E-07 | 1.17419E-07 | 1.13544E-07 | 1.11331E-07 | 1.10783E-07 | 1.10619E-07 | 1.10463E-07 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Cr (g/km) | Diesel | Passenger Cars | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | | Light Duty Vehicles | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 |
| | | Heavy Vehicles | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | Gasoline | Passenger Cars | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | | Motorcycles | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | CNG | Heavy Vehicles | - | - | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | LPG | Passenger Cars | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ni (g/km) | Diesel | Passenger Cars | 5.83E-06 | 5.78E-06 | 5.90E-06 | 5.68E-06 | 5.23E-06 | 5.19E-06 | 5.19E-06 | 5.14E-06 |
| | | Light Duty Vehicles | 7.80E-06 | 7.65E-06 | 7.41E-06 | 7.28E-06 | 6.78E-06 | 6.76E-06 | 6.77E-06 | 6.70E-06 |
| | | Heavy Vehicles | 2.22E-05 | 2.19E-05 | 2.49E-05 | 2.49E-05 | 2.28E-05 | 2.34E-05 | 2.37E-05 | 2.35E-05 |
| | Gasoline | Passenger Cars | 5.75E-06 | 5.73E-06 | 5.71E-06 | 5.55E-06 | 5.48E-06 | 5.47E-06 | 5.47E-06 | 5.47E-06 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 2.62E-06 | 2.62E-06 | 2.58E-06 | 2.40E-06 | 2.30E-06 | 2.28E-06 | 2.27E-06 | 2.27E-06 |
| | | Motorcycles | 3.42E-06 | 3.50E-06 | 3.52E-06 | 3.34E-06 | 3.23E-06 | 3.15E-06 | 3.13E-06 | 3.11E-06 |
| | CNG | Heavy Vehicles | - | - | 7.37E-06 | 7.37E-06 | 7.37E-06 | 7.37E-06 | 7.37E-06 | 7.37E-06 |
| | LPG | Passenger Cars | 1.41E-06 | 1.46E-06 | 1.49E-06 | 1.44E-06 | 1.41E-06 | 1.40E-06 | 1.40E-06 | 1.39E-06 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Se (g/km) | Diesel | Passenger Cars | 8.20E-07 | 8.11E-07 | 8.26E-07 | 7.97E-07 | 7.35E-07 | 7.31E-07 | 7.30E-07 | 7.23E-07 |
| | | Light Duty Vehicles | 1.11E-06 | 1.08E-06 | 1.05E-06 | 1.03E-06 | 9.62E-07 | 9.58E-07 | 9.59E-07 | 9.50E-07 |
| | | Heavy Vehicles | 3.03E-06 | 3.00E-06 | 3.50E-06 | 3.53E-06 | 3.22E-06 | 3.33E-06 | 3.38E-06 | 3.36E-06 |
| | Gasoline | Passenger Cars | 8.09E-07 | 8.03E-07 | 8.00E-07 | 7.79E-07 | 7.70E-07 | 7.69E-07 | 7.69E-07 | 7.70E-07 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 3.52E-07 | 3.52E-07 | 3.46E-07 | 3.21E-07 | 3.07E-07 | 3.03E-07 | 3.03E-07 | 3.02E-07 |
| | | Motorcycles | 4.77E-07 | 4.87E-07 | 4.89E-07 | 4.65E-07 | 4.49E-07 | 4.39E-07 | 4.36E-07 | 4.33E-07 |
| | CNG | Heavy Vehicles | - | - | 6.89E-07 | 6.89E-07 | 6.89E-07 | 6.89E-07 | 6.89E-07 | 6.89E-07 |
| | LPG | Passenger Cars | 1.89E-07 | 1.94E-07 | 1.96E-07 | 1.91E-07 | 1.89E-07 | 1.88E-07 | 1.88E-07 | 1.88E-07 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| Zn (g/km) | Diesel | Passenger Cars | 1.38E-04 | 1.39E-04 | 1.41E-04 | 1.37E-04 | 1.26E-04 | 1.25E-04 | 1.25E-04 | 1.24E-04 |
| | | Light Duty Vehicles | 1.94E-04 | 1.91E-04 | 1.88E-04 | 1.86E-04 | 1.74E-04 | 1.74E-04 | 1.74E-04 | 1.72E-04 |
| | | Heavy Vehicles | 5.08E-04 | 5.06E-04 | 5.79E-04 | 5.92E-04 | 5.43E-04 | 5.61E-04 | 5.68E-04 | 5.68E-04 |
| | Gasoline | Passenger Cars | 1.37E-04 | 1.38E-04 | 1.38E-04 | 1.35E-04 | 1.33E-04 | 1.33E-04 | 1.33E-04 | 1.33E-04 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 6.59E-05 | 6.59E-05 | 6.53E-05 | 6.28E-05 | 6.14E-05 | 6.10E-05 | 6.10E-05 | 6.09E-05 |
| | | Motorcycles | 7.34E-05 | 7.51E-05 | 7.57E-05 | 7.26E-05 | 7.06E-05 | 6.95E-05 | 6.91E-05 | 6.88E-05 |
| | CNG | Heavy Vehicles | - | - | 2.83E-04 | 2.83E-04 | 2.83E-04 | 2.83E-04 | 2.83E-04 | 2.83E-04 |
| | LPG | Passenger Cars | 7.48E-05 | 7.70E-05 | 7.79E-05 | 7.60E-05 | 7.48E-05 | 7.46E-05 | 7.45E-05 | 7.44E-05 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

Table 3.126 – Road transportation distance based implied emission factor (g/km) for persistent organic pollutant

| Pollutant | Fuel | Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dioxins and Furans (g/km) | Diesel | Passenger Cars | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00003 |
| | | Light Duty Vehicles | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00004 | 0.00003 |
| | | Heavy Vehicles | 0.00010 | 0.00012 | 0.00014 | 0.00015 | 0.00014 | 0.00015 | 0.00013 | 0.00012 |
| | Gasoline | Passenger Cars | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00004 | 0.00003 | 0.00003 | 0.00003 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |
| | | Heavy Vehicles | - | - | - | - | - | - | - | - |
| | | Mopeds | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | | Motorcycles | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 | 0.00002 |
| | CNG | Heavy Vehicles | - | - | 0.00026 | 0.00029 | 0.00029 | 0.00029 | 0.00026 | 0.00024 |
| | LPG | Passenger Cars | 0.00003 | 0.00003 | 0.00003 | 0.00003 | 0.00004 | 0.00003 | 0.00003 | 0.00003 |
| | | Light Duty Vehicles | - | - | - | - | - | - | - | - |

### 3.2.3.2.4 Activity Data

#### *3.2.3.2.4.1 Vehicle Fleet*

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

Table 3.127 – Vehicle fleet synthesis (including Azores and Madeira)

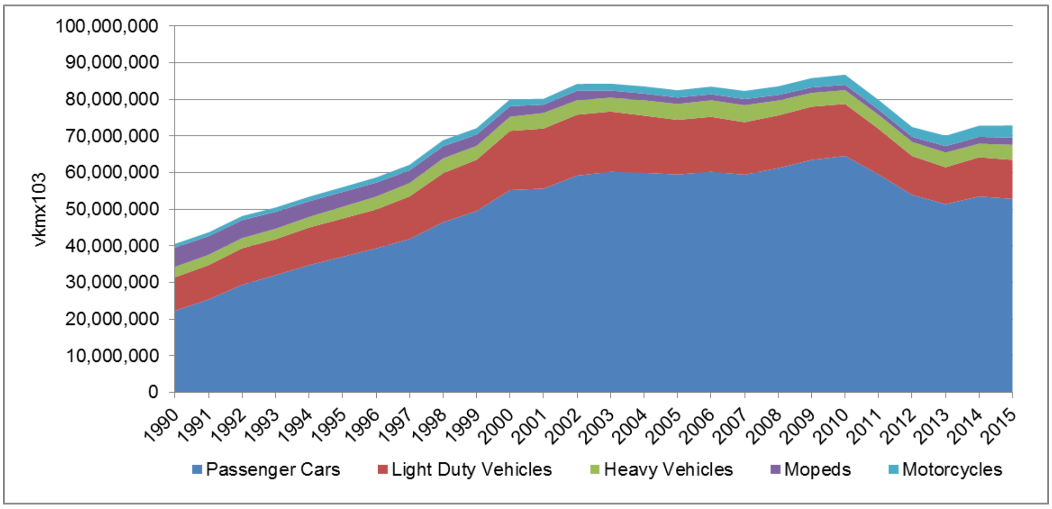
| Vehicle Type | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| Passenger Cars | 1,616,141 | 2,702,221 | 3,743,315 | 4,185,542 | 4,191,286 | 3,803,363 | 3,690,706 | 3,612,644 |
| Light Duty Vehicles | 449,918 | 545,091 | 684,953 | 751,144 | 718,869 | 628,816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

The growth of gasoline passenger cars has decreased over the last years. It was observed a decrease in the number of this type of vehicles while diesel passenger cars have increased. After an initial growth, LPG fuelled vehicles have stabilized as a small percentage of passenger cars. The number of mopeds is decreasing according with data from ISP.

### *3.2.3.2.4.2 Distances Travelled*

Total road traffic activity has increased 81.25% between 1990 and 2015.

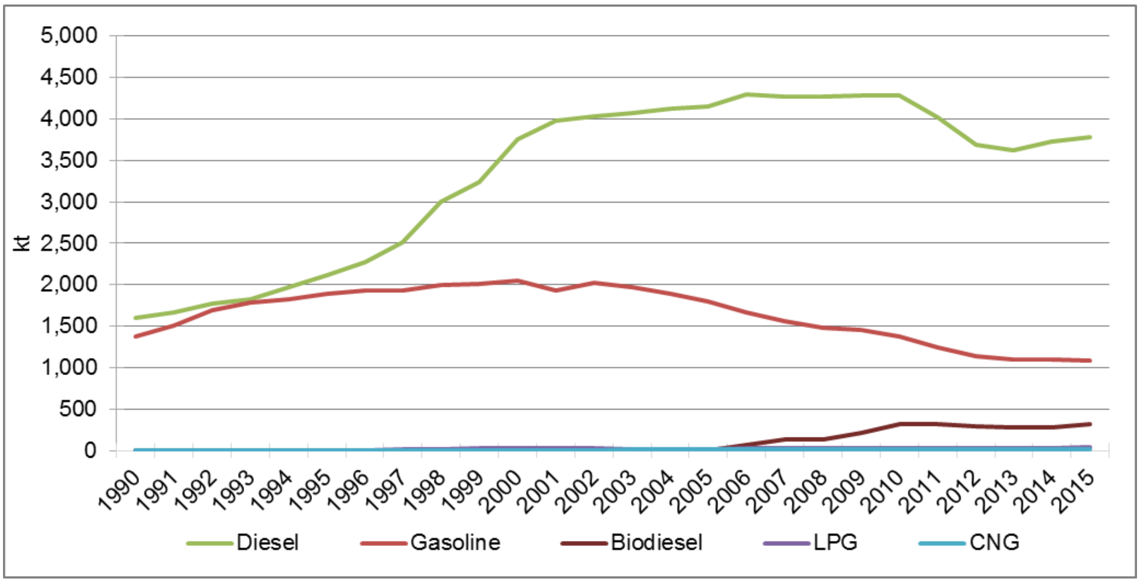
Figure 3.62 – Kilometers travelled by vehicle type (vkmx$10^3$) (including Azores and Madeira)



### 3.2.3.2.4.3 Fuel Consumption

Fuel consumption from road transport sector is available from the revised energy balances from DGEG and is presented in the following figure and ANNEX C: ENERGY (NFR 1).

Figure 3.63 – Fuel consumption from road transport sector




Source: DGEG

Fuel consumption was also estimated from the fuel consumption factors given from COPERT IV. The bottom-up versus top-down correction factor was derived from the differences between estimated and real fuel consumption as explained.

### 3.2.3.2.5 Category-specific QA/QC and Verification

Differences were found in fuel consumption time series taken as a sum from COPERT IV compared to total fuel sales data taken from the energy balance. In 2015 the estimated fuel consumption compared to sales are: Gasoline -8%; Diesel 5%; LPG -84%; CNG -98%. These differences are corrected in COPERT IV to equal fuel sales in order to ensure full consistency between Energy Statistics and inventory.

### 3.2.3.2.6 Recalculations

Recalculations for this source category comprise:

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

### 3.2.3.2.7 Further Improvements

No further improvements are planned for this sector.

### 3.2.3.3 *Railways (NFR 1.A.3.c)*

#### 3.2.3.3.1 Overview

Although there has been a growing electrification of railway lines in Portugal during latest years, locomotives, shunting locomotives and railcars are still responsible for substantial part of rail transport and consequent emission of GHG in exhaust.

#### 3.2.3.3.2 Methodology

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

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

where

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

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

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

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

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

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

For all other pollutants the following formula was used:

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

where

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

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

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

#### 3.2.3.3.3 Emission Factors

Emission factors, expressed in kg/t of fuel, were set from available proposed emission factors in EMEP/CORINAIR Handbook (EEA, 2002; EEA, 2016), IPCC 2006 Guidelines (IPCC, 2006) and MEET project, and are presented in next table.

Table 3.128 – Low Heating Value (LHV) in Railways

| Fuel | | NAPFUE | LHV |
|---|---|---|---|
| | | | MJ/kg |
| Coal | S | 102 | 31.0 |
| Coke | S | 108 | 29.4 |
| Diesel-oil | L | 204 | 42.6 |
| Biodiesel | B | 223 | 37.0 |

Table 3.129 – Emission factors in Railways

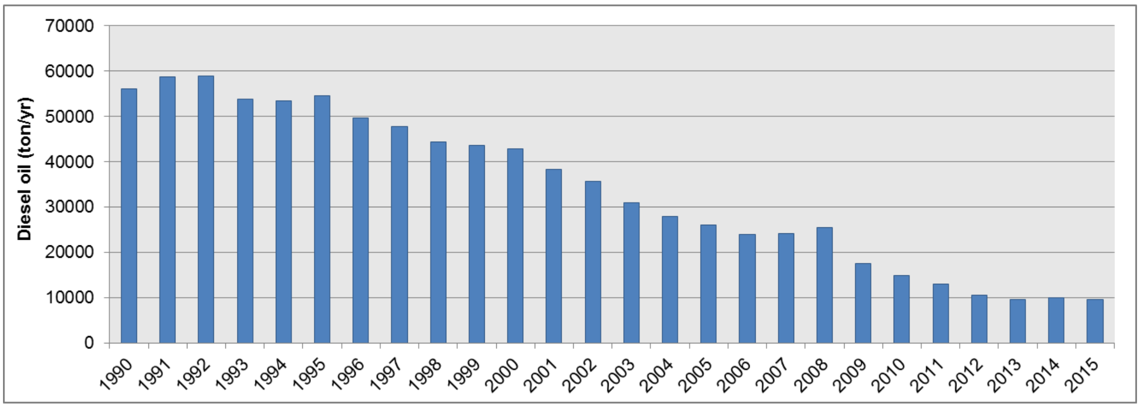
| Fuel | Coal | | | Coke | | | Diesel-oil | | | Biodiesel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ (v) | 55.63 | kg/t | Guidebook | 55.63 | kg/t | Guidebook | 55.63 | kg/t | Guidebook | 55.63 | kg/t | Guidebook |
| NMVOC (iv) | 5.08 | kg/t | Guidebook | 5.08 | kg/t | Guidebook | 5.08 | kg/t | Guidebook | 5.08 | kg/t | Guidebook |
| CO (v) | 19.60 | kg/t | Guidebook | 19.60 | kg/t | Guidebook | 19.60 | kg/t | Guidebook | 19.60 | kg/t | Guidebook |
| TSP | 1.52 | kg/t | Guidebook | 1.52 | kg/t | Guidebook | 1.52 | kg/t | Guidebook | 1.52 | kg/t | Guidebook |
| $PM_{10}$ | 1.44 | kg/t | Guidebook | 1.44 | kg/t | Guidebook | 1.44 | kg/t | Guidebook | 1.44 | kg/t | Guidebook |
| $PM_{2.5}$ | 1.37 | kg/t | Guidebook | 1.37 | kg/t | Guidebook | 1.37 | kg/t | Guidebook | 1.37 | kg/t | Guidebook |
| BC | 0 | % PM2.5 | Guidebook | 0 | % PM2.5 | Guidebook | 0.65 | % PM2.5 | Guidebook | 0.00 | % PM2.5 | Guidebook |
| Pb | 1.22 | g/t | Guidebook | 1.22 | g/t | Guidebook | 0.59 | g/t | Guidebook | 0.59 | g/t | Guidebook |
| Cd | 0.01 | g/t | Guidebook | 0.01 | g/t | Guidebook | 0.01 | g/t | Guidebook | 0.01 | g/t | Guidebook |
| As | 0.05 | g/t | Guidebook | 0.05 | g/t | Guidebook | 0.05 | g/t | Guidebook | 0.05 | g/t | Guidebook |
| Cr | 0.05 | g/t | Guidebook | 0.05 | g/t | Guidebook | 0.05 | g/t | Guidebook | 0.05 | g/t | Guidebook |
| Cu | 1.70 | g/t | Guidebook | 1.70 | g/t | Guidebook | 1.70 | g/t | Guidebook | 1.70 | g/t | Guidebook |
| Ni | 0.07 | g/t | Guidebook | 0.07 | g/t | Guidebook | 0.07 | g/t | Guidebook | 0.07 | g/t | Guidebook |
| Se | 0.01 | g/t | Guidebook | 0.01 | g/t | Guidebook | 0.01 | g/t | Guidebook | 0.01 | g/t | Guidebook |
| Zn | 1.00 | g/t | Guidebook | 1.00 | g/t | Guidebook | 1.00 | g/t | Guidebook | 1.00 | g/t | Guidebook |
| PAH | 3.32 | g/t | Guidebook | 3.32 | g/t | Guidebook | 3.32 | g/t | Guidebook | 3.32 | g/t | Guidebook |

(iv) Average of EMEP/CORINAIR (Eurpean values) and IPCC (US values);
(v) Average of EMEP/CORINAIR, IPCC and MEET;

### 3.2.3.3.4 Activity Data

Consumption of fuel in the railway transport sector is available by fuel type from 1990 to 2015 from the energy balance produced by General-Directorate of Geology and Energy (DGEG) and are presented in ANNEX C: ENERGY (NFR 1). Besides some very small use of coal and coke until 1996, and biodiesel since 2006, the majority of combustible energy refers to use of gas oil[23]. The quantities that were consumed have been decreasing steadily since 1992 due to electrification of the power lines, as can be seen in Figure 3.64.

Figure 3.64 - Consumption of diesel oil in the railway transport sector




### 3.2.3.3.5 Category-specific QA/QC and Verification

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

### 3.2.3.3.6 Recalculations

No recalculations were made.

### 3.2.3.3.7 Further Improvements

No further improvements are planned for this sector.

## 3.2.3.4 *Water Borne Navigation (NFR 1.A.3.d)*

### 3.2.3.4.1 Overview

This sector refers to domestic ship transport between Portuguese ports in mainland territory. Water borne navigation emissions from Madeira and Azores islands are not covered by the IIR. Emissions are primarily estimated for all territory. Then emissions islands are subtracted according with the domestic distance travelled allocated to each seaport.

### 3.2.3.4.2 Methodology

Statistics on fuel used in shipping activities are available at national level as an aggregated figure provided in the energy balance from the energy authority. Detailed ship movements are also

[23] Gas oil represents no less than 98.4 per cent of total annual use of combustible energy.

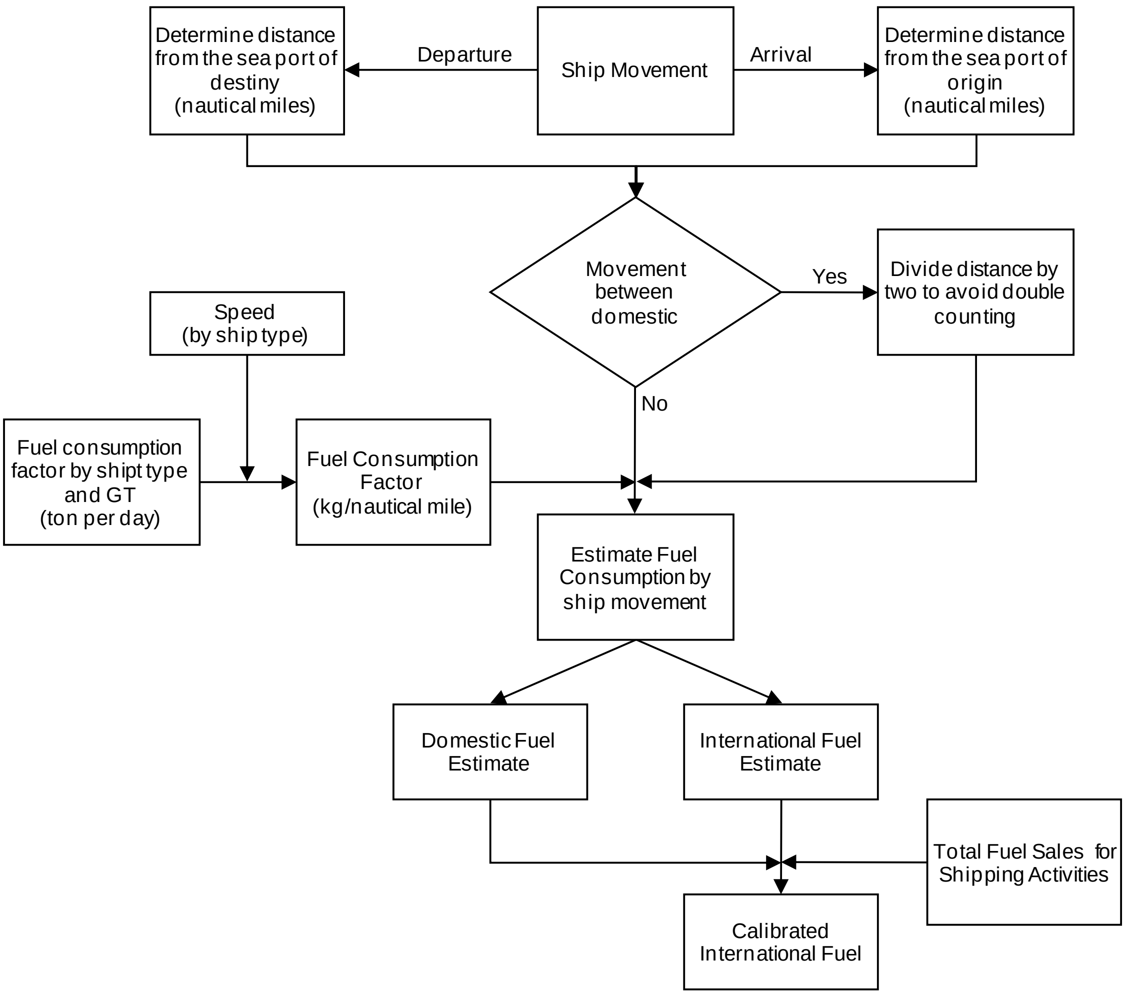
available, as well as some technical information on the ships such as gross tonnage and ship type.

The methodology used for the calculation of emissions from shipping activities is in accordance with the ship movement methodology from the detailed methodology of EMEP/CORINAR air pollutant emission inventory guidebook (version from August 2002).

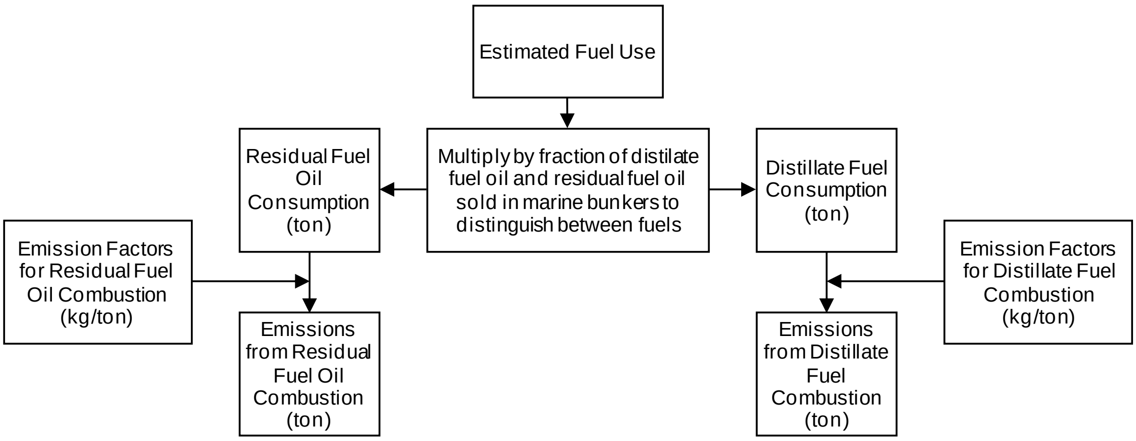
The methodology takes into account the fuel used as well as the type of ship, the distance travelled and the speed of vessel. Therefore, according with IPCC Guidelines, this approach consists in a detailed method (tier 2 or 3). Since fuel consumption is used for top-down calibration, tier 2 method could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

The general approach could be described as follows:

Figure 3.65 – Generic methodology flowchart.




Emissions factors vary according with the type of fuel used. To distinguish between residual and distillate fuel an additional calculation step is required:




### 3.2.3.4.3 Emission Factors

Emission factors and energy content were obtained from several sources. The energy content of residual and distillate fuels was provided by the energy authority (DGEG). The emission factors were obtained from EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook.

Table 3.130 – Low Heating Value (LHV) for navigation

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

Source: DGEG

Table 3.131 – Emission factors for navigation

| Fuel | Gas Oil | | | Residual Fuel-oil | | |
|---|---|---|---|---|---|---|
| Pollutant | Value | Unit | Reference | Value | Unit | Reference |
| $NO_x$ | 72.0 | kg/t | Guidebook | 72.0 | kg/t | Guidebook |
| $SO_x$ | (1) 4.000<br>(2) 2.000<br>(3) 1.000 | kg/t | Guidebook | 53.4 | kg/t | Guidebook |
| NMVOC | 2.4 | kg/t | Guidebook | 2.4 | kg/t | Guidebook |
| CO | 7.4 | kg/t | Guidebook | 7.4 | kg/t | Guidebook |

(1) Until year 2000, inclusive;
(2) Between year 2000 and 2010;
(3) After year 2010.
Source: EMEP/CORINAIR

The fuel consumption factors (expressed in tonne per day) are dependent from the ship type and from the gross tonnage. The equations used to derive fuel consumption factors were obtained from EMEP/CORINAIR.

Table 3.132 – Consumption factors

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

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

### 3.2.3.4.4 Activity Data

#### *3.2.3.4.4.1 Ships movements in national sea ports*

The activity data from navigation is based on ship movement for individual ships in each national seaport comprehending nine ports in Portugal mainland and four in islands of Madeira and Azores.

The data provided by national seaports reports to the years 1990 and 1995; and to the period between 2000 and 2015. The number of movements and the distances travelled for the period 1991-1994 and 1996-1999 were estimated according with a trend line established between years with available data.

For most cases, data on origin and destiny was also available per movement which allowed to estimate the distances travelled and to distinguish between domestic and international movements.

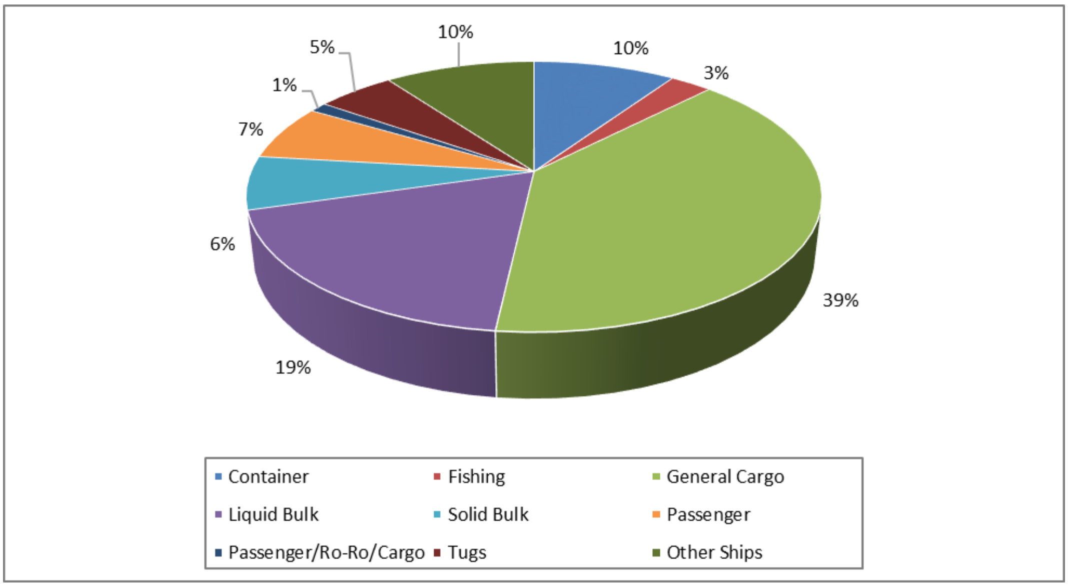
Table 3.133 – Ship docks

| Sea Port | Location | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aveiro | Mainland | docks | 876 | 1,098 | 1,009 | 1,028 | 961 | 837 | 922 | 988 | 1,025 |
| Caniçal | Madeira | docks | 76 | 76 | 76 | 178 | 390 | 276 | 283 | 274 | 241 |
| Faro | Mainland | docks | 163 | 163 | 163 | 32 | 12 | 70 | 35 | 79 | 85 |
| Figueira da Foz | Mainland | docks | 315 | 297 | 307 | 321 | 476 | 471 | 523 | 528 | 496 |
| Funchal | Madeira | docks | 1,063 | 1,063 | 1,063 | 948 | 758 | 771 | 719 | 640 | 664 |
| Leixões | Mainland | docks | 2,742 | 2,896 | 3,050 | 2,814 | 2,612 | 2,608 | 2,564 | 2,627 | 2,735 |
| Lisboa | Mainland | docks | 5,586 | 4,993 | 3,869 | 3,474 | 3,129 | 2,652 | 2,658 | 2,709 | 2,605 |
| Ponta Delgada | Azores | docks | 1,080 | 1,080 | 1,080 | 1,078 | 1,035 | 912 | 886 | 810 | 831 |
| Portimão | Mainland | docks | 34 | 34 | 37 | 42 | 136 | 56 | 105 | 50 | 70 |
| Porto Santo | Madeira | docks | 402 | 402 | 402 | 400 | 392 | 383 | 368 | 349 | 348 |
| Setúbal | Mainland | docks | 1,453 | 1,453 | 1,699 | 1,592 | 1,632 | 2,604 | 1,426 | 1,576 | 1,627 |
| Sines | Mainland | docks | 1,038 | 979 | 808 | 1,124 | 1,632 | 1,636 | 1,991 | 1,994 | 901 |
| Viana do Castelo | Mainland | docks | 254 | 293 | 348 | 214 | 179 | 248 | 214 | 227 | 198 |

### 3.2.3.4.4.2 Ship Fleet

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

Figure 3.66 – Ship fleet.




### 3.2.3.4.4.3 Fuel consumption

Domestic fuel consumption was estimated using a bottom-up approach from fuel consumption factors. International fuel is estimated by subtracting the domestic fuel to the total fuel sales.

Although water borne navigation emissions from Madeira and Azores islands are not covered by the IIR, the figures presented concern all the Portuguese territory – continental mainland and islands. The reason is that emissions are primarily estimated for all territory and only then occurs the process of spatial allocation whereby emissions from mainland and islands are separated according with the domestic distance travelled allocated to each seaport.

The result of spatial allocation of fuel consumption is presented below.

Table 3.134 – Total fuel sales (ton)

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

Source: DGEG

Table 3.135 – Estimated fuel consumption (ton)

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

Table 3.136 – Estimated fuel consumption after top-down calibration (ton)

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

Table 3.137 – Spatial allocation of fuel consumption in mainland territory (ton)

| Fuel | Region | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| Residual Fuel-oil | Domestic | 37,315 | 32,306 | 28,629 | 29,736 | 32,571 | 35,463 | 37,439 | 37,863 |
| Residual Fuel-oil | International | 317,684 | 218,063 | 393,008 | 374,269 | 415,105 | 585,736 | 516,018 | 496,034 |
| **Residual Fuel-oil** | Total | 354,999 | 250,369 | 421,637 | 404,004 | 447,676 | 621,199 | 553,457 | 533,897 |
| Gas-oil | Domestic | 14,094 | 12,202 | 10,814 | 11,231 | 12,302 | 13,395 | 14,141 | 14,301 |
| Gas-oil | International | 95,119 | 111,136 | 98,818 | 84,113 | 67,713 | 67,596 | 63,628 | 123,525 |
| **Gas-oil** | Total | 109,213 | 123,338 | 109,631 | 95,344 | 80,016 | 80,991 | 77,769 | 137,826 |

#### *3.2.3.4.4.3.1 Tugs Fuel consumption*

Data concerning tugs assistance operations within the national seaports allowed the incorporation of these emissions in the inventory. Tug fuel consumption was estimated for each manoeuvring ship in a seaport following the criteria shown in the Table 3.148. Specific tug fuel consumption factors were supplied by IPTM.

Table 3.138 – Criteria employed in the tugs fuel consumption estimation.

| Ship Type | Seaport | Assisted Arrivals (%) | Assisted Departures (%) | N.º Of Tugs/Arrival | N.º Of Tugs/Departure |
|---|---|---|---|---|---|
| Small Size | All | 20 | 0 | 1 | 0 |
| Medium Size | All | 50 | 25 | 1 | 1 |
| Large Size | All | 100 | 100 | 2 | 1 |
| Super Large Size | Sines and Leixões | 100 | 100 | 3 | 2 |
| Super Large Size | All except Sines and Leixões | 100 | 100 | 2 | 2 |

This estimation required the ship size classification expressed in table below.

Table 3.139 – Ship type classification for tugs fuel consumption estimation.

| Ship Type | gt |
|---|---|
| Small Size | gt≤1000 |
| Medium Size | 10000≤gt<1000 |
| Large Size | 50000≤gt<10000 |
| Super Large Size | gt>50000 |

gt: gross tonnage

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

##### 3.2.3.4.5 Category-specific QA/QC and Verification

Energy consumption was compared with data from the energy balance reported by DGEG. No differences were found between total fuel estimated with the described methodology and total fuel reported in the energy balance.

##### 3.2.3.4.6 Recalculations

Recalculations for this source category comprise:

- update and correction of the 2014 data due to a compilation error detected during the QA/QC procedure

##### 3.2.3.4.7 Further Improvements

No further improvements are planned for this sector.

### 3.2.4 Small Combustion (NFR 1.A.4)

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

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

#### 3.2.4.1 *Commercial/Institutional (NFR 1.A.4.a)*

##### 3.2.4.1.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in commercial, services and institutional sector. In this sector small other mobile sources are not considered because no separation between fuel consumption is possible in the energy balance.

#### 3.2.4.1.2 Methodology

Emissions of $SO_x$ are directly related to the fuel content of the fuel, and were estimated from:

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

where:

$Emi_{SOx(s)}$ - Total emissions of SOx from sub-sector s (t/yr);

$S_{(f,s,t)}$- Sulphur content of fuel f used in sub-sector s and equipment t in year y (%);

$Fuel_{Cons(f,s,t)}$ – Fuel consumption for each particular fuel and in each equipment of technology t (t/yr).

In the case of emissions of Heavy Metals the following equation was used:

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

and,

$HM_{p (f,s)}$ - Heavy Metal p emission estimated from consumption of fuel f in sub-sector s (t/yr);

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

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

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

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

Emissions were estimated from fuel/energy consumption using either mass balance ($SO_x$) or emission factors, according to the pollutant, and using a IPCC Tier 2 methodology.

Emissions of other pollutants that were also calculated from energy activity rate use the following basic formula (Energy Approach):

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

where:

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

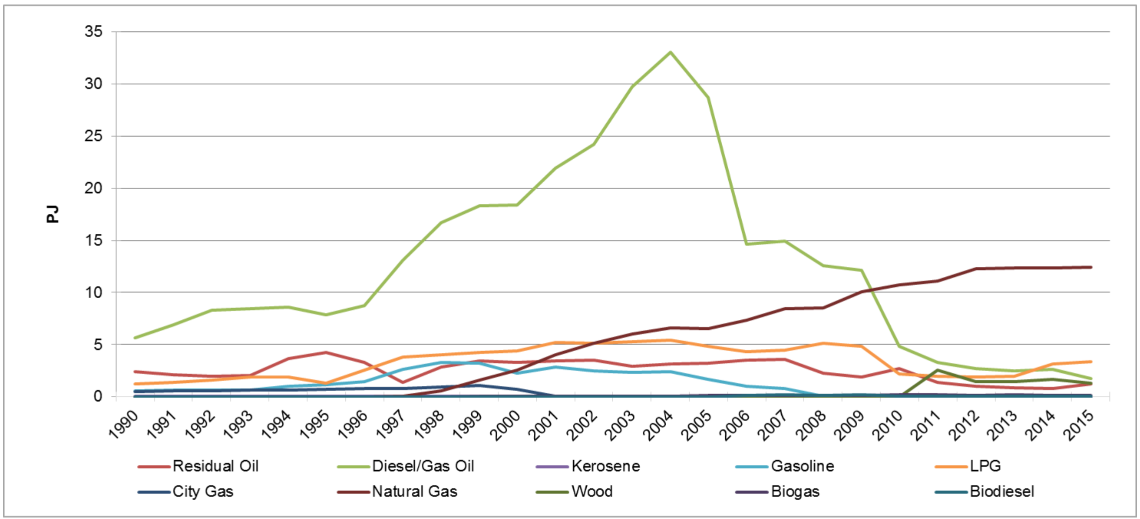
$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except $CO_2$ in kg/GJ);

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

### 3.2.4.1.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following figures and ANNEX C: ENERGY (NFR 1).

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




The Diesel/Gas Oil time series show a drop in consumption from 2005 to 2006. This fact results from reallocation, in the energy balance, of road gas oil from services not specified to agriculture (DGEG). There is a decrease in diesel oil consumption in 2010 for the services sector that results from the incorporation of data from the 2010 Survey on Energy Consumption in the Residential Sector. This decrease is coupled with an increase in diesel consumption in the residential sector.

Figure 3.68 – Total Energy Consumption in fuels in the commercial/services/institutional sector

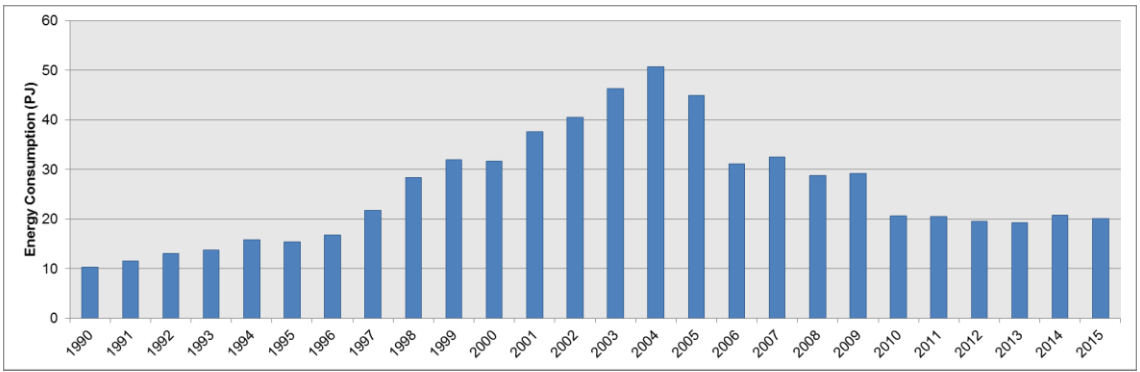
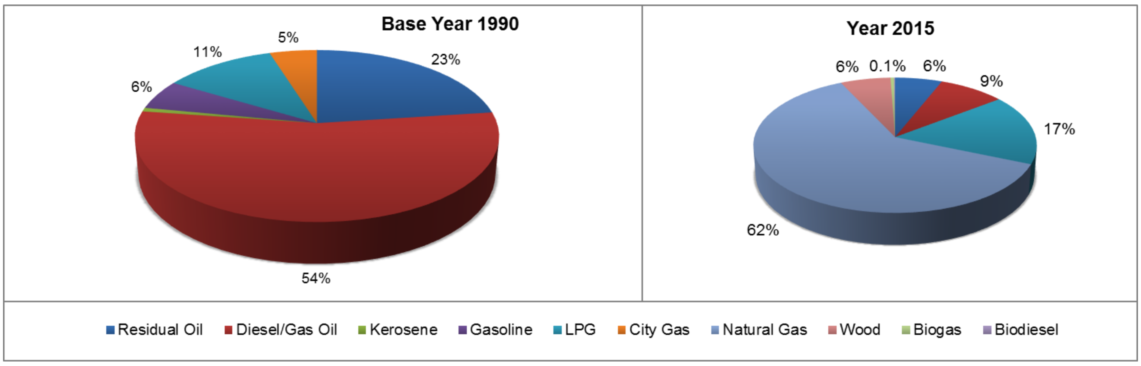


Figure 3.69 – Consumption of energy in fuels in the commercial/services/institutional sector in 1990 and 2015




### 3.2.4.1.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA,2016);
- 2006 IPCC Revised Guidelines (IPPC,2006).

Table 3.140 – Low Heating Value (LHV) - Commercial, services and institutional sector

| Fuel | | NAPFUE | LHV MJ/kg |
|---|---|---|---|
| Residual Oil | L | 203 | 40.0 |
| Gas Oil | L | 204 | 42.6 |
| Diesel Oil | L | 205 | 42.6 |
| Kerosene | L | 206 | 43.8 |
| Motor Gasoline | L | 208 | 44.0 |
| LPG | L | 303 | 46.0 |
| City Gas | L | 308 | 15.7 |
| Natural Gas | G | 301 | 46.1 |
| Biogas | B | 309 | 34.7 |
| Biodiesel | B | 223 | 37.0 |

Table 3.141 – Emissions factors - Commercial, services and institutional sector (1/2)

| Fuel | Residual Oil | | | Gas Oil / Diesel Oil | | | Kerosene | | | Motor Gasoline | | | LPG | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pollutant | Value | Unit | Reference | Value | Unit | Reference | Value | Unit | Reference | Value | Unit | Reference | Value | Unit | Reference |
| $NO_x$ | 513 | g/GJ | Guidebook | 513 | g/GJ | Guidebook | 513 | g/GJ | Guidebook | 513 | g/GJ | Guidebook | 40 | g/GJ | Guidebook |
| NMVOC | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook | 2 | g/GJ | Guidebook |
| CO | 66 | g/GJ | Guidebook | 66 | g/GJ | Guidebook | 66 | g/GJ | Guidebook | 66 | g/GJ | Guidebook | 30 | g/GJ | Guidebook |
| TSP | 20 | g/GJ | Guidebook | 20 | g/GJ | Guidebook | 20 | g/GJ | Guidebook | 20 | g/GJ | Guidebook | 0.45 | g/GJ | Guidebook |
| $PM_{10}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| $PM_{2.5}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| BC | 56 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook |
| Pb | 0.0032 | g/ton | Guidebook | 0.0034 | g/ton | Guidebook | 0.0035 | g/ton | Guidebook | 0.0035 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook |
| Cd | 0.0002 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.000012 | g/ton | Guidebook |
| Hg | 0.0048 | g/ton | Guidebook | 0.0051 | g/ton | Guidebook | 0.0053 | g/ton | Guidebook | 0.0053 | g/ton | Guidebook | 0.004600 | g/ton | Guidebook |
| As | 0.0012 | g/ton | Guidebook | 0.0013 | g/ton | Guidebook | 0.0013 | g/ton | Guidebook | 0.0013 | g/ton | Guidebook | 0.005520 | g/ton | Guidebook |
| Cr | 0.0080 | g/ton | Guidebook | 0.0085 | g/ton | Guidebook | 0.0088 | g/ton | Guidebook | 0.0088 | g/ton | Guidebook | 0.000035 | g/ton | Guidebook |
| Cu | 0.0088 | g/ton | Guidebook | 0.0094 | g/ton | Guidebook | 0.0096 | g/ton | Guidebook | 0.0097 | g/ton | Guidebook | 0.000003 | g/ton | Guidebook |
| Ni | 0.0003 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.0004 | g/ton | Guidebook | 0.0004 | g/ton | Guidebook | 0.000023 | g/ton | Guidebook |
| Se | 0.0044 | g/ton | Guidebook | 0.0047 | g/ton | Guidebook | 0.0048 | g/ton | Guidebook | 0.0048 | g/ton | Guidebook | 0.000506 | g/ton | Guidebook |
| Zn | 1.16 | g/ton | Guidebook | 1.24 | g/ton | Guidebook | 1.27 | g/ton | Guidebook | 1.28 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook |
| DioxFur | 1.40 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook | 0.50 | µg TEQ/TJ | Guidebook |
| PAH | 0.80 | mg/t | Guidebook | 0.86 | mg/t | Guidebook | 0.88 | mg/t | Guidebook | 0.88 | mg/t | Guidebook | 0.14 | mg/t | Guidebook |

Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.142 – Emissions factors - Commercial, services and institutional sector (2/2)

| Fuel | City Gas | | | Natural Gas | | | Biogas | | | Biodiesel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 40 | g/GJ | Guidebook | 40 | g/GJ | Guidebook | 40 | g/GJ | Guidebook | 513 | g/GJ | Guidebook |
| NMVOC | 2 | g/GJ | Guidebook | 2 | g/GJ | Guidebook | 2 | g/GJ | Guidebook | 25 | g/GJ | Guidebook |
| CO | 30 | g/GJ | Guidebook | 30 | g/GJ | Guidebook | 30 | g/GJ | Guidebook | 66 | g/GJ | Guidebook |
| TSP | 0.45 | g/GJ | Guidebook | 0.45 | g/GJ | Guidebook | 0.45 | g/GJ | Guidebook | 20 | g/GJ | Guidebook |
| $PM_{10}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| $PM_{2.5}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| BC | 5.4 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook |
| Pb | 0.000024 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook | 0.000052 | g/ton | Guidebook | 0.00296 | g/ton | Guidebook |
| Cd | 0.000004 | g/ton | Guidebook | 0.000012 | g/ton | Guidebook | 0.000009 | g/ton | Guidebook | 0.00022 | g/ton | Guidebook |
| Hg | 0.001569 | g/ton | Guidebook | 0.004607 | g/ton | Guidebook | 0.003470 | g/ton | Guidebook | 0.00444 | g/ton | Guidebook |
| As | 0.001883 | g/ton | Guidebook | 0.005529 | g/ton | Guidebook | 0.004164 | g/ton | Guidebook | 0.00111 | g/ton | Guidebook |
| Cr | 0.000012 | g/ton | Guidebook | 0.000035 | g/ton | Guidebook | 0.000026 | g/ton | Guidebook | 0.00740 | g/ton | Guidebook |
| Cu | 0.000001 | g/ton | Guidebook | 0.000004 | g/ton | Guidebook | 0.000003 | g/ton | Guidebook | 0.00814 | g/ton | Guidebook |
| Ni | 0.000008 | g/ton | Guidebook | 0.000023 | g/ton | Guidebook | 0.000018 | g/ton | Guidebook | 0.00030 | g/ton | Guidebook |
| Se | 0.000173 | g/ton | Guidebook | 0.000507 | g/ton | Guidebook | 0.000382 | g/ton | Guidebook | 0.00407 | g/ton | Guidebook |
| Zn | 0.000024 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook | 0.000052 | g/ton | Guidebook | 1.07 | g/ton | Guidebook |
| DioxFur | 0.50 | µg TEQ/TJ | Guidebook | 0.50 | µg TEQ/TJ | Guidebook | 0.50 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook |
| PAH | 0.05 | mg/t | Guidebook | 0.14 | mg/t | Guidebook | 0.11 | mg/t | Guidebook | 0.74 | mg/t | Guidebook |

Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.143 – Emissions factors for Sulphur content of fuels (%S) - Commercial, services and institutional sector

| Year | Residual Fuel Oil | Diesel/ Gas Oil | Kerosene | Motor Gasoline | LPG | City Gas | Natural Gas | Biogas | Biodiesel |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 2.84 | 0.30 | 0.15 | 0.100 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 1995 | 2.60 | 0.25 | 0.15 | 0.100 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 2000 | 2.60 | 0.15 | 0.15 | 0.100 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 2005 | 1.00 | 0.10 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 2010 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 2013 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 2014 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |
| 2015 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.0 | 0.0 |

(a) Weighted average of gas oil and diesel oil for heating

##### 3.2.4.1.5 Category-specific QA/QC and Verification

To further improve the QA/QC analysis a comparison between fuel consumption values reported by DGEG and IEA (International Energy Agency) was made. Only minor differences in natural gas consumption between data sources were identified for Commercial and Public Services sector (less than 10 per cent). For petroleum product the differences between data sources are greater than natural gas (around 30 per cent). DGEG reported that there were compilation errors in the information sent to IEA, which may explain the differences found.

##### 3.2.4.1.6 Recalculations

No recalculations were made.

##### 3.2.4.1.7 Further Improvements

No further improvements are planned for this sector.

#### 3.2.4.2 *Residential (NFR 1.A.4.b)*

##### 3.2.4.2.1 Overview

The sources covered in this chapter refer to those emissions resulting from combustion in the residential sector. In this sector small other mobile sources are not considered because no separation between fuel consumption is possible with DGEG's energy balance data.

##### 3.2.4.2.2 Methodology

Emissions of $SO_x$ are directly related to the fuel content of the fuel, and were estimated from:

$$Emis_{SOx(s)} = 2 * \Sigma_f \Sigma_t [S_{(f,s,t,y)} /100 * Fuel_{Cons(f,s,t)}]$$

where:

$Emis_{SOx(s)}$ - Total emissions of SOx from sub-sector s (t/yr);

$S_{(f,s,t)}$- Sulphur content of fuel f used in sub-sector s and equipment t in year y (%);

$Fuel_{Cons(f,s,t)}$ – Fuel consumption for each particular fuel and in each equipment of technology t (t/yr).

In the case of emissions of Heavy Metals the following equation was used:

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

and,

$HM_{p\ (f,s)}$ - Heavy Metal p emission estimated from consumption of fuel f in sub-sector s (t/yr);

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

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

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

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

Emissions were estimated from fuel/energy consumption using either mass balance ($SO_x$) or emission factors, according to the pollutant, and using a IPCC Tier 2 methodology.

Emissions of other pollutants that were also calculated from energy activity rate use the following basic formula (Energy Approach):

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

where:

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

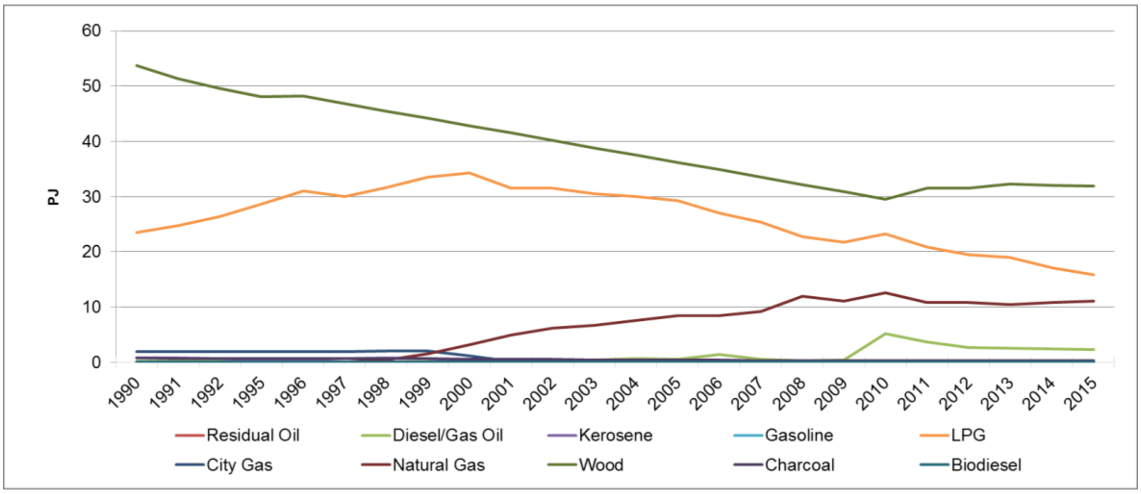
$EF_{(f,s,t,p)}$ - Emission Factor for fuel f used in sub-sector s and equipment t in year y (g/GJ except $CO_2$ in kg/GJ);

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

#### 3.2.4.2.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG and are presented in the following figures and in ANNEX C: ENERGY (NFR 1). Charcoal consumption was obtained from an inquiry made to the residential sector by DGEG.

Figure 3.70 – Fuels consumption in the residential sector




There is an increase in diesel oil consumption in 2010 for the residential sector that results from the incorporation of data from the 2010 Survey on Energy Consumption in the Residential Sector. This increase is coupled with a decrease in diesel consumption in the services sector.

Figure 3.71 – Total Energy Consumption in fuels in the residential sector

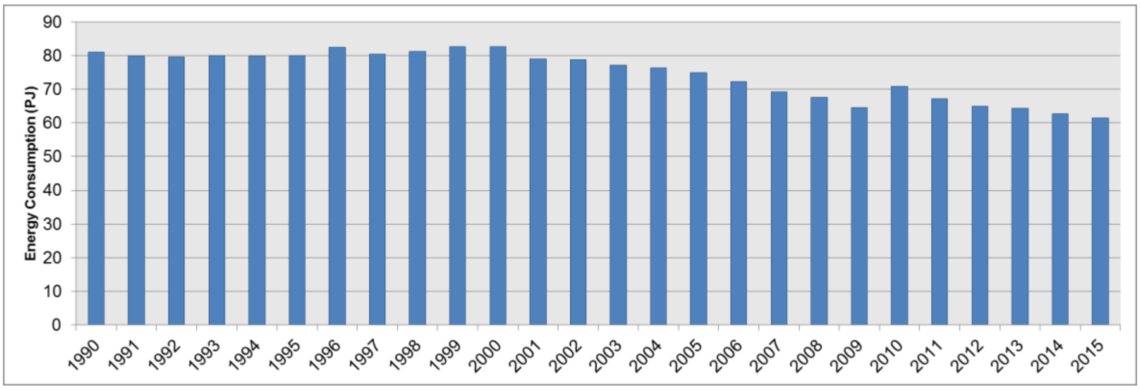
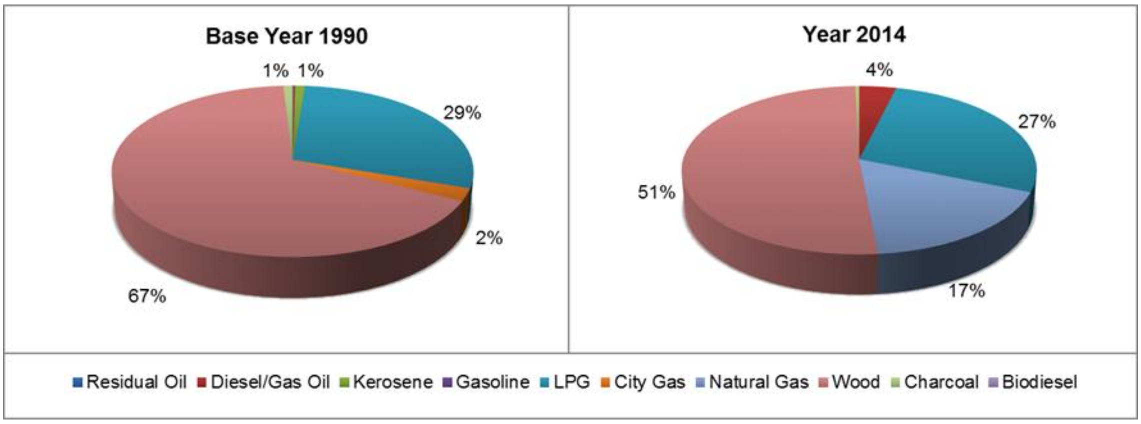



Figure 3.72 – Consumption of energy in fuels in the residential sector in 1990 and 2015



### 3.2.4.2.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA,2016);
- 2006 IPCC Revised Guidelines (IPPC,2006).

Table 3.144 – Low Heating Value (LHV) – Residential sector

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

Table 3.145 – Emissions factors – Residential sector (1/2)

| Fuel | Residual Oil | | | Gas Oil / Diesel Oil | | | Kerosene | | | Motor Gasoline | | | LPG | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 51 | g/GJ | Guidebook | 69 | g/GJ | Guidebook | 51 | g/GJ | Guidebook | 51 | g/GJ | Guidebook | 48 | g/GJ | Guidebook |
| NMVOC | 1 | g/GJ | Guidebook | 0.2 | g/GJ | Guidebook | 0.7 | g/GJ | Guidebook | 0.7 | g/GJ | Guidebook | 1.9 | g/GJ | Guidebook |
| CO | 57 | g/GJ | Guidebook | 4 | g/GJ | Guidebook | 57 | g/GJ | Guidebook | 57 | g/GJ | Guidebook | 25 | g/GJ | Guidebook |
| TSP | 1.9 | g/GJ | Guidebook | 1.9 | g/GJ | Guidebook | 1.9 | g/GJ | Guidebook | 1.9 | g/GJ | Guidebook | 0.90 | g/GJ | Guidebook |
| $PM_{10}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| $PM_{2.5}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| BC | 8.5 | % PM2.5 | Guidebook | 3.9 | % PM2.5 | Guidebook | 8.5 | % PM2.5 | Guidebook | 8.5 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook |
| Pb | 0.00048 | g/ton | Guidebook | 0.00051 | g/ton | Guidebook | 0.00053 | g/ton | Guidebook | 0.00053 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook |
| Cd | 0.00004 | g/ton | Guidebook | 0.00004 | g/ton | Guidebook | 0.00004 | g/ton | Guidebook | 0.00004 | g/ton | Guidebook | 0.000012 | g/ton | Guidebook |
| Hg | 0.00480 | g/ton | Guidebook | 0.00511 | g/ton | Guidebook | 0.00525 | g/ton | Guidebook | 0.00528 | g/ton | Guidebook | 0.004600 | g/ton | Guidebook |
| As | 0.00008 | g/ton | Guidebook | 0.00009 | g/ton | Guidebook | 0.00009 | g/ton | Guidebook | 0.00009 | g/ton | Guidebook | 0.005520 | g/ton | Guidebook |
| Cr | 0.00800 | g/ton | Guidebook | 0.00852 | g/ton | Guidebook | 0.00875 | g/ton | Guidebook | 0.00880 | g/ton | Guidebook | 0.000035 | g/ton | Guidebook |
| Cu | 0.00520 | g/ton | Guidebook | 0.00554 | g/ton | Guidebook | 0.00569 | g/ton | Guidebook | 0.00572 | g/ton | Guidebook | 0.000003 | g/ton | Guidebook |
| Ni | 0.00020 | g/ton | Guidebook | 0.00021 | g/ton | Guidebook | 0.00022 | g/ton | Guidebook | 0.00022 | g/ton | Guidebook | 0.000023 | g/ton | Guidebook |
| Se | 0.00008 | g/ton | Guidebook | 0.00009 | g/ton | Guidebook | 0.00009 | g/ton | Guidebook | 0.00009 | g/ton | Guidebook | 0.000506 | g/ton | Guidebook |
| Zn | 0.017 | g/ton | Guidebook | 0.018 | g/ton | Guidebook | 0.018 | g/ton | Guidebook | 0.018 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook |
| DioxFur | 5.90 | µg TEQ/TJ | Guidebook | 1.80 | µg TEQ/TJ | Guidebook | 5.90 | µg TEQ/TJ | Guidebook | 5.90 | µg TEQ/TJ | Guidebook | 1.50 | µg TEQ/TJ | Guidebook |
| PAH | 14.0 | mg/t | Guidebook | 14.91 | mg/t | Guidebook | 15.31 | mg/t | Guidebook | 15.40 | mg/t | Guidebook | 0.14 | mg/t | Guidebook |

Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.146 – Emissions factors – Residential sector (2/2)

| Fuel | City Gas | | | Natural Gas | | | Wood | | | Charcoal | | | Biodiesel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 48 | g/GJ | Guidebook | 48 | g/GJ | Guidebook | 73 | g/GJ | Guidebook | 73 | g/GJ | Guidebook | 69 | g/GJ | Guidebook |
| NMVOC | 1.9 | g/GJ | Guidebook | 1.9 | g/GJ | Guidebook | 410 | g/GJ | Guidebook | 410 | g/GJ | Guidebook | 0.2 | g/GJ | Guidebook |
| CO | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook | 4000 | g/GJ | Guidebook | 4000 | g/GJ | Guidebook | 4 | g/GJ | Guidebook |
| TSP | 0.90 | g/GJ | Guidebook | 0.90 | g/GJ | Guidebook | 531 | g/GJ | Guidebook | 531 | g/GJ | Guidebook | 2 | g/GJ | Guidebook |
| $PM_{10}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 95 | % TSP | Guidebook | 158 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| $PM_{2.5}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 93 | % TSP | Guidebook | 154 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| BC | 5.4 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook | 4.8 | % PM2.5 | Guidebook | 7 | % PM2.5 | Guidebook | 3.9 | % PM2.5 | Guidebook |
| Pb | 0.000024 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook | 0.339 | g/ton | Guidebook | 0.678 | g/ton | Guidebook | 0.00044 | g/ton | Guidebook |
| Cd | 0.000004 | g/ton | Guidebook | 0.000012 | g/ton | Guidebook | 0.163 | g/ton | Guidebook | 0.326 | g/ton | Guidebook | 0.00004 | g/ton | Guidebook |
| Hg | 0.001569 | g/ton | Guidebook | 0.004607 | g/ton | Guidebook | 0.007 | g/ton | Guidebook | 0.014 | g/ton | Guidebook | 0.00444 | g/ton | Guidebook |
| As | 0.001883 | g/ton | Guidebook | 0.005529 | g/ton | Guidebook | 0.002 | g/ton | Guidebook | 0.005 | g/ton | Guidebook | 0.00007 | g/ton | Guidebook |
| Cr | 0.000012 | g/ton | Guidebook | 0.000035 | g/ton | Guidebook | 0.289 | g/ton | Guidebook | 0.577 | g/ton | Guidebook | 0.00740 | g/ton | Guidebook |
| Cu | 0.000001 | g/ton | Guidebook | 0.000004 | g/ton | Guidebook | 0.075 | g/ton | Guidebook | 0.151 | g/ton | Guidebook | 0.00481 | g/ton | Guidebook |
| Ni | 0.000008 | g/ton | Guidebook | 0.000023 | g/ton | Guidebook | 0.025 | g/ton | Guidebook | 0.050 | g/ton | Guidebook | 0.00019 | g/ton | Guidebook |
| Se | 0.000173 | g/ton | Guidebook | 0.000507 | g/ton | Guidebook | 0.006 | g/ton | Guidebook | 0.013 | g/ton | Guidebook | 0.00007 | g/ton | Guidebook |
| Zn | 0.000024 | g/ton | Guidebook | 0.000069 | g/ton | Guidebook | 6.4 | g/ton | Guidebook | 12.9 | g/ton | Guidebook | 0.02 | g/ton | Guidebook |
| DioxFur | 1.50 | µg TEQ/TJ | Guidebook | 1.50 | µg TEQ/TJ | Guidebook | 430 | µg TEQ/TJ | Guidebook | 430 | µg TEQ/TJ | Guidebook | 1.80 | µg TEQ/TJ | Guidebook |
| PAH | 0.05 | mg/t | Guidebook | 0.14 | mg/t | Guidebook | 4331 | mg/t | Guidebook | 8661 | mg/t | Guidebook | 12.95 | mg/t | Guidebook |

Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.147 – Emissions factors for Sulphur content of fuel (%S) – Residential sector

| Year | Residual Fuel Oil | Diesel/ Gas Oil | Kerosene | Motor Gasoline | LPG | City Gas | Natural Gas | Wood / Charcoal | Biodiesel |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 2.84 | 0.30 | 0.15 | 0.100 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 1995 | 2.60 | 0.20 | 0.15 | 0.100 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 2000 | 2.60 | 0.05 | 0.15 | 0.100 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 2005 | 1.00 | 0.01 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 2010 | 1.00 | 0.01 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 2013 | 1.00 | 0.01 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 2014 | 1.00 | 0.01 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |
| 2015 | 1.00 | 0.01 | 0.15 | 0.015 | 0.0016 | 0.0 | 0.0007 | 0.03 | 0.0 |

#### 3.2.4.2.5 Category-specific QA/QC and Verification

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

#### 3.2.4.2.6 Recalculations

No recalculations were made.

#### 3.2.4.2.7 Further Improvements

No further improvements are planned for this sector.

### 3.2.4.3 *Agriculture / Forestry / Fishing: Stationary (NFR 1.A.4.c.i)*

#### 3.2.4.3.1 Overview

Emission considered in this source category cover stationary combustion in the agriculture, forestry and fishing sectors. Mobile sources for these sectors were included in 1.A.4.c.ii and 1.A.4.c.iii.

#### 3.2.4.3.2 Methodology

Emissions of $SO_x$ are directly related to the fuel content of the fuel, and were estimated from:

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

where:

$Emi_{SOx(s)}$ - Total emissions of SOx from sub-sector s (t/yr);

$S_{(f,s,t)}$- Sulphur content of fuel f used in sub-sector s and equipment t in year y (%);

$Fuel_{Cons(f,s,t)}$ – Fuel consumption for each particular fuel and in each equipment of technology t (t/yr).

In the case of emissions of Heavy Metals the following equation was used:

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

and,

$HM_{p\ (f,s)}$ - Heavy Metal p emission estimated from consumption of fuel f in sub-sector s (t/yr);

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

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

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

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

Emissions were estimated from fuel/energy consumption using either mass balance ($SO_x$) or emission factors, according to the pollutant, and using the IPCC Tier 2 methodology.

Emissions of other pollutants that were also calculated from energy activity rate use the following basic formula (Energy Approach):

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

where:

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

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

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

#### 3.2.4.3.3 Activity Data

Data on fuel consumption was obtained from the annual energy balances compiled by DGEG. To account the true stationary fuel consumption in the fishing sector, bunker fuel sales (also given by DGEG) were subtracted to the energy balance fishing sector consumption. Further explanation on bunker fuel sales are given in sector 1.A.4.c.iii. Fuel consumption values used in this source category emission estimation are presented in the following figures and in ANNEX C: ENERGY (NFR 1).

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

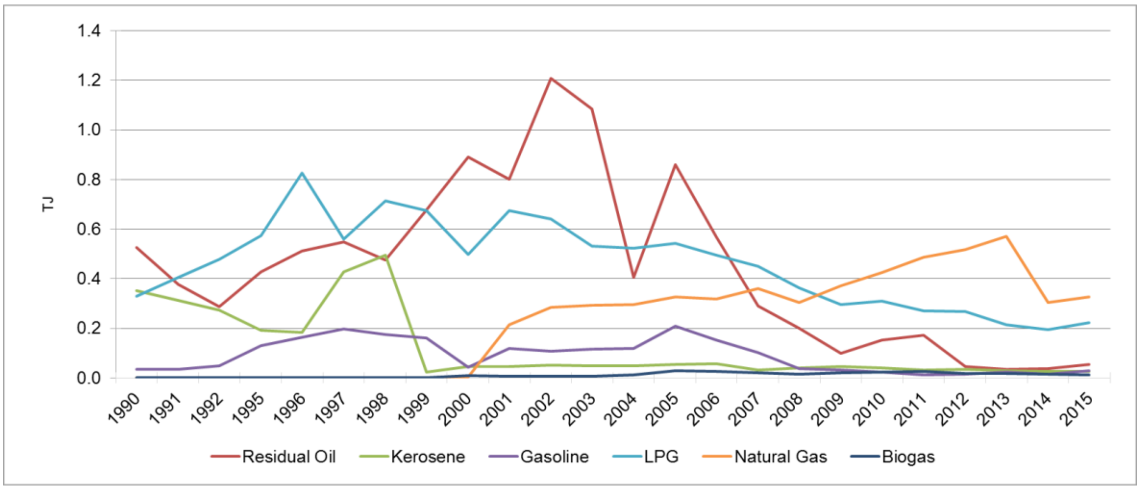



Figure 3.74 – Total Energy Consumption in fuels in the agriculture and forestry sector (excluding mobile sources)

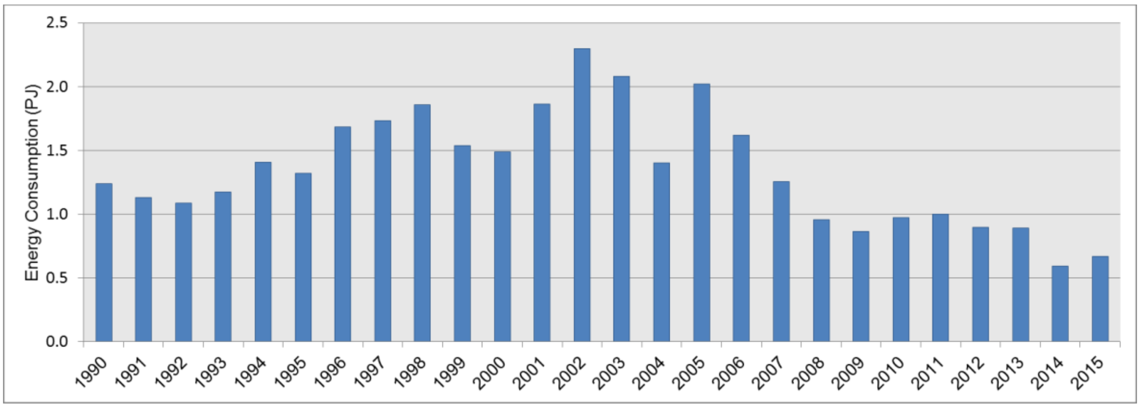



Figure 3.75 – Consumption of energy in fuels in the agriculture and forestry sector (excluding mobile sources) in 1990 and 2015

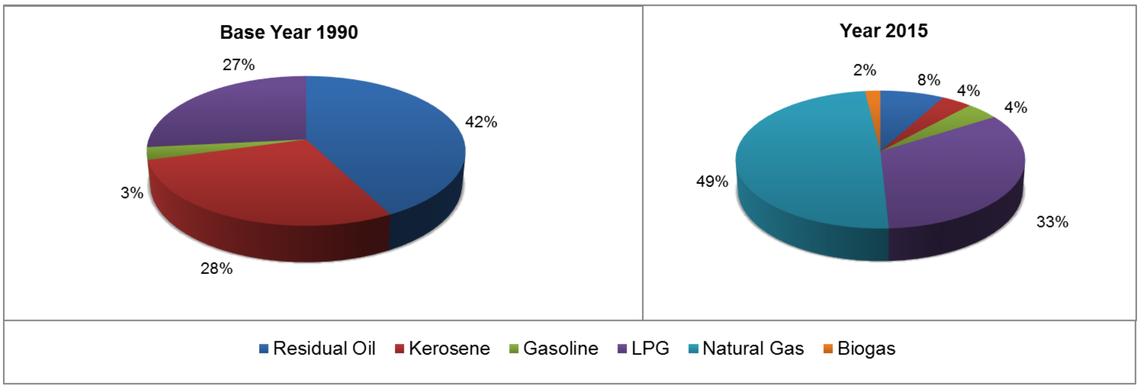


Figure 3.76 – Fuel consumed in fisheries (excluding consumption in fishing vessels)

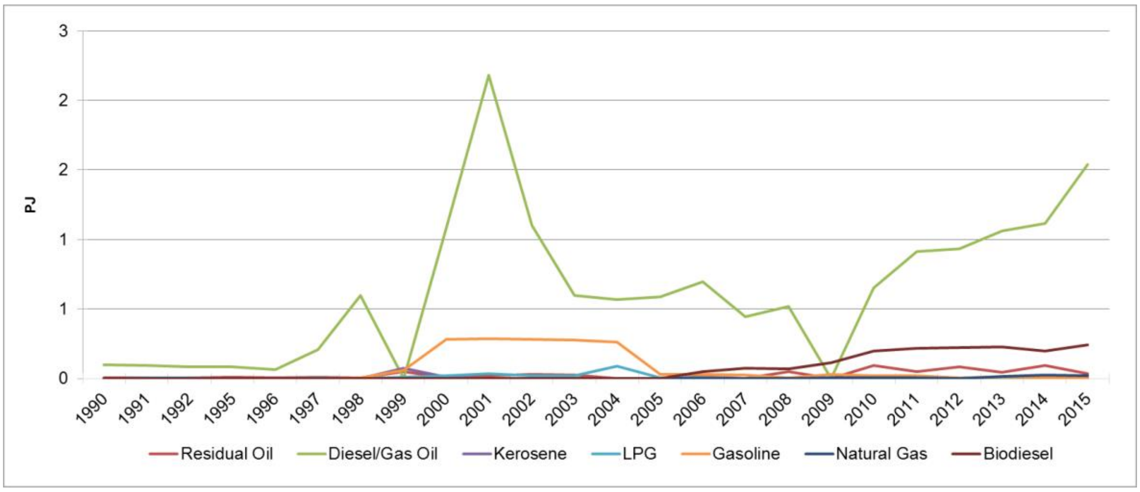



Figure 3.77 – Total Energy Consumption in fuels in fisheries (excluding consumption in fishing vessels)

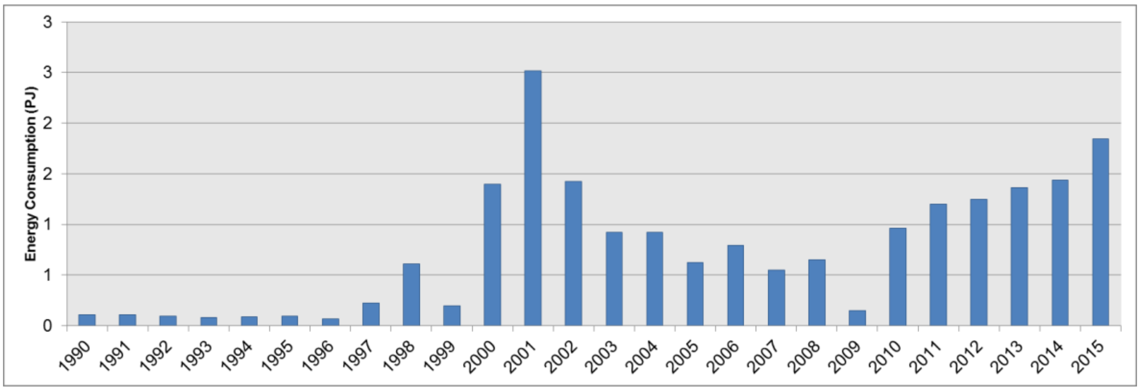
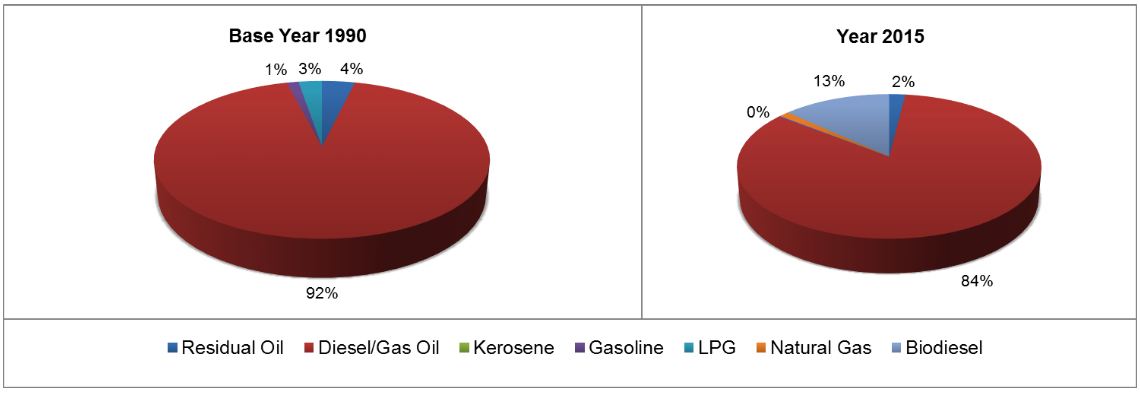



Figure 3.78 – Consumption of energy in fuels in fisheries (excluding consumption in fishing vessels) in 1990 and 2015



#### 3.2.4.3.4 Emission Factors

The emission factors that were used were collected from international bibliography sources, namely:

- EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA, 2016);
- 2006 IPCC Revised Guidelines (IPPC, 2006).

Table 3.148 – Low Heating Value (LHV) – Agriculture, forestry and fishing sectors (except mobile sources)

| Fuel | | NAPFUE | LHV |
|---|---|---|---|
| | | | MJ/kg |
| Residual Oil | L | 203 | 40.00 |
| Gas Oil | L | 204 | 42.60 |
| Kerosene | L | 206 | 43.75 |
| Motor Gasoline | L | 208 | 44.00 |
| LPG | L | 303 | 46.00 |
| Natural Gas | G | 301 | 46.07 |
| Biogas | B | 309 | 34.70 |
| Biodiesel | B | 223 | 37.00 |

Table 3.149 – Emissions factors - Agriculture, forestry and fishing sectors (except mobile sources) (1/2)

| Fuel | Residual Oil | | | Gas Oil | | | Kerosene | | | Motor Gasoline | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 513 | g/GJ | Guidebook | 513 | g/GJ | Guidebook | 513 | g/GJ | Guidebook | 513 | g/GJ | Guidebook |
| NMVOC | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook | 25 | g/GJ | Guidebook |
| CO | 66 | g/GJ | Guidebook | 66 | g/GJ | Guidebook | 66 | g/GJ | Guidebook | 66 | g/GJ | Guidebook |
| TSP | 20 | g/GJ | Guidebook | 20 | g/GJ | Guidebook | 20 | g/GJ | Guidebook | 20 | g/GJ | Guidebook |
| $PM_{10}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| $PM_{2.5}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| BC | 56 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook | 56.0 | % PM2.5 | Guidebook |
| Pb | 0.0032 | g/ton | Guidebook | 0.0034 | g/ton | Guidebook | 0.0035 | g/ton | Guidebook | 0.0035 | g/ton | Guidebook |
| Cd | 0.0002 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook |
| Hg | 0.0048 | g/ton | Guidebook | 0.0051 | g/ton | Guidebook | 0.0053 | g/ton | Guidebook | 0.0053 | g/ton | Guidebook |
| As | 0.0012 | g/ton | Guidebook | 0.0013 | g/ton | Guidebook | 0.0013 | g/ton | Guidebook | 0.0013 | g/ton | Guidebook |
| Cr | 0.0080 | g/ton | Guidebook | 0.0085 | g/ton | Guidebook | 0.0088 | g/ton | Guidebook | 0.0088 | g/ton | Guidebook |
| Cu | 0.0088 | g/ton | Guidebook | 0.0094 | g/ton | Guidebook | 0.0096 | g/ton | Guidebook | 0.0097 | g/ton | Guidebook |
| Ni | 0.0003 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook | 0.0004 | g/ton | Guidebook | 0.0004 | g/ton | Guidebook |
| Se | 0.0044 | g/ton | Guidebook | 0.0047 | g/ton | Guidebook | 0.0048 | g/ton | Guidebook | 0.0048 | g/ton | Guidebook |
| Zn | 1.16 | g/ton | Guidebook | 1.24 | g/ton | Guidebook | 1.27 | g/ton | Guidebook | 1.28 | g/ton | Guidebook |
| DioxFur | 1.40 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook |
| PAH | 0.80 | mg/t | Guidebook | 0.86 | mg/t | Guidebook | 0.88 | mg/t | Guidebook | 0.88 | mg/t | Guidebook |

Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.150 – Emissions factors - Agriculture, forestry and fishing sectors (except mobile sources) (2/2)

| Fuel | LPG | | | Natural Gas | | | Biogas | | | Biodiesel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 40 | g/GJ | Guidebook | 40 | g/GJ | Guidebook | 40 | g/GJ | Guidebook | 513 | g/GJ | Guidebook |
| NMVOC | 2 | g/GJ | Guidebook | 2 | g/GJ | Guidebook | 2 | g/GJ | Guidebook | 25 | g/GJ | Guidebook |
| CO | 30 | g/GJ | Guidebook | 30 | g/GJ | Guidebook | 30 | g/GJ | Guidebook | 66 | g/GJ | Guidebook |
| TSP | 0.45 | g/GJ | Guidebook | 0.45 | g/GJ | Guidebook | 0.45 | g/GJ | Guidebook | 20 | g/GJ | Guidebook |
| $PM_{10}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| $PM_{2.5}$ | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook | 100 | % TSP | Guidebook |
| BC | 5.4 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook | 5.4 | % PM2.5 | Guidebook | 56 | % PM2.5 | Guidebook |
| Pb | 0.00007 | g/ton | Guidebook | 0.00007 | g/ton | Guidebook | 0.00005 | g/ton | Guidebook | 0.0030 | g/ton | Guidebook |
| Cd | 0.00001 | g/ton | Guidebook | 0.00001 | g/ton | Guidebook | 0.00001 | g/ton | Guidebook | 0.0002 | g/ton | Guidebook |
| Hg | 0.00460 | g/ton | Guidebook | 0.00461 | g/ton | Guidebook | 0.00347 | g/ton | Guidebook | 0.0044 | g/ton | Guidebook |
| As | 0.00552 | g/ton | Guidebook | 0.00553 | g/ton | Guidebook | 0.00416 | g/ton | Guidebook | 0.0011 | g/ton | Guidebook |
| Cr | 0.00003 | g/ton | Guidebook | 0.00004 | g/ton | Guidebook | 0.00003 | g/ton | Guidebook | 0.0074 | g/ton | Guidebook |
| Cu | 0.00000 | g/ton | Guidebook | 0.00000 | g/ton | Guidebook | 0.00000 | g/ton | Guidebook | 0.0081 | g/ton | Guidebook |
| Ni | 0.00002 | g/ton | Guidebook | 0.00002 | g/ton | Guidebook | 0.00002 | g/ton | Guidebook | 0.0003 | g/ton | Guidebook |
| Se | 0.00051 | g/ton | Guidebook | 0.00051 | g/ton | Guidebook | 0.00038 | g/ton | Guidebook | 0.0041 | g/ton | Guidebook |
| Zn | 0.00007 | g/ton | Guidebook | 0.00007 | g/ton | Guidebook | 0.00005 | g/ton | Guidebook | 1.07 | g/ton | Guidebook |
| DioxFur | 0.50 | µg TEQ/TJ | Guidebook | 0.50 | µg TEQ/TJ | Guidebook | 0.50 | µg TEQ/TJ | Guidebook | 1.40 | µg TEQ/TJ | Guidebook |
| PAH | 0.14 | mg/t | Guidebook | 0.14 | mg/t | Guidebook | 0.11 | mg/t | Guidebook | 0.74 | mg/t | Guidebook |

Note: PAH is defined as Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene and Indeno[1,2,3-cd]pyrene

Table 3.151 – Emissions factors for Sulphur content of fuels (%S) - Agriculture, forestry and fishing sectors (except mobile sources)

| Year | Residual Fuel Oil | Gas Oil | Kerosene | Motor Gasoline | LPG | Natural Gas | Biogas | Biodiesel |
|---|---|---|---|---|---|---|---|---|
| 1990 | 2.84 | 0.30 | 0.15 | 0.100 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 1995 | 2.60 | 0.25 | 0.15 | 0.100 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 2000 | 2.60 | 0.15 | 0.15 | 0.100 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 2005 | 1.00 | 0.10 | 0.15 | 0.015 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 2010 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 2013 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 2014 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0007 | 0.0 | 0.0 |
| 2015 | 1.00 | 0.05 | 0.15 | 0.015 | 0.0016 | 0.0007 | 0.0 | 0.0 |

#### 3.2.4.3.5 Category-specific QA/QA and Verification

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

#### 3.2.4.3.6 Recalculations

No recalculations were made.

#### 3.2.4.3.7 Further Improvements

No further improvements are planned for this sector.

### 3.2.4.4 *Agriculture / Forestry / Fishing: Off-road Vehicles and Other Machinery (NFR 1.A.4.c.ii)*

#### 3.2.4.4.1 Overview

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

Only gas-oil is assumed to be an energy source for mobile equipments in this activity. Although emissions from mobile sources in agriculture and forestry are reported under category source 1.A.4.c.i, methodology used to estimate emissions from this activity is better presented here together with the other individualized mobile sources. Consumption of biodiesel with gas oil was assumed in the energy balance data, in accordance with the explained in 1.A.2. methodology chapter.

#### 3.2.4.4.2 Methodology

Emissions for all pollutants are estimated with the following formula:

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

where

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

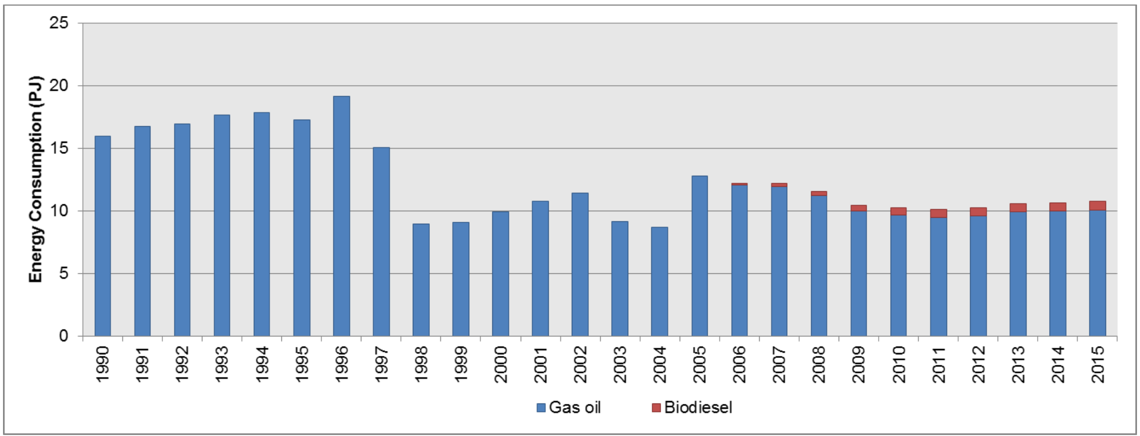
EF$_{(p)}$ - Emission factor for pollutant p (kg/t);

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

### 3.2.4.4.3 Activity Data

Consumption of fuels in the agriculture and forestry sector is available from 1990 to the latest inventory year from General-Directorate of Geology and Energy (DGEG) in the energy balance. Although there is no clear specification, in the original database, in which combustion equipment each fuel is used it was assumed that all gas-oil is used in machines and other off-road vehicles. The same suppositions were made for biodiesel since both are used together. Energy consumption are presented in figure below and in ANNEX C: ENERGY (NFR 1).

Figure 3.79 – Fuel consumption in machines and other off-road vehicles




### 3.2.4.4.4 Emission Factors

The set of emission factors utilized to estimate air emissions from use of gas oil in agriculture machines and other off-road vehicles were determined as the average value of the values proposed in tables I-47 and I-49 of the Revised 2006 IPCC Guidelines (IPCC,2006), except the emission factor for Particulate Matter and Black Carbon, set from the EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA,2016). In general for biodiesel EF were considered the same as for gas oil, with the exceptions shown in the following tables.

Table 3.152 – Low Heating Value (LHV) – Agriculture machines and other off-road vehicles

| Fuel | | NAPFUE | LHV |
|---|---|---|---|
| | | | MJ/kg |
| Diesel/Gas Oil | L | 204 | 42.60 |
| Biodiesel | B | 223 | 37.00 |

Table 3.153 – Emissions factors - Agriculture machines and other off-road vehicles

| Fuel | Gas Oil | | | Biodiesel | | |
|---|---|---|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 56.9 | g/kg | Guidebook | 56.9 | g/kg | Guidebook |
| NMVOC | 8.4 | g/kg | Guidebook | 8.4 | g/kg | Guidebook |
| CO | 20.7 | g/kg | Guidebook | 20.7 | g/kg | Guidebook |
| TSP | 1.7 | g/kg | Guidebook | 1.7 | g/kg | Guidebook |
| $PM_{10}$ | 1.7 | g/kg | Guidebook | 1.7 | g/kg | Guidebook |
| $PM_{2.5}$ | 1.7 | g/kg | Guidebook | 1.7 | g/kg | Guidebook |
| BC | 57 | % PM2.5 | Guidebook | 57 | % PM2.5 | Guidebook |
| Pb | 0.20 | g/ton | Guidebook | 0.20 | g/ton | Guidebook |
| Cd | 0.01 | g/ton | Guidebook | 0.01 | g/ton | Guidebook |
| Hg | 0.00 | g/ton | Guidebook | 0.00 | g/ton | Guidebook |
| As | 0.05 | g/ton | Guidebook | 0.05 | g/ton | Guidebook |
| Cr | 0.05 | g/ton | Guidebook | 0.05 | g/ton | Guidebook |
| Cu | 1.70 | g/ton | Guidebook | 1.70 | g/ton | Guidebook |
| Ni | 0.07 | g/ton | Guidebook | 0.07 | g/ton | Guidebook |
| Se | 0.01 | g/ton | Guidebook | 0.01 | g/ton | Guidebook |
| Zn | 1.00 | g/ton | Guidebook | 1.00 | g/ton | Guidebook |
| DioxFur | 0.0 | µg TEQ/TJ | Guidebook | 0.0 | µg TEQ/TJ | Guidebook |
| PAH | 3.32 | g/ton | Guidebook | 3.32 | g/ton | Guidebook |

#### 3.2.4.4.5 Uncertainty Assessment

To be developed in the future.

#### 3.2.4.4.6 Category-specific QA/QA and Verification

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

#### 3.2.4.4.7 Recalculations

No recalculations were made.

#### 3.2.4.4.8 Further Improvements

No further improvements are planned for this sector.

### 3.2.4.5 *Agriculture / Forestry / Fishing: National Fishing (NFR 1.A.4.c.iii)*

#### 3.2.4.5.1 Overview

This chapter deals with emissions from fishing ships and boats. Emissions associated with fuel consumption in fishing industry, aquaculture or sea ports that are realized inland and not in water vessels are included in 1.A.4.c.i.. Fishing bunker represent emission from local costal fishing, deep-see fishing and cod-fish fishing vessels.

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

#### 3.2.4.5.2 Methodology

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

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

where

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

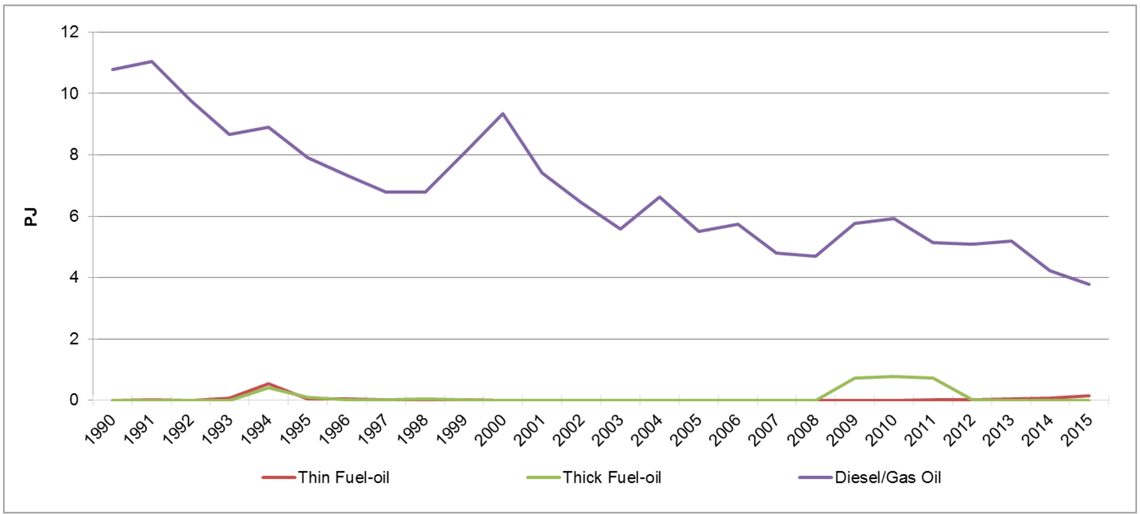
$EF_{(n,f,p)}$ - Quantity of pollutant p emitted, variable with fuel type f and ship class n (kg/t);

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

#### 3.2.4.5.3 Activity Data

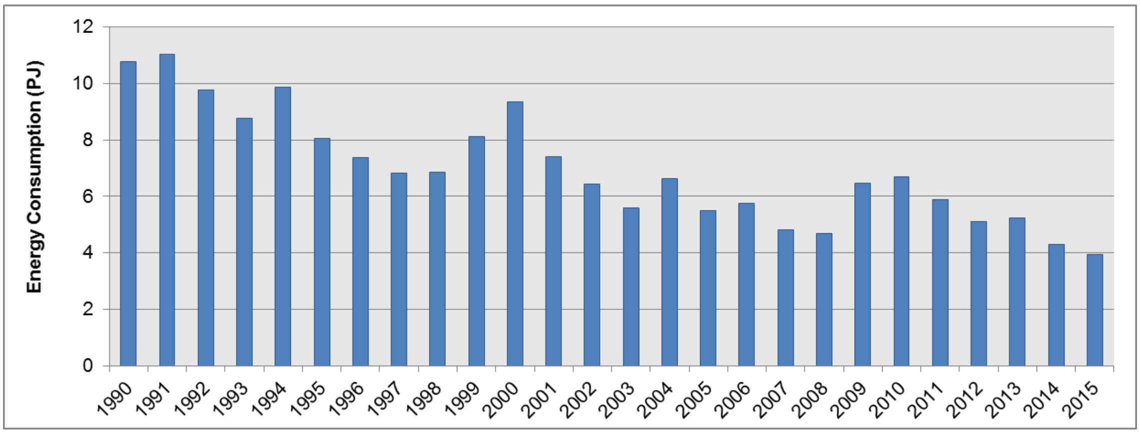
Data on fuel consumption in the fishing sector was obtained from DGEG's energy balance. Since there is no distinction between fishing vessels and static equipment in this data source new data was obtained concerning bunker fuel sales (source: DGEG). With this new data a separation between fuel consumption in mobile and non-mobile equipment was possible. Fuel consumption reported by DGEG as bunker sales is presented in the following figures and in ANNEX C: ENERGY (NFR 1).

Figure 3.80 – Fuel consumed in fishing bunkers (GJ) [24]



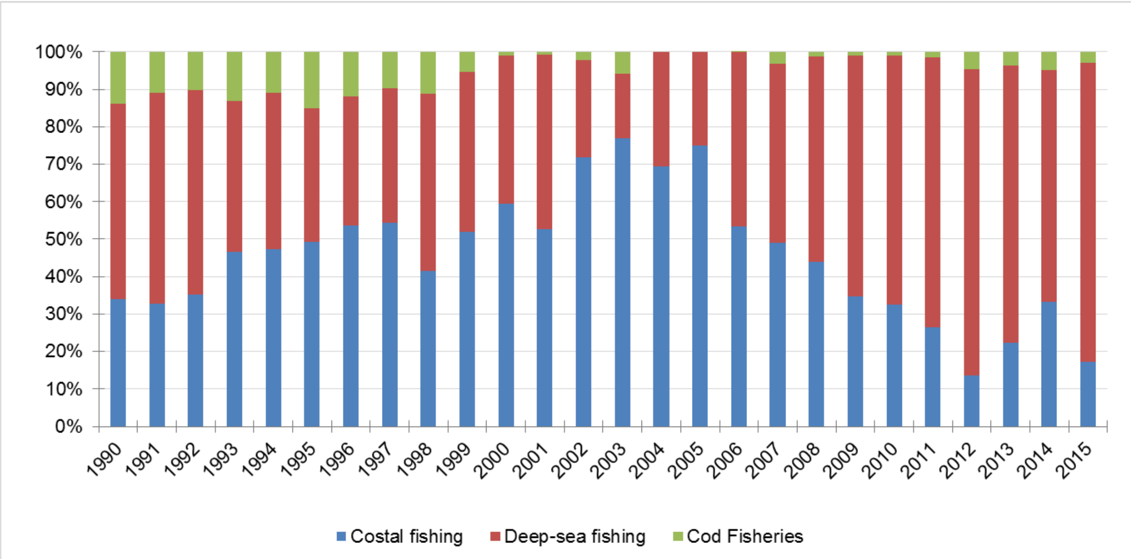

[24] The same situation that was described for transport navigation is true here. It was possible to distinguish between thin-fuel-oil, thick-fuel-oil and NATO's naphtha, gas-oil and diesel oil, but available emission factors again do not distinguish these fuel types

Figure 3.81 – Total energy consumption in fishing bunkers




Additional information in DGEG annual reports, allows for the division of each fuel type in several different fishing activities: (1) Local coastal fishing; (2) Deep-sea fishing and (3) Cod-fish fishing vessels[25]. Percentage for each type of fisheries is presented in next figure.

Figure 3.82 – Consumption of fuel by fishing vessel type in percentage of total consumption in bunkers for fisheries




### 3.2.4.5.4 Emission Factors

Except for sulphur oxide, emissions were estimated using default emission factors (kg/t) from IPCC 1996 Revised Guidelines (table I-47 in IPCC,1997) for most pollutants. The following criteria were used to choose the most suitable emission factors:

[25] 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.

- "Ocean-going ships" for national and international transport navigation, deep-sea fishing and cod fishing;
- "Boat" in the case of coastal fishing vessels.

Sulphur oxide emissions are dependent on sulphur content of fuel. Particulate matter emission factors are from EMEP/EEA air pollutant emission inventory guidebook 2016 (EEA,2016). Emission factors are presented in the following tables.

Table 3.154 – Low Heating Value (LHV) - Water Borne Navigation and Fishing Vessels

| Fuel | | LHV |
|---|---|---|
| | | MJ/kg |
| Coastal Fisheries | Gas Oil | 42.60 |
| Other Fisheries | | |
| Coastal Fisheries | Biodiesel | 37.00 |
| Other Fisheries | | |
| Coastal Fisheries | Fuel-oil | 40.00 |
| Other Fisheries | | |

Table 3.155 – Emissions factors - Water Borne Navigation and Fishing Vessels

| | | Coastal Fisheries | Other Fisheries | Coastal Fisheries | Other Fisheries | Coastal Fisheries | Other Fisheries |
|---|---|---|---|---|---|---|---|
| **Fuel** | | **Gas Oil** | | **Biodiesel** | | **Fuel-oil** | |
| **Pollutant** | **Unit** | **Value** | **Value** | **Value** | **Value** | **Value** | **Value** |
| $SO_x$ | % | 0.3 | 0.3 | 0.0 | 0.0 | 2.8 | 2.8 |
| $NO_x$ | g/kg | 67.5 | 87.0 | 67.5 | 87 | 67.5 | 87 |
| NMVOC | g/kg | 4.9 | 4.9 | 4.9 | 5 | 4.9 | 4.9 |
| CO | g/kg | 21.3 | 1.9 | 21.3 | 1.9 | 21.3 | 1.9 |
| TSP | kg/t | 1.5 | 1.5 | 1.5 | 1.5 | 6.2 | 6.2 |
| $PM_{10}$ | kg/t | 1.5 | 1.5 | 1.5 | 1.5 | 6.2 | 6.2 |
| $PM_{2.5}$ | kg/t | 1.4 | 1.4 | 1.4 | 1.4 | 5.6 | 5.6 |
| BC | % PM2.5 | 31 | 31 | 31 | 31 | 12 | 12 |
| Pb | g/ton | 0.20 | 0.20 | 0.20 | 0.20 | 1.30 | 1 |
| Cd | g/ton | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 |
| Hg | g/ton | 0.05 | 0.05 | 0.05 | 0.05 | 0.02 | 0.02 |
| As | g/ton | 0.05 | 0.05 | 0.05 | 0.05 | 0.50 | 0.50 |
| Cr | g/ton | 0.04 | 0.04 | 0.04 | 0.04 | 0.20 | 0.20 |
| Cu | g/ton | 0.05 | 0.05 | 0.05 | 0.05 | 0.50 | 0.50 |
| Ni | g/ton | 0.07 | 0.07 | 0.07 | 0.07 | 30 | 30 |
| Se | g/ton | 0.20 | 0.20 | 0.20 | 0.20 | 0.40 | 0.40 |
| Zn | g/ton | 0.50 | 0.50 | 0.50 | 0.50 | 0.90 | 0.90 |

### 3.2.4.5.5 Category-specific QA/QA and Verification

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

##### 3.2.4.5.6 Recalculations

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

##### 3.2.4.5.7 Further Improvements

No further improvements are planned for this sector.

### 3.2.5 Other (including Military) (NFR 1.A.5)

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

The energy balance does not provide a specific fuel consumption classification for military operations. Fuel consumption reported under category "Serviços" includes fuel used in military operations however it is not possible to explicity derive the fraction of fuel used only in military operations. Therefore emissions from military operations, except military aviation, are reported under category NFR 1 A 4 Small Combustion. For military aviation it was assumed that all jet fuel reported under category "Serviços" was used for military aviation since jet fuel could be considered as an aviation specific fuel.

#### 3.2.5.1 *Other Mobile (NFR 1.A.5.b)*

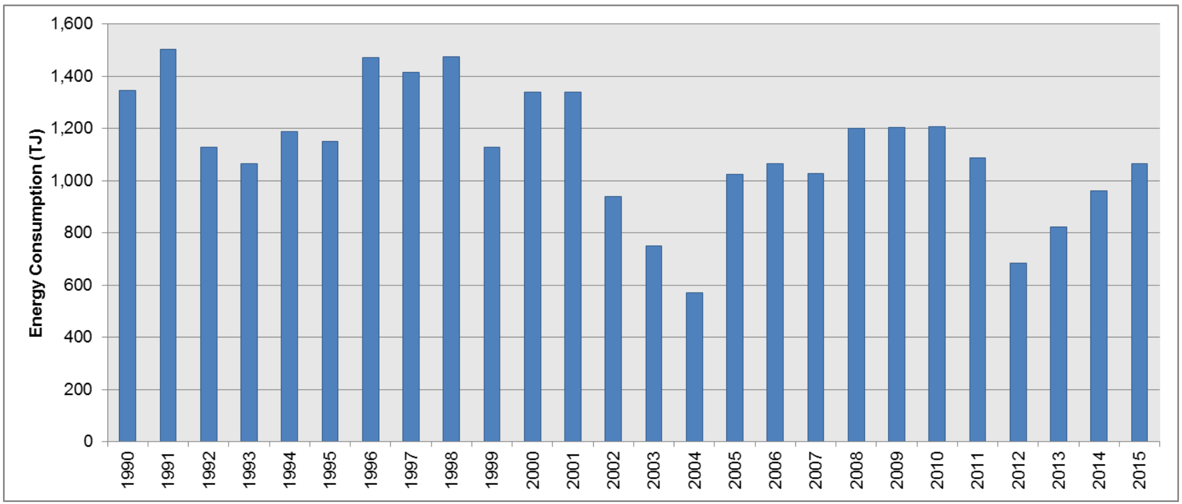
Emissions from military reported under category 1 A 5 b include only military aviation.

The energy balance does not provide a specific fuel consumption classification for military operations. Fuel consumed in military operations is reported under category "Serviços". Therefore emissions from military operations, except military aviation, are reported under category NFR 1 A 4 Small Combustion. For military aviation it was assumed that all jet fuel reported under category "Serviços" was used for military aviation since jet fuel could be considered as an aviation specific fuel.

According with the IPCC Good Practice Guidelines, all the jet fuel for military operations was considered to be domestic since there is no information available regarding origins and destinies of the military aircraft movements that could be used to distinct domestic from international consumption.

The following figure shows the amount of jet fuel used for military operations provided by the national energy balance under the *Serviços* classification. All fuels under *Serviços* were already considered in the inventory besides jet fuel. Energy was estimated using a country specific LHV of 43.00 MJ/kg reported by the national energy authority.

Figure 3.83 – Energy Consumption in Military aviation




The emission factors used to estimate emissions were obtained from IPCC default emission factors and EMEP/CORINAIR.

Table 3.156 – Emission factors – Military Aviation

| Fuel | Jet Fuel | | |
|---|---|---|---|
| **Pollutant** | **Value** | **Unit** | **Reference** |
| $NO_x$ | 300 | kg/TJ | Guidebook |
| NMVOC | 50 | kg/TJ | Guidebook |
| CO | 100 | kg/TJ | Guidebook |
| SOx | 19 | kg/TJ | Guidebook |
| Pb | 0.45 | g/ton | Guidebook |
| Cd | 0.3 | g/ton | Guidebook |
| Hg | 0.0 | g/ton | Guidebook |
| As | 0.0 | g/ton | Guidebook |
| Cr | 0.1 | g/ton | Guidebook |
| Cu | 1.1 | g/ton | Guidebook |
| Ni | 0.3 | g/ton | Guidebook |
| Se | 0.0 | g/ton | Guidebook |
| Zn | 3.0 | g/ton | Guidebook |

#### 3.2.5.1.1 Recalculations

No recalculations were made for this subsector.

#### 3.2.5.1.2 Further Improvements

No further improvements are planned for this sector.

## 3.2.6 Fugitive Emissions from Solid Fuels (NFR 1.B.1.)

### 3.2.6.1 *Coal Mining and Handling*

#### 3.2.6.1.1 Overview

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

Since 1990 in Portugal there was extraction of coal at only two coal mines, but both were latter closed down in 1992 and 1994 and did not resume activity since. Both mines - *Pejão* and *S. Pedro da Cova* - are located in northern region of Portugal. Coal from these mines is classified as lignite, it has a low energy value and it was used mainly as fuel for one public power energy plant near Oporto (*Tapada do Outeiro* power plant). Moreover the coal production during the exploration period was of small importance (less than 300 kt in 1990, see figure below). Both mines (Pejão and S. Pedro da Cova) are of the underground type.

Emissions of carbon dioxide and sulphur oxides may occur from mining activity when burning of coal deposits occurs or when flaring is used to control air emissions or recover energy. Because the occurrence of coal burning on-site or flaring is unknown for both Portuguese mines, emissions of these pollutants from this source are not included in the inventory.

Emissions of methane from abandoned mines may still continue after mine closure, even if mines are sealed.

Emissions from fuel combustion for coal extraction are included under category 1.A.1.c.1.

#### 3.2.6.1.2 Methodology

$$Emi = EF * Coal_U * 10^{-3}$$

where

Emi - Emissions of pollutant x in year y (t);

EF – Emission factor (kg/t of coal);

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

#### 3.2.6.1.3 Emission Factors

It were used the following emission factors:

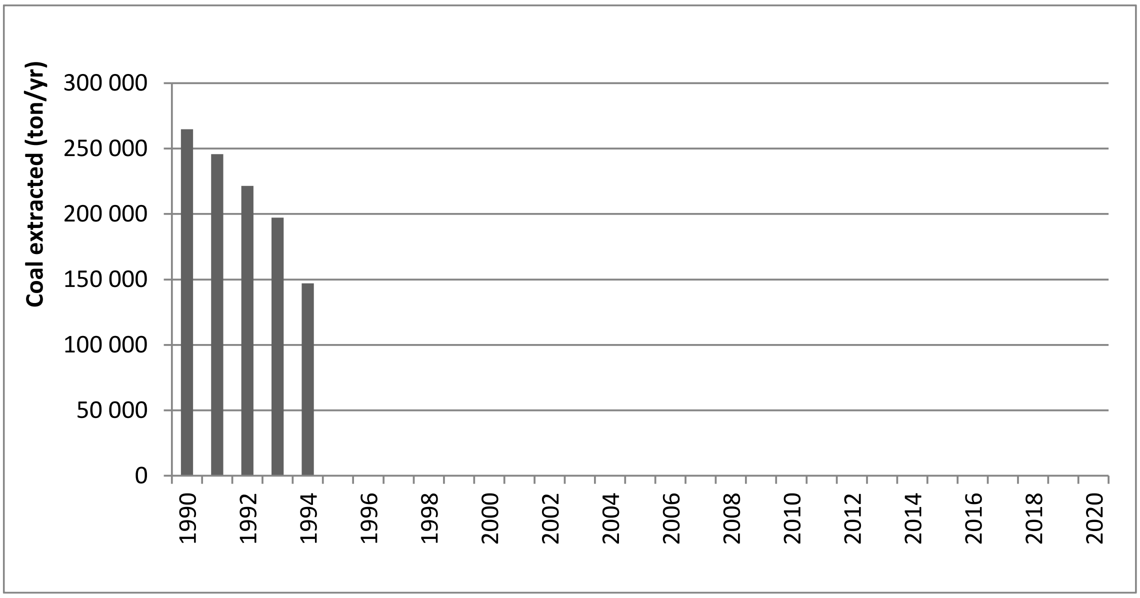
Table 3.157– Emission Factors for coal extraction and processing

| Parameter | Emission Factor | Unit | Source |
|---|---|---|---|
| NMVOC | 0.8 | Kg/t of coal | EMEP/EEA emission inventory guidebook 2013 |
| TSP | 0.089 | Kg/t of coal | EMEP/EEA emission inventory guidebook 2013 |
| PM10 | 0.042 | Kg/t of coal | EMEP/EEA emission inventory guidebook 2013 |
| PM2.5 | 0.005 | Kg/t of coal | EMEP/EEA emission inventory guidebook 2013 |

#### 3.2.6.1.4 Activity data

The quantity of extracted coal has decreased towards the final closure of both mines in 1994, as may be seen in next figure. Statistical information is from Geological Resources reports from DGEG.

Figure 3.84 – Quantities of coal extracted from mines in Portugal




#### 3.2.6.1.5 Recalculations

No recalculations were made.

#### 3.2.6.1.6 Further Improvement

No further improvements are expected.

### 3.2.7 Fugitive Emissions from Oil Production and Refining (NFR 1.B.2.a)

#### 3.2.7.1 *Overview*

Extraction and production of crude oil did never occur in the Portuguese territory. Therefore, fugitive emissions comprehend only those resulting from refining, storage and transport of crude oil, other raw materials, intermediate products and final products - particularly gasoline - from terminal receiving of crude oil and other petroleum products till delivering to final consumer. According to available methodologies air emissions considered include:

- Marine Terminals and Ballast water;

- Emissions from refinery operations not including emissions from combustion of fuels, such as: Flaring and venting in oil refining and; Emissions due to storage of raw materials, intermediate products and final products in the refinery;

- Emissions from refinery dispatch station;

- Emissions from the transport and distribution of petroleum products in the Portuguese Territory, including transport depots and service stations.

### 3.2.7.2 *Transport of Crude/ Marine Terminals (NFR 1.B.2.a.i)*

#### 3.2.7.2.1 Overview

Emissions from this source consist mainly of volatile organic compounds, including methane, that escape to atmosphere during transport of crude oil to refineries for processing. The three oil refineries considered in the inventory where all located at a small distance from the sea coast. Crude oil is received near refineries by sea tankers and transported directly to each refinery by small connecting pipelines. Most of emissions from crude oil transportation occur at tank downloading.

#### 3.2.7.2.2 Methodology

Emissions of methane and non-methane volatile organic compounds (NMVOC) where estimated from:

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

where

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

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

EF - emission factor for methane or NMVOC (mg/t crude oil).

#### 3.2.7.2.3 Emission Factors

Table 3.158 – Total Organic Emission Factors for Marine Vessel Loading Operations (values obtained from Table 5.2-2 and Table 5.2-6 of USEPA AP-42 Emission Factors)

| Loading Operations | Gasoline (mg/L) | Crude26 (mg/L) | Jet Naphta – JP-4 (mg/L) | Jet Kerosene (mg/L) | Distillate Oil nº2 (mg/L) | Residual Oil nº6 (mg/L) |
|---|---|---|---|---|---|---|
| Ships/ocean barges | 215 | 73 | 60 | 0.63 | 0.55 | 0.004 |

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

[26] VOC Emission Factors for a typical crude oil are 15 percent lower than the total organic factors shown, in order to account for methane and ethane. All products other than crude oil can be assumed to have VOC factors equal to total organic factors.

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

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

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

Where,

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

$F_S$ - Saturation Factor (0 to 1);

$P_V$ - True Vapour Pressure (psia);

$M_V$ - Molecular Weight (lb/mol);

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

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

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

#### 3.2.7.2.4 Activity data

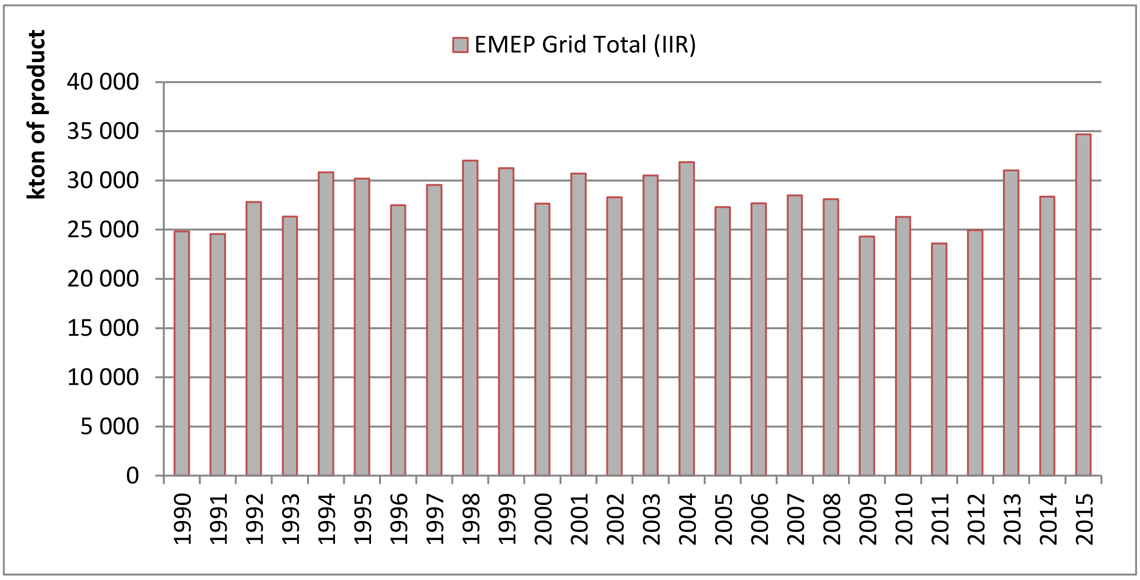
Data was obtained for year 2005, from:

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

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

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

Figure 3.85 – Total amounts of loaded and unloaded crude and fuels in Marine Terminals (kt)




#### 3.2.7.2.5 Recalculations

No recalculations were made.

### 3.2.7.3 *Refining and Storage (NFR 1.B.2.a.iv)*

#### 3.2.7.3.1 Overview

In 1990 there were three oil refining plants in Portugal, located in Oporto, Lisbon and Sines. After 1993, the Lisbon unit was closed for all activity and only two units remain now operating.

The refining process converts crude oil - which is a complex mixture of hydrocarbon compounds with impurities of sulphur, nitrogen, oxygen and heavy metals - into oil products used as fuels, asphalts, lubricants or feedstock for the organic and inorganic chemical industry. Processes included in Portuguese refineries include:

- Separation process: isolation of individual constituents of crude using differences in boiling-point, using atmospheric and vacuum distillation and recovery of light end gases;
- Conversion process. These may be also classified as:
  - Cracking - Chemical transformation of separated fractions breaking molecules of heavy molecular weight into smaller ones, including visbreaking;
  - Polymerisation of small molecules combined in bigger molecules with different characteristics. Alkylation has similar objectives;
  - Chemical transformations that change molecular structure such as Isomerization, reforming and asphalt blowing

- Treatment processes. Operations which include hydrodesulfurization, hydrotreating, chemical sweetening, acid gas removal, 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).

NMVOC and methane emissions may also result from "normal" leaks[27] scattered through the refinery site in pneumatic devices such as valves, failure of connections, flanges, pump and compressor shafts, seals and instruments. Release of gases may also follow system failure, that usually occurs during unplanned events, such as sudden pressure surge from failure of a pressure regulator, and pressure relief systems that protect the equipment from damage. In Portuguese refineries, pressure relief systems are usually connected to collection system and transported to a flare. There may be also NMVOC emissions resulting from non-condensable fraction at the steam ejectors or vacuum pumps of the Vacuum distillation. Emissions in flares are discussed in "Venting and Flaring in Oil Industry" below.

Use of some catalytic converters, such as Fluid Catalytic Cracking and Platforming units, are used to convert heavy oils into lighter products, by action of heat, pressure and catalysts. Fluidized-bed Catalytic Cracking (FCC) use finely divided catalysts suspended in a riser with hot vapour from the fresh feed. Catalytic processes result in operations emissions, when the coke that is deposited in the catalytic bed over time has to be burned in the regenerator equipment. Emissions from catalyst regeneration are also included in this source category.

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 be oxidized to $SO_2$ in the tail gas incinerator before being released to atmosphere.

### 3.2.7.3.2 Methodology

#### *3.2.7.3.2.1 Storage and Tanks*

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

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

emission factor (EF in g/t) and relying in the time series of total throughput petroleum materials processed (t/yr) as an indicator of activity[28].

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

### *3.2.7.3.2.2 Fugitive Emissions and Catalyst Recovery*

Air emissions from these refining operations where estimated from:

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

where

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

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

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

Total crude use was used as activity data to estimate fugitive emissions from leakages, according to the available emission factors in literature. Concerning Catalyst recovery activity data is coke burnt during catalyst regeneration.

### *3.2.7.3.2.3 Sulphur Recovery*

Emissions of $SO_x$ occurring due to limitations of the sulphur recovery system were estimated annually according to the following procedure:

$$Emi_{SOx} = 64/32 * [S_{Inc} + S_{Prod} * (100-Claus_{EFIC})/Claus_{EFIC}]$$

where

$Emi_{SOx}$ – Emissions of sulphur oxides from sulphur recovery in tail gas (t S/yr);

$S_{Inc}$ - sulphur in tail gas that is incinerated to $SO_x$ because Claus unit was not operational (t S/yr);

$Claus_{EFIC}$ – percent efficiency of overall Claus unit (%);

$S_{Prod}$ - total elemental sulphur produced in the Claus unit (t S/yr).

## 3.2.7.3.3 Emission Factors

### *3.2.7.3.3.1 Storage/ Tanks*

For the period 2002-2005, GALP, the single petroleum refinery operator in Portugal, in collaboration with the Portuguese Environment Agency (APA), performed a detailed inventory of NMVOC emissions from tanks in Oporto and Sines refineries using TANKS 4.0 (USEPA,1990). The inventory has been extended to marketing terminal storage tanks (including data from all

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

companies operating in the Portuguese territory). For the period 1990-2001 and from 2006 onwards, data was estimated using stock changes values from DGEG energy balance.

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[29].

Emissions were determined relying on methodologies that vary according to each tank type. The possible type of tanks, a very short description of their characteristics and the percentage of each tank type in existence in 2005 in Oporto and Sines refineries are presented in the table below.

Table 3.159 – Type of tanks classes distinguished in TANKS4.0 model and percentage of tanks per tank type in Oporto and Sines refineries in 2005 (%).

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

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

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

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

Table 3.160 – Types of losses from tanks for storage of organic compounds and petroleum products

| Tank | Loss | Description |
|---|---|---|
| Fixed Roof | Breathing | Expulsion of vapour from a tank through vapour expansion and contraction, which are the results of changes in temperature and barometric pressure |
| | Working | Combined loss from filling and emptying. Evaporation during filling operations is a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapours are expelled from the tank. Evaporative loss during emptying occurs when air drawn into the tank during liquid removal becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space. |
| Floating Roof | Rim Seal | The majority of rim seal vapour losses have been found to be wind induced. |
| | Withdrawal | Occur as the liquid level, and thus the floating roof, is lowered. Some liquid remains on the inner tank wall surface and evaporates. |
| | Deck Fitting | Deck fittings can be a source of evaporative loss when they require openings in the deck, such as: access hatches, gauges, rim vents, deck drains, guide-poles, columns, wells, vacuum breakers and ladders. |
| Internal Floating | Deck Seam | Seams may not be completely vapour tight if the deck is not welded |

Finally the resultant emission factors, obtained dividing total tank emissions by total throughput [30]in each refinery, are presented in next table. From 2006 onwards the emission factors were forecasted based on total throughput.

Table 3.161 – Final emission factor for evaporation of NMVOC from storage and tank in refineries

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

(a) Average value from Sines and Oporto refineries

### *3.2.7.3.3.2 Fugitive Emissions*

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

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

Table 3.162 – Emission Factors for fugitive emissions of NMVOC in operation processes in petroleum refineries

| Pollutant | EF<br>Kg NMVOC/ t crude |
|---|---|
| NMVOC | 0.9 |

### *3.2.7.3.3.3 Recovery of Catalysts*

From information collected from the refinery at Sines (quantities of coke burnt in FCC unit during 2002 and monitoring data for $NO_x$, $SO_x$ and particulate matter) plant specific emission factors were established for this process. For carbon monoxide emission factors from USEPA (1995) were used, but because original emission in the original reference source are expressed in volume of fresh feed – and this activity rate it is not available from the refinery – the original emission factor was corrected, by multiplication by the ratio of the $NO_x$ emission factor in both information sources (monitoring data and USEPA). Carbon dioxide emission factor was set assuming that coke is 92 percent carbon. Final emission factors may be verified in the next table.

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

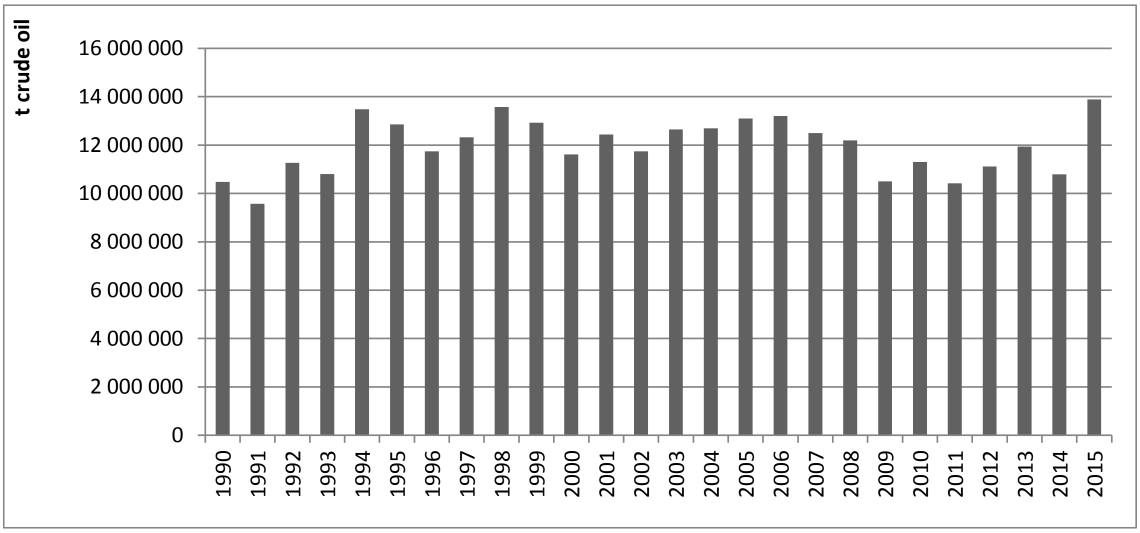
Table 3.163 – Emission Factors used to estimate emissions from catalyst regeneration (kg/t coke burned)

| Parameter | Emission Factor<br>kg/t coke |
|---|---|
| $SO_x$ | 31.9 |
| $NO_x$ | 3.6 |
| CO | 5.8 |
| PM | 6.8 |

### 3.2.7.3.4 Activity data

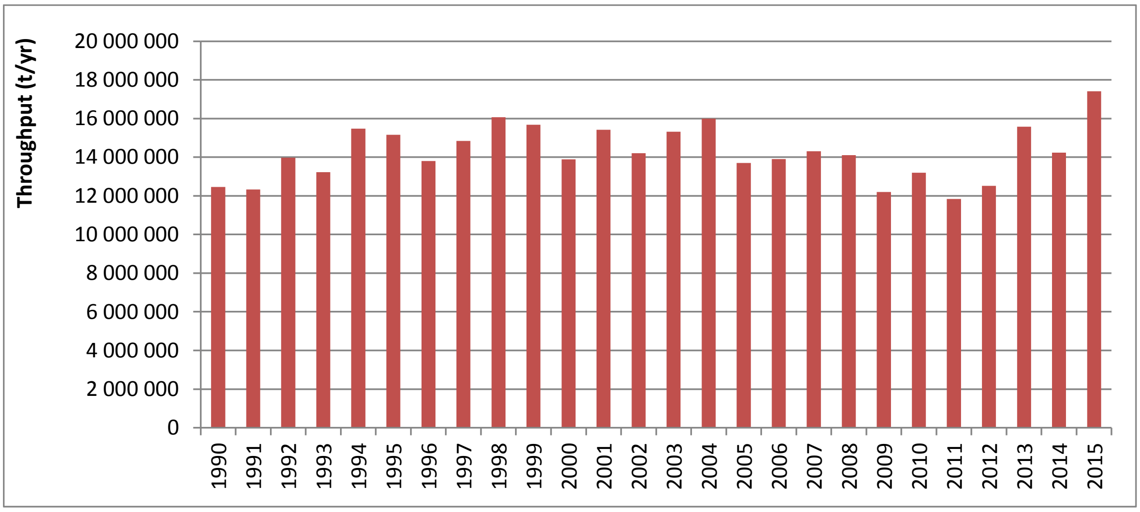
The activity data to estimate discharge of unburned organic compounds or process emissions is total crude oil processed (see next figure).

Figure 3.86 – Total Crude Oil Processed in Refineries (t)




Total throughput in each refinery was used to estimate NMVOC emissions from storage and tanks. Total throughput represents not only crude oil entered into the refinery but also other petroleum products that are imported or moved between refineries. This indicator was considered the most suitable variable to be multiplied by the national emission factor. Total throughput for all refineries, according to information delivered by GALP, is presented in figure below.

Figure 3.87 – Total throughput entered in Lisbon, Oporto and Sines refineries (t)




For FCC, and other processes where there happens recovery of catalysts, activity data is total coke burnt. Annual burning of coke in Sines refinery, both in FCC and in Platforming is available from PETROGAL up to 2003. Combustion of coke from catalysts in Oporto refinery was only available for 2001-2002, and was assumed constant over the period 1990-2004. From 2005 onwards, data is obtained directly from EU-ETS for both Sines and Oporto refineries.

Total sulphur recovered in the refineries was available from the balance of petroleum products in annual publications from DGEG, from 1990 to 2004. From 2005 onwards, data was obtained from refineries publication “Data Book de Segurança, Saúde e Ambiente”.

Sulphur recovery has been increasing from 1996 onwards, expressing the technology changes set by the auto-oil program. From 2013 onwards, there is a new sulphur recovery unit in one of the refineries, leading to an increase in the Sulphur recovered. The efficiencies of Claus units vary from 95 to 98 percent, 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.

##### 3.2.7.3.5 Recalculations

No recalculations were made.

##### 3.2.7.3.6 Further Improvements

No further improvements are planned for this sector.

#### 3.2.7.4 *Distribution of Oil Products (1.B.2.a.v)*

##### 3.2.7.4.1 Overview

This sub-source sector includes emissions of volatile organic compounds resulting from distribution of refinery products, mainly gasoline:

- (1) Terminal Dispatch Stations in Refineries. Emissions of volatile organic compounds occurring inside refineries during filling of transport vehicles - trucks, rail cars - when dispatching products of the refining unit. Most emissions occur when light products with high level of volatile compounds are dispatched;
- (2) Transport and Depots, occurring in storage tanks outside the refineries and over the country;
- (3) Service Stations, including emissions from tank loading from trucks and when refuelling consumer cars.

Emissions may result from:

- Leakage. Evaporation of liquid products by flaws and seal leakage, pumps and valve systems;
- Displacement emissions, due to displacement of air in tanks by the incoming liquid;
- Breathing emissions in tanks;
- Vapours emitted when filling vehicles in result of displacement of filling air and from splashing and turbulence during filling;
- Unwanted spillage.

### 3.2.7.4.2 Methodology

#### *3.2.7.4.2.1 Filling Underground Tanks*

From "Portaria 646/97" it is assumed that since 2005 it is used "bottom loading with vapour return" (Stage IB) for latter recovering (VRU) or destruction (VDU). Before 2005 it is not known the type of filling used and it is assumed that 50% of the service stations had vapour return and 50% hadn't the Stage IB in place.

Before 2005 emissions estimates are based on:

$$E_{FUT} = V_{StageIB} \times TVP \times EF_{StageIB} + V_{other} \times TVP \times EF_{other}$$

Where,

$E_{FUT}$ - Emissions Filling Underground Tanks (kg)

TVP – True  Vapour Pressure (kPa)

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

$EF_{StageIB}$ - Emission Factor for Filling Underground Tanks at Service Stations with Stage IB ($kg/m^3/kPa$ TVP)

$V_{ohter}$ - Gasoline throughput at Service Stations without Stage IB ($m^3$)

$EF_{other}$ – Emission Factor for Filling Underground Tanks at Service Stations without Stage IB ($kg/m^3/kPa$ TVP)

Since 2005, the emissions estimates are based on:

$$E_{FUT} = V_{StageIB} \times EF_{StageIB}$$

Where,

$E_{FUT}$ - Emissions Filling Underground Tanks (kg)

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

EFStageIB – Emission Factor for Filling Underground Tanks at Service Sations with Stage IB ($kg/m^3/Kpa$ TVP)

### 3.2.7.4.3 Emission Factors

#### *3.2.7.4.3.1 Filling Underground Tanks*

Emission factors were obtained from "Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1".

Table 3.164 – Filling Underground Tank (Stage I) NMVOC Emission Factors

| Filling Underground Tank | Emission Factor (kg/m³/kPa TVP) |
|---|---|
| Without Stage IB | 2.44E-02 |
| With Stage IB | 1.1E-03 |

### *3.2.7.4.3.2 Underground Tank Breathing and Emptying*

The NMVOC emission factor source is “Concawe – Air pollutant emission estimation methods for EPER and PRTR reporting by refineries (revised) – report no. 9/05R – Appendix 3 – Table A3.1” (=3.30E-03 kg/m³/kPa TVP).

### *3.2.7.4.3.3 Vehicle Refuelling Operations (Stage II)*

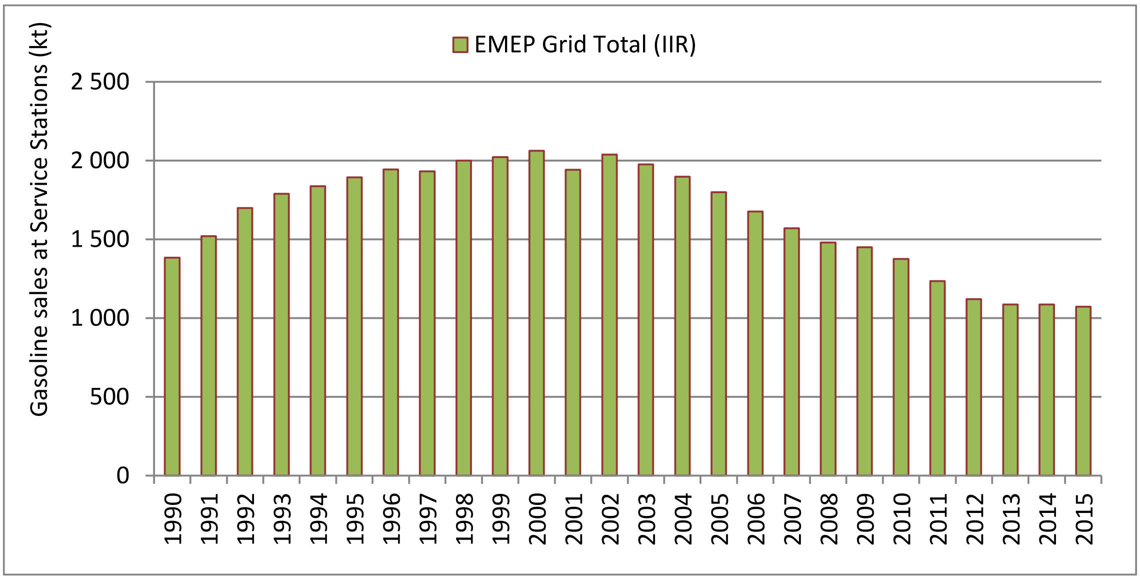
Table 3.165 – Vehicle Refuelling Operations (Stage II) NMVOC Emission Factors

| Vehicle Refuelling Operations | Emission Factor (kg/m³/kPa TVP) |
|---|---|
| Drips and Minor Spillage | 2.20E-03 |
| Refuelling with no emission controls in operations (without Stage II measures) | 3.67E-02 |

### 3.2.7.4.4 Activity data

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

Figure 3.88 – Fuel Sales at Service Stations (t)




### 3.2.7.4.5 Recalculations

A correction was made in a compilation error.

#### 3.2.7.4.6 Further Improvements

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

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

#### 3.2.8.1 *Overview*

Flares were used at the three refineries in Portugal to control and burn non-condensable gases recovered from leakages and blow down operations, which would otherwise be emitted as volatile organic compounds. Although smokeless and complete combustion is always an objective, sometimes the gas influx exceeds flare combustion capacity and partly unburned organic compounds are emitted: NMVOC and CO.

#### 3.2.8.2 *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.

NMVOC emissions are estimated from:

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

Where,

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

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

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

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

CO and $NO_x$ emissions are estimated from:

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

Where,

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

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

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

$SO_x$ emissions are estimated from:

$$Emis_{SOx} = EF_{SOx} * S_{(m/m)} * Flare_{GAS(y)} * 10^{-3}$$

Where,

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

$EF_{SOx}$ – Emission factor (Kg/t gas);

$S_{(m/m)}$ – Sulphur content of the gas flared (kg S/kg gas);

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

### 3.2.8.3 *Emission Factors*

Emission factor for NMVOC was set from "Concawe – Air pollutant emission estimation methods for E-PRTR reporting by refineries – report no. 1/09".

Emission factors for CO, $NO_x$ and $SO_x$ were set from "Concawe – Air pollutant emission estimation methods for E-PRTR reporting by refineries – report no. 1/09".

Sulphur content was obtained from the refineries.

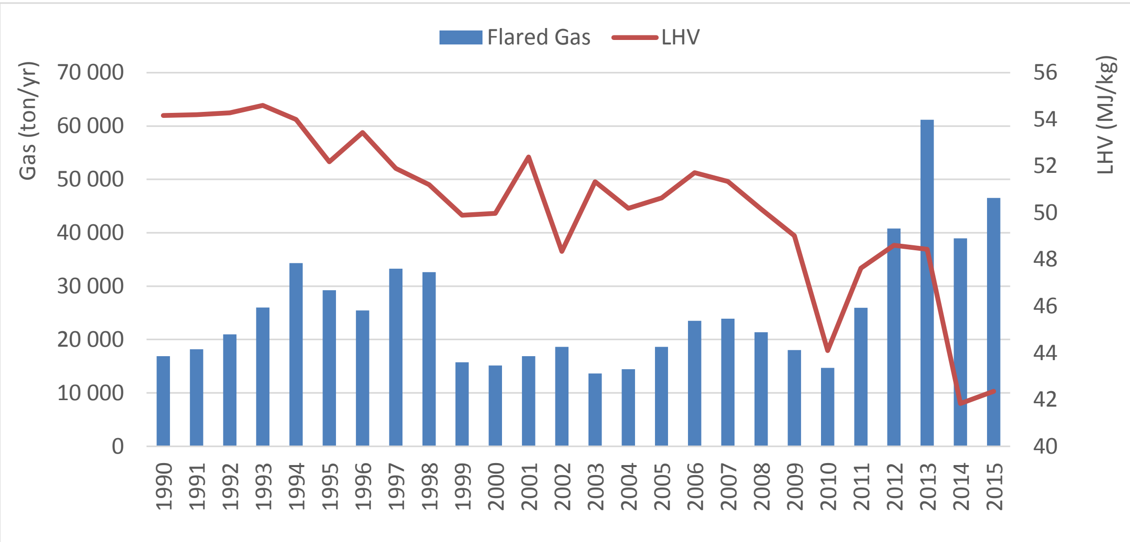
Table 3.166 – Emission Factors for flaring in refineries

| Pollutant | EF Unit | EF |
|---|---|---|
| NMVOC | kg/t gas | 5 |
| CO | kg/t gas | 0.177 |
| $NO_x$ | kg/t gas | $3.22x10^{-2}$ |
| $SO_x$ | kg/t gas | $2x10^{3}$ |

### 3.2.8.4 *Activity data*

Total flare gas consumed in the three units and Low Heating Value were made available from PETROGAL for the period 1990-2004. From 2005 onwards, data is obtained from EU-ETS.

Figure 3.89 – Total consumption of flare gas in Portuguese refineries and Low Heating Value



### 3.2.8.5 *Recalculations*

No recalculations were made.

### 3.2.8.6 *Further Improvements*

Considering that the energy sector is the most prevalent emission source, special efforts must always be made to improve emission estimates, even if they affect smaller energy sub-sectors. Future improvements to the inventory will depend on the conclusions of the Methodological Development Plan for the implementation of the National System, which is being made with direct contact with the main stakeholders of the energy sector, and in close collaboration of the inventory team from APA. Although the main conclusions from this report are still not set in a final report and plan, the following preliminary routes may be here identified.

- Better integration between activity data in the air emissions inventory and other surveys such as LCP directive, *Autocontrolo* program, EPER/E-PRTR, the EU-ETS Carbon Market and the energy surveys (co-generation) made annually by DGEG. Contacts are being made to implement it. Particular work is being done to streamline the collection of data and emission estimates between the inventory and the EU-ETS, following the promotion efforts that are being made by the European Commission;

- Determination of country-specific emission factors ($SO_x$, $NO_x$ and PM) from monitoring data collected from the *Autocontrolo* program;

- Consistency Checks on Refining/Storage timeseries.

# 4 INDUSTRIAL PROCESSES (NFR 2)

## 4.1 Category Sources

### 4.1.1 Mineral Industry (NFR 2.A)

#### 4.1.1.1 *Cement Production (NFR 2.A.1)*

##### 4.1.1.1.1 Overview

There are six cement production plants operating in Portugal, mostly dedicated to Portland cement production[31] 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[32].

Although emissions may result from both fuel and raw material, they are reported in Energy (CRF 1.A.2.f) for simplicity sake.

##### 4.1.1.1.2 Methodology

For cement production emissions estimated, for all pollutants except black carbon, the methodology used is:

$$E = AD * EF * 10^{-3}$$

Where,

E – Total emission of each pollutant (t);

AD – Clinker Production (t of Clinker);

EF – Emission Factor (kg/t of clinker).

For black carbon, the methodology used is:

$$E = \% \, Fuely * EPM2.5 * EFy$$

Where,

E – Total emission of black carbon (t) related to each type of fuel (liquid, solid, gaseous, biomass);

$E_{PM2.5}$ – Emissions of $PM_{2.5}$ (t);

[31] There is also some production of white Portland cement, which is characterized by a lower iron and manganese constant, than grey cement, and it is used mainly for decorative purposes. There are also in Portugal smaller additional cement plants but that do not produce clinker.

[32] One calciner is a false pre-calciner.

EF – Emission Factor related to each type of fuel (liquid, solid, gaseous, biomass) - kg/t of clinker.

#### 4.1.1.1.3 Emission Factors

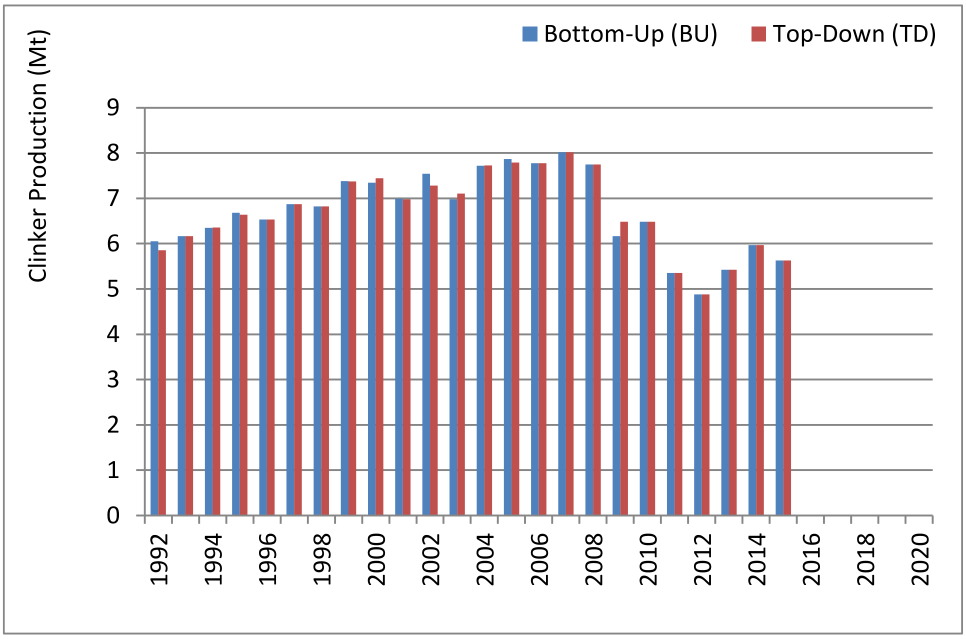
Table 4.1 – Emission Factors for Cement Production

| Pollutant | Unit | Emission Factor | Source |
|---|---|---|---|
| SOx | kg/t clinker | [0.050 – 4.100] | Plant Specific (Monitoring Data) |
| NOx | kg/t clinker | [1.106 – 3.700] | Plant Specific (Monitoring Data) |
| NMVOC | kg/t clinker | | Plant Specific (Monitoring Data) |
| NH3 | kg/t clinker | [0.005 – 1.041] | Plant Specific (Monitoring Data) |
| PM2.5 | kg/t clinker | [0.014 – 0.309] | Plant Specific (Monitoring Data) |
| PM10 | kg/t clinker | [0.014 – 0.309] | Plant Specific (Monitoring Data) |
| TSP | kg/t clinker | [0.014 – 0.309] | Plant Specific (Monitoring Data) |
| BC | % of $PM_{2.5}$ | [6.4 – 56.0] | EMEP/Corinair emission inventory guidebook (Table 3-2 to 3-5) |
| CO | kg/t clinker | [0.06 – 1.80]] | Plant Specific (Monitoring Data) |
| Pb | kg/t clinker | [$3.00x10^{-5}$ – $1.51x10^{-3}$] | Plant Specific (Monitoring Data) |
| Cd | kg/t clinker | [$1.10x10^{-6}$ – $2.77x10^{-3}$] | Plant Specific (Monitoring Data) |
| Hg | kg/t clinker | [$1.87x10^{-6}$ – $2.52x10^{-5}$] | Plant Specific (Monitoring Data) |
| As | kg/t clinker | [$2.24x10^{-7}$ – $5.57x10^{-4}$] | Plant Specific (Monitoring Data) |
| Cr | kg/t clinker | [$1.49x10^{-5}$ – $1.58x10^{-3}$] | Plant Specific (Monitoring Data) |
| Cu | kg/t clinker | [$2.82x10^{-5}$ – $2.60x10^{-3}$] | Plant Specific (Monitoring Data) |
| Ni | kg/t clinker | [$6.38x10^{-7}$ – $1.88x10^{-3}$] | Plant Specific (Monitoring Data) |
| Se | kg/t clinker | [$7.50x10^{-5}$ – $1.00\ x10^{-4}$] | Plant Specific (Monitoring Data) |
| Zn | kg/t clinker | [$2.69x10^{-5}$ – $8.77x10^{-4}$] | Plant Specific (Monitoring Data) |
| PCDD/PCDF | kg/t clinker | [$1.64x10^{-12}$ – $2.38x10^{-11}$] | Plant Specific (Monitoring Data) |
| Benzo(a)pyrene | kg/t clinker | NE | - |
| Benzo(b)fluoranthene | kg/t clinker | NE | - |
| Benzo(k)fluoranthene | kg/t clinker | NE | - |
| Indeno(1,2,3-cd)pyrene | kg/t clinker | NE | - |
| HCB | kg/t clinker | NE | - |
| PCBs | kg/t clinker | NE | - |

#### 4.1.1.1.4 Activity Data

In emissions estimates it is used clinker production data provided from the facilities (Bottom-Up) for the entire period. We also obtained clinker production data from National Statistics (Top-Down) and made the comparison of Figure 4.1. The 2009 clinker production value from national statistics is an outlier and this situation has been communicated to national statistics authorities.

Figure 4.1 – Clinker Production




The decrease from 2011 to 2012 is 0.47 Mt and is due to a demand decrease in Portugal, Spain and North Africa market. From 2013 to 2014 there is an overall increase in clinker production of 0.54 Mt due to exports rise to Africa and South America. In 2015 there is a decrease of 0.34 Mt of clinker produced, due to a contraction of external market sales, related both to supply excess in the Mediterranian area and to a consumption decrease in Africa.

#### 4.1.1.1.5 Recalculations

There are no recalculations.

#### 4.1.1.1.6 Further Improvements

We will revise plant specific emission factors based on updated monitoring data, and will introduce these values in future submissions.

### 4.1.1.2 *Lime Production (NFR 2.A.2)*

#### 4.1.1.2.1 Overview

Lime is produced through calcination, a process of thermal conversion (at temperatures at about 900-1200ºC) in a kiln, of carbonate bearing materials (mostly limestone and dolomite, but aragonite, chalk, marble or sea shells could be also used) releasing carbon dioxide and leaving calcium oxide (CaO) or magnesium oxide (MgO) as valuable products.

Lime products include several different forms:

- Quicklime or high calcium lime. A material composed of calcium oxide (CaO, it is produced by heating limestone with heavy $CaCO_3$ content (at least 50 percent) to high temperatures. It is used in building, agriculture and chemical processes (manufacture of $Na_2CO_3$, NAOH, steel, refractory material, $SO_2$ absorption, $CaC_2$, glass, pulp and paper, sugar and ore concentration and refining). It is also used in waste and water treatment;

- Dolomite quicklime. Produced in a similar mode to quicklime but from dolomitic limestone or magnesite, rocks that contain both calcium carbonate and magnesium carbonate (MgO is usually around 30 to 45 percent in content). Dolomite quicklime is a mixture of CaO and MgO;

- Calcium Hydroxide, slaked lime, dead lime, burned lime or hydrated lime: $Ca(OH)_2$ It is produced from CaO and water. When an equivalent quantity of water is used is called slaked lime, when an excess water is used is milk of lime and a clear solution of $Ca(OH)_2$ in water is limewater. It is used as an industrial alkali and in the preparation of mortar (slaked lime plus sand) which sets to solid by reconversion of the hydroxide to CaCO3 (Sharp, 1981);

- Hydraulic Lime. A mixture of calcium oxide (CaO) and silicates, it is an intermediate product between lime and cement.

There are 5 dedicated lime production plants under ETS in Portugal (7 until 2008 and 6 until 2013).

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.

#### 4.1.1.2.2 Methodology

For lime production emissions estimates, the used methodology is:

$$E = AD * EF * 10^{-3}$$

Where,

E – Total emission of each pollutant (t);

AD – Lime Production (t of lime);

EF – Emission Factor (kg/t of lime).

#### 4.1.1.2.3 Emission Factors

Table 4.2 – Emission Factors for lime production

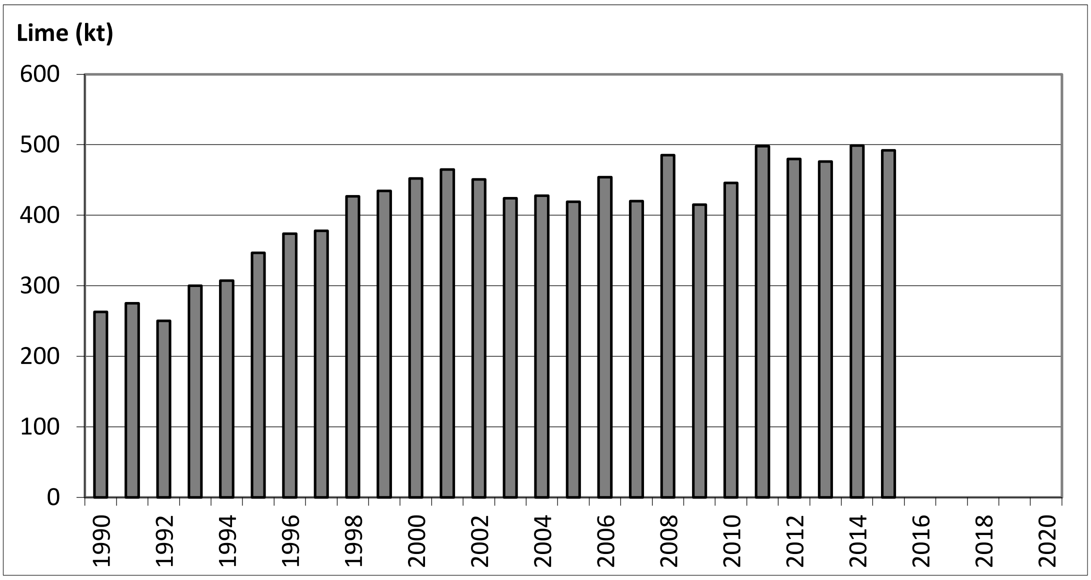
| Pollutant | Unit | Emission Factor | Source |
|---|---|---|---|
| SOx | kg/t lime | 0.006 | Table 11.17-5 of USEPA AP-42 |
| NOx | kg/t lime | 0.12 | Table 11.17-5 of USEPA AP-42 |
| NMVOC | - | NE | - |
| NH3 | - | NA | - |
| PM2.5 | kg/t lime | 0.05 | EMEP/EEA emission inventory guidebook 2009 (Table 3.1) |
| PM10 | kg/t lime | 0.24 | EMEP/EEA emission inventory guidebook 2009 (Table 3.1) |
| TSP | kg/t lime | 0.59 | EMEP/EEA emission inventory guidebook 2009 (Table 3.1) |
| BC | % of $PM_{2.5}$ | 0.46 | EMEP/EEA emission inventory guidebook 2013 (Table 3.1) |
| CO | kg/t lime | 0.23 | Table 11.17-5 of USEPA AP-42 |
| Pb | - | NE | - |
| Cd | - | NE | - |
| Hg | - | NE | - |
| As | - | NA | - |
| Cr | - | NA | - |
| Cu | - | NA | - |
| Ni | - | NA | - |
| Se | - | NA | - |
| Zn | - | NA | - |
| PCDD/PCDF | - | NA | - |
| Benzo(a)pyrene | - | NA | - |
| Benzo(b)fluoranthene | - | NA | - |
| Benzo(k)fluoranthene | - | NA | - |
| Indeno(1,2,3-cd)pyrene | - | NA | - |
| HCB | - | NA | - |
| PCBs | - | NA | - |

#### 4.1.1.2.4 Activity Data

Lime production was obtained directly from the lime production plants from 2010 onwards. From 1990 to 2009, activity data was estimated based on National Statistics trend.

Lime production in the iron and steel industry was available from information received from the industry for the period 1991-1994. For the remaining years annual lime production, for which data was unavailable, was forecasted using energy consumption as surrogate indicator. After year 2002 production of lime in this unit was interrupted and the production line dismantled. All lime produced in the iron and steel plant was high calcium lime.

Figure 4.2 – Lime Production (kt)




The Lime production values in 2015 are 1.9 times higher than in 1990.

##### 4.1.1.2.5 Recalculations

No recalculations were made.

##### 4.1.1.2.6 Further Improvements

We will estimate plant specific emission factors based on monitoring data, and will introduce these values in future submissions.

#### 4.1.1.3 *Glass Production (NFR 2.A.3)*

##### 4.1.1.3.1 Overview

Glass is normally made from sand, limestone, soda ash, and possibly recycled broken glass. It is made submitting these materials to a high temperature which are thereafter made solid without crystallization (semi-solid state).

Glass involves carbon dioxide emissions, from decarbonizing of limestone and carbonate materials under high temperature conditions. Carbonate materials vary with the desired product and comprehend typically limestone, dolomite, soda ash (sodium carbonate) and other carbonate compounds of potassium, barium or strontium.

Combustion emissions from glass production were already considered in source sector 1A2, estimated from fuel consumption data or production data. Some anthracite coal is used also as additive in glass production. However, because the consumption of this material is already considered in the energy balance, to avoid double counting of emissions from coal use are not considered here[33].

### 4.1.1.3.2 Methodology

Carbon dioxide emissions from glass production were estimated from:

$$Emission_{CO2(t,y)} = EF_{CO2(t)} * Carbonate_{(t,y)}$$

where

$Emission_{CO2(t,y)}$ - annual emission of carbon dioxide from consumption of specific carbonate (t/yr);

$Carbonate_{(t,y)}$ - Carbonate of type t consumed in a given year y (t/yr);

$EF_{CO2(t)}$ - emission factor from consumption of carbonate t (t $CO_2$/t carbonate)

### 4.1.1.3.3 Emission Factors

The following emission factors were considered in the estimates:

Table 4.3 – Emission Factors considered

| Parameter | Unit | Considered in NFR sector | Flat Glass | Container Glass | Crystal Glass |
|---|---|---|---|---|---|
| NMVOC | Kg/t Glass | 1 A 2 f | 0.1 (a) | 4.5 (a) | 4.7 (a) |
| SOx | Kg/t Glass | 1 A 2 f | 1.5 (a) | 1.7 (a) | 2.8 (a) |
| NOx | Kg/t Glass | 1 A 2 f | 4.0 (a) | 3.1 (a) | 4.3 (a) |
| CO | Kg/t Glass | 1 A 2 f | 0.1 (a) | 0.1 (a) | 0.1 (a) |
| TSP | Kg/t Glass | 2 A 3 | 1.0 (c) | 0.7 (c) | 8.4 (c) |
| $PM_{10}$ | % (m/m) | 2 A 3 | 0.95 (d) | 0.95 (d) | 0.95 (d) |
| $PM_{2.5}$ | % (m/m) | 2 A 3 | 0.91 (d) | 0.91 (d) | 0.91 (d) |
| Pb | Kg/t Glass | 2 A 3 | 1.2E-02 (e) | 1.2E-02 (e) | 1.0E-02 (e) |
| Cd | Kg/t Glass | 2 A 3 | 1.5E-04 (e) | 1.5E-04 (e) | 1.5E-04 (e) |
| Hg | Kg/t Glass | 2 A 3 | 5.0E-05 (e) | 5.0E-05 (e) | 5.0E-05 (e) |
| As | Kg/t Glass | 2 A 3 | 1.2E-04 (e) | 1.2E-04 (e) | 1.0E-04 (e) |
| Cr | Kg/t Glass | 2 A 3 | 2.4E-03 (e) | 2.4E-03 (e) | 2.5E-03 (e) |
| Cu | Kg/t Glass | 2 A 3 | 6.0E-04 (e) | 6.0E-04 (e) | 5.0E-04 (e) |
| Ni | Kg/t Glass | 2 A 3 | 1.9E-03 (e) | 1.9E-03 (e) | 2.0E-03 (e) |
| Se | Kg/t Glass | 2 A 3 | 1.8E-02 (e) | 1.8E-02 (e) | 2.0E-02 (e) |
| Zn | Kg/t Glass | 2 A 3 | 1.1E-02 (e) | 1.1E-02 (e) | 1.0E-02 (e) |

(a) USEPA AP-42 – Chapter 11.15 – Table 11.15-2 (VOC emission factor); (b) Assumed 10% of NMVOC emission factor; (c) USEPA AP-42 – Chapter 11.15 – Table 11.15-1 (Uncontrolled); (d) USEPA AP-42 – Chapter 11.15 – Table 11.15-3 (particle size distributions); (e) Emission Factors Manual Parcom-Atmos

(b) Source: USEPA (1986)

[33] They were not used to derive the country specific emission factors for instance.

NMVOC, SOx, NOx and CO emissions have been reported in NFR sector "1 A 2 f" for consistency purposes with the GHG submission in the CRF Reporter, since it is not possible to add pollutants to the sector "2 A 3". All the other pollutants are reported in NFR sector "2 A 3", since they are not reported also in the GHG submission in the CRF Reporter and no consistency between reports need to be assured.

#### 4.1.1.3.4 Activity Data

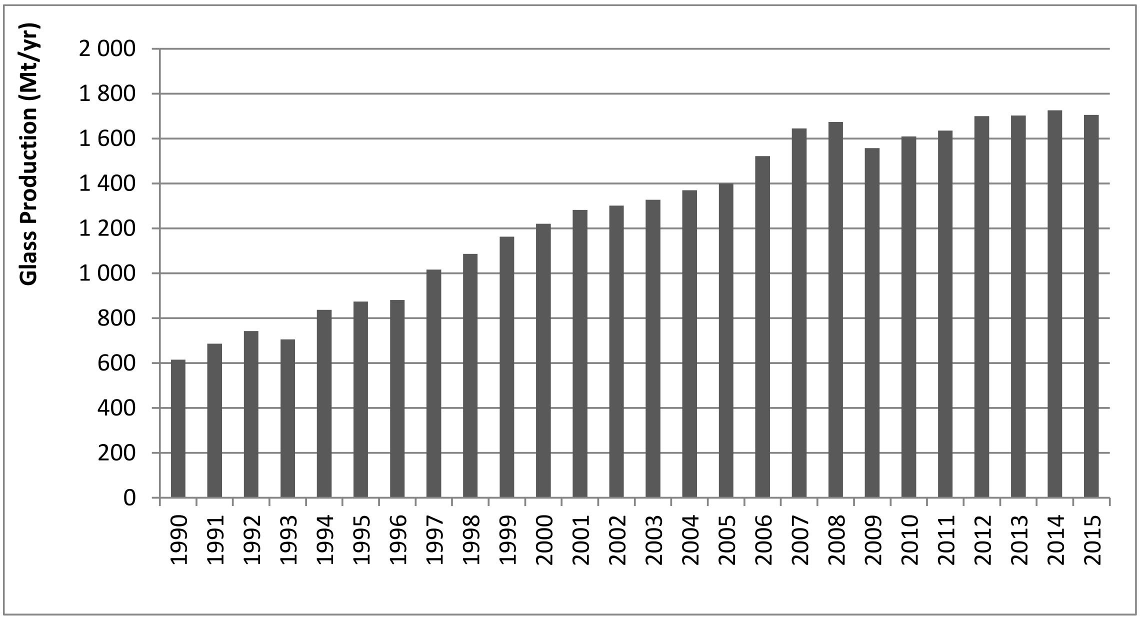
We don't use data from INE because not all products are reported in weight, but instead are measured in area-units ($m^2$) or number of produced pieces.

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

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

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

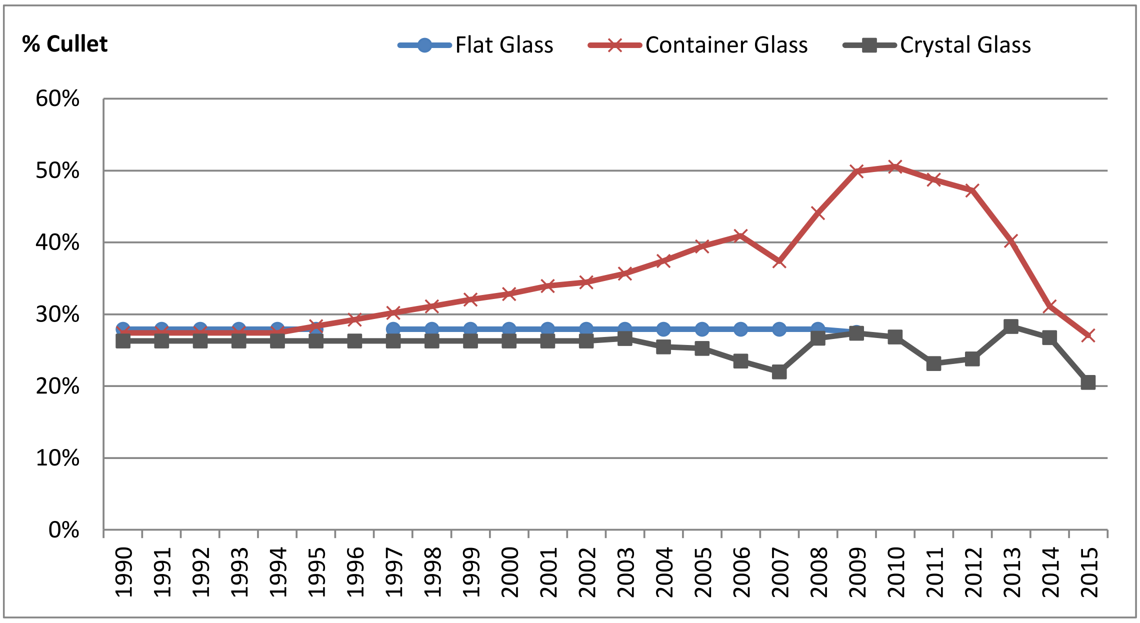
Figure 4.3 - Glass production




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

Cullet incorporation ratio could be checked in the next figure.

Figure 4.4 - % of Cullet incorporation by type of glass




#### 4.1.1.3.5 Recalculations

No recalculations were made.

#### 4.1.1.3.6 Further Improvements

Estimates of emissions due to the production of glass wool and rock wool are still not available due to lack of statistical information for activity data. Although it is foreseen that this are minor emission sources, efforts are being made to obtain this information and establish emission estimates for this source.

## 4.1.2 Chemical Industry (NFR 2.B)

### 4.1.2.1 *Ammonia Production (NFR 2.B.1)*

#### 4.1.2.1.1 Overview

In 1990 there were two plants producing ammonia in Portugal, but one of the plants has stopped activity already in the beginning of that year.From 1991-2008, there was only one plant producing ammonia. In 2009, this plant was closed and the ammonia production has been relocated to India.

Ammonia is synthesized from nitrogen and hydrogen, by the following reaction:

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

Nitrogen is obtained from atmospheric air.

Depending on the type of fossil fuel, two different methods are applied to produce the hydrogen for ammonia production: steam reforming or partial oxidation. In Portugal, hydrogen is obtained from partial oxidation of heavy hydrocarbons.

Gasification of heavy hydrocarbons follows the reaction:

$$2CH_n + O_2 \rightarrow 2CO + nH_2$$

Emissions result from the process, either from escape of ammonia ($NH_3$) or either from release of products from feedstock (CO and NMVOC).

#### 4.1.2.1.2 Methodology

Emissions estimates for all pollutants are estimated by the use of emission factors multiplied by the quantity of material manufactured:

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

where

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

ActivityRate $_{(y)}$ - quantity of ammonia produced in year y (t/yr);

EF $_{(p)}$ - emission factor for pollutant p (kg/ t)

#### 4.1.2.1.3 Emission Factors

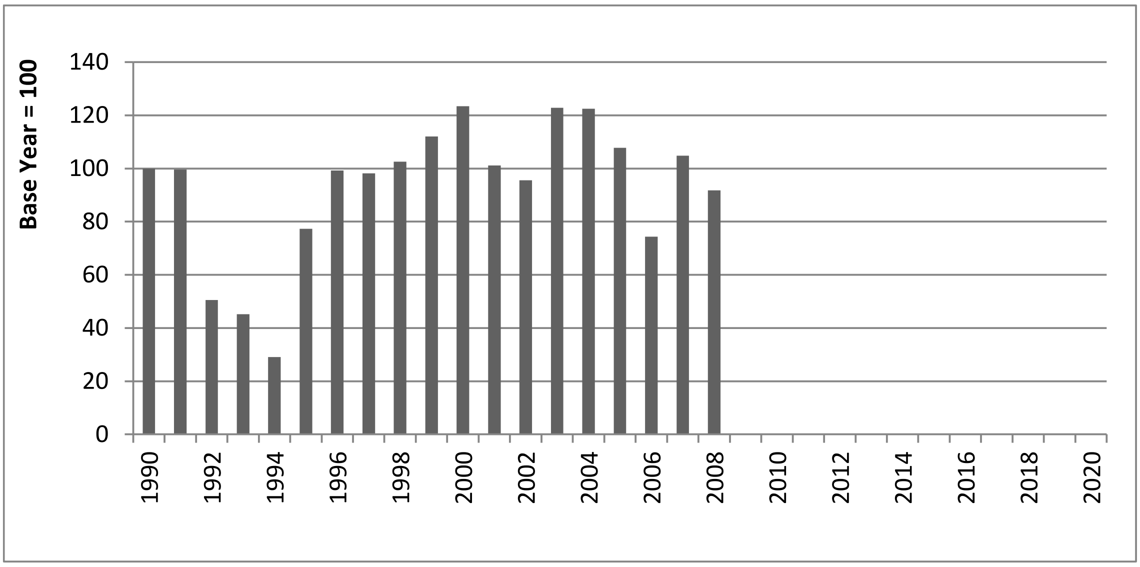
Due to confidentiality constraints it is not possible to publish the chosen emission factors.

#### 4.1.2.1.4 Activity Data

In 1990 there were two plants producing ammonia in Portugal, but one of the plants has stopped activity already in the beginning of that year. From 1991-2008, there was only one plant producing ammonia. In 2009, this plant was closed and the ammonia production has been relocated to India.

Due to confidentiality constraints, it is not possible to present any absolute information concerning activity data for this source activity, neither ammonia nor urea production.

Figure 4.5 – Trend in Ammonia production



The overall trend in the amount of ammonia produced in the period may be depicted in the Figure 4.5, from where it is evident the significant inter-annual changes in the period 1991-1996.The reason for the low emission values in the period 1992-1994 is the $NH_3$ production decrease in this period. According to information provided by the facility, in this period there were technical problems that led to several interruptions in the production.

Ammonia production data was obtained from the facilities for the period 1990-2008. From 2009 onwards there is no ammonia production. This data is consistent with national statistics ammonia production data.

##### 4.1.2.1.5 Recalculations

In Portugal, hydrogen is obtained from partial oxidation of heavy hydrocarbons. Emission factors have been corrected in order to be fully consistent with partial oxidation process.

##### 4.1.2.1.6 Further Improvements

No further improvements are planned.

### 4.1.2.2 *Nitric Acid (NFR 2.B.2)*

##### 4.1.2.2.1 Overview

There are only three industrial plants producing nitric acid in Portugal, located in Estarreja, Alverca and Lavradio. In all, weak nitric acid (60 percent) is produced from ammonia, using catalytic (Platinum-rhodium alloy catalysts) oxidation of ammonia with air to $NO_2$ at medium pressure, and subsequent absorption with water to form nitric acid in a dual-stage process.

Nitric Acid manufacture results in air emissions primarily of $NO_x$ (NO and $NO_2$), trace amounts of $HNO_3$ acid mist, ammonia ($NH_3$) and Nitrous Oxide ($N_2O$). The great majority of emissions are conveyed in the tail gas from the absorption tower. Emissions of $NO_x$ are controlled by catalytic reduction. Ammonia emissions from Nitric Acid are not estimated in the inventory, due to the absence of applicable emission factors or monitoring data.

##### 4.1.2.2.2 Methodology

For all pollutants emissions are estimated using the following equation:

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

where

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

$ActivityRate_{(y)}$ – production of Nitric Acid in year y (t/yr);

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

##### 4.1.2.2.3 Emission Factors

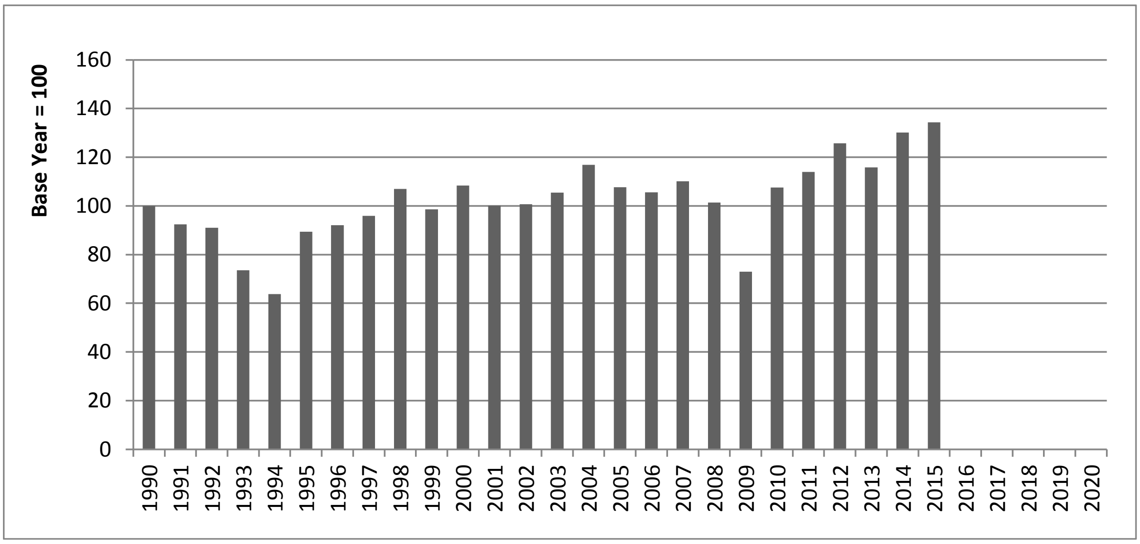
Due to confidentiality constraints it is not possible to publish the chosen emission factors. They were estimated based on monitoring data from the facilities.

#### 4.1.2.2.4 Activity Data

The activity data that was used to estimate emissions from this sub-source sector is subjected to confidentiality constraints due to the limited number of existing production units and may not be presented here in actual figures, but only in relation to production in 1990 (trends).

Activity Data is obtained directly from the facilities. One of the plants was closed during year 2010 and replaced by a new facility.

Figure 4.6 – Trend in Nitric Acid production




#### 4.1.2.2.5 Recalculations

No recalculations were made.

#### 4.1.2.2.6 Further Improvements

No further improvements are planned for this sector.

### 4.1.2.3 *Non GHG emissions from Inorganic Chemistry and Fertilizer Industry*

#### 4.1.2.3.1 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.

##### *4.1.2.3.1.1 Sulphuric Acid Production*

In 1990 in Portugal there were two industrial units producing sulphuric acid from mineral processing and more two additional industrial plants producing $H_2SO_4$ by recovery of sulphur. In 1990 and 1991 both industrial plants producing sulphuric acid from pyrites were closed and thereafter only sulphur recovery process remained active. In 2008, emissions of $SO_x$ from sulphuric acid production result from recovery of sulphur - and abatement of air emission - in an ammonia industrial plant that uses a high sulphur content raw material, Vacuum Residual Fuel oil (VRF), as feedstock. In 2009, the only facility that produced ammonia in Portugal was closed and the production was relocated to India.

Production of sulphuric acid (Contact Process) comprehends a first step, where $SO_2$ is formed from oxidation of elemental sulphur with air, followed by conversion to $SO_3$, in a catalytic converter, and finally the absorption of this gas in a strong acid solution.

In the case of sulphur recovery units, a flux of hydrogen sulphide, coming from the partial oxidation of the feedstock, is converted into $H_2SO_4$, also by air oxidation, but without previous conversion to elemental sulphur. The process then proceeds in a similar fashion to sulphuric acid production. Although emissions of $SO_x$ from recovery of sulphur occur in the Claus unit and in the flare, all are reported in the same source category (2B5-Other Chemical Industry) in NFR 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.

##### *4.1.2.3.1.2 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 Nitate (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.

#### 4.1.2.3.2 Methodology

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

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

where

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

ActivityRate $_{(y)}$ - Indicator of activity in the production process: quantity of product produced in year y, as a general rule for this emission source sector (t/yr);

EF $_{(p)}$ - emission factor for pollutant p (kg/ t)

In the case of sulphur recovery with sulphuric acid production, total SOx 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[34]:

$$Emi_{SOx(y)} = 2 * Feedstock_{(y)} * S_{Feed(y)} * 10^{-2} – 32/98 * Prod_{H2SO4\ (y)}$$

where

$EmiSOx_{(y)}$ - Emission of sulphur oxides[35] (t/yr);

$FeedStock_{(y)}$ - Annual consumption of feedstock (t/yr)

$S_{Feed(y)}$ - Sulphur content of feedstock (%);

$Prod_{H2SO4\ (y)}$ - production of sulphuric acid from sulphur recovery in year y (t/yr).

#### 4.1.2.3.3 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. Due to confidentiality constraints, the emission factors for sulphuric acid are not published.

Table 4.4 – Emission Factors for inorganic chemical industry processes (1/2)

| Pollutant | Urea | Ammonium Sulphate | Ammonium Nitrate |
|---|---|---|---|
| | kg/t Urea | kg/t (NH4)2 SO4 | kg/t NH4 O3 |
| NMVOC | - | 1.04 (f) | - |
| $NH_3$ | 9.66 (d) | | 2.0(g) + 1.4(b) |
| PM | 2.01 (d) | 0.02 (f) | 2.4(h) + 2.5(b+h) |
| PM10 | 1.82 (d) | 0.02 | 2.4 + 2.0(h) |
| PM2.5 | 1.61 (d) | 0.02 | 2.4 + 2.0(h) |

[34] For the time being this procedure is only feasible for two years: 1990 and 1993. For the remaining years the average emission factor (kg SOx/kg S in VRF) for 1990 and 1993 was used to estimate emissions.

[35] In fact, this emissions include also $H_2S$ and other sulphur compounds, but it is assumed that they are converted to $SO_x$ in atmosphere.

Table 4.5 – Emission Factors for inorganic chemical industry processes (2/2)

| Pollutant | NPK | CN, CMN | Normal SS | Triple SS | DAP |
|---|---|---|---|---|---|
| | kg/t | kg/t | kg/t | kg/t | kg/t |
| $NH_3$ | 1.89 (c) | 0.1 (b) | 4.91 (c) | 0.82 (i) | 1.0 (g) |
| PM | 4.2 (c+h) | 0.6 (b) | 4.09 (c) | 0.73 (i) | 0.3 (g) |
| PM10 | 3.4 | 0.5 | 4.09 | 0.73 | 0.3 |
| PM2.5 | 3.4 | 0.5 | 4.09 | 0.73 | 0.3 |

(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 (1993h)
(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 cannot be made explicit in IIR due to confidential constraints.

#### 4.1.2.3.4 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.

##### *4.1.2.3.4.1 General*

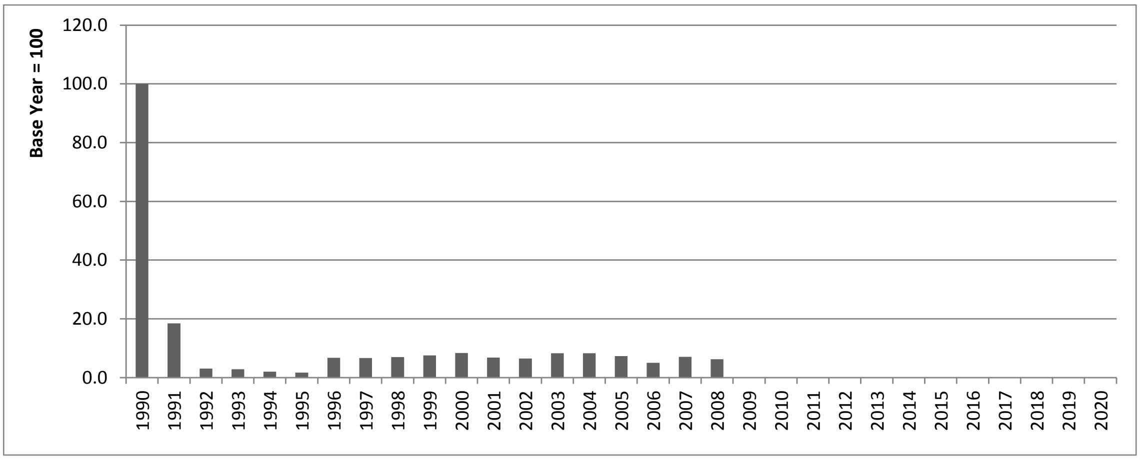
- national statistical information. IAIT industrial survey was available for years 1990-91 and IAPI industrial survey was used thereafter. Change from IAIT to IAPI represents a methodological shift made by INE, involving change in questionnaire, classification of economic activities, product and materials 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 APA 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;

### *4.1.2.3.4.2 Sulphuric Acid*

Figure 4.7 – Trend in total sulphuric acid production, including sulphur recovery




The amount 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:

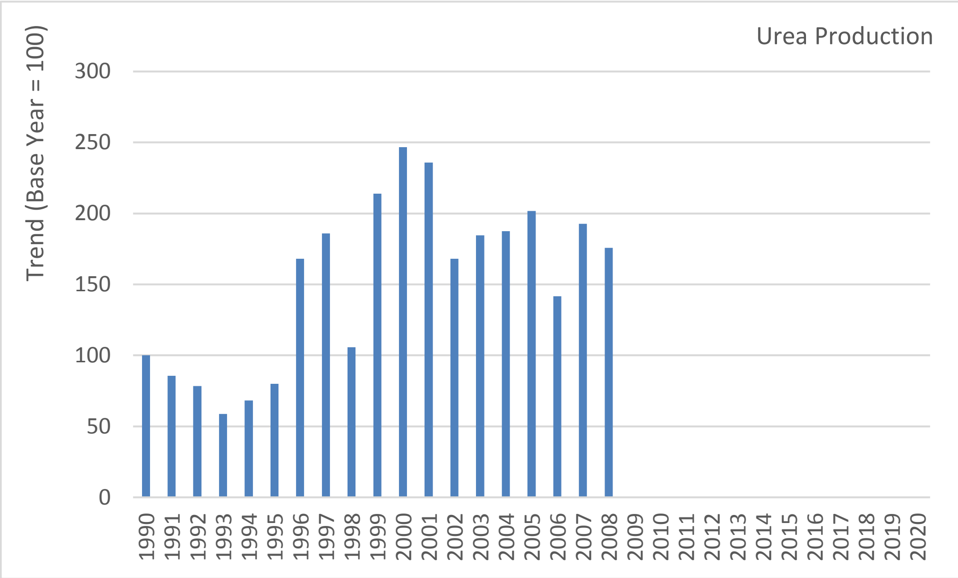
- Consumption of feedstock VRF, and its sulphur content, was available from the only industrial plant in Portugal also for a limited number of years – 1990 till 1994 – but a strong linear relation between feedstock consumption and ammonia production could be established from available data[36];
- Production of ammonia in Portugal is available from the only existing facility for the period 1990-2008. From 2009 onwards there is no ammonia production since the facility was stopped and the production relocated to India;
- Finally a linear relation was also set between VRF consumption and the quantity of $H_2SO_4$ that was recovered.

### *4.1.2.3.4.3 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.

[36] For confidentiality reasons original data and relation may not be reported in IIR

Figure 4.8 – Trend in Urea production




#### *4.1.2.3.4.4 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.

### 4.1.2.3.5 Recalculations

No recalculations were made.

### 4.1.2.3.6 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, Industry Associations and E-PRTR. Best Available Technologies (BAT) should be considered also in the determination of future emission factors. In general, information from Regional inventory surveys, E-PRTR and monitoring under *Autocontrolo* program may also allow better insight of technologies of this sector and may possibly improve methodologies and emission factors.

For some fertilizers, FAO database has statistical information concerning production, but which do not agree with national statistical databases. Efforts will be made to explain differences, and compatibilize both information sources if possible. Also, efforts must be done to clarify incorporation of some basic fertilizer in mixtures, obtained by granulation, in order to avoid double counting. Preferably information should be collected directly from industrial plants.

Specific issues to improve comprehend the revision of the different reporting placement for SOx emissions from flaring in sulphur recovery.

#### 4.1.2.4 *Organic Chemical Industry (NFR 2.B.10.a)*

##### 4.1.2.4.1 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 feed-stocks.

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[37]:

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

[37] This list is not extensive to chemical production in Portugal, but comprehends only those products for which there are emission estimate methodologies and emission factors

#### 4.1.2.4.2 Methodology

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

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

where

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

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

$EF_{(p)}$ - emission factor (kg/ t)

In the case of carbon black, where CO2 emissions result from liberation of carbon in tail gas to atmosphere, emissions were estimated using a simple mass balance:

$$44 / 12 * C_{TailGas} = C_{Feedstock} + C_{AuxFuels} – C_{CarbonBlack}$$

Where,

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

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

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

$C_{CarbonBlack}$ – carbon stored in carbon black and not emitted to atmosphere (t C/yr);

#### 4.1.2.4.3 Emission Factors

A specific and detailed inventory survey was made for BOREALIS unit in 1993-1994[38]. Emissions estimated for this period where 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[39]. Emissions from flares and flue gas combustor where included in the emission factors.

[38]Unpublished.

[39] This is an integrated industrial plant and it is difficult to attribute emissions to specific products.

Table 4.6 – Emission Factors for determination of process emissions in Borealis (kg/t)

| Fábrica | NMVOC |
|---|---|
| Ethylene | 0.8 |
| 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 2009 - 2012, to a detailed inventory exercise. Consequently emission factors were established for carbon black unit and emission estimates were extended for the rest of the time series using carbon black production as indicator of activity rate. Carbon Gas emissions include also emissions suffering partial combustion.

Table 4.7 – Emission Factors in calculation of Carbon Black process emissions

| Pollutant | Process Emissions (kg/t carbon black) | EF Source |
|---|---|---|
| CO2 | 2,379 | Carbon Balance Approach |
| CH4 | 0.060 | IPCC 2006 Guidelines |
| NOx | 9.390 | EMEP Guidebook 2016 |
| CO | 1.160 | Instalation Data |
| NMVOCs | 0.540 | Instalation Data |
| SOx | 10.96 | Sulphur Balance Approach |
| TSP | 0.148 | Instalation Data |
| PM10 | 0.133 | Instalation Data |
| PM2.5 | 0.130 | Instalation Data |
| BC | 0.013 | EMEP Guidebook 2016 |

Emission factors for the Phthalic Anhydride Plant are from US-EPA (1983) and are presented in the table below:

Table 4.8 – Emission Factors for the production of Phthalic Anhydride

| Pollutant | kg/t |
|---|---|
| SOx | 4.7 |
| NMVOC | 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 4.9 – Emission Factors for Nitrocellulose production (explosives)

| FE (Kg/t) | SOx | NOx |
|---|---|---|
| Total | 34.7 | 14 |
| Nitration reactors | 0.7 | 7 |
| Nitric acid concentrator | - | 7 |
| Sulphuric acid concentrator | 34 | - |

Source: USEPA (1983)

- It was assumed that the production of nitroglycerin is similar, in what concerns emissions, to nitrocellulose production, and the same emission factors were used;
- Black powder is made from carbon, sulphur and saltpetre ($KNO_3$) mixed together. There are no references to emissions from its 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 4.10 – Emission Factors for TNT production (explosives)

| kg/t | SOx | NOx |
|---|---|---|
| TNT - Batch process (Total) | 36.5 | 78.5 |
| Nitration reactors | | |
| Fume recovery | - | 12.5 |
| Acid recovery | - | 27.5 |
| Nitric acid concentrators | - | 18.5 |
| Sulphuric acid concentrators (with ESP) | 7 | 20 |
| Red water (Sellite exhaust) | 29.5 | - |

Source: USEPA (1983)

Emission factors for all other chemical producing units follow international bibliography sources, particularly AP42 (US-EPA).

Table 4.11 – Emission factors for chemical organic industrial processes

| Compound | EF (kg/t) | |
|---|---|---|
| | NMVOC | PM |
| VCM | 2.5 [a] | - |
| LDPE | 2.4 [b] | 0.031 [b] |
| PVC | 0.2[b] | 0.263 [b] |
| PP | 4.0 [b] | 1.5 [b] |
| PS | 0.12 [b] | 0.004 [b] |
| Formaldehyde | 5.0 | - |

(a) USEPA (AP-42);

(b) (b) EMEP/EEA emission inventory guidebook 2009

##### 4.1.2.4.4 Activity Data

Activity data used to estimate emissions may not be reported in IIR, due to confidentiality issues that result from the limited number of units concerned for each individual compound.

For Repsol Petrochemical Plant in Sines - produced quantities are available from 1990 onwards. Production of carbon black and explosives is available from 1990 onwards 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).

##### 4.1.2.4.5 Recalculations

Review of the time series of activity data and emission factors for the Carbon Black sector.

##### 4.1.2.4.6 Further Improvements

Because emissions from production processes depend largely on  specific conditions in each industrial plant, and because there are very few units in Portugal using a specific chemical manufacturing process, it is essential that the national inventory relays more and more in detailed plant information, i.e. increasing the number of Large Point Sources. Only deep knowledge of LPS units will allow quantification of air emission with reduced uncertainty, either using technology specific emission factors from literature or either using monitoring data. This improvement may imply coordination with E-PRTR exercise, the European carbon trading scheme, Regional Air Emission Inventories, cooperation with industry associations or specific inquiries.

Also, the quality of emission estimates from this sub-source sector will be improved in next submissions, following the on-going efforts to improve the inventory of NMVOC from industry, that are been done under the background works for the revision of the Ceiling Directive of the UE.

### 4.1.3 Metal Production (NFR 2.C)

#### 4.1.3.1 *Iron and Steel Production (NFR 2.C.1)*

##### 4.1.3.1.1 Overview

Iron results from reduction of the iron element present in mineral ores by contact with coke - reducing agent - at high temperatures in the blast furnace. The resulting material, pig iron – and also scrap in some steel plants - is transformed into steel into subsequent furnaces which may be a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF). Coke, sinter and lime are intermediate materials necessary for iron and steel production.

Sintering modifies the structure of ore material making it more suitable for iron formation, by converting fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product. Sintering emissions occur from the windbox, discharge and sinter crusher, coolers and screens. Emissions from sintering, which result from a combustion process with contact, are reported under 1.A.2, although the emission factors are reported in this chapter.

Coke is produced by destructive distillation of imported fossil coal in coke ovens, where coal is subjected to heat in an oxygen-free atmosphere until all volatile components in the coal evaporate, forming a fuel used in industry, the Coke Gas. Process heat comes from the combustion of gases between the coke chambers. Excluding emissions associated with coke production resulting from use of fuels in under-fired heating furnaces (which are accounted in Energy source sector 1A1), air emissions from the cokerie 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 1.A.2.a – Combustion in Manufacturing Industries and Construction. The emissions that are quantified here, in source 2.C, are only those resulting from casting operations and seal leaks at top of furnace.

In Basic Oxygen Furnace original material are re-melted with the addition of substantial source of oxygen which is lanced (injected) and oxidizes part of the carbon associated with iron: This carbon is emitted mostly as CO (contributing nevertheless to ultimate $CO_2$ emissions). Other emissions from BOF are iron oxides, oxides of other metals and sulphur and particulate matter. In EAF the original material, which is basically scrap, is subjected to an electric discharge that also reduces carbon content. Emissions in furnaces may also result from carbon additives such as limestone and coke.

Steel is finally finished in rolling mills. Emissions from this finishing process are mostly particulate matter besides combustion pollutants which is already included in emissions from the 1.A.2.a sector.

Lime is necessary for the blast furnace charging and EAF mixtures.

Emissions of ultimate fossil $CO_2$ are the result of the oxidation of carbon in coke, anodes and electrodes. Part of the carbon may be sequestered in final product and not emitted to atmosphere as carbon dioxide. Only emissions of carbon that has origin in fossil fuels should be considered as emissions of final or ultimate CO2 and not those from the use of biomass origin carbon - charcoal. Emissions of carbon may occur as CO and NMVOC but it is assumed that they are subsequently converted in atmosphere in carbon dioxide. Some carbon may remain in pig iron after initial reducing in blast furnace and partly may be emitted from oxidation in the BOF. Also EAF furnaces may result in carbon emission but from consumption of graphite anodes in the process.

Other pollutants may be emitted during steel production as result of its presence (or presence of its precursors) in original ore or in the material used to produce coke. That is the case of $SO_x$ and heavy metals. But because combustion occurs with contact, emissions are modified - increase or decrease - by contact of combustion gases with products and emissions cannot be estimated by mass balance alone.

$NO_x$ 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 matter 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 cokerie, blast furnace and sintering were closed and only steel furnaces and trimming remain as emission sources.

From 2002 onwards, there is only secondary steel production in Portugal.

We do a cross-check between data received from the two plants and the energy balance data. Part of the differences (coke and coal consumption) is considered under source “1.A.2.a”. The differences related to other fuels are reported under source “1.A.2.g.viii”, since this could be a misallocation from the energy balance.

#### 4.1.3.1.2 Methodology

Emissions are simply calculated from multiplication of activity levels by a suitable emission factor:

$$Emission_{(p,y)} = \Sigma_a[EF_{(p,a)} * Activity_{Indicator\ (p,a,y)}] * 10^{-3}$$

and,

Emission $_{(p,y)}$ - Emission of pollutant p in a specific year y from all sector activities and equipments (t/yr);

Activity $_{Indicator\ (p,act,y)}$ - Most suitable indicator for emissions of a particular pollutant p resulting from a specific source activity or equipment a (t/yr);

EF $_{(p,act)}$ - Emission factor specific of pollutant and activity/ equipment a (kg/t).

Emissions from sintering 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).

Methodology to estimate emissions from combustion of coke gas and blast furnace gas were already discussed in source sector 1A.2.a - manufacturing industries and construction (iron and steel) - and 1A.1.c.1 - Manufacture of Solid Fuels.

#### 4.1.3.1.3 Emission Factors

Emissions factors for production process in the period 1990-2001 were set mostly from CORINAIR/EMEP also with contributions from IPCC96 and US-EPA AP42.

From 2002 onwards, it were used plant specific emission factors based on monitoring data for $SO_x$, $NO_x$, NMVOC, CO, particulate matter, heavy metals, PCBs, PAHs and PCDD/PCDF.

#### 4.1.3.1.4 Activity Data

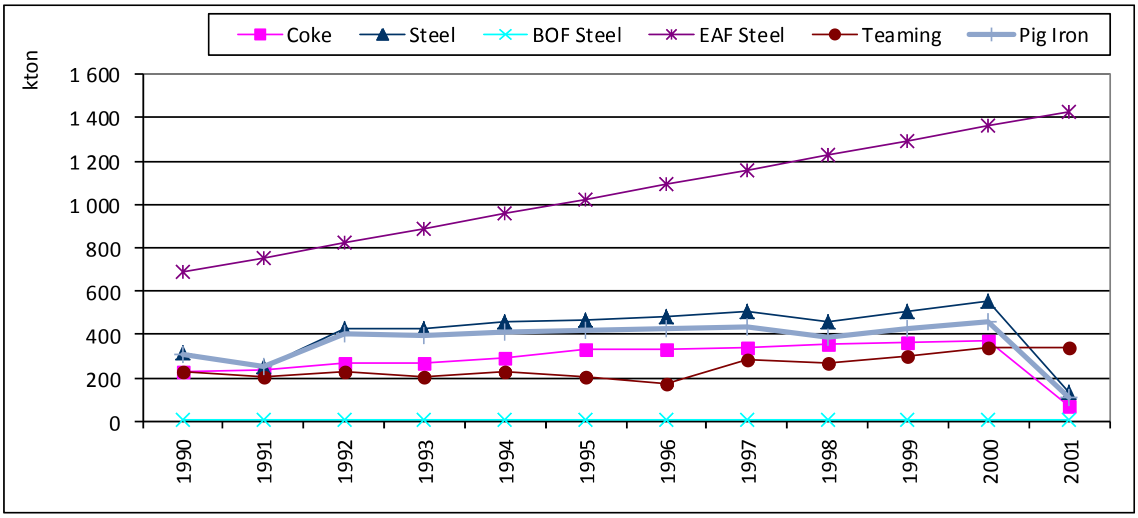
There are differences in the activity data used in estimates for the period 1990-2001 and from 2002 onwards.

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

- Coke production is available from DGEG (Cokerie Balance) annually from 1990 to 2001. From 2002 onwards there is no coke production in the iron and steel industry in Portugal;
- production time series for sinter, pig iron and steel production in blast furnace are available from industrial plant from 1990 to 1994 (APA direct survey). Thereafter and until 2001, annual values were estimated using coke production as surrogate data. From 2002 onwards there is no sinter, pig iron and steel production in blast furnace;
- Steel resulting from BOF in Seixal Iron and Steel Plant was estimated from production data in 1990 and forecasted until 2001; from 2002 onwards there is no steel production resulting from BOF.
- the same procedure was used to establish the full time series of scrap use and lime consumption, although in this case information data from the industrial plant was available from 1990 to 1994;
- steel production and scrap use in the EAF oven in Maia steel plant was available for 1990 and forecasted in the period 1991-2001 based on energy consumption;

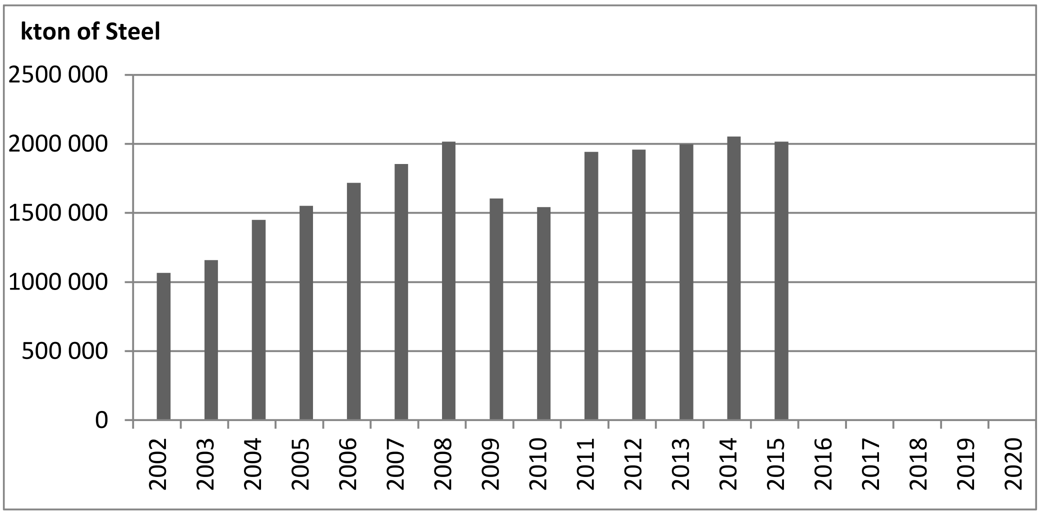
Production of total steel and intermediate products in the period 1990-2001 could be checked in the next figure.

Figure 4.9 – Production of iron and steel, production/consumption of intermediate products of the iron and steel industry: coke, sinter and pig iron, and consumption of scrap (1990-2001)



Production of secondary steel from 2002 onwards could be checked in the next figure.

Figure 4.10 – Production of secondary steel from 2002 onwards




Fuel consumption values are cross-checked with fuel consumption data from energy balance in order to avoid emissions underestimation.

##### 4.1.3.1.5 Recalculations

We did a cross-check between data received from the two plants and the energy balance data. Part of the differences (coke and coal consumption) is now considered under source “1.A.2.a”. The differences related to other fuels are reported under source “1.A.2.g.viii”, since this could be a misallocation from the energy balance.

##### 4.1.3.1.6 Further Improvements

Streamline between fuel consumption reported by the plants and the nergy balance data for iron and steel sector. The results from this streamline could lead to emissions reallocation

### 4.1.4 Other Solvent and Product Use (2.D – 2.L)

#### 4.1.4.1 *Domestic solvent use including fungicides (NFR 2.D.3.a)*

##### 4.1.4.1.1 Methodology

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 This sector addresses emissions from the use of solvent containing products by the public in their homes. This sector does not include the use of decorative paints which is covered by source category 2.D.3.d Coating Applications.

NMVOC’s are used in a large number of products sold for use by the public. These include:

- Cosmetics and toiletries; Products for the maintenance or improvement of personal appearance, health or hygiene.
- Household products; Products used to maintain or improve the appearance of household durables.
- Construction/Do-It-Yourself; Products used to improve the appearance or the structure of buildings such as adhesives and paint remover.
- Car care products; Products used for improving the appearance of vehicles to maintain vehicles or winter products such as antifreeze.

Pesticides such as garden herbicides and insecticides and household insecticide sprays may be considered as consumer products. Most agrochemicals, however, are produced for agricultural use and fall outside the scope of this section.

Emission from this sector were calculated using a Tier 1 approach. This approaches uses a single emission factor expressed on a person basis which was multiplied by the population to derive emissions from domestic solvent use.

$$NMVOC_i = Population_i \times EF_{NMVOC}/1000$$

where:

$NMVOC_i$ - Emissions of NMVOC associated to the use of domestic products containing solvents [t]

$Population_i$ – inhabitants in year i;

$EF_{NMVOC}$ - Emission factor associated with the use of domestic products containing solvents [kg/person/year]

#### 4.1.4.1.2 Emission Factors

Emission factor for NMVOC was obtained from EMEP/CORINAIR Guidebook, 2013. This default emission factor has been derived from an assessment of the emission factors presented in GAINS model developed by IIASA.

Table 4.12 – Default emission factor.

| Description | Unit | Value |
|---|---|---|
| Emission factor for domestic solvent use including fungicides | kg/person/year | 2.7 |

#### 4.1.4.1.3 Activity Data

Table 4.13 - Activity data (inhabitants)

| Description | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| Inhabitants | 9 970 441 | 10 043 180 | 10 256 658 | 10 569 592 | 10 636 979 | 10341330 |

Source: National Statistics Institute (INE)

#### 4.1.4.1.4 Recalculations

No recalculations were made.

### 4.1.4.2 *Road Paving with Asphalt (NFR 2.D.3.b)*

#### 4.1.4.2.1 Overview

Emission estimates reported in this source category include emissions occurring from paving road surfaces with asphalt materials as well as emissions occurring during operation of hot mix asphalt plants. Emissions from production of asphalt emulsions and cold asphalt mixtures are not included in the inventory estimates, being assumed that they are negligible.

Roads pavement with asphalt is done by the application of several layers over road bed. In volume, the majority of pavement is composed of layers of a compact aggregate and an asphalt binder (asphalt concrete). Asphalt concretes are classified either as 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 (150º-160º)[40]. 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 (40-60º).

Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers[41]. Cure may result from water evaporation alone or from the formation of chemical ionic bonds between aggregate materials (anionic and cationic emulsions). Asphalt cut-backs are asphalt cements fluidized by mixture with petroleum distillates: heavy fuel oil (Slow Cure), Kerosene (Medium Cure) or Gasoline/naphta (Rapid Cure).

Emissions from application of pavement are mostly composed of NMVOC and certain toxic substances as HAP. Cutback asphalts result in the highest emissions due to the evaporation of part of the diluent containing VOC. Emulsified asphalts may also result in NMVOC emissions if they contain solvents in their composition – and they may contain up to 12 percent of solvents. Hot mix asphalts in the other hand, result in minimum NMVOC emissions during application, because the organic component has high molecular weight and low 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 percent of total paved areas (APORBET).

Emissions during fabrication of asphalt concretes are estimated only for hot mix asphalt and comprehend NMVOC and Particulate Material that escape mostly from the drier. Other pollutants are also emitted but they result mostly from combustion of fuels and are considered in chapter

[40]That are needed to fluidize the asphalt cement.

[41] And also a solvent in several emulsion types.

Energy (1A2)[42]. Emission estimates for hot-mix are only made here for pollutants NMVOC and PM, while emission of other pollutants are covered in emission estimates made for Energy in Manufacturing Industries and Construction (1A2) using fuel combustion in building and construction activity[43].

Emissions during production of emulsions, cutback binders and cold mix asphalt concretes are not estimated and assumed negligible[44].

It was still not possible to distinguish the part of asphalt materials that is used in road pavement and other uses, such as building isolation or asphalt roofing, and therefore all emissions from production of asphalts – except emissions from fuel combustion – are included in this source category.

#### 4.1.4.2.2 Methodology

Ultimate carbon dioxide emissions are calculated assuming that solvents are 100 per cent composed of VOC (USEPA, 2001) and that emitted VOC have on average 60 per cent of carbon[45]:

$$Emi_{CO2} = 44 / 12 * 0.60 * Emi_{NMVOC}$$

Different methodologies were used to estimate emissions of NMVOC during asphalt application or from asphalt production.

##### *4.1.4.2.2.1 Application of Asphalt Concretes and Liquefied Asphalts*

Calculation of NMVOC emissions during application of asphalt materials is done solely for cutback asphalts and emulsion asphalts. Emissions from application of hot mix asphalts are not quantified and are assumed negligible.

Non methane emissions of volatile organic compounds from liquefied asphalt are dependent on the quantity of distillate or solvent that is added to bitumen and on the rapidity of the curing process, which in itself is a function of the distillate that is used. The following formula was used to estimate emissions from this source, and were adapted from (USEPA, 1997; USEPA, 2001):

$$Emi_{NMVOC\,(y)} = Cure_{FC} * Binder_{(y)} * d_{Bin}^{-1} * SLV_{Fac} * d_{SLV}$$

where

$Emi_{NMVOC\,(y)}$ - Emissions of NMVOC from asphalt application during year y (t/yr);

[42] To avoid duplication of emissions and because from statistical information is not possible to separate fuel use in this particular activity sector.

[43] It is not possible to distinguish fuel combustion in hot mix production activity.

[44] 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.

[45]Normal carbon content for medium linear simple hydrocarbons.

Binder (y) – Total quantity of asphalt binder used in road paving during year y (t/yr);

$SLV_{Fac}$ - Fraction of distillate (solvent) in asphalt ($m^3/m^3$);

$d_{Slv}$ - density of solvent added to liquefied asphalt (kg/l);

$d_{BIN}$ - density of bitumen binder mixture (kg/l);

$Cure_{FC}$ - Factor dependent on cure, expressing the percentage of total distillate that evaporates as emission (l/l).

###### *4.1.4.2.2.2 Hot Mix Asphalt Production*

For calculation of hot mix production emissions, emission calculation is based on total product:

$$Emi_{(p,y)} = Hotmix_{Batch\ (y)} * EF_{(p)} + Hotmix_{Drum\ (y)} * EF_{(p)}$$

Where,

$Emi_{(p,y)}$ – Total emissions for pollutant p occurring in year y from Hot mix asphalt production (t);

$Hotmix_{Batch\ (y)}$ and $Hotmix_{Drum\ (y)}$ – Production of Hot mix asphalt, respectively in discontinuous (batch) and continuous (drum) plants (t/yr);

$EF_{(p)}$ and $EF_{(p)}$ – Emission Factors for pollutant p used respectively in discontinuous (batch) and continuous (drum) plants (t/yr);

Although available methodologies allow the calculation of emissions of several other pollutants from Hot mix asphalt production, in order to avoid double counting – and because fuel consumption in this activity could not be individualized from total fuel use in construction and building – only emissions of NMVOC and PM were estimated here. Although double counting could nevertheless be made for these pollutants, it was considered that the production process results in specific emissions of these two pollutants, which would be under-estimated if they would be estimated solely from fuel combustion. Particulate matter is enhanced by manipulation of aggregate materials and some NMVOC result not from incomplete combustion of fuel but also from partial evaporation of bitumen components.

##### 4.1.4.2.3 Emission Factors

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 4.14 – Emission Parameters for road paving with asphalt

| Parameter | Cutback | Emulsions |
|---|---:|---:|
| $SLV_{Fac}$ | 25 % | 3 % |
| $d_{SLV}$ | 0.95 kg/l | 0.85 kg/l |
| $d_{Bin}$ | 0.95 kg/l | 0.85 kg/l |
| Cure type | Medium Cure (MC) | - |
| $Cure_{FC}$ | 0.75 kg/kg | 1 kg/kg |

Emission factors used to estimate NMVOC and PM emissions from hot mix plants are from USEPA (2000) and are presented in next table.

Table 4.15 –- Emission Parameters for Hot Mix asphalt production

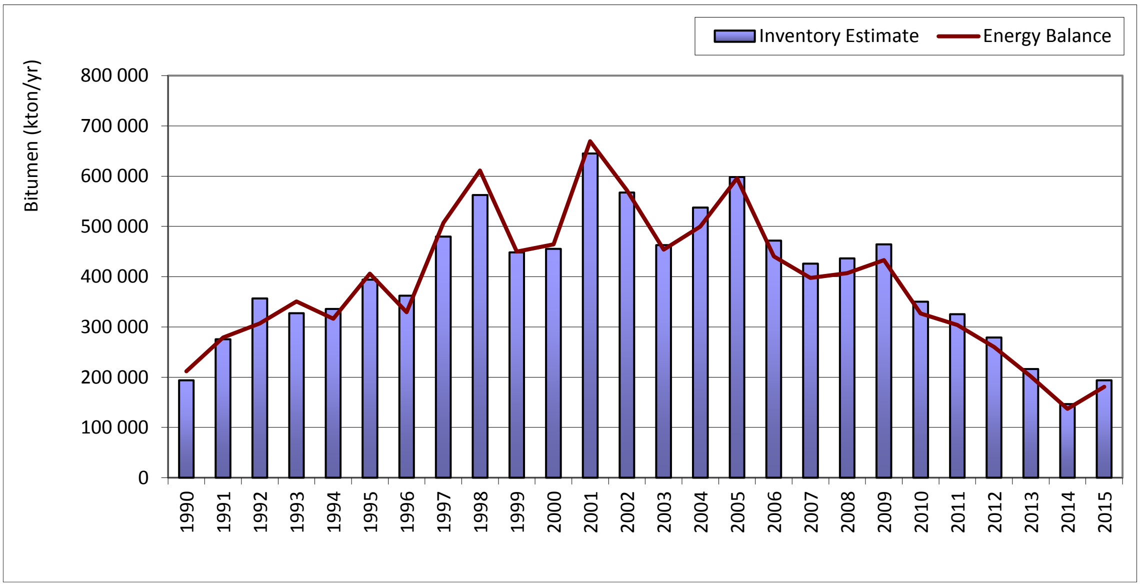
| Pollutant | Continuous | Batch | Unit EF |
|---|---|---|---|
| PM | 14 | 16 | kg/t |
| PM10 | 23 | 14 | % |
| PM2.5 | 5.5 | 1 | % |
| NMVOC | 32.0 | 22.1 | g/t |

Source: USEPA (2000)

#### 4.1.4.2.4 Activity Data

The total quantity of bitumen sold to construction and building economic sector is available from the Energy Balance and was collected by the General Directorate of Energy and Geology (DGEG) based on surveys[46], and it is presented in the figure below. Although this time series was not used in the inventory, it is nevertheless used for the verification that the estimates made for each asphalt materials, which are subsequently explained, are coherent with total sale statistics.

Figure 4.11 – Total consumption of bitumen in the construction sector according to sales from DGEG Energy Balance and sum of values of asphalt used according to the inventory




Cutback asphalt is seldom used in Portugal and it is sold only by two companies, according to information gathered at APORBET, the Portuguese Association of Producers of Bitumen Materials. Annual sales were assumed equal to annual consumption and may be seen in the table below and figure above. Total emulsions applied are available from EAPA for 1997 and beyond. For previous years, use of emulsions was estimated from the total quantity of asphalt materials applied as road pavement, also from EAPA, and considering a percentage of that bitumen that is

[46] Original data from DGE is in toe and was converted to ton by factor 0.96 toe/ton, energy conversion factor used by DGE

emulsions. It was also assumed that this percentage was zero in 1990 and has increased to 19 per cent in 1996. From 1991 onwards, data on hot mix concrete asphalt production is obtained from EAPA. Bitumen in hot mix asphalt was estimated considering that it equals 5 per cent of hot mix asphalt. Although this last figure is not necessary for the inventory it was nevertheless estimated in order to verify if total bitumen sales, from DGEG, match the sum of individual estimates. Total production of hot mix concrete asphalts is presented in the figure below.

Table 4.16 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal (t)

| Asphalt | Unit | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cutback | ton | 4 100 | 3 500 | 2 700 | 3 100 | 2 600 | 676 | 407 | 1 232 | 933 | 162 | 576 | 824 | 501 |
| Emulsified | ton | 0 | 10 567 | 21 133 | 36 576 | 49 852 | 65 025 | 100 517 | 110 000 | 130 000 | 95 000 | 86 000 | 107 000 | 116 000 |

| Asphalt | Unit | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cutback | ton | 340 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Emulsified | ton | 112 665 | 93 600 | 65 000 | 40 500 | 36 556 | 37 441 | 39 824 | 30 049 | 27 934 | 23 934 | 18 560 | 12 595 | 16 650 |

Figure 4.12 – Quantities of asphalt binders (cutback and emulsified asphalts) consumed in Portugal

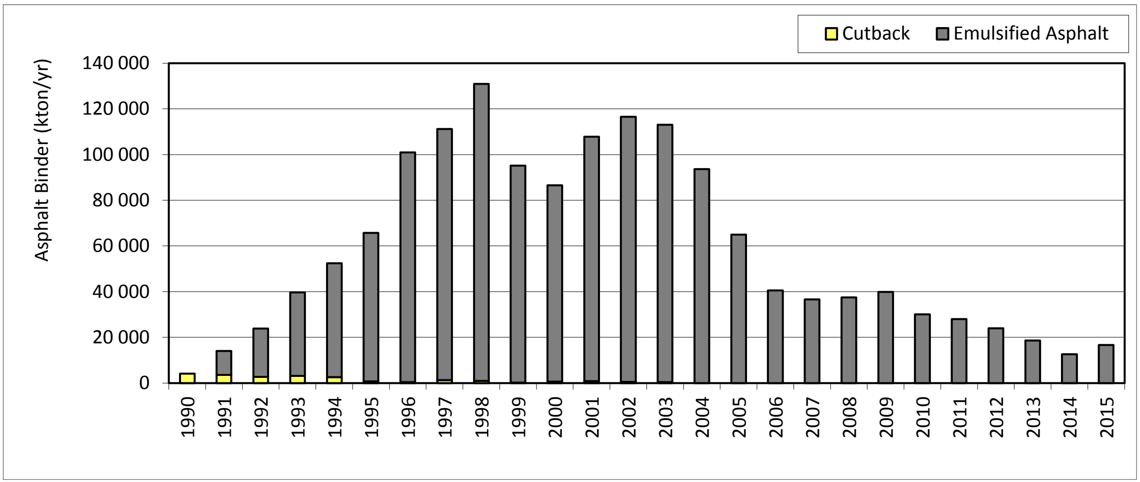
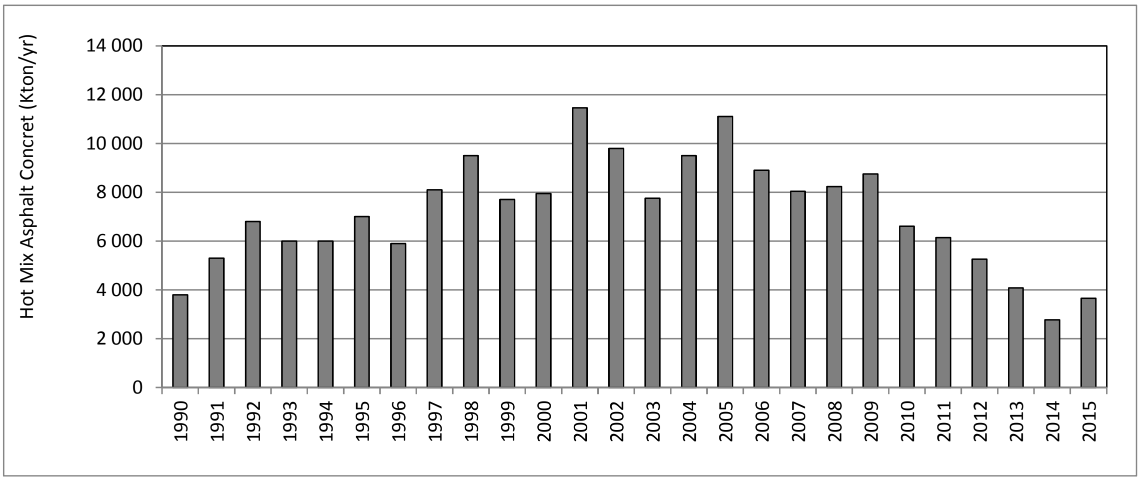



Figure 4.13 – Total Production of Hotmix Asphalt



Emissions of Hot Mix Production depend if the equipment is batch or continuous. Desegregation of Hot Mix production per equipment was done assuming a constant proportion of 46 per cent continuous equipment and 54 per cent batch, which is an expert guess (PTEN, 2002).

#### 4.1.4.2.5 Recalculations

No recalculations were made.

#### 4.1.4.2.6 Further Improvements

No further improvements are planned.

### 4.1.4.3 *Coating applications (NFR 2.D.3.d)*

#### 4.1.4.3.1 Overview

This sub-source sector covers NMVOC emissions resulting from the use of coating materials – interpreted as the application of a continuous layer in a surface with the objective of protecting the surface or enhancing its appearance[47] – 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 sector NFR 2.D.3.g.

Emissions from paint use occur after paint is applied as a coating layer, irrespective of the application methodology: spraying (air pressure or electrostatic), spreading by roller or brush, dipping and electro-deposition, and happen from evaporation of solvent during paint cure. All organic compounds that evaporate are considered NMVOC emissions except if they are recovered and treated by any control equipment such as incineration or absorption.

All emissions from paint activity are included here, such as those arising from car manufacturing, car repairing, all uses of paints in industry, naval vessels construction and repairing, building and construction activities and domestic use.

The distinction between coating operations in construction and building and domestic use is not very relevant because there are no many substantial differences between these two activities, in what concerns formulation of paints and application techniques (mostly spreading).

#### 4.1.4.3.2 Methodology

NMVOC emissions from use of coating materials are estimated in a simple manner using the following formulation:

$$Emi_{NMVOC(a,p,y)} = \Sigma_a \Sigma_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

[47] Non continuous applications of coatings is printing industry and is included in other sub-source category. Application of continuous layers for gluing materials, by the use of glues or adhesives is also considered elsewhere.

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from use/application of coating substances during year y (t/yr);

$Coating_{CONS(a,p,y)}$ – Use of coating substance p in economic activity a during year y (t coater/yr);

$EF_{(p)}$ – NMVOV emission factor (solvent content) resulting from application of substance p (kg/t).

For specific sectors were more detailed activity data and emissions factors were available a product base methodology was used. This is the case for:

- Cars manufacturing;
- Truck cabin coating;
- Leather finishing.

The product based methodology can be described as following.

$$Emi_{NMVOC(p,y)} = \Sigma_a \Sigma_p [EF_{(p)} * Coating_{CONS(a,p,y)}] * 10^{-3}$$

Where

$Emi_{NMVOC(p,y)}$ – NMVOC emissions resulting the production of product p during year y (t/yr);

$Product_{(p,y)}$ – Production units of product p during year y (cars/yr, truck cabins/yr, kg leather/yr);

$EF_{(p)}$ – NMVOV emission factor for production of product p (kg/car, kg/truck cabin, kg/kg leather)

p – product (cars, truck cabin, leather).

#### 4.1.4.3.3 Emission Factors

Emission factors were taken from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). Control strategies were obtained from GAINS model developed by IIASA (http://gains.iiasa.ac.at).

Default emission factors and abatment technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_t \left( \frac{CS_{(t,y)}}{100} \times \left(1 - \frac{AT_{(t)}}{100}\right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatment technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatment technology t (%);

t – abatment technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

In cases where industrial detailed information was not available, Tier 1 emission factors for industrial paint application were used. This emission factor is based on the quantity of coating applied.

Table 4.17 – NMVOC Tier 1 emission factor for industrial application

| NFR | NFR Title | Tier 1 EF | EF Unit |
|---|---|---|---|
| 2 D 3 d | Industrial coating application | 400 | g/kg paint |

Source: (EEA/EMEP, 2013)

#### *4.1.4.3.3.1 Construction and buildings (SNAP 060103)*

Table 4.18 – Default emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Construction and buildings | g/kg paint | 230 |

Source: (EEA/EMEP, 2013)

Table 4.19 – Abatment technology

| Abatment Technology | Efficiency |
|---|---|
| Substitution with dispersion/emulsion (2-3 wt-% solvent) | 39 |
| Substitution with water-based paints (efficiency 80%) | 26 |
| Substitution with high solids paints (efficiency 40-60%) | 4 |
| Substitution with dispersion/emulsion and water-based paints | 65 |
| Substitution with dispersion/emulsion and high solids paints | 43 |
| Substitution with dispersion/emulsion, water-based and high solids paints | 70 |

Source: (EEA/EMEP, 2013)

Table 4.20 – Control strategy

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Substitution with dispersion/emulsion (2-3 wt-% solvent) | % | 0 | 0 | 100 | 50 | 0 | 0 |
| Substitution with water-based paints (efficiency 80%) | % | 0 | 100 | 0 | 0 | 0 | 0 |
| Substitution with high solids paints (efficiency 40-60%) | % | 100 | 0 | 0 | 0 | 0 | 0 |
| Substitution with dispersion/emulsion and water-based paints | % | 0 | 0 | 0 | 0 | 0 | 0 |
| Substitution with dispersion/emulsion and high solids paints | % | 0 | 0 | 0 | 0 | 0 | 0 |
| Substitution with dispersion/emulsion, water-based and high solids paints | % | 0 | 0 | 0 | 50 | 100 | 100 |

Source:**Fonte especificada inválida.**

Table 4.21 – Final emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF | g/kg paint applied | 221 | 170 | 140 | 105 | 69 | 69 |

#### *4.1.4.3.3.2 Wood (SNAP 060107)*

Table 4.22 – Default emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Wood | g/kg paint applied | 800 |

Source: (EEA/EMEP, 2013)

Table 4.23 – Abatment technology

| Abatment Technology | Unit | Efficiency |
|---|---|---|
| Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 35% | % | 75 |
| Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 75% | % | 75 |
| Wood coating-Coated surface-Combination of the above options | % | 75 |
| Wood coating-Coated surface-Low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping) | % | 0 |
| Wood coating-Coated surface-Medium solids systems (55% solvent content), application process with an efficiency of 75% | % | 31 |
| Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 35% | % | 94 |
| Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 75% | % | 94 |
| Uncontroled | % | 0 |

Source: (EEA/EMEP, 2013)

Table 4.24 – Control strategy

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 35% | % | 0.0 | 0.0 | 0.0 | 0.0 | 7.5 | 7.5 |
| Wood coating-Coated surface-High solids coating systems (20% solvent content), application process with an efficiency of 75% | % | 0.0 | 0.0 | 0.0 | 0.0 | 20.3 | 20.3 |
| Wood coating-Coated surface-Combination of the above options | % | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Wood coating-Coated surface-Low solids systems (80% solvent content) and application process with an efficiency of 75% (electrostatic, roller coating, curtain coating, dipping) | % | 38.1 | 38.1 | 38.1 | 38.4 | 20.0 | 20.0 |
| Wood coating-Coated surface-Medium solids systems (55% solvent content), application process with an efficiency of 75% | % | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 35% | % | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| Wood coating-Coated surface-Very high solids systems (5% solvent content), application process with an efficiency of 75% | % | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 |
| Uncontroled | % | 14.0 | 14.0 | 14.0 | 13.7 | 4.4 | 4.4 |

Source:**Fonte especificada inválida.**

Table 4.25 – Final emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF | g/kg paint applied | 440 | 440 | 440 | 440 | 273 | 273 |
| Final EF | t/t | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 |
| Final EF | wt % | 44 | 44 | 44 | 44 | 27 | 27 |

### *4.1.4.3.3.3 Manufacture of automobiles (SNAP 060101)*

Table 4.26 – Default emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Manufacture of automobiles: Car coating | kg/car | 8 |

Source: (EEA/EMEP, 2013)

Table 4.27 – Abatment technology

| Abatment Technology | Unit | Efficiency |
|---|---|---|
| Water-based primer; solvent-based | % | 10 |
| Solvent-based primer; water-based basecoat | % | 40 |
| Water-based primer and basecoat | % | 50 |
| Add on: incinerator on drying oven | % | 10 |
| Add on: Incinerator on drying oven; activated carbon adsorption on spray booth & thermal incineration | % | 40 |

Source: (EEA/EMEP, 2013)

Table 4.28 – Control strategy

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Manufacture of automobiles-Vehicles-Process modification and substitution | % Efficiency of abatment technology mix | 0 | 22.5 | 45 | 67.5 | 90 | 90 |

Table 4.29 – Final emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF Car coating | kg/car | 8.0 | 6.2 | 4.4 | 2.6 | 0.8 | 0.8 |

### *4.1.4.3.3.4 Truck cabin coating (SNAP 060108)*

Table 4.30 – Default emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Industrial coating application: Vehicle refinishing | kg/vehicle | 8 |

Source: (EEA/EMEP, 2013)

Table 4.31 – Abatment technology

| Abatment Technology | Unit | Efficiency |
|---|---|---|
| 50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel | % | 40 |
| 50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths | % | 45 |
| 80% two layer - 20% one layer; waterborne primer and basecoat, high solid clear coat, waterborne solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel | % | 60 |
| Uncontroled | % | 0 |

Source: (EEA/EMEP, 2013)

Table 4.32 – Control strategy

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| 50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel | % | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% two layer - 50% one layer; waterborne primer, high solid basecoat, clear coat and solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel; partial VOC abatement in the enamel spray booths | % | 0 | 0 | 0 | 0 | 0 | 0 |
| 80% two layer - 20% one layer; waterborne primer and basecoat, high solid clear coat, waterborne solid coat; improvement of cleaning stages; incineration on electrophoresis oven applied; improved solvent recovery/consumption reduction; incineration on primer and enamel | % | 0 | 0 | 0 | 0 | 0 | 0 |
| Uncontroled | % | 100 | 100 | 100 | 100 | 100 | 100 |

Table 4.33 – Final emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF truck cabin coating | kg/vehicle | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |

#### *4.1.4.3.3.5 Leather finishing (SNAP 060108)*

Table 4.34 – Default emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Industrial coating application: leather finishing | g/kg leather | 200 |

Source: (EEA/EMEP, 2013)

Table 4.35 – Abatment technology

| Abatment Technology | Unit | Efficiency |
|---|---|---|
| Use of water based products (30 wt-% solvent content) | % | 65 |
| Add on: Thermal oxidation | % | 81 |
| Add on: Biofiltration | % | 81 |
| Uncontroled | % | 0 |

Source: (EEA/EMEP, 2013)

Table 4.36 – Control strategy

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Use of water based products (30 wt-% solvent content) | % | 0 | 0 | 0 | 10 | 30 | 50 |
| Add on: Thermal oxidation | % | 0 | 0 | 0 | 0 | 0 | 0 |
| Add on: Biofiltration | % | 0 | 0 | 0 | 0 | 5 | 5 |
| Uncontroled | % | 100 | 100 | 100 | 90 | 65 | 45 |

Table 4.37 – Final emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF leather finishing | g/kg leather | 200.0 | 200.0 | 200.0 | 187.0 | 152.9 | 126.9 |

### 4.1.4.3.4 Activity Data

The available and reliable information concerning the use of paints is restricted to a small number of activities in Portugal. From IAIT and IAPI industrial surveys, 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, imports and exports according to:

$$Total_{Cons(y)} = Production_{(y)} + Imports_{(y)} - Exports_{(y)}$$

where:

$Total_{Cons(y)}$ - Consumed paint and varnish in year y (t/yr);

$Production_{(y)}$ - National Produced paint and varnish in year y (t/yr);

$Imports_{(y)}$ - Imported paint and varnish in year y (t/yr);

$Exports_{(y)}$ - Exported paint and varnish in year y (t/yr).

Annual production of paints, according to information collected in IAIT and IAPI surveys, from INE, is presented in Table 4.38.

A synthesis of the information available in the statistics on external commerce trade (INE) is presented in Table 4.39.

Total consumption of paints was calculated and the resultant time series is presented in Table 4.40.

Table 4.38 – National production of paints (t)

| Parameter | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Produced paints | 115 892 | 117 358 | 109 426 | 93 969 | 101 145 | 95 328 | 114 015 | 124 512 | 141 700 | 137 979 | 142 082 | 154 210 | 154 992 |

| Parameter | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Produced paints | 155 081 | 154 221 | 149 706 | 148 908 | 165 048 | 161 165 | 135 826 | 155 209 | 133 748 | 119 692 | 121 150 | 128 383 | 161 593 |

Table 4.39 – Paint import and export (t)

| Parameter | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imports | 7 679 | 10 340 | 12 211 | 14 431 | 21 986 | 25 084 | 27 845 | 28 980 | 31 912 | 32 230 | 35 434 | 36 885 | 37 990 |
| Exports | 5 336 | 5 626 | 5 785 | 5 415 | 7 534 | 8 130 | 12 854 | 11 614 | 14 670 | 13 622 | 13 823 | 16 171 | 20 545 |

| Parameter | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imports | 36 398 | 38 680 | 37 097 | 37 371 | 35 624 | 35 883 | 34 466 | 33 044 | 45 556 | 41 781 | 41 308 | 43 525 | 46 687 |
| Exports | 23 827 | 25 973 | 34 089 | 40 749 | 43 510 | 42 435 | 36 546 | 39 398 | 40 338 | 35 838 | 35 433 | 35 770 | 37 364 |

Table 4.40 – Estimated paint consumption (t)

| Parameter | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apparent Consumption | 118 236 | 122 073 | 115 853 | 102 984 | 115 596 | 112 282 | 129 006 | 141 878 | 158 941 | 156 587 | 163 694 | 174 924 | 172 437 |

| Parameter | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Apparent Consumption | 167 651 | 166 928 | 152 714 | 145 530 | 157 162 | 154 612 | 133 746 | 148 855 | 138 965 | 125 635 | 127 026 | 136 138 | 170 916 |

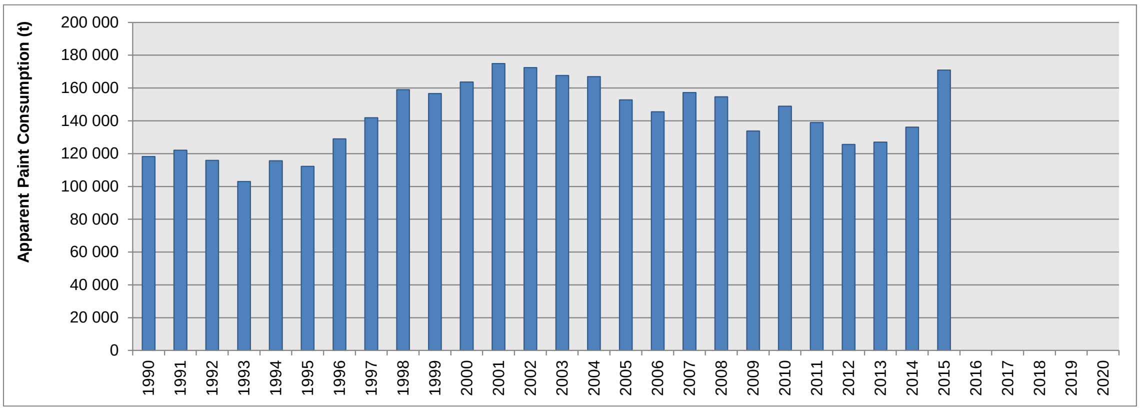



Figure 4.14 - Total consumption of paints in Portugal

Finally total consumption of paint was disaggregated by the economic activity where the paint is used. In first place, from IAIT and IAIP industrial surveys, it was possible to determine consumption of coating materials per economic activity but only for the industry sector: results from IAIT and IAPI are presented in Table 4.41. The remaining use of water based paints and solvent based paints was attributed to the use domestic, services and construction[48].

[48] No further disaggregation by this uses is possible from available statistical information

Table 4.41 - Paint and varnish consumption by snap

| SNAP | NFR Title | SNAP Title | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60103 | Decorative coating | Paint application: | 10 738 | 10 326 | 9 248 | 8 388 | 8 760 | 8 486 | 9 447 | 9 225 | 7 761 | 7 069 | 8 399 | 7 866 | 7 524 |
| 60104 | Decorative coating | Paint application: | 91 969 | 95 902 | 92 001 | 79 659 | 92 249 | 90 715 | 102 421 | 111 519 | 129 668 | 125 779 | 130 608 | 147 593 | 147 528 |
| 60101 | Industrial coating | Paint application: | 111 | 111 | 111 | 111 | 111 | 249 | 709 | 1 142 | 1 143 | 1 130 | 2 595 | 1 528 | 1 528 |
| 60107 | Industrial coating | Paint application: | 6 508 | 6 824 | 5 583 | 5 917 | 5 567 | 4 061 | 4 813 | 5 057 | 4 626 | 3 849 | 2 836 | 3 862 | 3 872 |
| 60108 | Industrial coating | Other industrial | 8 475 | 8 475 | 8 475 | 8 475 | 8 475 | 8 475 | 11 609 | 15 400 | 16 351 | 19 319 | 20 891 | 14 867 | 12 827 |
| 60108 | Industrial coating | Other industrial | 391 | 391 | 391 | 391 | 391 | 391 | 562 | 523 | 381 | 433 | 631 | 534 | 534 |
| 60108 | Industrial coating | Other industrial | 154 | 154 | 154 | 154 | 154 | 154 | 154 | 154 | 154 | 137 | 330 | 201 | 152 |

| SNAP | NFR Title | SNAP Title | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60103 | Decorative coating | Paint application: | 7 328 | 8 613 | 9 242 | 10 373 | 10 374 | 11 120 | 8 385 | 9 846 | 7 390 | 6 658 | 8 117 | 8 116 | 8 258 |
| 60104 | Decorative coating | Paint application: | 145 161 | 144 863 | 129 412 | 115 964 | 130 607 | 123 686 | 108 092 | 119 610 | 114 339 | 102 732 | 102 239 | 110 388 | 145 548 |
| 60101 | Industrial coating | Paint application: | 1 528 | 1 274 | 1 232 | 1 346 | 1 540 | 1 441 | 911 | 1 212 | 1 190 | 1 142 | 1 129 | 1 139 | 1 157 |
| 60107 | Industrial coating | Paint application: | 3 740 | 4 333 | 4 493 | 5 078 | 5 257 | 5 402 | 4 244 | 5 018 | 3 918 | 3 464 | 4 033 | 4 884 | 4 372 |
| 60108 | Industrial coating | Other industrial | 10 787 | 8 746 | 9 074 | 13 489 | 10 061 | 13 324 | 11 952 | 13 110 | 12 069 | 11 583 | 11 452 | 11 555 | 11 524 |
| 60108 | Industrial coating | Other industrial | 534 | 320 | 363 | 489 | 242 | 158 | 99 | 113 | 110 | 106 | 105 | 106 | 107 |
| 60108 | Industrial coating | Other industrial | 102 | 52 | 130 | 137 | 621 | 923 | 973 | 1 159 | 1 138 | 1 092 | 1 079 | 1 089 | 1 106 |

Table 4.42 Final activity data used for paint application emission calculation

| SNAP Title | Unit | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paint application: construction and buildings | t paint | 10 738 | 10 326 | 9 248 | 8 388 | 8 760 | 8 486 | 9 447 | 9 225 | 7 761 | 7 069 | 8 399 | 7 866 | 7 524 |
| Paint application: domestic use (except 060107) | t paint | 91 969 | 95 902 | 92 001 | 79 659 | 92 249 | 90 715 | 102 421 | 111 519 | 129 668 | 125 779 | 130 608 | 147 593 | 147 528 |
| Paint application: manufacture of automobiles | n vehicles | 134 109 | 139 145 | 156 142 | 90 462 | 76 324 | 100 170 | 177 518 | 210 174 | 208 458 | 199 250 | 195 309 | 200 089 | 193 917 |
| Paint application: w ood | t paint | 6 508 | 6 824 | 5 583 | 5 917 | 5 567 | 4 061 | 4 813 | 5 057 | 4 626 | 3 849 | 2 836 | 3 862 | 3 872 |
| Other industrial paint application | t paint | 8 475 | 8 475 | 8 475 | 8 475 | 8 475 | 8 475 | 11 609 | 15 400 | 16 351 | 19 319 | 20 891 | 14 867 | 12 827 |
| Other industrial paint application: truck cabin coating | n vehicles | 9 608 | 9 164 | 4 947 | 3 949 | 2 228 | 2 557 | 3 012 | 4 847 | 5 246 | 5 724 | 6 929 | 7 088 | 6 378 |
| Other industrial paint application: leather finishing | t leather | 834 | 834 | 834 | 733 | 651 | 534 | 603 | 806 | 1 480 | 2 098 | 2 386 | 7 399 | 10 718 |

| SNAP Title | Unit | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paint application: construction and buildings | t paint | 7 328 | 8 613 | 9 242 | 10 373 | 10 374 | 11 120 | 8 385 | 9 846 | 7 390 | 6 658 | 8 117 | 8 116 | 8 258 |
| Paint application: domestic use (except 060107) | t paint | 145 161 | 144 863 | 129 412 | 115 964 | 130 607 | 123 686 | 108 092 | 119 610 | 114 339 | 102 732 | 102 239 | 110 388 | 145 548 |
| Paint application: manufacture of automobiles | n vehicles | 171 207 | 161 465 | 146 340 | 152 884 | 173 864 | 173 054 | 125 965 | 157 552 | 185 370 | 158 278 | 154 743 | 158 715 | 153 189 |
| Paint application: w ood | t paint | 3 740 | 4 333 | 4 493 | 5 078 | 5 257 | 5 402 | 4 244 | 5 018 | 3 918 | 3 464 | 4 033 | 4 884 | 4 372 |
| Other industrial paint application | t paint | 10 787 | 8 746 | 9 074 | 13 489 | 10 061 | 13 324 | 11 952 | 13 110 | 12 069 | 11 583 | 11 452 | 11 555 | 11 524 |
| Other industrial paint application: truck cabin coating | n vehicles | 5 576 | 6 687 | 6 203 | 6 101 | 5 935 | 5 789 | 4 202 | 4 396 | 3 788 | 3 657 | 3 951 | 4 019 | 3 929 |
| Other industrial paint application: leather finishing | t leather | 10 611 | 8 758 | 8 932 | 13 122 | 16 043 | 13 171 | 12 431 | 14 854 | 11 946 | 9 010 | 7 987 | 7 148 | 7 936 |

Table 4.43 Final NMVOC emission factors data used for paint application emission calculation

| SNAP Title | Unit | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paint application: construction and buildings | g/kg paint app | 220.8 | 210.7 | 200.6 | 190.4 | 180.3 | 170.2 | 164.2 | 158.2 | 152.3 | 146.3 | 140.3 | 133.2 | 126.0 |
| Paint application: domestic use (except 060107) | g/kg paint app | 220.8 | 210.7 | 200.6 | 190.4 | 180.3 | 170.2 | 164.2 | 158.2 | 152.3 | 146.3 | 140.3 | 133.2 | 126.0 |
| Paint application: manufacture of automobiles | kg/car | 8.0 | 7.6 | 7.3 | 6.9 | 6.6 | 6.2 | 5.8 | 5.5 | 5.1 | 4.8 | 4.4 | 4.0 | 3.7 |
| Paint application: wood | g/kg paint | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 | 439.9 |
| Other industrial paint application | g/kg paint | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 |
| Other industrial paint application: truck cabin coating | kg/vehicle | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Other industrial paint application: leather finishing | g/kg leather | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 197.4 | 194.8 |

| SNAP Title | Unit | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paint application: construction and buildings | g/kg paint app | 118.9 | 111.8 | 104.7 | 97.5 | 90.4 | 83.3 | 76.1 | 69.0 | 69.0 | 69.0 | 69.0 | 69.0 | 69.0 |
| Paint application: domestic use (except 060107) | g/kg paint app | 118.9 | 111.8 | 104.7 | 97.5 | 90.4 | 83.3 | 76.1 | 69.0 | 69.0 | 69.0 | 69.0 | 69.0 | 69.0 |
| Paint application: manufacture of automobiles | kg/car | 3.3 | 3.0 | 2.6 | 2.2 | 1.9 | 1.5 | 1.2 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Paint application: wood | g/kg paint | 439.9 | 439.9 | 439.9 | 406.6 | 373.3 | 340.0 | 306.7 | 273.4 | 273.4 | 273.4 | 273.4 | 273.4 | 273.4 |
| Other industrial paint application | g/kg paint | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 |
| Other industrial paint application: truck cabin coating | kg/vehicle | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Other industrial paint application: leather finishing | g/kg leather | 192.2 | 189.6 | 187.0 | 180.2 | 173.4 | 166.5 | 159.7 | 152.9 | 147.7 | 142.5 | 137.3 | 132.1 | 126.9 |

#### 4.1.4.3.5 Recalculations

- No recalculations were made.

#### 4.1.4.3.6 Further Improvements

No further improvements are planned for this sector.

### 4.1.4.4 *Degreasing and dry cleaning (NFR 2.D.3.e; 2.D.3.f)*

#### 4.1.4.4.1 Overview

Degreasing refers to operation processes, usually realized within industrial activities, where solvents are used as degreasers to clean products and materials from water insoluble substances (fats), such as oil, grease, wax or tars. This cleaning procedure precedes normally the application of other treatment processes and occurs mainly in metal industry, plastics products manufacturing, rubber[49], textiles, glass, paper and fiber-glass, etc. Usually solvents used to achieve degreasing are petroleum distillates, chlorinated hydrocarbons, ketones and alcohols, and the cleaning process is usually done in tanks, which may have some form of emissions control (solvent recovery).

In essence dry-cleaning has the same objective to degreasing, seeking to remove, by the aid of solvents, of contamination or dirt from cloths, textile, furs, leather, down leathers, textiles or other objects made of fibers.

#### 4.1.4.4.2 Methodology

Assuming that all solvents consumed during degreasing and dry-cleaning evaporate, NMVOC emission will be equal to the amount of solvents used. If it is considered that annual consumption of solvents in an economic activity is used to replenish the quantity of solvent that was lost, then annual NMVOC emissions may be estimated from the annual consumption of solvent. This methodology overcomes the need of being aware of the portion of solvent that is recovered.

In the case of the dry-cleaning activity it was assumed that either the solvent is lost directly to atmosphere, or if it is conveyed to water or retained in clothes, but it will eventually reach atmosphere by evaporation.

For the dry cleaning sector other methodologies, based on quantities of washed cloths, are recommended by several sources (USEPA, 1981; EMEP/CORINAIR). However, in Portugal there is no sufficient information to use this other approach.

$CO_2$ emissions are derived by assuming that 60 percent of the mass emissions of NMVOC is carbon:

$$U_{CO2} = NMVOC * 0.6 * (44/12)$$

where:

$U_{CO2}$ - Ultimate $CO_2$ (t);

NMVOC - Global emissions of NMVOC (t).

[49] Emissions from degreasing in this industry are included under rubber processing

#### 4.1.4.4.3 Activity Data

Statistical information concerning total solvent use, from the National Statistics Institute (INE), was used to estimate VOC emissions. Consumption of solvents, presented in Table 4.44, was based on consumption of volatile organic materials in the metal and plastic industries, from IAIT and IAPI statistical surveys.

Table 4.44 - Solvent use in degreasing operations in metal and plastic industries (t)

| Sub-Sector / Year | 1990 | 1991 | 1992 onwards |
|---|---|---|---|
| Metal Degreasing | 1 552 | 1 415 | 1 484 |

Source:IAIT and IAPI industrial surveys (INE)

There is no available statistical information concerning consumption of solvents and other materials in dry-cleaning activity, because this activity is not included under IAIT and IAPI industrial surveys. Therefore, it was assumed that all PER (Tetra-chloro-ethylene)[50] consumed in Portugal is used in dry-cleaning[51] activity and that all PER used is imported (no national production). Annual apparent consumption was estimated from INE's statistical databases on external trade from 1990 onwards and assumed as equal to solvent use.

Table 4.45 - Annual consumption of PER (Tetra-chloro-ethylene) (t)

| Parameter | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|
| Imports | 2 172 | 1 155 | 1 649 | 0 | 1 108 | 882 |
| Exports | 0 | 0 | 0 | 0 | 49 | 39 |
| Apparent Consumption | 2 172 | 1 155 | 1 649 | 0 | 1 059 | 843 |

Source: INE

#### 4.1.4.4.4 Recalculations

Production, exports and imports of PER have been revised for year 2014 based on national statistics.

#### 4.1.4.4.5 Further Improvements

No further improvements are planned for this sector.

[50] 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.

[51] There is no reference to PER consumption in other industrial activities according to IAIT and IAPI industrial surveys from INE.

### 4.1.4.5 *Chemical products, manufacture and processing (NFR 2.D.3.g)*

#### 4.1.4.5.1 Polyester processing (SNAP 060301)

##### *4.1.4.5.1.1 Methodology*

Emissions from polyester processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). A tier 2 approach was used as activity data and emissions factors were stratified for polyester processing.

Emissions were estimated from the quantity of polyester processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{POYESTER(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from polyester processing (t/yr);

$EF_{NMVOC}$ – NMVOC emission factor for polyester processing (g/kg monomer used);

$Prod_{FOAM(y)}$ – Quantity of monomer used y (t/yr).

##### *4.1.4.5.1.2 Emission Factors*

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). The emissions factor was assumed constant for all covered period.

Table 4.46 – NMVOC foam processing emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Polyester processing | g/kg monomer used | 50 |

Source: (EEA/EMEP, 2013)

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

$$Emi_{CO2} = Emi_{NMVOC} * 0.6 * (44 / 12)$$

##### *4.1.4.5.1.3 Activity Data*

Data on polyester is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 4.47 –Polyester processed

| SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Polyester processing | t monomer | 5 | 57 | 870 | 405 | 1 061 | 1767 |

Source: INE

##### *4.1.4.5.1.4 Recalculations*

No recalculations were made.

##### *4.1.4.5.1.5 Further Improvements*

No further improvements are planned for this sector.

#### 4.1.4.5.2 Polyvinylchloride processing (SNAP 060302)

##### *4.1.4.5.2.1 Methodology*

Emissions from polyvinylchloride processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). A tier 1 approach was used as specific emissions factors from the EEA/EMEP guidebook were not available for polyvinylchloride processing.

Emissions were estimated from the quantity of polyvinylchloride resin processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RESIN(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from polyvinylchloride processing (t/yr);

$EF_{NMVOC}$ – NMVOC emission factor for polyvinylchloride processing (g/kg resin);

$Prod_{RESIN(y)}$ – Quantity of polyvinylchloride resin (t/yr).

##### *4.1.4.5.2.2 Emission Factors*

The default emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). The emissions factor was assumed constant for all covered period.

Table 4.48 – Tier 1 emission factor for chemical product use

| Source category | Unit | NMVOC |
|---|---|---|
| Chemical products, manufacture and processing | g/kg product | 10 |

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60% of carbon:

$$Emi_{CO2} = Emi_{NMVOC} * 0.6 * (44 / 12)$$

##### *4.1.4.5.2.3 Activity Data*

Data on polyvinylchloride is available from the IAPI industrial surveys from INE. The values, collected from original INE’s database, are reported in table below.

Table 4.49 – Polyvinylchloride processed

| SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Polyvinylchloride processing | t PVC | 95 993 | 102 618 | 138 944 | 74 862 | 60 512 | 57780 |

Source: INE

##### *4.1.4.5.2.4 Recalculation*

Production, imports and exports have been revised for year 2014, based on national statistics.

##### *4.1.4.5.2.5 Further Improvements*

No further improvements are planned for this sector.

#### 4.1.4.5.3 Polyurethane and polystyrene foam processing (SNAPs 060303 and 060304)

##### *4.1.4.5.3.1 Methodology*

Emissions from polyurethane and polystyrene foam processing were estimated according with the EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). A tier 2 approach was used as activity data and emissions factors were stratified for polyurethane and polystyrene foams.

Emissions were estimated from the quantity of foam processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{FOAM(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from foam processing (t/yr);

$EF_{NMVOC}$ – NMVOC emission factor for foam processing (g/kg foam processed);

$Prod_{FOAM(y)}$ – Quantity of foam processed in year y (t/yr).

##### *4.1.4.5.3.2 Emission Factors*

The technology specific emission factor was obtained from EEA/EMEP air pollutant emission inventory guidebook (EEA/EMEP, 2013). The emission factor was assumed constant for all covered period.

Table 4.50 – NMVOC foam processing emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Polyurethane foam processing | g/kg foam processed | 120 |
| Polystyrene foam processing | g/kg foam processed | 60 |

Source: (EEA/EMEP, 2013)

Ultimate carbon dioxide emissions are calculated assuming that emitted VOC have on average 60% of carbon:

$$Emi_{CO2} = Emi_{NMVOC} * 0.6 * (44 / 12)$$

#### *4.1.4.5.3.3 Activity Data*

Data on polyurethane and polystyrene foam is available from the IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 4.51 –Foam processed

| SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Polyurethane processing | t foam | 5 700 | 6 322 | 11 704 | 16 989 | 10 038 | 17456 |
| Polystyrene processing | t foam | 11 222 | 14 454 | 22 212 | 16 561 | 16 995 | 22652 |

Source: INE

#### *4.1.4.5.3.4 Recalculations*

Production, imports and exports have been revised for year 2014, based on national statistics.

#### *4.1.4.5.3.5 Further Improvements*

No further improvements are planned for this sector.

### 4.1.4.5.4 Rubber processing (SNAP 060305)

#### *4.1.4.5.4.1 Methodology*

Emissions from rubber processing was estimated according with EMEP/CORINAIR Guidebook. Rubber processed for tyre production is not included in this sector.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC} \times Proc_{RUBBER(y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC total emissions from rubber processing (t/yr);

$EF_{NMVOC}$ – NMVOC default emission factor for rubber processing (g/kg rubber produced);;

$Prod_{RUBBER(p,y)}$ – Production of rubber in year y (t/yr).

#### *4.1.4.5.4.2 Emission Factors*

The emission factor used for rubber processing was obtained from EMEP/CORINAIR guidebook. The emission factor was assumed constant for all covered period.

Table 4.52 – NMVOC rubber processing emission factor

| SNAP | Unit | NMVOC |
|---|---|---|
| Rubber processing | g/kg rubber produced | 8 |

Source: EMEP/CORINAIR 2013, 3.C Chemical products, table 3-5, pp18

###### 4.1.4.5.4.3 *Activity Data*

Production data of rubber artefacts was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in table below.

Table 4.53 –Rubber processed

| SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Rubber processed | t rubber | 26 871 | 24 484 | 29 915 | 32 818 | 68 442 | 18136 |

Source: INE

###### 4.1.4.5.4.4 *Recalculations*

Production, imports and exports have been revised for year 2014, based on national statistics.

###### 4.1.4.5.4.5 *Further Improvements*

No further improvements are planned for this sector.

##### 4.1.4.5.5 Paints, Inks and Glues Manufacturing (SNAPs 060307, 060308 and 060309)

###### 4.1.4.5.5.1 *Methodology*

Emissions from paints, inks and glue manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the quantity of rubber processed according to:

$$Emi_{NMVOC(p,y)} = EF_{NMVOC\ (y)} \times ProductManuf_{(p,y)} \times 10^{-3}$$

Where:

$Emi_{NMVOC(p,y)}$ – NMVOC emissions from manufacturing of product p in year y (t/yr);

$EF_{NMVOC(y)}$ – NMVOC emission factor for production of paints, inks and glue during year y (g/kg product);

$ProductManuf_{(p,y)}$ – Quantity of product p manufactured in year y (t/yr);

p – product (paint, ink, glue)

y - year

###### 4.1.4.5.5.2 *Emission Factors*

Emission factors were taken from EMEP/CORINAIR guidebook 2013. Control strategies were obtained from GAINS model developed by IIASA (http://gains.iiasa.ac.at).

Default emission factors and abatment technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_{t} \left( \frac{CS_{(t,y)}}{100} \times \left(1 - \frac{AT_{(t)}}{100}\right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatment technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatment technology t (%);

t – abatment technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

Table 4.54 – Default emission factor (Source: EMEP/CORINAIR 2013)

| SNAP | Unit | NMVOC |
|---|---|---|
| Paints, Inks and Glue Manufacturing | g/kg product | 11 |

Table 4.55 – Abatment technology (Source: EMEP/CORINAIR 2013)

| Abatment Technology | Unit | Efficiency |
|---|---|---|
| Use of good practices | % | 27 |

Table 4.56 – Control strategy (Source: IIASA, 2009)

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Use of good practices | % | 0 | 0 | 0 | 50 | 100 | 100 |
| No control | % | 100 | 100 | 100 | 50 | 0 | 0 |

Table 4.57 – Final emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF | g/kg product | 11.0 | 11.0 | 11.0 | 9.5 | 8.0 | 8.0 |

#### *4.1.4.5.5.3 Activity Data*

Production data of paints, inks and glue was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in the following table.

Table 4.58 – Production of paints, inks and glue

| SNAP | SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|---|
| 060307 | Paints manufacturing | t paint | 117 961 | 96 320 | 146 854 | 158 181 | 169 908 | 178 268 |
| 060308 | Inks manufacturing | t ink | 3 677 | 1 166 | 3 266 | 2 262 | 3 485 | 2 269 |
| 060309 | Glues manufacturing | t glue | 29 666 | 23 451 | 79 466 | 60 524 | 61 882 | 43 596 |

Source: INE

#### *4.1.4.5.5.4 Recalculations*

Production, imports and exports have been revised for year 2014, based on national statistics.

#### *4.1.4.5.5.5 Further Improvements*

No further improvements are planned for this sector.

### 4.1.4.5.6 Manufacture of Tyres (SNAP 060314)

#### *4.1.4.5.6.1 Methodoloy*

Emissions from tyre manufacturing were estimated according with EMEP/CORINAIR Guidebook.

NMVOC emissions were estimated from the number of tyres produced according to:

$$Emi_{NMVOC(y)} = EF_{NMVOC\ (y)} \times Tyres_{(y)} \times 10^{-6}$$

Where:

$Emi_{NMVOC(y)}$ – NMVOC emissions from manufacturing of tyres during year y (t/yr);

$EF_{NMVOC(y)}$ – NMVOC emission factor for manufacturing of tyres in year y (g/tyre);

$Tyres_{(y)}$ – Number of tyres produced in year y (n./yr);

y - year

#### *4.1.4.5.6.2 Emission Factors*

Emission factors were taken from EMEP/CORINAIR guidebook 2013. Control strategies were obtained from GAINS model developed by IIASA (http://gains.iiasa.ac.at).

Default emission factors and abatment technologies were obtained from EMEP/CORINAIR, then the control strategy suggested by IIASA was applied in the following manner.

$$EF_{NMVOC(y)} = \sum_{t} \left( \frac{CS_{(t,y)}}{100} \times \left(1 - \frac{AT_{(t)}}{100}\right) \times EF_{NMVOC(default)} \right)$$

Where:

$EF_{NMVOC(y)}$ – NMVOC emission factor in year y (t/yr);

$CS_{(t,y)}$ – Control strategy, share of abatment technology t during year y (%);

$AT_{(t)}$ – Efficiency of abatment technology t (%);

t – abatment technology;

$EF_{NMVOC(default)}$ – Default NMVOC emission factor.

Table 4.59 – Default emission factor (Source: EMEP/CORINAIR 2013)

| SNAP | Unit | NMVOC |
|---|---|---|
| Tyre production | g/kg tyre | 10 |

Table 4.60 – Abatment technology (Source: EMEP/CORINAIR 2009)

| Abatment Technology | Unit | Efficiency |
|---|---|---|
| Process optimisation: Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent) | % | 30 |
| New processes: Use of 25% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvents | % | 75 |

Table 4.61 – Control strategy (Source: IIASA, 2009)

| Technology | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Process optimisation: Use of 70% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvent) | % | 0 | 22 | 43 | 43 | 43 | 43 |
| New processes: Use of 25% solvent-based adhesives, coatings, inks and cleaning agents (90 wt-% solvents | % | 0 | 29 | 57 | 57 | 57 | 57 |
| No control | % | 100 | 50 | 0 | 0 | 0 | 0 |

Since the final emission factor is expressed in g/kg tyre, a convertion factor was used to obtain emission factor expressed in g/tyre in order to use the activity data provided by INE. A convertion factor of 15kg/tyre was used.

Table 4.62 – Final NMVOC emission factor

| Parameter | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|
| Final EF | g/kg tyre | 10 | 7 | 4 | 4 | 4 | 4 |
| Final EF | g/tyre | 150 | 108 | 67 | 67 | 67 | 67 |

#### *4.1.4.5.6.3 Activity Data*

Production data for tyres was available from the IAIT and IAPI industrial surveys from INE. The values, collected from original INE's database, are reported in the following table.

Table 4.63 – Production of tyres

| SNAP | SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|---|
| 060314 | Manufacture of tyres | tyres | 4 218 714 | 5 891 971 | 11 605 755 | 14 748 990 | 15 595 153 | 18 105 066 |

Source: INE

#### *4.1.4.5.6.4 Recalculations*

Production, imports and exports have been revised for year 2014, based on national statistics.

#### *4.1.4.5.6.5 Further Improvements*

No further improvements are planned for this sector.

### 4.1.4.6 *Printing Industry (NFR 2.D.3.h – SNAP 060403)*

#### 4.1.4.6.1 Overview

Printing involves the application of an ink to several materials by presses, the most common of which is paper, but also cardboard, wood, plastics and metallic artifacts are subjected to this process. Emissions are very dependent of the printing technology because it (i.e., the type of press equipment) dictates the types of inks and coatings – and its solvent content - that can be used and defines, to a large extent, the emissions and the control techniques that are applicable (USEPA,1985). The following technologies are available:

- lithography: the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellant to ink, by action of a dampener. In offset lithography the image is applied to a rubber-covered blanket cylinder and then transferred onto the substrate. This technique dominates the production of books and pamphlets and has been used increasing in newspapers;

- rotogravure: uses cylindrical image carrier, where the printing area is below the non printing area. The low relive is filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder. Used mostly in packaging, advertising, greeting cards, art books, catalogues, and directories;

- flexography: the image carrier, made of rubber or elastic photopolymers on which the printing areas are above the non printing areas. Used mostly in packaging, advertising newspapers, books, magazines, financial and legal document and directories;

- letterpress: similar to flexography, it uses a relief printing plate, but these plates differ from flexographic plates in that they have a rigid backing and are not "flexible." Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to non-heatset web offset;

- screen: the ink is passed onto the surface to be printed by forcing it through a porous image carrier (stencil), in which the printing area is open and the non-printing area is sealed off. It is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles;

- plateless: Images printed on paper by laser printers, photo copiers, fax machines, and ink jets

NMVOC emissions from printing result from the evaporation of solvents that are components of the ink or that are added (dilution) just prior to printing activities. Emissions may also result from the use of cleaning products and dampeners. Emissions may occur during drying at air or at ovens (heat set).

#### 4.1.4.6.2 Methodology

Emissions from printing industry was estimated according with Tier 1 methodology from EMEP/CORINAIR Guidebook.

$$Emi_{NMVOC(y)} = EF_{(i)} * INK_{CONS(y)} \times 10^{-3}$$

Where

$Emi_{NMVOC(y)}$ – NMVOC emissions resulting from printing activities during year y (t/yr);

$Ink_{CONS(y)}$ – Use of printing ink during year y (t/yr);

$EF_{(i)}$ – NMVOC emission factor (solvent content) for ink use (g/kg ink).

Ultimate $CO_2$ emissions are calculated assuming that 60 percent of the mass emissions of NMVOC is carbon and it is converted to carbon dioxide in the atmosphere. All solvents are assumed to have fossil origin and hence all ultimate $CO_2$ emissions are included in the inventory.

$$U_{CO2} = NMVOC * 0.6 * (44 / 12)$$

where:

$U_{CO2}$ - Ultimate $CO_2$ (t/yr);

NMVOC - Global emissions of NMVOC (t/yr).

#### 4.1.4.6.3 Emission Factors

The emission factor used for printing activities was obtained from EMEP/CORINAIR guidebook. The same emission factor was used for the entire time series.

Table 4.64 – NMVOC emission factor for printing activities

| SNAP | Unit | NMVOC |
|---|---|---|
| Printing | g/kg ink | 500 |

Source: EMEP/CORINAIR 2013

#### 4.1.4.6.4 Activity Data

Consumption of inks in printing industry according to printing product is available from the INE's statistical database for the period 1990-2010, which is summarized in the following table. The 2015 values were forecasted based on 1990-2010 values and on GDP trend.

Table 4.65 – Consumption of inks in printing industry

| SNAP | SNAP Title | Unit | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|---|
| 060403 | Printing Industry | t ink | 5 372 | 5 372 | 9 290 | 8 722 | 9 336 | 8 914 |

Source: INE

#### 4.1.4.6.5 Recalculations

Production, imports and exports have been revised for year 2014, based on national statistics.

#### 4.1.4.6.6 Further Improvements

No further improvements are planned for this sector.

### 4.1.4.7 *Application of glues and adhesives (NFR 2.D.3.i – SNAP 060405)*

#### 4.1.4.7.1 Methodology

$$NMVOC = Cons_{Nat} \times FE_{Nat} + Imp \times FE_{imp}$$

where:

NMVOC = Global emissions of NMVOC (t)

$Cons_{Nat}$ = Domestic consumption of glues and adhesives produced in Portugal (t)

$FE_{Nat}$ = Emission factor for glues and adhesives produced in Portugal (kg NMVOC/t Ink)

Imp = Imported glues and adhesives (t)

$FE_{imp}$ = Emission factor associated with the use of imported glues and adhesives.

$$Cons_{Nat} = Prod_{Nat} - Exp$$

where:

$Cons_{Nat}$ = Consumed glues and adhesives produced in Portugal (t)

$Prod_{Nat}$ = National production of glues and adhesives (t)

Exp = Exported glues and adhesives (t)

#### 4.1.4.7.2 Emission Factors

To estimate the emission factor applied for the use of national glues and adhesives, the ratio of the amount of solvents consumed (Table 4.66 from INE) during manufacture processes with the amount of glues and adhesives manufactured was computed, and an average emission factor obtained (Table 4.67). The emission factor for VOC emission from the manufacture of glue and adhesives was subtracted from this value to obtain the emission factors for use of national produced glue and adhesives.

Table 4.66 - Solvents consumption in glue and adhesives manufacture (t).

| | 1989 | 1990 | 1991 |
|---|---|---|---|
| Methyl ketone | 361 | 328 | 328 |
| Dibutyl phthalate | 97 | 134 | 143 |
| Ethyl Acetate | 373 | 351 | 355 |
| Hexane | 1 567 | 1 357 | 1 277 |
| Benzene | 295 | 354 | 335 |
| Toluene | 1 839 | 1 690 | 1 799 |
| Other solvents | 1 876 | 2 010 | 2 003 |
| Total | 6 408 | 6 224 | 6 240 |

Table 4.67 - National emission factors (kg/t).

| | 1989 | 1990 | 1991 | Average |
|---|---|---|---|---|
| For production and use of glue and adhesives | 190 | 172 | 175 | 179 |
| Only for use of glue and adhesives | 170 | 152 | 155 | 159 |

For non-natural imported glues and adhesives the CORINAIR90 Default Emission Factor was used: 600 kg/t. It is considered that natural based glue does not contribute to NMVOC emission.

#### 4.1.4.7.3 Activity Data

Table 4.68 - Activity Data for non natural glues and adhesives (t)

| Year | 1990 | 1991 | 1992 onwards |
|---|---|---|---|
| National Production (t) | 36 297 | 35 769 | 35 473 |
| Imports (t) | 2 192 | 2 328 | 2 260 |
| Exports (t) | 707 | 532 | 620 |

Source: National Statistics Institute (INE)

#### 4.1.4.7.4 Uncertainty Assessment

Activity data and emission factors have a high level of uncertainty and errors were assumed to be 100 per cent in both cases.

#### 4.1.4.7.5 Recalculations

No recalculations were made for this source sector.

### 4.1.4.8 *Preservation of Wood (NFR 2.D.3.i – SNAP 060406)*

#### 4.1.4.8.1 Overview

Preservation of wood, against weathering, fungi and insect attack, is applied to wood furniture, artifacts an building and construction materials. It is usually done by impregnation or immersion of timber in organic solvent based preservatives (light organic solvent-based preservatives LOSP, composed of hydrocarbon vehicle – usually white spirit – carrying a pesticide active ingredient), creosote or water based preservatives (inorganic solutions of Cu, Cr or As in water).

Creosote, the earliest and most widespread preservation product is an oil prepared from coal tar distillation, and contains a high proportion of aromatic compounds such as PAH. It has been substituted by water based products.

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote.

#### 4.1.4.8.2 Methodology

$$Emi_{NMVOC\ (y)} = Consumption_{(y)} * FE_{Consumption}$$

where:

$Emi_{NMVOC(y)}$ - Emissions of NMVOC associated to consumption of wood preservation products (t)

$Consumption_{(y)}$ - Consumption of wood preservation products (t)

$FE_{Consumption}$ - Emission factor associated to the consumption of wood preservation products.

#### 4.1.4.8.3 Emission Factors

CORINAIR90 Emission Factor Handbook proposes three emission factors for VOC emission from wood preservation, depending on the type of product used. The emission factor is 100 kg/t of product applied for creosote; 900 kg/t for solvent based products and 0 for water based products.

The available data do not discriminate the share of the several types of preservation products, therefore, it was assumed that the main product used in Portugal is creosote.

#### 4.1.4.8.4 Activity Data

Table 4.69 - Wood preservation products consumption (t)

| Year | 1990 | 1991 | 1992 onwards |
|---|---|---|---|
| Wood Preservation products Consumption (t) | 2083 | 2900 | 2491 |

Source: National Statistics Institute (INE)

#### 4.1.4.8.5 Uncertainty Assessment

The activity data and emission factors have a high level of uncertainty and errors therefore an uncertainty of 100 per cent was assumed in both cases.

#### 4.1.4.8.6 Recalculations

No recalculations were made for this source sector.

### 4.1.4.9 *Paper pulp production (NFR 2.H.1)*

#### 4.1.4.9.1 Overview

In Portugal there were in 1990 six paper pulp plants using the kraft process and two units using the acid sulphide process. Later, in 1993, one of the smaller of the acid sulphide plants was decommissioned and nowadays only 6 plants remain in operation.

Kraft pulping is essentially a digestion process of wood by a solution of sodium sulphide ($Na_2S$) and sodium hydroxide (NaOH) (white liquor) at elevated temperature and pressure that dissolves lignin and leaves cellulose fibbers unbind. Apart from digestion other relevant industrial processes include pulp washing, pulp drying, chemical recovery of reactants (sulphur and quicklime) and possibly bleaching. Recovery of sulphur from the spend cooking liquor and washing water (black liquor) includes combustion in the recovery furnace, after concentration in evaporators, and reaction with water and quicklime of the green liquor in a causticizing tank generating white liquor and lime mud. Quicklime is recovered by combustion in a lime kiln.

Emissions of sulphur compounds, including mercaptans, dimethyl sulphide, dimethyl disulphide and $H_2S$, occur in digester and blow tank relieves, in evaporators, and in the lime kiln. In the recovery furnace sulphur compounds are oxidized to $SO_x$, but these are emissions already included in combustion in manufacturing industries (1A2 source sector).

Acid sulphide involves also chemical digestion of wood but using $SO_2$ absorbed in a base solution. Washing, drying and recovery of chemicals are also part of this production process.

#### 4.1.4.9.2 Methodology

Air emissions (t/yr) for each pollutant are estimated from production of air dried paper pulp ($Pulp_{PROD}$ - t AD/yr) after applying emission factors (EF - kg/t AD) specific of each pollutant:

$$Emission_{(p,y)} = EF_{(p)} * Pulp_{PROD\ (y)} * 10^{-3}$$

#### 4.1.4.9.3 Emission Factors

The following emissions factors (kg/ t AD pulp) were used to estimate process emissions, respectively for the Kraft and sulphide process plants. They were set from US-EPA AP42 and other sources and include emissions realized in:

- Kraft process: Digester, Brown Stock Washers, Black Liquor Evaporators, Non condensable gases, Smelt dissolving tank, Fluid Bed Calciner and Bleaching;
- Acid sulphide: Digester and Blow Pit.

Table 4.70 – Emission Factors for paper pulp production (non-combustion)

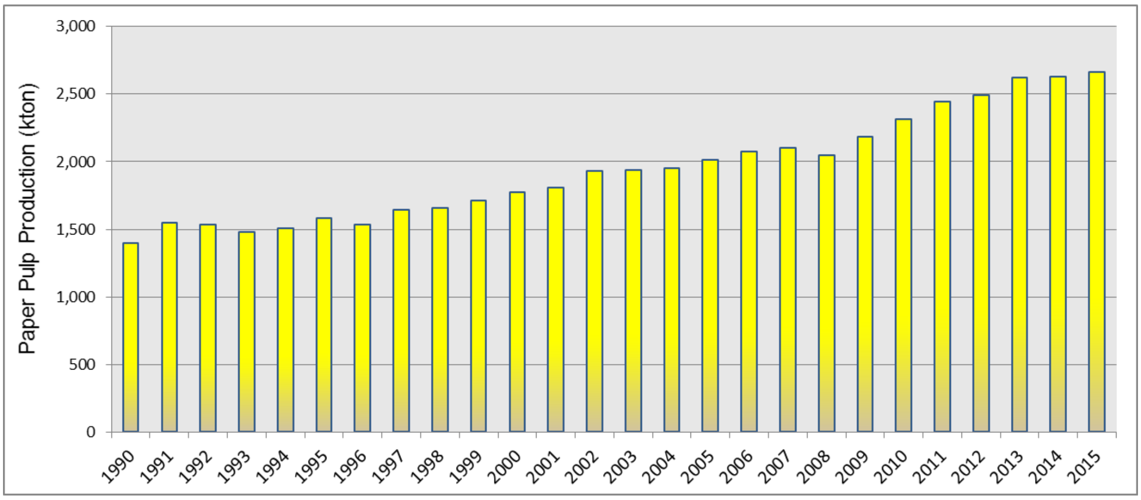
| Process | $SO_x$ | $NO_x$ | NMVOC | TSP | $PM_{10}$ (%) | $PM_{2.5}$ (%) | $PM_1$ (%) |
|---|---|---|---|---|---|---|---|
| Kraft | 0.31 | 1.95 | 2.74 | 3.5 | 88.5 | 73 | 40 |
| Sulphide | 35.5 | NA | NA | NA | NA | NA | NA |

#### 4.1.4.9.4 Activity Data

Production of paper pulp expressed in air dried weight was obtained directly from CELPA (the Portuguese Paper Industry Association). Since 2010, activity data is obtained from EU-ETS. Acid Sulphide production is only a minor component of total production[52] but may not be published individualised due to confidentiality constraints. However, sulphide production is about 5 to 8 per cent of total paper pulp produced in Portugal, according to years. Paper pulp production has been increasing from 1990 onwards.

The following figure presents total production of paper pulp.

Figure 4.15 – Total production of paper pulp - Kraft and semi-sulphide




#### 4.1.4.9.5 Recalculations

No recalculations were made.

[52] Specific information for sulphide pulping can not be delivered because presently there is only one plant operating which raised confidential constraints.

### 4.1.4.10 *Food Manufacturing (NFR 2.H.2)*

#### 4.1.4.10.1 Overview

Emissions from food manufacturing include all processes in the food production chain which occur after the slaughtering of animals and the harvesting of crops.

Emissions occur primarily from the following sources:

- The cooking of meat, fish and poultry, releasing mainly fats and oils and their degradation products;
- The processing of sugar beet and cane and the subsequent refining of sugar;
- The processing of fats and oils to produce margarine and solid cooking fat;
- The baking of bread, cakes, biscuits and breakfast cereals;
- The processing of meat and vegetable by-products to produce animal feeds;
- The roasting of coffee beans.

#### 4.1.4.10.2 Methodology

Emissions where estimated by a Tier 2 methodology using EMEP/EEA emission inventory guidebook 2009 default emission factors multiplied by the quantity of material produced:

$$Emission_{NMVOC\ (y)} = EF_{NMVOC} * ActivityRate_{(y)} * 10^{-3}$$

where

$Emission_{NMVOC}$ - annual emission of NMVOC in year y (t/yr);

ActivityRate - Indicator of activity in the production process (t/yr);

$EF_{NMVOC}$ - emission factor (kg/ t)

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

$$Emi_{CO2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

#### 4.1.4.10.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (Food and Drink).

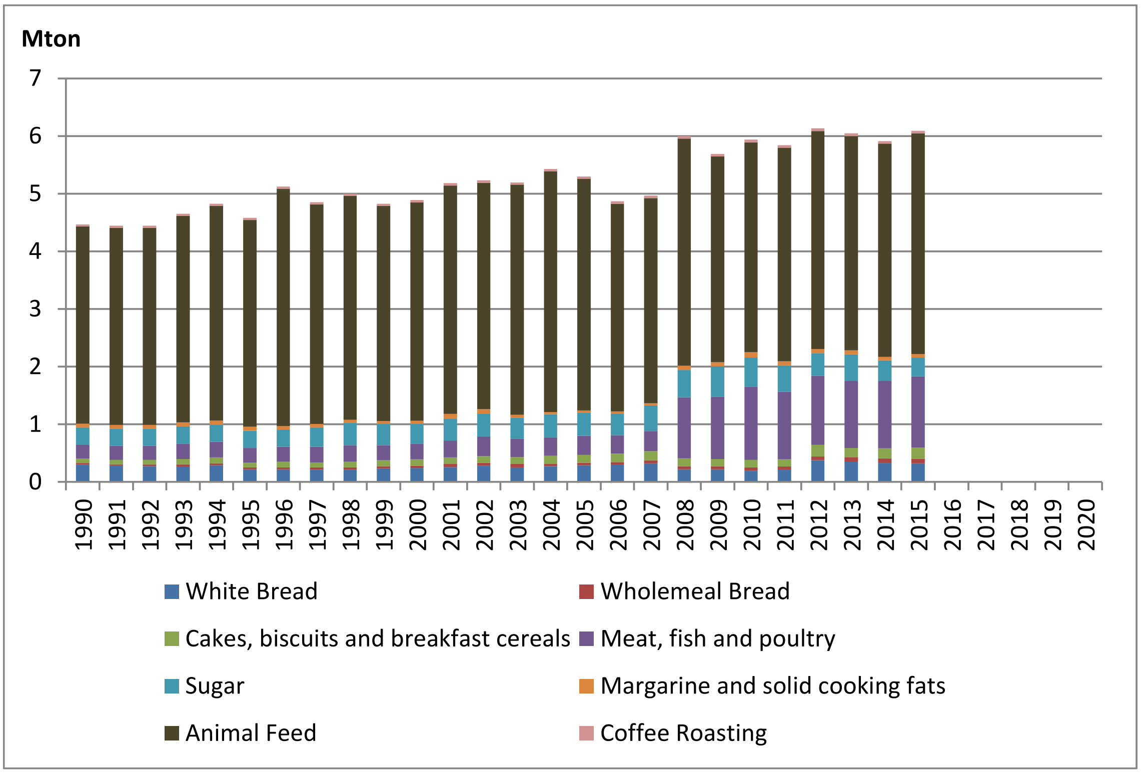
Table 4.71 – Emission Factor for each food product

| Food Product | Unit | EF |
|---|---|---|
| White Bread | Kg/t | 4.5 |
| Wholemeal Bread | Kg/t | 3 |
| Cakes, biscuits and breakfast cereals | Kg/t | 1 |
| Meat, fish and poultry | Kg/t | 0.3 |
| Sugar | Kg/t | 10 |
| Margarine and solid cooking fats | Kg/t | 10 |
| Animal feed | Kg/t | 1 |
| Coffee roasting | Kg/t | 0.55 |

#### 4.1.4.10.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4.16 – Food manufacturing by food product




#### 4.1.4.10.5 Recalculations

No recalculations were made.

#### 4.1.4.10.6 Further Improvements

No further improvements are planned.

### 4.1.4.11 *Drink Manufacturing (NFR 2.H.2)*

#### 4.1.4.11.1 Overview

Emissions may occur during any of the four stages which may be needed in the production of an alcoholic beverage:

– Preparation of the feedstock;
– Fermentation;

- Distillation of fermentation products;
- Maturation.

#### 4.1.4.11.2 Methodology

We used the same methodology described in Food Manufacturing sector.

#### 4.1.4.11.3 Emission Factors

Emission factors are from EMEP/EEA emission inventory guidebook 2009 (Food and Drink).

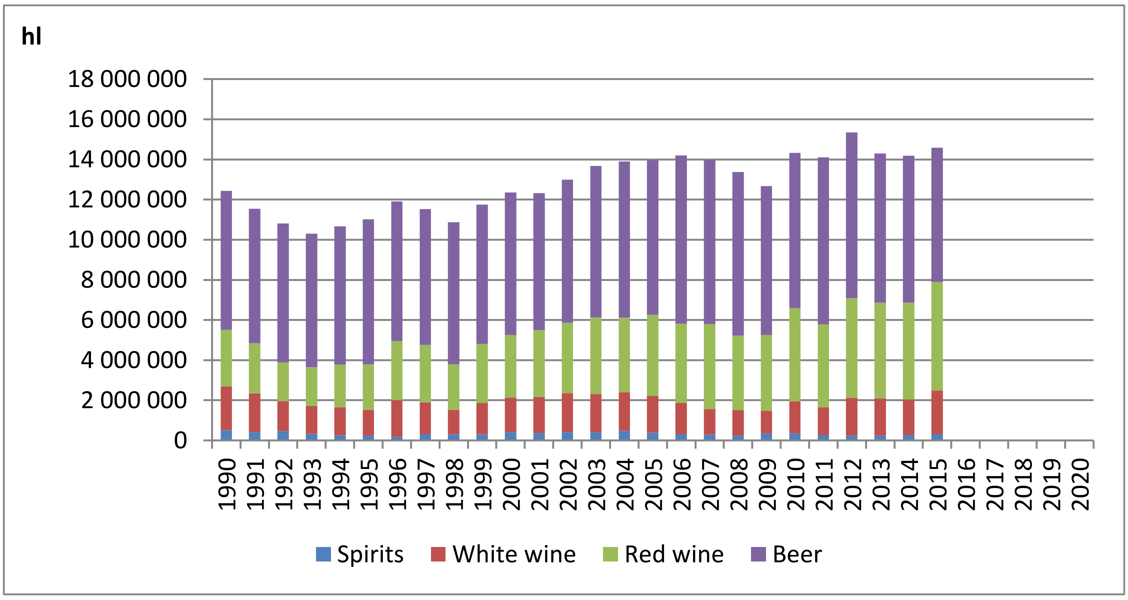
Table 4.72 – Emission Factor for each alcoholic beverage

| Alcoholic Beverage | Unit | EF |
|---|---|---|
| White Wine | Kg/hl | 0.035 |
| Red Wine | Kg/hl | 0.080 |
| Beer | Kg/hl | 0.035 |
| Spirits | Kg/hl | 6 |

#### 4.1.4.11.4 Activity Data

Information about activity data for this sector is from National Statistics Institute (INE) for the entire period.

Figure 4.17 – Drink manufacturing by alcoholic beverage




#### 4.1.4.11.5 Recalculations

No recalculations were made.

#### 4.1.4.11.6 Further Improvements

No further improvements are planned.

### 4.1.4.12 *Wood Chipboard Production (NFR 2.I)*

#### 4.1.4.12.1 Methodology

Emissions where estimated by the use of emission factors multiplied by the quantity of material produced:

$$Emission_{NMVOC\ (y)} = EF_{NMVOC} * ActivityRate_{(y)} * 10^{-3}$$

where

$Emission_{NMVOC}$ - annual emission of NMVOC in year y (t/yr);

ActivityRate - Indicator of activity in the production process (t/yr);

$EF_{NMVOC}$ - emission factor (kg/ t)

$$Emi_{CO2} = 44 / 12 * 0.85 * Emi_{NMVOC}$$

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 percent of carbon:

#### 4.1.4.12.2 Emission Factors

Emission factor is 0.9 kg/t, from Corinair90 Default Emission Factor Handbook.

#### 4.1.4.12.3 Activity Data

Information about activity data for this sector is still scarce and limited to 1990, 2001-2007 and to 2010 onwards, from National Statistics Institute (INE). For the period 1991-2000 and 2008-2009 data has been interpolated.

#### 4.1.4.12.4 Recalculations

No recalculations were made.

#### 4.1.4.12.5 Further Improvements

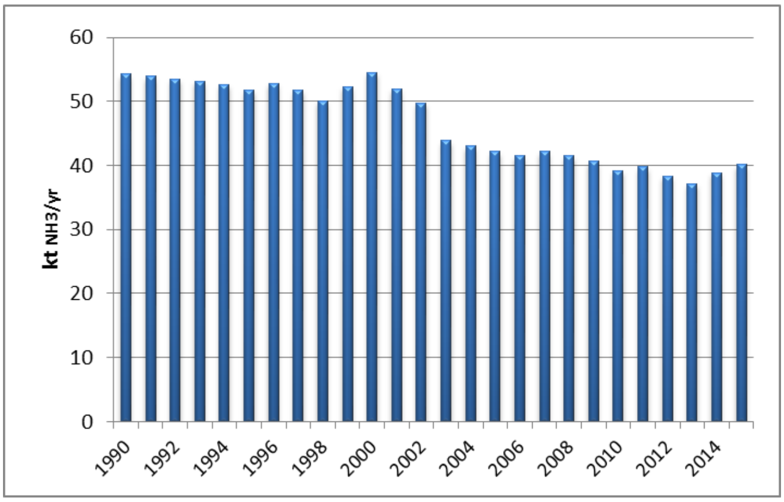
No further improvements are planned.

# 5 AGRICULTURE (NFR 3)

## 5.1 Overview

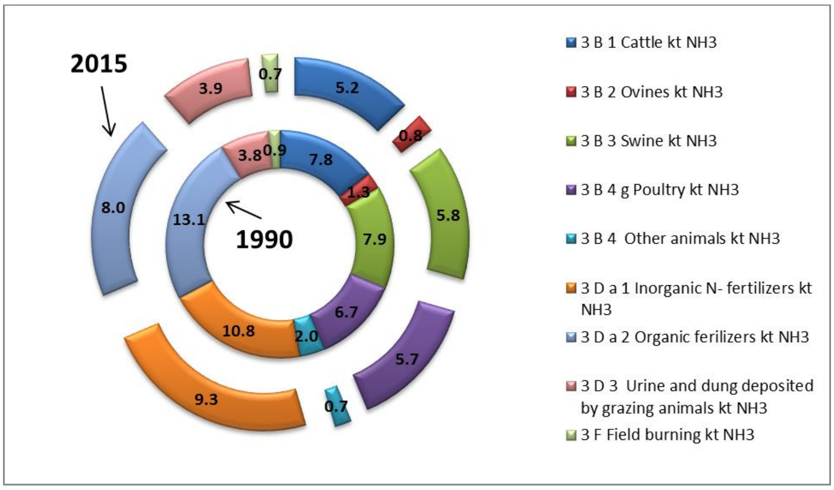
Agriculture activities generate the largest part of $NH_3$ national emissions. In 2015, $NH_3$ emissions from the agriculture sector were 40.1 kt, corresponding to 89.3 % of the national[53] $NH_3$ emissions. From 1990 to 2015, $NH_3$ agriculture emissions decreased 26.1 %. From 2005 to 2015 the ratio of decrease is lower staying at 4.9 %.The complete time series trend is shown in figure below.

Figure 5.1– Total NH3 emissions from agriculture – trends




Overall, $NH_3$ emissions from agriculture presented reductions between 1990 and 2015 in the different source categories. Next figure shows the ammonia emissions in the years 1990 and 2015 by category of emission sources.

Figure 5.2– NH3 emissions by source category in the years 1990 (internal ring) and 2015 (external ring)



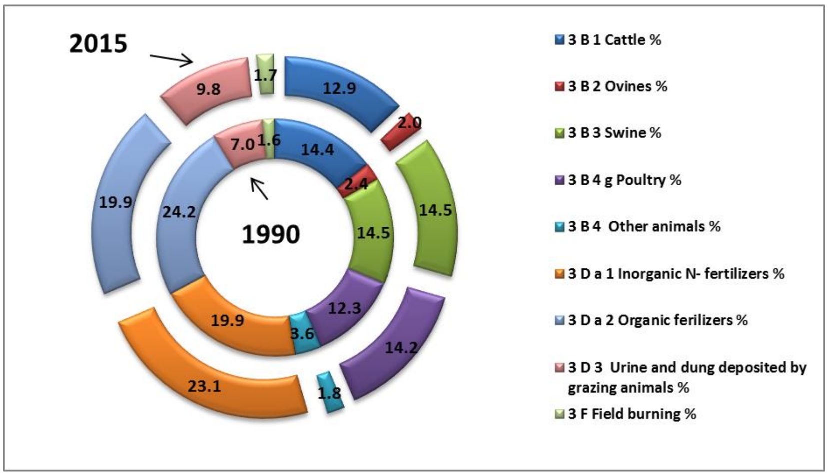

The most significant reductions are related to a decrease in the number of animals (cattle, sheep, goats and swine) and therefore a decrease in the amount of manure managed and applied to soil.

[53] See section 1.4 – Geographical and sectoral coverage of this Informative Inventory Report

The reduction in cattle is related mainly with dairy cows and changes to the milk quota scheme under the Common Agricultural Policy (CAP). Extensive production systems have been supported in the context of Common Agricultural Policy (CAP) through measures, either in the 1st or in the 2nd pillar, which promote the maintenance or improvement of permanent pastures that are directly grazed by cattle, sheep or goats. The result is a greater percentage of animals in pasture and consequently more $NH_3$ emissions from urine and dung deposited in pasture.

The relative importance of each source (NFR codes) of $NH_3$ emissions from agriculture, in 1990 and 2015, is presented in Figure below.

Figure 5.3 - Comparative share of $NH_3$ emissions by source, in1990 and in 2015 (%)



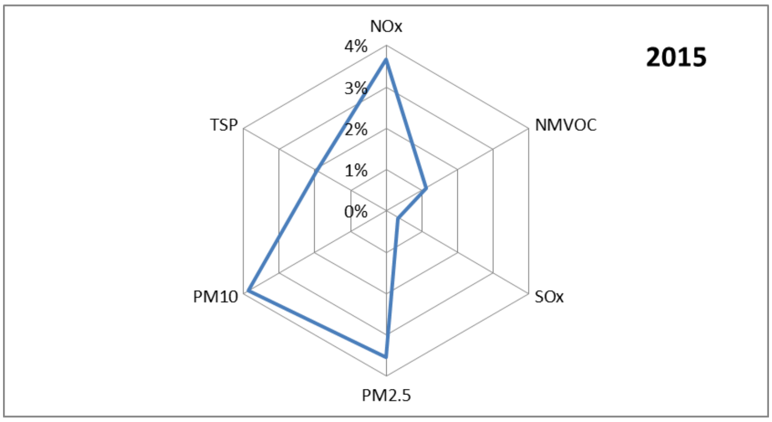

Besides $NH_3$ emissions the Portuguese Inventory includes also other pollutant emissions estimates related with agricultural activity that are summarized as follow:

- From Manure management (3B): NO, NMVOC, $PM_{2.5}$, $PM_{10}$, TSP
- From Crop production and agricultural soils (3D): NO, NMVOC, $PM_{2.5}$, $PM_{10}$
- From field burning of agricultural residues (3F): NO, NMVOC, $SO_x$, $PM_{2.5}$, $PM_{10}$, TSP,BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F and PAHs

In Portugal the use of fungicides with HCB as active substance is not allowed since 1986 according to information of the National Authority responsible for the management and authorization of plant protection products. Thus the Portuguese inventory does not include HCB emissions related to the use of pesticides.

The contribution of agriculture emissions of $NO_x$, $SO_x$, NMVOC, PM2.5, PM10 and TSP in total national emissions of these pollutants is represented in the next Figure for the year 2015.

Figure 5.4 – Contribution (%) of agricultural emissions of air pollutants other than $NH_3$, in total national emissions in 2015




## 5.2 Recalculations

The major changes between last year submission and this year submission result from the following actions:

- revision of 2013 and 2014 values of N inorganic fertilizers updated by INE;
- revision of 2013 and 2014 data of sewage sludge applied to agricultural soils, updated by the waste sector;
- implementation of the tier 2 methodology of EMEP/EEA Guidebook 2016 to estimate $NH_3$ emissions from N inorganic ferilizers applied to soil;
- insertion of the N fraction leached during solid manure storage in the Nflow calculations. N leached was calculated using IPCCC 2006 Guidelines and this revision assure the complete coherence of N flow in both inventories submissions, UNFCCC and UNECE/CLRTAP;
- minor corrections as a result of internal QA/QC procedures.

## 5.3 Source Categories

### 5.3.1 Manure Management (NFR 3B)

#### 5.3.1.1 *Methodology*

For all 3B sub source categories; were estimated emissions for pollutants recommended in *EMEP/EEA air pollutant emission inventory guidebook 2016* (EMEP/EEA, Guidebook 2016): $NH_3$; NO; NMVOC; $PM_{2.5}$; $PM_{10}$ and TSP.

Methodologies, activity data, parameters and emission factors used for the calculation of each pollutant emissions are summarized in Table below.

Table 5.1 – Methods, activity data, parameters and emission factors used by pollutant for manure management

| Pollutant | Method | Activity data | Parameters | Emission Factor |
|---|---|---|---|---|
| $NH_3$ | Tier 2 | NS | CS, D | D |
| NO | Tier 2 | NS | CS, D | D |
| NMVOC | Tier 2 | NS | CS, D | D |
| $PM_{2.5}$ | Tier 1 | NS | - | D |
| $PM_{10}$ | Tier 1 | NS | - | D |
| TSP | Tier 1 | NS | - | D |

NS – National Statistics; CS – Country Specific; D – Default Tier 2 or Tier 1 from the guidebook

For $NH_3$ and NO emissions estimates, Portugal used the Tier 2 mass flow approach described in the EMEP/EEA Guidebook 2016, chapter 3B – Manure management[54]. From the N-flow calculation process were obtained $NH_3$ emission estimates from manure management systems which occur from livestock housing, yards, storage, on field application and grazing. In the same process are also calculated NO emissions from manure storage and the net amount of Nitrogen returned to soil from manure (after N losses from emissions during building, yard, storage, manure application and from leaching of solid manure storage) which is used in the calculations of NO emissions in chapter 3D – Crop production and agricultural soils. The same calculations were done for the net return of N during grazing which is also used to estimate NO emissions in chapter 3D.

Emission estimates are done separately for each animal category (NFR 3B1a,b;3B2;3B4d,e,f,h and 3Bgi,ii,iii,iv ).

For NMVOC emission estimates were used the calculation algorithms (cattle and all other animals) recommended by the EMEP/EEA Guidebook 2016, (pg.27 and 28), which covers different sources emissions from: silage store and feed, livestock housing, manure storage, manure application to soil and grazing animals.

PM emissions were estimate using a Tier 1 methodology:, $Emi_{PM(i)}=EF_{(i)}*N_{(i)}$, where $EF_{(i)}$ is the emission factor for the specific animal category i and $N_{(i)}$ is the number of animals of the category i that are presented within the year. PM emissions are originate mainly for feed

#### 5.3.1.2 *Activity data*

General census on agriculture[55] and animal husbandry activities are made every 10 years by the National Statistical Institute (INE). The first census was made in 1952/54, followed by exercises in 1968, 1979, 1989, 1999 and 2009. Last census (RA, 2009), considered the survey of all national territory at the same time. Inquiries were done at each individual production unit by direct interview,

The general agriculture census is subjected to several Quality Control measures by INE. The complete National Methodological Report is available at Eurostat website http://ec.europa.eu/eurostat/web/agriculture/national-methodology-reports.

Also, through Farm Structure Survey[56] about 40 000 farms (production units) were surveyed, every two years. From 2010 the interval between surveys has been extended to 3 years. The complete National Methodological Report of 2013 farm structure survey is also available at Eurostat website (same link).

[54] Calculations were done based on the excel spreadsheet provided in the Appendix B of chapter 3B – Manure management of the guidebook 2013 with the updates of the guidebook 2016.

[55] In Portuguese, Recenseamento Geral Agrícola (RGA 1989 and RGA 1999), Recenseamento Agrícola (RA 2009). The framework for the production of this statistics is established in the Regulation (EC) nº 1166/2008 of the European Parliament and of the Council of 19 November.

[56] Inquérito à estrutura das explorações agrícolas, in Portuguese.The framework for the production of this statistics is the same that for General Agriculture Census, i. e., the Regulation (EC) nº 1166/2008 of the European Parliament and of the Council of 19 November.

Annually livestock numbers[57] for cattle, swine, sheep and goats are estimated through the National Animal Registration database (SNIRA).

Using these data sources, INE built consistent time series of annual livestock numbers from 1987 to 2015 for cattle, swine, sheep and goats disaggregated per region[58], age and sex.

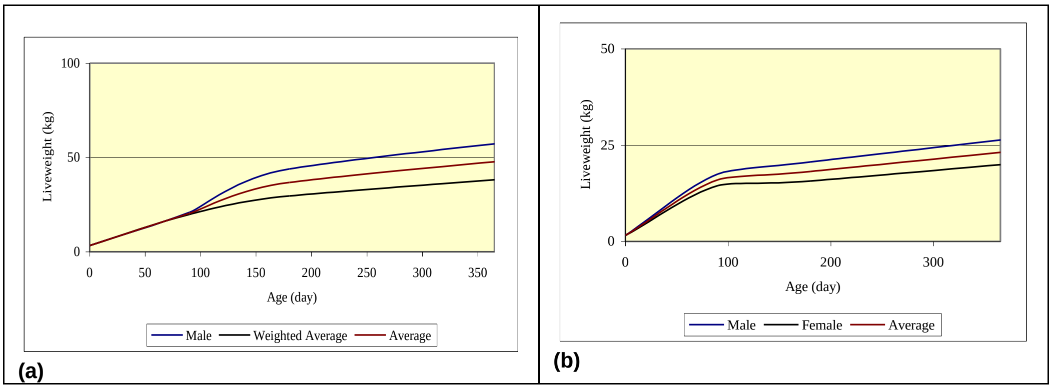
All original figures in statistical database represent the annual average population.

Statistical data from the INE for the sheep and the goats does not distinguish the category "lambs" or "kids". The annual sheep and goat population is disaggregated between two broad categories: "ewes" and "other ovine", for sheep, and "does" and "other caprine", for goats. Thus, the annual number of lambs and kids was set from the number of registered slaughtered animals, as published by the National Statistics Institute (INE). The number of lambs and kids reported as activity data represents the equivalent annual average of animals, i.e.:

| Lambs/Kids (hd) = Annual Slaughter (hd/yr) * Age_Slaughter (days) / 365 |
|---|

The age at which slaughter occurs (Age_Slaughter) was determined from the inverse function of the evolution pattern of growth[59] for both species, Figure 5.5 , using the weight at slaughter that was calculated from the information published by INE, which values are presented in Figure 5.6. Resultant average ages vary from 107 to 128 days for sheep and 69 to 104 days for kids.

Figure 5.5 – Evolution pattern of growth for Sheep (a) and Goats (b)

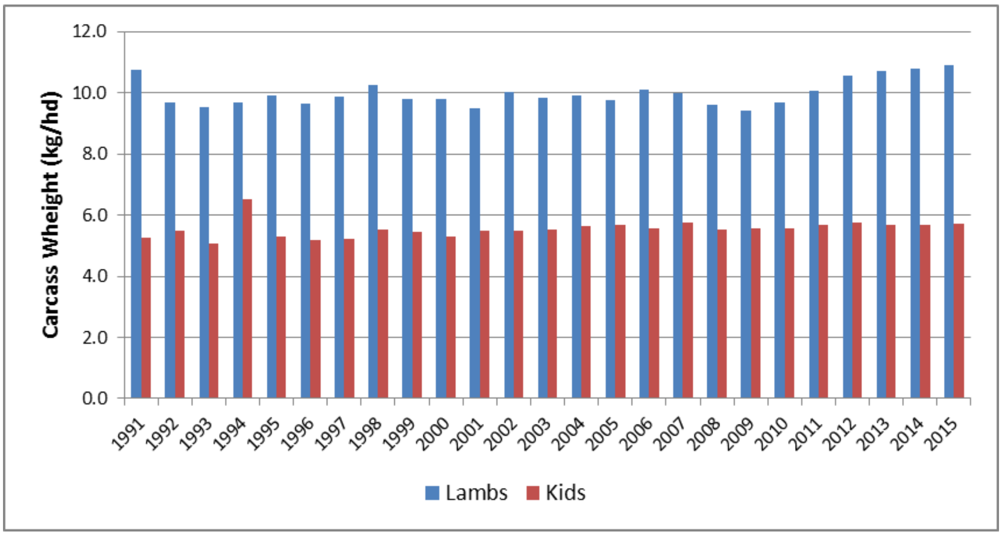



[57] The framework for the production of this annual statistics, livestock numbers and meat production, is established in the Regulation (EC) nº 1165/2008 of the European Parliament and of the Council of 19 November:

[58] A total of 7 regions were available: the 5 regions in mainland Portugal (NUT II level), Norte, Centro, Lisboa e Vale do Tejo, Alentejo and Algarve and the two Autonomous regions of Azores and Madeira.

[59] Set up from the information on the s existent breeds in Portugal, complemented by information in Jarrige (1988) concerning growth pattern.

Figure 5.6 - Lambs and kids average carcass weight at slaughtering




The number of animals remaining from the total ovine and caprine numbers after subtraction of number of females (ewes and does) and the number of youngsters (lambs and kids) is reported as "Other Ovine" and "Other Caprine". These animals are mostly adult males, but also young animals that are kept to reproductive functions and are not slaughtered.

The population of horses, mules and asses, poultry and rabbits is established from the results of the Agricultural Census and the Farm Structure Survey. The disaggregation of hens for eggs production and hens for chicks' production was obtained from the Annual Survey of eggs production and the Annual Survey of Industrial Poultry, published by the INE.

Gaps in the livestock time series were corrected with linear interpolation

For all animal types the value that was considered as activity data is the average of the last three years, i.e.: the activity data reported for year n (1990 given as example) is the average of livestock numbers for n-2, n-1 and n (1988, 1989 and 1990).

In Table 5.2 is presented the annual livestock numbers (1990, 1995, 2000, 2005, 2010 and 2013 to 2015) that are activity data for emission estimates from: manure management (3B), urine and dung deposited by grazing animals (3Da2) and animal manure applied to soil (3Da3). The complete time-series data can be seen in ANNEX D: AGRICULTURE (NFR 3).

Also in Table 5.2 is shown the correspondence of animals type with the respective sub source category - 3B1a,b;3B2;3B4d,e,f,h and 3Bgi,ii,iii,iv.

In a consistent way the same activity data were used for UNFCCC and for UNECE/CLRTAP emission inventory.

Table 5.2– Animal numbers (thousands)

| Animal class | Sub-class | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| Dairy-Cattle (3B1a) | Dairy cows | 394 | 383 | 353 | 290 | 255 | 236 | 233 | 235 |
| Non-dairy cattle (3B1b) | Beef calfs (<1 yr) | 46 | 60 | 67 | 104 | 114 | 119 | 113 | 112 |
| | Calfs M.Rep. (<1 yr) | 186 | 162 | 144 | 136 | 123 | 136 | 142 | 152 |
| | Calfs F Rep. (<1 yr) | 177 | 158 | 174 | 183 | 171 | 191 | 198 | 209 |
| | Males 1-2 yrs | 112 | 103 | 82 | 81 | 66 | 54 | 53 | 58 |
| | Beef Fem. 1-2 yrs | 18 | 22 | 17 | 17 | 20 | 19 | 17 | 15 |
| | Females rep. 1-2 yrs | 111 | 109 | 127 | 135 | 137 | 135 | 139 | 148 |
| | Steers (>2 yrs) | 38 | 33 | 26 | 25 | 38 | 42 | 39 | 37 |
| | Heifers Beef (>2 yrs) | 4 | 10 | 6 | 9 | 12 | 14 | 15 | 15 |
| | Heifers rep. (>2 yrs) | 45 | 52 | 67 | 94 | 110 | 105 | 103 | 96 |
| | non-dairy cows | 242 | 273 | 345 | 397 | 438 | 443 | 450 | 461 |
| Swine (3B3) | Piglets (<20 kg) | 727 | 726 | 663 | 574 | 597 | 658 | 681 | 713 |
| | Fatt. Pigs (20-50 kg) | 662 | 660 | 585 | 467 | 448 | 464 | 472 | 485 |
| | Fatt. Pigs (50-80 kg) | 525 | 525 | 483 | 368 | 360 | 366 | 369 | 380 |
| | Fatt. Pigs (80-110 kg) | 218 | 198 | 174 | 214 | 244 | 263 | 273 | 285 |
| | Fatt. Pigs (> 110 kg) | 44 | 44 | 38 | 41 | 36 | 25 | 28 | 30 |
| | Boars (>50 kg) | 26 | 26 | 20 | 12 | 7 | 5 | 5 | 6 |
| | Sows, pregnant | 210 | 211 | 195 | 191 | 179 | 159 | 159 | 162 |
| | Sows, non-pregnant | 124 | 132 | 124 | 68 | 66 | 68 | 69 | 71 |
| Sheep (3B2) | Ewes | 2 292 | 2 339 | 2 410 | 2 293 | 1 915 | 1 683 | 1 638 | 1,620 |
| | Other Ovine | 663 | 817 | 733 | 234 | 191 | 167 | 162 | 155 |
| | Lambs | 307 | 278 | 319 | 322 | 277 | 263 | 267 | 275 |
| Goats (3B4d) | Does | 614 | 517 | 460 | 380 | 356 | 342 | 333 | 324 |
| | Other Caprine | 149 | 151 | 129 | 57 | 40 | 36 | 36 | 37 |
| | kids | 47 | 41 | 33 | 26 | 29 | 27 | 25 | 23 |
| Equidae (3B4e; 3B4f) | Horses | 33 | 48 | 58 | 52 | 38 | 27 | 26 | 26 |
| | Asses & Mules | 118 | 103 | 69 | 40 | 22 | 15 | 14 | 13 |
| Poultry (3B4gi,ii,iii,iv) | Hens, reproductive | 3 421 | 3 271 | 2 644 | 3 056 | 3 453 | 3 179 | 3 060 | 2,960 |
| | Hens eggs | 7 539 | 7 745 | 9 060 | 7 349 | 7 867 | 7 138 | 6 887 | 6,803 |
| | Broilers | 18 524 | 18 813 | 24 374 | 18 686 | 19 207 | 17 847 | 17 313 | 17,045 |
| | Turkeys | 1 149 | 945 | 1 208 | 798 | 1 445 | 956 | 831 | 769 |
| | Other poultry | 1 667 | 1 648 | 1 707 | 1 353 | 1 522 | 1 178 | 1 084 | 1,038 |
| Other (3B4h) | Rabbits[1] | 475 | 401 | 336 | 289 | 255 | 193 | 177 | 169 |

1-reproductive females

### 5.3.1.3 *Parameters*

#### Nitrogen Excretion

The quantity of nitrogen excreted per head (Nexc rates) used in the inventory were established on the basis of the nitrogen excretion rates proposed by the Revised Agriculture Good Practice Code (CBPA - Código de Boas Práticas Agrícolas), and are the same that are published in Annex XII of Portaria[60] nº 259/2012, 8th August.

[60] Nacional law related with the implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources

This process was conducted in close coordination with the Ministry of Agriculture expert team including the INIAV experts[61]. The following procedures were also considered on the analysis done:

- Compliance of the nitrogen excretion rates from CBPA with livestock information used in the inventory;
- Resort to expert guess when animal types are not covered in CBPA, by comparing with similar animal types reported in this document.

For dairy cows CBPA defines the nitrogen excretion rate as a function of milk production. The base nitrogen value for dairy-cattle is 115 kg N/hd/yr for 7000 kg milk produced/hd/year. For different milk production values the extrapolation procedures defined in CBPA are the following:

- The Nex decreases 10 per cent for every 1000 kg less of milk production;
- The Nex increases 2 per cent for every 1000 kg extra of milk production.

Whereas the production of milk from different years the corresponding excretion rates are given in Table 5.3.

Finally, Table 5.4 shows the excreta coefficients for all categories and subcategories animals which are used in inventory as well as the default values set in EMEP Guidebook 2016.

In a consistent way the same Nex rates are used for UNFCC and for UNECE/CLRTAP emission inventory.

[61]Coordinated by Drª Fátima Calouro, expert from INIAV - National Institute for Agriculture and Veterinary Research

Table 5.3 – Dairy cattle - Milk production values and corresponding Nex

| Year | Milk per Cow (kg/hd/yr) | Nex (kg/hd/yr) |
|---|---|---|
| 1990 | 4 464 | 85.8 |
| 1991 | 4 440 | 85.6 |
| 1992 | 4 412 | 85.2 |
| 1993 | 4 111 | 81.8 |
| 1994 | 4 322 | 84.2 |
| 1995 | 4 556 | 86.9 |
| 1996 | 4 747 | 89.1 |
| 1997 | 4 813 | 89.8 |
| 1998 | 4 973 | 91.7 |
| 1999 | 5 718 | 100.3 |
| 2000 | 6 262 | 106.5 |
| 2001 | 6 502 | 109.3 |
| 2002 | 7 032 | 115.1 |
| 2003 | 6 768 | 112.3 |
| 2004 | 6 775 | 112.4 |
| 2005 | 7 233 | 115.5 |
| 2006 | 7 337 | 115.8 |
| 2007 | 7 311 | 115.7 |
| 2008 | 7 634 | 116.5 |
| 2009 | 7 826 | 116.9 |
| 2010 | 7 886 | 117.0 |
| 2011 | 7 929 | 117.1 |
| 2012 | 8 178 | 117.7 |
| 2013 | 8 000 | 117.3 |
| 2014 | 8 548 | 118.6 |
| 2015 | 8 287 | 118.0 |

Table 5.4 – N excretion rate per head and by animal class/subclass (Nex)

| Animal Class | Animal sub class | Nex (kg N/hd/yr) | |
|---|---|---|---|
| | | Country Specific | Default Guidebook |
| Dairy-cattle | Dairy Cows | 118.0 | 105 |
| Non-dairy cattle | Beef calfs (<1 yr) | 25.00 | 41 |
| | Calfs, Males for Rep. (<1 yr) | | |
| | Calfs, Females for Rep. (<1 yr) | | |
| | Males 1-2 yrs | 40.00 | |
| | Beef Fem. 1-2 yrs | | |
| | Females for R. 1-2 yrs | | |
| | Steers (>2 yrs) | 41.00 | |
| | Heifers for Beef (>2 yrs) | 55.00 | |
| | Heifers for Rep. (>2 yrs) | | |
| | Non-dairy cows | 80.0 | |
| Swine | Piglets (<20 kg) | 0.00 | 12.1 |
| | Fat. Pigs (20-50 kg) | 9.00 | |
| | Fat Pigs (50-80 kg) | 13.00 | |
| | Fat Pigs (80-110 kg) | | |
| | Fat Pigs (> 110 kg) | | |
| | Boars (>50 kg) | 18.0 | 34.5 |
| | Sows, pregnant | 20.0 | |
| | Sows, non-pregnant | 42.0 | |
| Sheep | Ewes | 9.17 | 15.5 |
| | Other Ovine | 6.60 | |
| | Lambs | 0.00 | |
| Goats | Does | 7.00 | |
| | Other Caprine | 6.60 | |
| | kids | 0.00 | |
| Equidae | Horses | 44.0 | 47.5 |
| | Asses, Mules and hynies | 22.0 | |
| Poultry | Hens Reproductive | 0.34 | 0.77 |
| | Hens eggs | 0.80 | |
| | Broilers | 0.45 | 0.36 |
| | Turkeys | 1.40 | 1.64 |
| | Other Poultry | 0.45 | 0.55 -1.26 |
| Other | Rabbits[1] | 9.00 | - |

1 Reproductive females

Values for piglet (<20kg), lambs and goat kids, are 0 kg N/hd/yr because the Nex is included with their respective mothers.

The Nex values for rabbits correspond to a breeding female with 40 young animals with a final weight of 2.7 to 3 kg per rabbit per year.

There is an acceptable agreement between country-specific values and EMEP Guidebook 2016 defaults for all species other than sheep and goats. These two categories nitrogen excretion rate appears to be low, when in comparison with default values, but it has similarities to those used by other parties.

The total quantity of nitrogen in manure per animal type, and its variation from 1990 to 2015, is presented in ANNEX D: AGRICULTURE (NFR 3).

The proportion of total ammoniacal-N (TAN) used for the N-mass flow methodology applied to calculate emissions of $NH_3$ is, for each animal type excretion, was obtained from Table 3.9 of EMEP/EEA Guidebook 2016.

### Manure Management Systems

Expert guess[62], based on survey data and field knowledge of technical personnel of the Ministry of Agriculture was used to establish the percent of each Management System in 1990. The same expertise was used to establish a prevailing trend in the period 1990-2010, considering the practices that are becoming more common and some results of legislation and institutional control. Although the exact year at which the situation changes is unknown, a linear evolution between year 1990 and the target year of 2010 was assumed, Table 5.5. Since no new data is available, for 2015 we assume the 2010 distribution.

The values for the fraction of manure handled in each MMS were revised for the 2010 submission by the Ministry of Agriculture technical personnel[63]. The MMS changes were only made to the 2010 values (1990 remained the same).

The different shares of Management Systems for Manure that we use are presented Table 5.6.

Table 5.5 – Annual variation of the share of each Manure Management System per animal type.

| Animal Type | Lagoon | Tanks | Solid Storage | Pasture |
|---|---|---|---|---|
| Dairy Cows | 0.100 | -0.850 | 0.750 | - |
| non-dairy cows | - | - | - | - |
| Other cattle | - | - | -1.500 | 1.500 |
| Ewes | - | - | - | - |
| Other ovine | - | - | - | - |
| Does | - | - | - | - |
| Other caprine | - | - | - | - |
| Sows | 0.250 | -0.450 | -0.100 | 0.300 |
| Other Swine | 0.250 | -0.350 | -0.050 | 0.150 |
| Hens | - | - | - | - |
| Broilers | - | - | -0.195 | 0.195 |
| Turkeys | - | - | -0.005 | 0.005 |
| Other poultry | - | 0.500 | -0.500 | - |
| Rabbits | - | - | - | - |
| Equidae | - | - | - | - |

Note: values represent the annual increment in the per cent of MMS use. Positive values represent increment in the per cent of the MMS. Negative values represent decrease in use

[62] Information received from Dr. Carlos Pereira, from the Ministry of Agriculture in 3, March 2005.

[63] Information received from Dr. Carlos Pereira, from the Ministry of Agriculture in 7, October 2009.

Table 5.6 – Share of each Manure Management System per animal type in 1990 and 2015 (equal to 2010) (%)

| Animal Type | 1990 | | | | | 2015 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lagoon | Tanks | Solid Storage | Pasture | Total | Lagoon | Tanks | Solid Storage | Pasture | Total |
| Dairy Cows | - | 35.0 | 35.0 | 30.0 | 100.0 | 2.0 | 18.0 | 50.0 | 30.0 | 100.0 |
| Non-dairy cows | - | - | - | 100.0 | 100.0 | - | - | - | 100.0 | 100.0 |
| Other cattle | - | - | 70.0 | 30.0 | 100.0 | | - | 40.0 | 60.0 | 100.0 |
| Ewes | - | - | 20.0 | 80.0 | 100.0 | - | - | 20.0 | 80.0 | 100.0 |
| Other ovine | - | - | 20.0 | 80.0 | 100.0 | - | - | 20.0 | 80.0 | 100.0 |
| Does | - | - | 20.0 | 80.0 | 100.0 | - | - | 20.0 | 80.0 | 100.0 |
| Other caprine | - | - | 20.0 | 80.0 | 100.0 | - | - | 20.0 | 80.0 | 100.0 |
| Sows | 80.0 | 15.0 | 3.0 | 2.0 | 100.0 | 85.0 | 6.0 | 1.0 | 8.0 | 100.0 |
| Other Swine | 80.0 | 15.0 | 3.0 | 2.0 | 100.0 | 85.0 | 8.0 | 2.0 | 5.0 | 100.0 |
| Hens | - | - | 100.0 | - | 100.0 | - | - | 100.0 | - | 100.0 |
| Broilers | - | - | 99.9 | 0.1 | 100.0 | - | - | 96.0 | 4.0 | 100.0 |
| Turkeys | - | - | 100.0 | - | 100.0 | - | - | 99.9 | 0.1 | 100.0 |
| Other poultry | - | - | 100.0 | - | 100.0 | - | 10.0 | 90.0 | - | 100.0 |
| Rabbits | - | - | 100.0 | - | 100.0 | - | - | 100.0 | - | 100.0 |
| Equidae | - | - | 60.0 | 40.0 | 100.0 | - | - | 60.0 | 40.0 | 100.0 |

Based on the same information are presented in Table 5.7 the proportion of N excreted on building, yard and grazing and in Table 5.8 the proportion of housed livestock managed on liquid and solid manure systems, for 1990 and 2015.

Table 5.7 – Proportion of N excreted on building, yard and grazing (%)

| Animal type | 1990 | | | 2015 | | |
|---|---|---|---|---|---|---|
| | Building | Yard | Grazing | Building | Yard | Grazing |
| Dairy Cows | 52.5 | 17.5 | 30.0 | 52.5 | 17.5 | 30.0 |
| Non-dairy cows | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 100.0 |
| Other cattle | 63.0 | 7.0 | 30.0 | 36.0 | 4.0 | 60.0 |
| Ewes | 19.6 | 0.4 | 80.0 | 19.6 | 0.4 | 80.0 |
| Other ovine | 19.6 | 0.4 | 80.0 | 19.6 | 0.4 | 80.0 |
| Does | 19.6 | 0.4 | 80.0 | 19.6 | 0.4 | 80.0 |
| Other caprine | 19.6 | 0.4 | 80.0 | 19.6 | 0.4 | 80.0 |
| Sows | 98.0 | 0.0 | 2.0 | 92.0 | 0.0 | 8.0 |
| Other Swine | 98.0 | 0.0 | 2.0 | 95.0 | 0.0 | 5.0 |
| Hens | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Broilers | 99.9 | 0.0 | 0.1 | 96.0 | 0.0 | 4.0 |
| Turkeys | 100.0 | 0.0 | 0.0 | 99.9 | 0.0 | 0.0 |
| Other poultry | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Rabbits | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Equidae | 60.0 | 0.0 | 40.0 | 60.0 | 0.0 | 40.0 |

Table 5.8 – Proportion of housed livestock managed on liquid and solid manure systems (%)

| Animal Type | 1990 | | 2015 | |
|---|---|---|---|---|
| | Liquid Manure | Solid Manure | Liquid Manure | Solid manure |
| Dairy Cows | 50.00 | 50.00 | 21.43 | 78.57 |
| Non-dairy cows | - | - | - | - |
| Other cattle | 0.00 | 100.00 | 0.00 | 100.00 |
| Ewes | 0.00 | 100.00 | 0.00 | 100.00 |
| Other ovine | 0.00 | 100.00 | 0.00 | 100.00 |
| Does | 0.00 | 100.00 | 0.00 | 100.00 |
| Other caprine | 0.00 | 100.00 | 0.00 | 100.00 |
| Sows | 96.94 | 3.06 | 98.91 | 1.09 |
| Other Swine | 96.94 | 3.06 | 97.89 | 2.11 |
| Hens | 0.00 | 100.00 | 0.00 | 100.00 |
| Broilers | 0.00 | 100.00 | 0.00 | 100.00 |
| Turkeys | 0.00 | 100.00 | 0.00 | 100.00 |
| Other poultry | 0.00 | 100.00 | 10.00 | 90.00 |
| Rabbits | 0.00 | 100.00 | 0.00 | 100.00 |
| Equidae | 0.00 | 100.00 | 0.00 | 100.00 |

### Other parameters

The amounts of straw used and the N inputs from animal bedding were based on the default values of table 3.7 of EMEP/EEA Guidebook 2016, chapter 3B – Manure management, and are shown in table below.

Table 5.9 – Annual average in the time serie of straw use in bedding - solid manure management systems and N content of straw

| Animal type | Straw (kg/hd/yr) | N added in straw (kg/hd/yr) |
|---|---|---|
| Dairy cattle | 1596.88 | 6.39 |
| Other cattle | 475.55 | 1.90 |
| Sheep & goats | 47.69 | 0.19 |
| Sows | 566.64 | 2.27 |
| Other swine | 192.42 | 0.77 |
| Horses & asses | 608.33 | 2.43 |

Specific parameters related to NMVOC emissions estimates are presented inTable 5.10 – Cattle and in Table 5.11– Other animal categories than cattle.

The values of gross feed intake (Mj / yr) for cattle categories and volatile solid excretion for all other animal categories than cattle are the same as those calculated (Tier 2) and reported in the submission UNFCCC. Detailed information for all-time series is presented in ANNEX D: AGRICULTURE (NFR 3).

Dairy cows in Portugal are predominantly stalled with a feed diet based on maize silage (40%), and hay/straw (10%) as raw feed and compound feed (50%) in a dry matter base. For other cattle it was assumed the same $Frac_{silage}$. For the all other animal categories than cattle the $Frac_{silage}$ was considered as zero.

Table 5.10 – Gross feed intake – cattle

| Animal type | Gross feed intake (Mj/hd/yr) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
| Dairy cattle | 82 918 | 83 465 | 96 905 | 105 142 | 109 817 | 111 341 | 115 441 | 112 978 |
| Other cattle | 55 221 | 56 213 | 57 008 | 57 097 | 58 019 | 57 432 | 57 387 | 57 255 |

Table 5.11 – Volatile solid excreted – all other animal categories than cattle

| Animal type | Volatile solid excreted (kg/hd/yr) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
| Sows | 230.62 | 232.95 | 233.82 | 211.33 | 212.77 | 218.01 | 218.55 | 219.17 |
| Other swine | 83.47 | 82.81 | 82.32 | 83.70 | 83.25 | 81.28 | 81.11 | 80.93 |
| Sheep | 183.64 | 186.93 | 184.31 | 175.23 | 174.77 | 173.74 | 173.18 | 172.45 |
| Goats | 170.48 | 168.62 | 169.66 | 174.68 | 174.74 | 175.41 | 175.59 | 178.36 |
| Horses | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 |
| Mules & asses | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 |
| Hens | 14.99 | 14.99 | 15.02 | 14.99 | 14.99 | 14.99 | 14.99 | 14.99 |
| Broilers | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 |
| Turkeys | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 |
| Other poultry | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 |
| Rabbits | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 |

#### 5.3.1.4 *Emission Factors*

The emission factors used to estimate **ammonia emissions** from manure management were obtained from table 3.9 of EMEP/EEA Guidebook 2016, chapter 3B - Manure management.

Ammonia emissions following manure application and from grazing animals are calculated in this source category but reported in the agricultural soils source category (3D).

Table 5.12 – Emission factors used for calculation of the NH3-N emissions from manure management. EF as proportion of TAN (volatilization rates)

| Animal Type | Manure Type | EF housing | EF yard | EF Storage | EF spreading | EF grazing |
|---|---|---|---|---|---|---|
| Dairy cattle | Slurry | 0.20 | 0.30 | 0.20 | 0.55 | 0.10 |
| | Solid | 0.19 | | 0.27 | 0.79 | |
| Other cattle | Slurry | 0.20 | 0.53 | 0.20 | 0.55 | 0.06 |
| | Solid | 0.19 | | 0.27 | 0.79 | |
| Sows | Slurry | 0.22 | - | 0.14 | 0.29 | 0.25 |
| | Solid | 0.25 | | 0.45 | 0.81 | |
| Other swine | Slurry | 0.28 | 0.53 | 0.14 | 0.4 | 0.20 # |
| | Solid | 0.27 | | 0.45 | 0.81 | |
| Sheep & Goats | Solid | 0.22 | 0.75 | 0.28 | 0.9 | 0.09 |
| Horses & asses | Solid | 0.22 | - | 0.35 | 0.9 | 0.35 |
| Hens | Solid | 0.41 | - | 0.14 | 0.69 | - |
| Broilers | Solid | 0.28 | - | 0.17 | 0.66 | - |
| Turkeys | Solid | 0.35 | - | 0.24 | 0.54 | - |
| Other poultry | Solid | 0.24 - 0.57 | - | 0.16 - 0.24 | 0.45 - 0.54 | - |
| Rabbits * | Solid | 0.28 | - | 0.17 | 0.66 | - |

*Not available, assumed the same EFs for broilers; # IPCC 2006 table 11.3 - chapter 11

Emission factors used to estimate **nitric oxide emissions** from manure management were obtained from table 3.10 of EMEP/EEA Guidebook 2016, chapter 3B - Manure management.

Table 5.13 – Emission factors used for calculation of the NO-N emissions from manure management. EF as proportion of TAN

| EF Storage | |
|---|---|
| Slurry | Solid |
| 0.0001 | 0.0100 |

In a consistent way the storage $N_2O$-N emission factors were derivated (kg TAN) from the ones that were used in the UNFCCC emission inventory. For the same reason the N fraction leached from solid storage of manure was calculated following the IPCC methodology and inserted in the N flow calculations (step 10, equation 30).

Emission factors used to estimate **NMVOC emissions** from this source category were from EMEP/EEA Guidebook 2016, table 3.11 for cattle and table 3.12 for all other animal categories than cattle, of chapter 3B - Manure management

There are no available NMVOC emission factors for manure applied to soil and for manure storage. Emissions from these two sources are estimated as fraction of those from livestock housing, as recommended by the methodology of the EMEP/EEA Guidebook 2016, pages 26 - 28 of chapter 3B – Manure management. The fraction is assumed to be the same ratio as for $NH_3$ emission (equations 48 and 49 for cattle categories; equations 54 and 55 for all livestock categories other than cattle).

NMVOC emissions following manure application and from grazing animals are calculated in this source category but reported in the agricultural soils source category (3D).

Table 5.14 – Default NMVOC tier 2 emission factors for cattle (kg NMVOC/MJ feed intake)

| Animal Type | EF sillage feed | EF house | EF grazing |
|---|---|---|---|
| Dairy cattle | 0.0002002 | 0.0000353 | 0.0000069 |
| Other cattle | 0.0002002 | 0.0000353 | 0.0000069 |

Table 5.15 – Default NMVOC tier 2 emission factors for all other animal categories than cattle (kg NMVOC/kg VS excreted)

| Animal Type | EF sillage feed | EF house | EF grazing |
|---|---|---|---|
| Sows | - | 0.00170300 | - |
| Other swine | - | 0.00704200 | - |
| Sheep & Goats | 0.01076000 | 0.00161400 | 0.00002349 |
| Horses & Asses | 0.01076000 | 0.00161400 | 0.00002349 |
| Hens | - | 0.00568400 | - |
| Broilers | - | 0.00914700 | - |
| Turkeys | - | 0.00568400 | - |
| Other poultry | - | 0.00568400 | - |
| Rabbits | - | 0.00161400 | - |

Emission factors used to estimate **particulate emissions** from animal husbandry were the default Tier 1 values from table 3.5 of EMEP/EEA Guidebook 2016, of chapter 3B-Manure management.

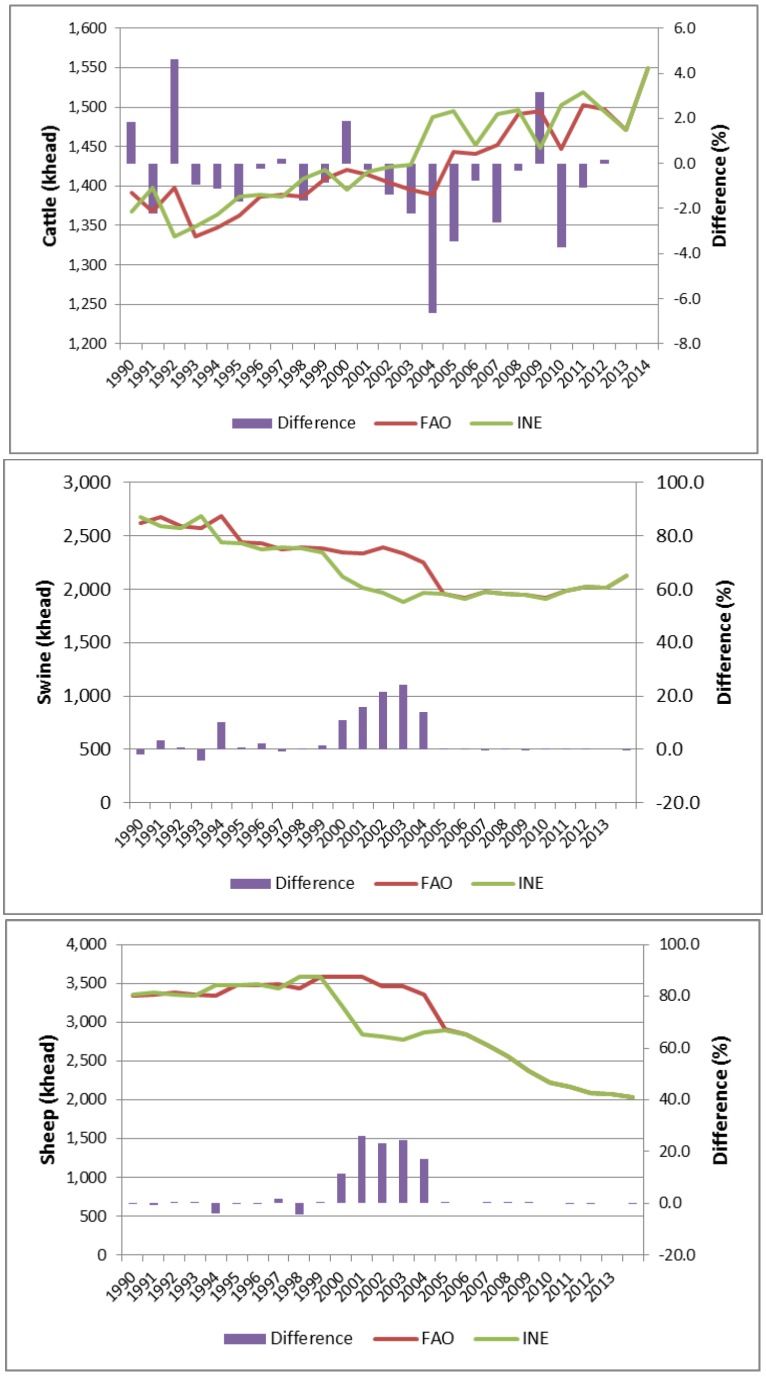
#### 5.3.1.5 *Uncertainties*

To be provided in the future

#### 5.3.1.6 *Quality Assessment of Livestock numbers*

Livestock numbers used in the inventory, as collected from National Statistics, were compared to FAO livestock numbers for years 1990-2014 (2015 not available), and results are presented in the below figures for cattle, swine and sheep.

Figure 5.7 – Comparison of Livestock numbers between national statistics and FAO database. Values represent the relative per cent difference to National Statistics



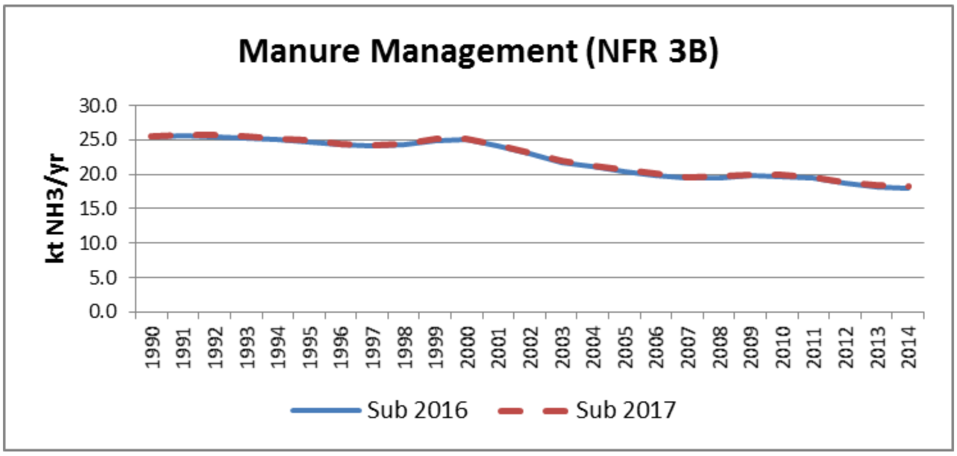

FAO and INE livestock numbers have a good adhesion for all species. For swine and sheep they are even the same from 2005 onwards. For cattle the values in almost of time series are the same but one year delayed. FAO livestock number of year n is equal to INE livestock number for the year n-1. Only from 2012 values total agree in both dataset. For emission estimations we used in the inventory a three average number so this delay between series is diminished.

#### 5.3.1.7 *Recalculations*

Recalculations made for 3B category are mainly due to minor corrections done as a result of an internal QA/QC. The most relevant was the the correction of the EF default value for solid storage manure of non dairy cattle. The correct value is 0.19 as presented in Table 5.12 but in previous submission it was use an incorrect value of 0.13.

For $NH_3$ emissions estimates the differences between last year submission and this year submission are represented in the figure below.

Figure 5.8 – Manure management NH3 emissions estimates, differences between submission 2016 and submission 2017




#### 5.3.1.8 *Further improvements*

It is planned to revisit the characterization of the manure management systems framed by the new national law[64] related with livestock farming.

### 5.3.2 Crop production and agricultural soils (NFR 3D)

For the source category 3D, the Portuguese inventory includes emission estimates of the pollutants from the sub sources categories, as described below:

Table 5.16 – Pollutant emissions estimates by sub source category 3D

| NFR code | Source | Pollutant emissions |
|---|---|---|
| 3Da1 | Inorganic N- fertilizers | $NH_3$; NO |
| 3Da2a | Animal manure applied to soil | $NH_3$; NO; NMVOC |
| 3Da2b | Other organic fertilizer applied to soil | $NH_3$; NO |
| 3Da3 | Urine and dung deposited by grazing animals | $NH_3$; NMVOC |
| 3De | Cultivated crops | NMVOC;$PM_2$.5;PM10;TSP |

Detailed information about methods, activity data and emission factors used are given in each source category chapter.

#### 5.3.2.1 *Inorganic N-fertilizers (NFR 3Da1)*

##### 5.3.2.1.1 Methodology

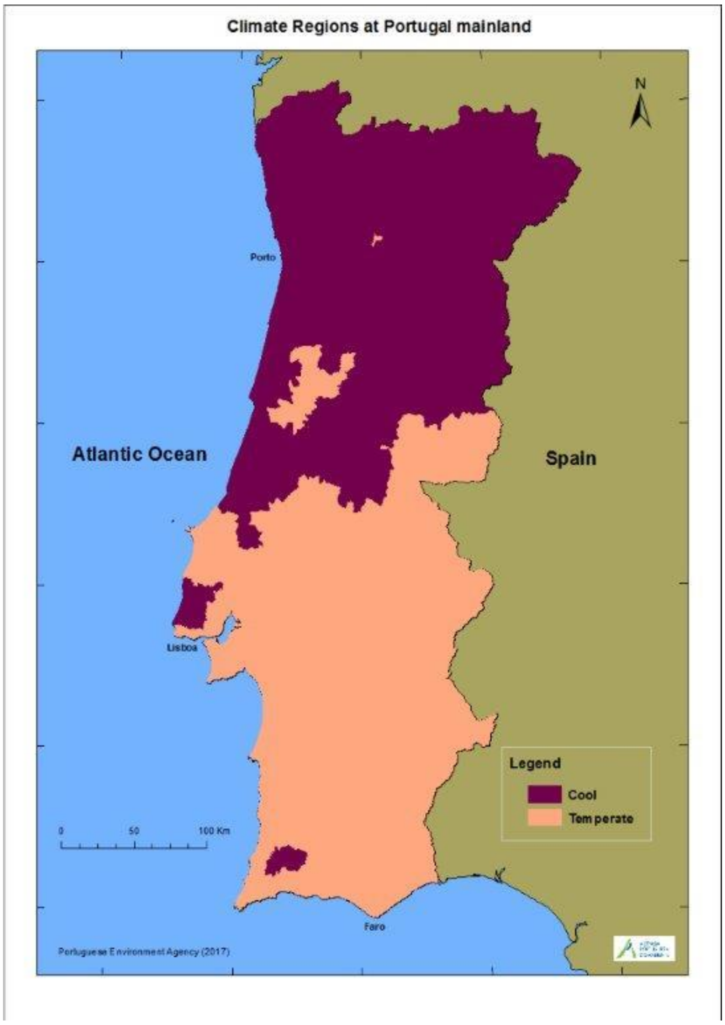
The **ammonia emissions** estimates from inprganic N - fertilizers are based on the tier 2 methodology of the EMEP/EEA Guidebook 2016, which provides different emission factors by

[64] Decree-Law nº 81/2013

type of fertilizer and emission region (table 3-2 of chapter 3D – Crop production and agricultural soils), considering the soil pH and the climate zone as defined in table 10.14 of chapter 10 of IPCC 2006.

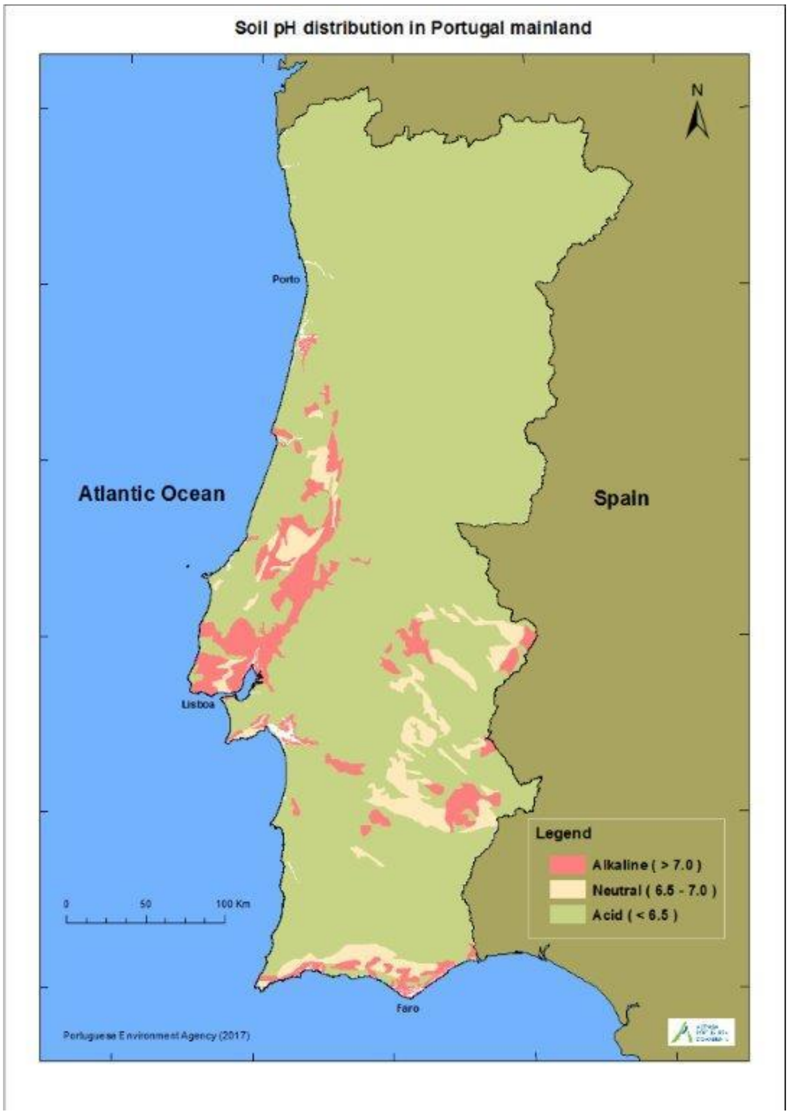
In Figures below are represented the distribution of climate zones and soil pH in Portugal mainland[65].

Figure 5.9 – Climate regions representation at Portugal mainland according to IPCC 2006 classification




[65] Azores and Madeira archipelagos are in temperate climatic zone with normal pH soil.

Figure 5.10 – Alkaline, Neutral and Acid soils representation at Portugal mainland




Source: "Acidez e Alcalinidade dos solos em Portugal" – Atlas do Ambiente (1984)

The proportion of the agricultural land in the different emissions regions that result from the combination of the areas within each climate zone (cool and temperate) in which the soil pH is above (high) or below[66] 7.0 (normal) is presented in the next table.

[66] Below or equal 7.0. Includes Neutral and Acid soils

Table 5.17 – Proportion (%) of the agricultural land in each emission region

| Emission regions | | Agricultural land % |
|---|---|---|
| Description | Code | |
| Normal Cool | NC | 37.73 |
| Normal Temperate | NT | 31.28 |
| High Cool | HC | 3.31 |
| High Temperate | HT | 27.68 |

The amount of each N fertilizer type applied in each emission region was estimate through the equation (3), page 16, of EMEP/EEA Guidebook 2016, chapter 3D – Crop production and agricultural soils. In table Table 5.18 are presented the calculation results for the year 2015.

Table 5.18 – Nitrogen amount (kt/yr) by type of fertilizer and emission region in 2015

| | Emission regions | | | |
|---|---|---|---|---|
| **Type of N fertilizer** | **NC** | **NT** | **HC** | **HT** |
| Ammonium nitrate (AN) | 1.76 | 1.46 | 0.15 | 1.29 |
| Ammonium phosphate (MAP&DAP) | 0.21 | 0.18 | 0.02 | 0.16 |
| Ammonium sulfate (AS) | 0.00 | 0.00 | 0.00 | 0.00 |
| Calcium ammonia nitrate (CAN) | 7.22 | 5.98 | 0.63 | 5.29 |
| Urea | 12.15 | 10.07 | 1.06 | 8.91 |
| Other NP & NPK | 10.27 | 8.51 | 0.90 | 7.53 |
| Other N | 14.06 | 11.66 | 1.23 | 10.31 |
| **Total** | **45.67** | **37.86** | **4.00** | **33.50** |

The **nitric oxide emissions** estimates from inorganic N-fertilizers application were calculated with a Tier 1 method (no Tier 2 available). Nitric oxide emissions from this source category were obtained with the amount of the N content of the fertilizer multiplied by the default Tier 1. However, it was only considered the amount of N- fertilizer proportional to the surface of the national soils predominantly neutral (pH 6.5 - 7.0) or alkaline (pH >7.0), based on the guidebook references that *in agricultural soils, where pH is likely to be maintained above 5, nitrification is considered to be the dominant pathway of NO emission* (page 8 of EMEP/EEA Guidebook 2016, chapter 3D – Crop production and agricultural soils).

### 5.3.2.1.2 Activity data

There are no available records of statistical information concerning the annual quantity of nitrogen used to agricultural soils or even available statistical information concerning sales of synthetic fertilizers. However, following the need to respond to other communitarian and international requests, such as the calculation of Agri-environmental Indicators "Nitrogen Balance" and "Fertilizer Consumption" for the EUROSTAT and OECD, the National Statistical Institute, having found the same lack of available data, produced a methodology (INE,2004), in collaboration with the Laboratório Químico Agrícola Rebelo da Silva and ADP, that estimates the Apparent Consumption of Fertilizers in the Agriculture activity (ACFA) by a simple mass balance, from national production and international market information data. The fertilizer consumption data reported by INE are obtained by the following methodology:

$$Consumption_{(f)} = Production_{(f)} + Import_{(f)} - Export_{(f)}$$

where,

$Consumption_{(f)}$ – Annual consumption in Portugal of nitrogen fertilizer f (ton N/yr);

$Production_{(f)}$ – Annual production in industrial plants in Portugal of nitrogen fertilizer f (ton N/yr);

$Import_{(f)}$ – Annual imports in Portugal of nitrogen fertilizer f (ton N/yr);

$Export_{(f)}$ - Annual exports in Portugal of nitrogen fertilizer f (ton N/yr).

The ACFA time series data produced by INE are only available from 1995, not covering the inventory base year (1990). Given the fact that there is not a clear trend in the available time-series, the average quantity of inorganic N fertilizers in the period 1995-2002, (158 500 t N/yr) was applied for all lacking years (1990-1994).

The complete time series of the annual consumption of the N-fertilizers type is included in the ANNEX D: AGRICULTURE (NFR 3). The Table 5.19 presents the same activity data for only a few years of the time series.

In a consistent way the same activity data were used for UNFCCC and for UNECE/CLRTAP emission inventory.

Table 5.19 – Nitrogen amount (kt/yr) by type of fertilizer

| Type of fertilizers | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| Ammonium nitrate (AN) | - | - | - | - | 4.01 | 7.70 | 4.63 | 4.67 |
| Ammonium phosphate (MAP&DAP) | 13.28 | 16.75 | 11.83 | - | 0.54 | 2.04 | 1.11 | 0.56 |
| Ammonium sulphate (AS) | 17.72 | 25.40 | 14.47 | 10.30 | 3.06 | 0.00 | 0.00 | 0.00 |
| Calcium ammonia nitrate (CAN) | 46.13 | 40.67 | 45.72 | 29.68 | 34.99 | 25.38 | 18.55 | 19.12 |
| Urea | 13.35 | 7.06 | 20.52 | 11.85 | 13.85 | 15.57 | 24.01 | 32.19 |
| Other NK & NPK | 49.54 | 40.76 | 57.74 | 39.94 | 24.90 | 24.57 | 30.27 | 27.21 |
| Other N | 18.49 | 15.18 | 19.72 | 10.90 | 18.90 | 35.39 | 44.26 | 37.27 |
| **TOTAL** | **158.50** | **145.82** | **170.01** | **102.66** | **100.25** | **110.64** | **122.84** | **121.03** |

### 5.3.2.1.3 Emission factors

The emission factors used to **estimate ammonia emissions** from synthetic N-fertilizers were obtained from table 3-2 of EMEP/EEA Guidebook 2016, of chapter 3D – Crop production and agricultural soils, and are presented in the table below.

Table 5.20 – $NH_3$ emission factors (kg $NH_3$/kg N applied)

| Type of fertilizers | Emission regions | | | |
|---|---|---|---|---|
| | NC | NT | HC | HT |
| Ammonium nitrate (AN) | 0.015 | 0.016 | 0.032 | 0.033 |
| Ammonium phosphate (MAP&DAP) | 0.050 | 0.051 | 0.091 | 0.094 |
| Ammonium sulfate (AS) | 0.000 | 0.000 | 0.000 | 0.000 |
| Calcium ammonia nitrate (CAN) | 0.008 | 0.008 | 0.017 | 0.017 |
| Urea | 0.155 | 0.159 | 0.164 | 0.168 |
| Other NP & NPK | 0.050 | 0.067 | 0.091 | 0.094 |
| Other N | 0.010 | 0.014 | 0.019 | 0.020 |

The emission factor used to estimate **nitric oxide emissions** from synthetic N-fertilizers was the default value of 0.04 kg NO / kg N applied (table 3-1 of EMEP/EEA Guidebook 2016, chapter 3D - Crop production and agricultural soils). The dominant pathway of NO emission is nitrification in agricultural soils where pH is likely to be maintained above 5.0, which in Portugal occur in 12.3% of mainland territory[67]. Nitric oxide emission estimates were done considering the proportional amount of the annual consumption of N-fertilizers.

#### 5.3.2.2 *Animal manure applied to soil (NFR 3Da2a)*

$NH_3$, NO and NMVOC emissions from animal manure applied to soil were calculated using the same methodologies and activity data described for the source category 3B - Manure management as it was already highlighted there.

The **NH3 emission factors** used for manure applied to soil were the ones referred in Table 5.12 of this Report – EF spreading - for each animal type.

The **emission factor** used to estimate **NO** emissions from manure applied to soil was the default value of 0.04 kg NO / kg N applied (table 3-1 of EMEP/EEA Guidebook 2016, of the chapter 3D – crop production and agricultural soils). The emission estimates were made with the same assumption that the dominant pathway of NO emission is nitrification in agricultural soils where pH is likely to be maintained above 5.0.

There are no available **NMVOC emission factors** for manure applied to soil and for manure storage. Emissions from these two sources are estimated as fraction of those from livestock housing, as recommended by the methodology of the EMEP/EEA Guidebook 2016, pages 26 - 28, chapter 3B – Manure management. The fraction is assumed to be the same ratio as for $NH_3$ emission (Chapter 3B - equations 48 and 49 for cattle categories; equations 54 and 55 for all livestock categories other than cattle)

#### 5.3.2.3 *Other organic fertilizers applied to soil (NFR 3Da2b; NFR 3Da2c )*

**a) Sewage sludge applied to soil** (SS)

**$NH_3$ emissions** from sewage sludge applied to soils ($Emi_{NH3}$) was estimated by:

[67] Source:Acidez e Alcalinidade dos solos de Portugal" – Atlas do Ambiente (1984)

$$Emi_{NH3} = SS * NSSF * EFss$$

where

SS - quantity of sewage sludge spread on agricultural lands (ton/yr)

NSSF - nitrogen fraction of sewage sludge (percentage of dry solids)

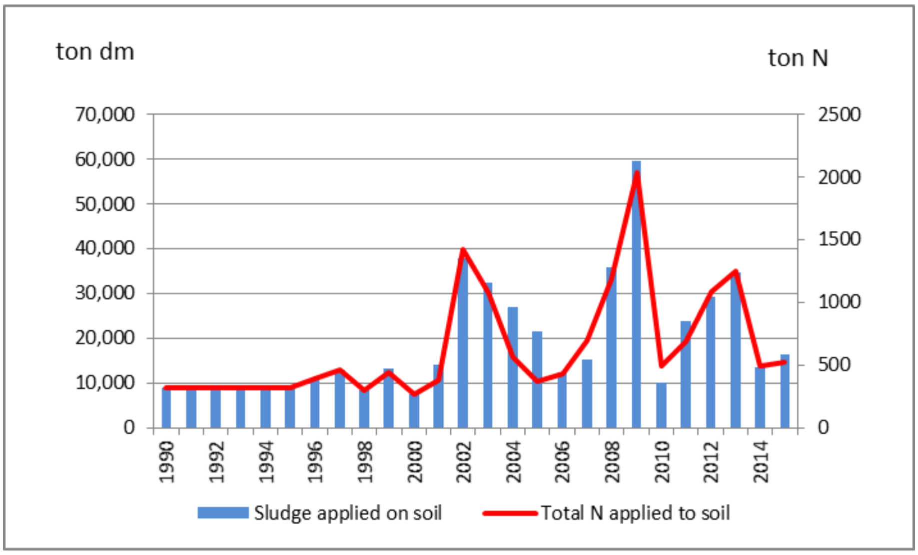
EFss - $NH_3$ emission factor for sewage sludge (kg $NH_3$ / Kg N applied)

The **emission factor** used to estimate **ammonia** emissions was obtained from EMEP/EEA Guidebook 2016, chapter 3D – crop production and agricultural soils, Annex 1, section A1.1.2, page 30[68], and is equal to 0.13 kg $NH_3$ / Kg of N applied to soil from sewage sludge.

**NO emissions** from sewage sludge application were estimate with the tier 1 methodology which consists by multiplying the N amount of sewage sludge applied to soil (SS * NSSF) by the **emission factor** of 0.04 kg NO/ kg of N applied to soil from sewage sludge. The NO emission factor was obtained from EMEP/EEA Guidebook 2016, chapter 3D – crop production and agricultural soils, Annex 2, section A 2.3, page 32.

The quantities of sewage sludge applied as soil amendment refer to data reported under the EU Directive 86/278/EEC on sewage sludge. Data for the latest years are considered to have a higher level of certainty and refer to data collected under Decree-Law n.º 276/2009 which establishes the use of sewage sludge on agricultural soils, transposing for the internal legal order the EU Directive no. 86/278/EEC, of 12 June. Data on the agriculture use of sludge under this legal provision is collected by the DRAPs (Regional Directorates for Agriculture and Fisheries), and are annually reported to the APA (Waste Department).

Figure 5.11 – Application of sewage sludge (t dm/yr) and quantities of N (ton N) applied in agriculture soils




[68] Development of Tier methodology for ammonia emissions from sewage sludge

**b) Compost from municipal solid waste applied to soil** (MSW)

**NH3 emissions** from MSW compost applied to soils ($EmiNH_3$) was estimated by:

$$Emi_{NH3} = MSW * NMSWF * EF_{MSW}$$

where

MSW - quantity of compost from MSW spread on agricultural lands (ton/yr)

NMSWF - nitrogen fraction of compost (%)

$EF_{MSW}$ - $NH_3$ emission factor for MSW compost (kg $NH_3$ / Kg N applied)

The **emission factor** used to estimate **ammonia** emissions was obtained from EMEP/EEA Guidebook 2016, table 3-1 of chapter 3D – Crpo production and agricultural soils and is equal to 0.08 kg $NH_3$ / Kg of N applied to soil from MSW compost .

**NO emissions** from MSW compost application were estimate with the tier 1 methodology which consists by multiplying the N amount of compost applied to soil (MSW * NMSWF) by the **emission factor** of 0.04 kg NO/ kg of N applied to soil from compost. The NO emission factor was obtained from EMEP/EEA Guidebook 2016, chapter 3D – crop production and agricultural soils, table 3-1.

The compost resulting from biological treatment of municipal solid waste (MSW) was only recognized as a fertilizer from June 2015 (Decree Law 103/2015). The decree establishes quality standards and control measures including the monitoring of the compost applied to agricultural soils. Therefore the accounting of this type of N amendment begins in 2015 and emisions, NH3 and NO, are estimate at the first time in this year submission.

In 2015 a total amount of 56 156 t of MSW compost was applied to agricultural soils which corresponds to the N amount application of 1 123 t.

#### 5.3.2.4 *Urine and dung deposited by grazing animals (NFR 3Da3)*

NH3, NO and NMVOC emissions from urine and dung deposited by grazing animals were calculated using the same methodologies and activity data described for the source category manure management 3B as it was already highlighted there.

The **NH3 emission factors** used for urine and dung deposited by grazing animals were the ones referred in Table 5.12 of this Report – EF grazing - for each animal type.

The **NMVOC emission factors** for urine and dung deposited by grazing animals were the ones referred in Table 5.14 and Table 5.15 of this Report – EF grazing - for each animal type.

The **emission factor** used to estimate **nitric oxide** emissions from N returned to soil from urine and dung deposited on soils by grazing animals was the default value of 0.04 kg NO / kg N applied (table 3-1 of EMEP/EEA Guidebook 2016, chapter 3D- Crop production and agricultural soils). The emission estimates were made with the same assumption that the dominant pathway of NO emission is nitrification in agricultural soils where pH is likely to be maintained above 5.0.

#### 5.3.2.5 *Cultivated crops and farm level agricultural operations (NFR 3De and 3Dc)*

In this sources categories the Portuguese inventory includes the NMVOC emissions estimates from crop process and $PM_{2.5}$, $PM_{10}$ and TSP emissions estimates from soil cultivation and crop harvesting.

The methodology used was a Tier 1 (EMEP/EEA Guidebook 2016) for all the above pollutants mentioned.

$$Emi_{pollutant} = AR_{area} * EF_{pollutant}$$

where

$Emi_{pollutant}$ – amount of pollutant emmited (kg)

$AR_{area}$ – area covered by crop (ha)

$EF_{pollutant}$ – emission factor of pollutant (kg/ha)

The same activity data were considered for NMVOC and PM emissions estimates, i.e, the crop area covered with grain cereals and forage (hay) which are presented in the Table 5.21.

Table 5.21 – Crop area (ha)

| Year | Crops |
|---|---|
| 1990 | 1 048641 |
| 1991 | 998 805 |
| 1992 | 980 620 |
| 1993 | 924 189 |
| 1994 | 888 768 |
| 1995 | 865 276 |
| 1996 | 866 570 |
| 1997 | 807 363 |
| 1998 | 784 539 |
| 1999 | 746 935 |
| 2000 | 742 494 |
| 2001 | 716 686 |
| 2002 | 674 645 |
| 2003 | 664 955 |
| 2004 | 623 696 |
| 2005 | 593 994 |
| 2006 | 537 812 |
| 2007 | 523 555 |
| 2008 | 510 623 |
| 2009 | 511 398 |
| 2010 | 475 618 |
| 2011 | 533 431 |
| 2012 | 617 110 |
| 2013 | 622 154 |
| 2014 | 405 128 |
| 2015 | 369 644 |

Emissions factors used are from table 3-1 of EMEP/EEA Guidebook 2016, chapter 3D – Crop production and agricultural soils, and are shown in next table

Table 5.22 – NMVOC, $PM_{2.5}$, $PM_{10}$ and TSP emission factors (kg/ha)

| NMVOC | $PM_{2.5}$ | $PM_{10}$ | TSP |
|---|---|---|---|
| 0.85 | 0.06 | 1.56 | 1.56 |

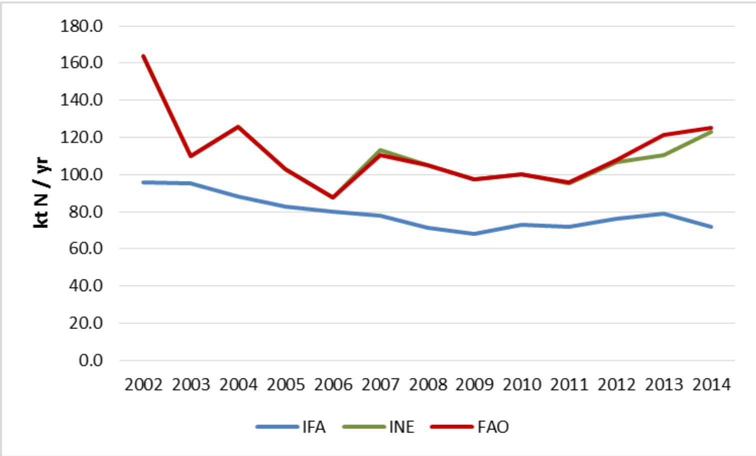
#### 5.3.2.6 *Uncertainties*

To be provided in the future.

### 5.3.2.7 *Quality assessment of inorganic fertilizer data*

A comparison was made between inventory data produced by National Statistical Authority (INE) and the databases of FAO (http://www.fao.org/faostat/en/#data/RF) and of IFA (http://ifadata.fertilizer.org/ucSearch.aspx) for the period 2002 – 2014. For previous years (1990-2001) FAO database archive has no data registers. In both databases (FAO and IFA) 2014 is the last year available. Comparison results are shown in the next Figure.

Figure 5.12 – Consumption of N- fertilizers in Portugal. Comparison data of INE (inventory) with FAO and IFA data (kt N / yr)




FAO and INE series agree quite well. The difference for 2013 is due to the recent update done by INE to the previous value that should then be transmitted by Eurostat to FAO, what apparently has not been made.

IFA data are lower than INE ones because IFA consumption statistics, follow the IFA definition “relate, to the extent possible, to real consumption” and not the apparent consumption concept. The restriction access to detailed information about the construction of IFA data set prevented a further understanding of these statistics, namely how “real consumption” values were produced. Until this issue is completely clarified we decided to keep INE statistics on apparent consumption to estimate emissions from synthetic fertilizers in a conservative approach.

Nevertheless we underline that both series trends show a decrease in fertilizer consumption when comparing with base year, 1990

### 5.3.2.8 *Recalculations*

The major recalculations in this source category were due to:

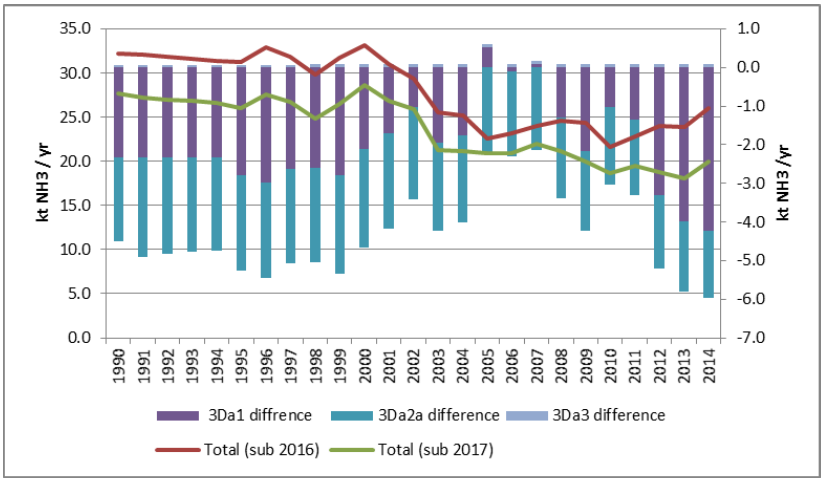
- revision of 2013 and 2014 values for apparent consumption of N inorganic fertilizers updated by INE;
- revision of 2013 and 2014 data of sewage sludge applied to agricultural soils, updated by the waste sector;
- implementation of the tier 2 methodology to estimate ammonia emissions from N inorganic fertilizers which includes the use of the new default emission factors by type of fertilizer and emission region (climate zone X pH soil). In a general way the previous emission factors (Guidebook 2013) were higher and the same for the two climate zone

and soil pH except for ammonium phosphate and ammonium sulphate application which represent about 0.5% (2015) of the N fertilizers applied in Portugal. The estimates of $NH_3$ emissins from N inorganic fertilizers decreases consequently;

- insertion of the N fraction leached during solid manure storage in the Nflow calculations of manure management systems. N leached was calculated using IPCCC 2006 Guidelines and this revision assure the complete coherence of N flow calculations in both inventories submissions, UNFCCC and UNECE/CLRTAP. The deduction of the N fraction leached during solid manure storage results in a decrease of the N amount of manure applied to soil;
- minor corrections as a result of internal QA/QC procedures.

For the $NH_3$ emissions estimates the differences between 2016 submission and this year submission are represented in the figure below.

Figure 5.13 – Crop production and agricultural soils NH3 emissions. Differences between submission 2016 and submission 2017




#### 5.3.2.9 *Further improvement*

As referred in the source category NFR 3B - manure management, it is planned to revisit the characterization of the manure management systems, framed by the new national law[69] related with livestock farming. It is likely that the possible outcome will also have impact in the emissions from manure applied to soil.

### 5.3.3 Field burning of agricultural residues (NFR 3F)

In-site burning of agricultural residues is still practiced nowadays in Portugal, being however forbidden by law-decree from May to September, when normally forest fires occur. The Portuguese inventory includes emission estimates of the pollutants described in the table below.

[69] Decree-Law nº 81/2013

Table 5.23 – Pollutant emission estimates from field burning of agricultural residues

| | Pollutants |
|---|---|
| Main Pollutants | $NH_3$, NMVOC, $NO_x$, $SO_x$ |
| Particulate Matter | $PM_{2.5}$, $PM_{10}$, TSP, BC |
| Other | CO |
| Heavy Metals | Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn |
| POP's | PCDD/PCDF, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indenol(1,2,3-cd)pyrene |

### 5.3.3.1 *Methodology*

Emissions of in-site burning of agricultural residues were estimated with the IPCC (2006) methodology to calculate emissions from biomass burning (volume 4, chapter 2, and page 2.42) which is summarized in the following equation:

$$Emission_{(p,crop,)} = A_{(crop)} * M_{B(crop)} * C_f * EF_{(p,crop)} * 10^{-3}$$

where

$Emission_{(p,crop,y)}$ - Emission estimate of pollutant p from field burning of residues from a specific crop (ton/year)[70];

$A_{(crop)}$ – correspond to the crop area where the practice of field burning residues occurs (ha/yr);

$M_{B(crop)}$ - biomass of a specific crop that is available for combustion (t dm/ha/yr);

$C_f$ – combustion factor, dimensionless;

$EF_{(p,crop)}$ - emission factor from field burning of agriculture residues of a specific crop (g/kg dm burnt).

### 5.3.3.2 *Activity data*

The burning of agricultural residues occur with the straw of cereals and with the material of pruning permanent crops such as vineyards, olive groves and other orchards.

Commonly the major fraction of rice stubbles and straw are burnt in the fields. Nevertheless the practice of incorporating straw into the soil often occurs too with special relevance on rice producing areas inside Natura 2000[71] limits. In these situations the practice of burning crop residues is forbidden[72] for reasons of conservation of natural habitats and animal species since 2000 until nowadays.

[70] For PCCD/PCDF is gl-TEQ

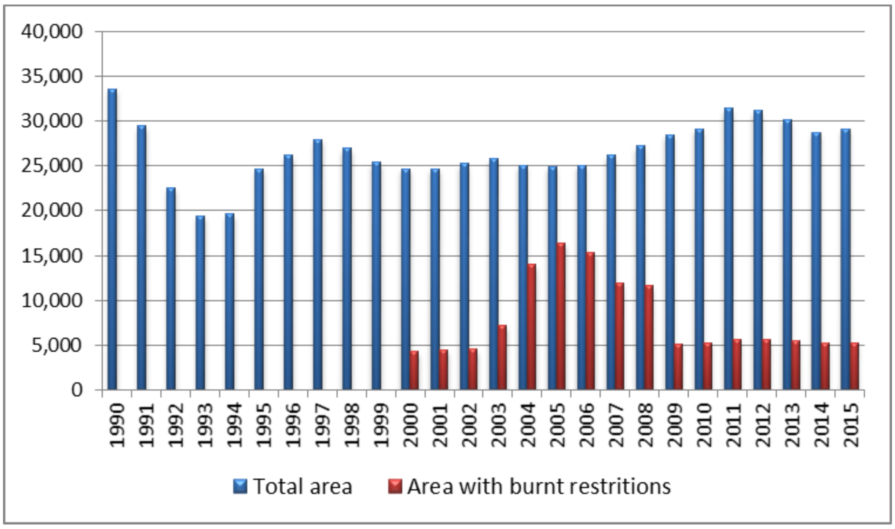
[71] Natura 2000 network includes Special Zones for Conservation (ZPC) established under Habitats Directive (92/43/ CEE) and Special Proctetion Zones (ZPE) established under Birds Directive (last revision 2009/147/CE). http://www.icnf.pt/portal/naturaclas/rn2000

[72] National Laws: DL 140/99 artº 11º (revised by DL 49/2005); RCM 177/2008 artº 21º; RCM 182/2008 artº 8º.

Outside the Natura 2000 network during the time period 2002-2008[73] all rice cultivation areas subjected to "Techniques of Integrated Production and Protection[74]" had the same burnt residues restrictions. Straw were left on ground and incorporated into soil by plowing before next crop season.

The next figure shows the evolution of rice cultivation areas where the practice of residues burnt is not allowed.

Figure 5.14 – Rice cultivation areas (ha) in Portugal




Source: Ministry of Agriculture, GPP

For other cereals the practice of straw burning occurs in 1% of the cultivated area according to the INE information based on the last General Agricultural Census (2009) which included a set of questions about some agricultural practices.

Each year the orchards, vineyards and olive groves are pruned and much of the resulting material of this action is burned in situ. This practice occurs in 22% of the orchards area, 52% of the vineyard area and 65% of the olive grove area, according to the information collected in the General Agricultural Census.

The amount of biomass available for combustion of cereal crops was estimated using the IPCC 2006 methodology, i.e, the regression equations in table 11.2 (volume 4, chapter 11, pg. 11.17).

The amounts of pruning material produced for each of the permanent crops are country specific[75] values presented in the Table 5.24.

Activity data and parameters used to estimate emissions from cereal and permanent crops residues burnt on fields are summarized in Table 5.24 for 2015.Combustion factors used for

[73] From 2009 onwards the limitation of residues burnt was removed (Circular / DSPFSV/ 08 from Directorate General of Agriculture and Rural Development -DGADR)

[74] "Modos de protecção e produção integrada" in the original in Portuguese.

[75] Source: Dias, J.J.Mestre (2002), " Utilização da biomassa: avaliação dos resíduos e utilização de pellets em caldeiras domésticas".

cereal crops are from IPCC 2006, table 2.6 of volume 4, chapter 2, page 2.49. It was considered a combustion factor equal to 1 for the pruning material from permanent crops.

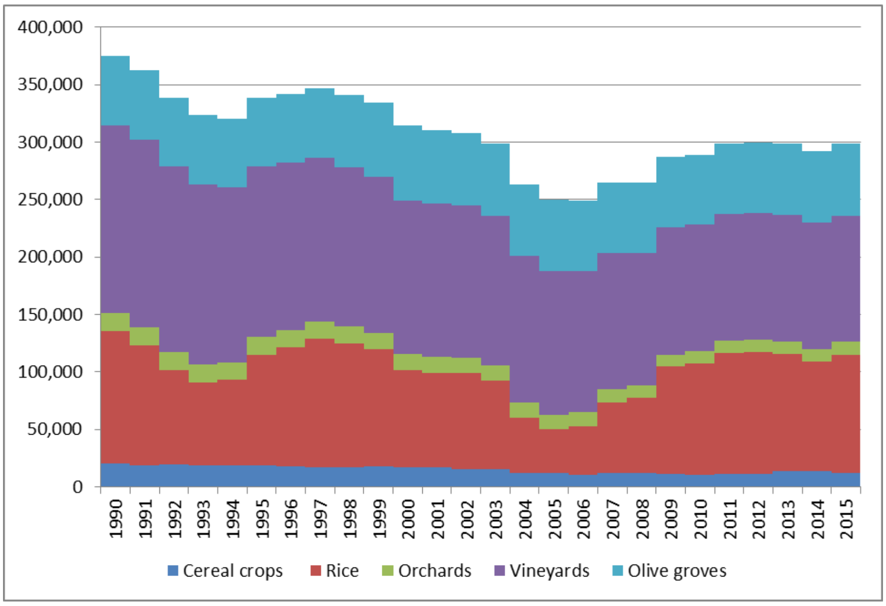
In a consistent way the same activity data were used for UNFCCC and for UNECE/CLRTAP emission inventory.

Table 5.24 – Activity data and parameters used to estimate emissions from on field burning of agricultural residues, for 2015

| Crop | Area with residues burnt (kha) | Biomass available for combustion (t dm/ha) | Combustion factor |
|---|---|---|---|
| Wheat | 0.40 | 3.24 | 0.90 |
| Barley | 0.21 | 2.42 | 0.90 |
| Maize | 1.37 | 8.18 | 0.80 |
| Rice | 16.42 | 7.82 | 0.80 |
| Other cereals | 0.82 | 2.01 | 0.90 |
| Orchards | 9.16 | 6.01 | 1.00 |
| Vineyard | 92.16 | 1.19 | 1.00 |
| Olive grove | 228.37 | 0.27 | 1.00 |

In figure below is presented the annual biomass burnt (t dm/yr) for the period 1990-2015.

Figure 5.15 – Annual Biomass burnt (t dm /yr) – 1990 to 2015




### 5.3.3.3 *Emission factors*

The emission factors used to estimate $NO_x$, NMVOC, $SO_x$, $NH_3$ and CO emissions from on field burning agricultural residues are presented in Table 5.25.

For $PM_{2.5}$, $PM_{10}$, TSP and BC emission estimates were used the emission factors presented in Table 5.26.

Table 5.25 – Emission factors for field burning of agricultural residues by pollutant and crop (kg/kg dm) – Main pollutants and CO

| Crop | NOx | NMVOC | SOx | $NH_3$ | CO |
|---|---|---|---|---|---|
| Wheat | 0.0023 | 0.0005 | 0.0005 | 0.0024 | 0.0667 |
| Barley | 0.0027 | 0.0117 | 0.0001 | 0.0024 | 0.0987 |
| Maize | 0.0018 | 0.0045 | 0.0002 | 0.0024 | 0.0388 |
| Rice | 0.0024 | 0.0063 | 0.0003 | 0.0024 | 0.0589 |
| Other cereals | 0.0023[#] | 0.0005[#] | 0.0005[#] | 0.0024[#] | 0.0667[#] |
| Orchards | 0.0030″ | 0.0007» | 0.0005[#] | 0.0024[#] | 0.1070″ |
| Vineyard | 0.0030″ | 0.0006» | 0.0005[#] | 0.0024[#] | 0.1070″ |
| Olive grove | 0.0030″ | 0.014» | 0.0005[#] | 0.0024[#] | 0.1070″ |

Sources: Wheat, barley, maize and rice from tables 3-3, 3-4, 3-5, and 3-6, respectively, of EMEP/EEA guidebook 2016; chapter 3F; [#]Table 3-1 of EMEP/EEA guidebook 2016, chapter 3F; »Table 2.5-5 AP_ 42 USEPA; ″Table 2.5 of IPCC guidelines 2006.

Table 5.26 – Emission factors for field burning of agricultural residues by pollutant and crop (kg/kg dm) - Particulate Matter

| Crop | $PM_{2.5}$ | $PM_{10}$ | TSP | BC |
|---|---|---|---|---|
| Wheat | 0.0054 | 0.0057 | 0.0058 | 0.0005 |
| Barley | 0.0074 | 0.0077 | 0.0078 | 0.0012 |
| Maize | 0.0060 | 0.0062 | 0.0063 | 0.00075 |
| Rice | 0.0055 | 0.0058 | 0.0058 | 0.0005 |
| Other cereals | 0.0054[#] | 0.0057[#] | 0.0058[#] | 0.0005[#] |
| Orchards | 0.0054[#] | 0.0057[#] | 0.0058[#] | 0.0005[#] |
| Vineyard | 0.0054[#] | 0.0057[#] | 0.0058[#] | 0.0005[#] |
| Olive grove | 0.0054[#] | 0.0057[#] | 0.0058[#] | 0.0005[#] |

Sources: Wheat, barley, maize and rice from tables 3-3, 3-4, 3-5, and 3-6, respectively, of EMEP/EEA guidebook 2016; chapter 3F; [#]Table 3-1 of EMEP/EEA guidebook 2016, chapter 3F

For all other pollutant emission estimates the emission factors used are those presented in the following two tables.

Table 5.27 – Emission factors for field burning of agricultural residues by pollutant and crop – POP's

| Crop | PCDD/PCDF (µg I -TEQ $t^{-1}$) | Benzo(a) pyrene (mg / kg dm) | Benzo(b) fluoranthene (mg / kg dm) | Benzo(k) fluoranthene (mg / kg dm) | Indeno(1,2,3-cd) pyrene (mg / kg dm) |
|---|---|---|---|---|---|
| Wheat | 0.5000[#] | 67.70 | 189.10 | 80.70 | 57.90 |
| Barley | 0.5000[#] | 98.80 | 307.40 | 77.00 | 38.20 |
| Maize | 0.5000[#] | 1 136.9 | 554.70 | 339.30 | 383.40 |
| Rice | 0.5000[#] | 0.92 | 19.00 | 31.5 | 14.50 |
| Other cereals | 0.5000[#] | 67.70[#] | 189.10[#] | 80.70[#] | 57.90[#] |
| Orchards | 0.5000[#] | 67.70[#] | 189.10[#] | 80.70[#] | 57.90[#] |
| Vineyard | 0.5000[#] | 67.70[#] | 189.10[#] | 80.70[#] | 57.90[#] |
| Olive grove | 0.5000[#] | 67.70[#] | 189.10[#] | 80.70[#] | 57.90[#] |

Sources: Wheat, barley, maize and rice from tables 3-3, 3-4, 3-5, and 3-6, respectively, of EMEP/EEA guidebook 2016; chapter 3F; [#]Table 3-1 of EMEP/EEA guidebook 2016, chapter 3F

Table 5.28 – Emission factors for field burning of agricultural residues by pollutant and crop (mg/kg dm) – Heavy Metals

| Crop | Pb | Cd | Hg | As | Cr | Ni | Se | Zn | Cu |
|---|---|---|---|---|---|---|---|---|---|
| Wheat | 0.1100 | 0.8800 | 0.1400 | 0.0064 | 0.0800 | 0.0520 | 0.0200 | 0.5600 | 0.0730 |
| Barley | 0.0036 | 0.2400 | 0.0960 | 0.0064# | 0.1400 | 0.0110 | 0.0390 | 0.4900 | 0.0036 |
| Maize | 0.0070 | 0.0360 | 0.0280 | 0.0130 | 0.1000 | 0.0360 | 0.0280 | 0.8400 | 0.0540 |
| Rice | 0.0720 | 0.1600 | 0.0330 | 0.0910 | 0.1000 | 0.0450 | 0.0480 | 0.9200 | 0.0880 |
| Other cereals | 0.1100# | 0.8800# | 0.1400# | 0.0064# | 0.0800# | 0.05200# | 0.0200# | 0.5600# | 0.0730# |
| Orchards | 0.1100# | 0.8800# | 0.1400# | 0.0064# | 0.0800# | 0.05200# | 0.0200# | 0.5600# | 0.0730# |
| Vineyard | 0.1100# | 0.8800# | 0.1400# | 0.0064# | 0.0800# | 0.05200# | 0.0200# | 0.5600# | 0.0730# |
| Olive grove | 0.1100# | 0.8800# | 0.1400# | 0.0064# | 0.0800# | 0.05200# | 0.0200# | 0.5600# | 0.0730# |

Sources: Wheat, barley, maize and rice from tables 3-3, 3-4, 3-5, and 3-6, respectively, of EMEP/EEA guidebook 2016; chapter 3F; #Table 3-1 of EMEP/EEA guidebook 2016, chapter 3F

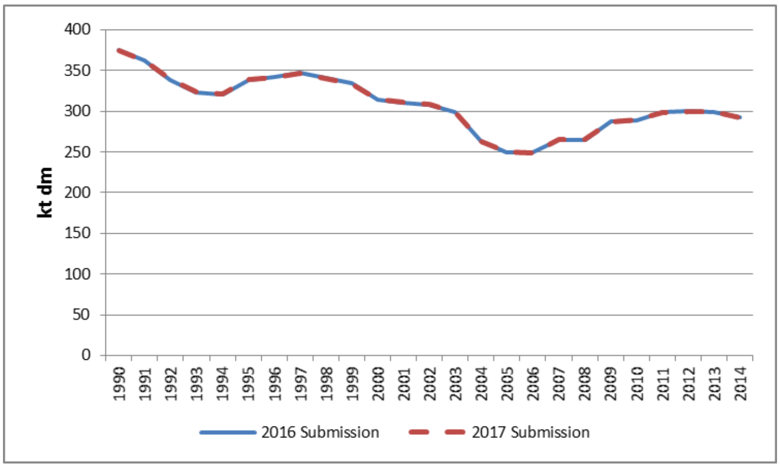
### 5.3.3.4 *Uncertainties*

To be provided in the future.

### 5.3.3.5 *Recalculations*

No recalculations to point out as shown in figure below

Figure 5.16 - Differences between previous submission (2016) and this year submission (2017) for the total amount of biomass burnt.




### 5.3.3.6 *Further improvements*

No specific improvements are planned.

# 6 WASTE (NFR 5)

## 6.1 Overview

Waste management and treatment of industrial and municipal wastes are sources of air pollutant emissions, such as $SO_2$, $NO_x$, CO, NMVOC, particulate matter, heavy metals and POPs.

The inventory covers emissions resulting from waste disposal on land, composting/digestion, waste incineration and cremation, treatment of liquid wastes, and sludge spreading.

Waste disposal on land, e.g. landfills that are significant sources of GHG (not included in this report), produce also NMVOC and $NH_3$ emissions (smaller amounts).

Wastewater treatment systems are also potential sources of NMVOC and $NH_3$.

Municipal solid wastes (MSW) and hazardous wastes incineration originates emissions of several pollutants, which depend on the type of incinerators, the degree of abatement techniques used and the composition of the waste combusted.

The inventory includes estimates for Particulates and Heavy Metals emissions from the incineration of municipal solid wastes (MSW) and clinical hazardous wastes. Furthermore, these source categories are also relevant in terms of Dioxins and Furans, PAHs and PCBs emissions.

The Guidelines determines emissions from incineration with energy recovery to be reported in the energy sector (sub-category 1A(a) Public electricity and heat production).

Incineration of municipal solid wastes (MSW) in Portugal is done in three modern units (two in Portugal Mainland) where energy is recovered, and thus these emissions are accounted for in the energy sector. The incineration of clinical waste occurs without energy recovery and is therefore allocated to the waste sector. Nevertheless, as the methodology applies for both situations (with and without energy recover), in order to avoid a double description, it is presented only once in this sub-section.

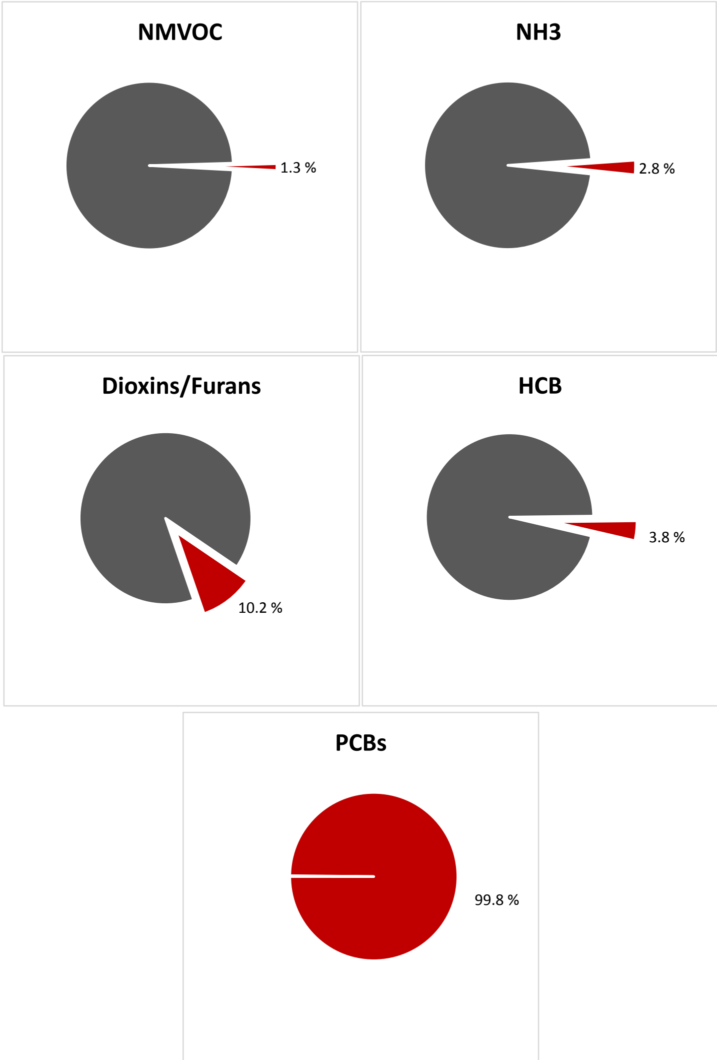
This sector includes also the incineration of industrial waste that occurs in industrial units without energy recovery.

Emissions from biogas combustion are also accounted and reported in the energy sector when there is energy recovery or in the waste sector when biogas is flared (without energy recovery).

The inventory includes also three other source categories: cremation of human corpses, sludge spreading (reported under agriculture category NFR 3Da2b) and car fires and building fires.

The next figure presents the contribution of the waste sector to the total emissions by substance.

Figure 6.1 – Share of the waste sector as a percentage of total emissions in 2015




## 6.2 Source categories

### 6.2.1 Solid Waste Disposal on Land (NFR 5 A)

#### 6.2.1.1 *NMVOC emissions from Solid Waste Disposal Sites (SWDS)*

##### 6.2.1.1.1 Methodology

Methane emissions are calculated on the basis of the First Order Decay Method (Tier 2), following the guidance from the 2006 IPCC Guidelines (Volume 5/ Chapter 3 on Solid Waste Disposal). The IPCC Waste Model was applied using Equations 3.2, 3.4 and 3.5 and a single-phase approach based on bulk waste (MSW). Emissions from industrial waste are estimated in a similar way.

NMVOC emissions are calculated using an emission factor of 0.01 t NMVOC/ t methane produced which is equivalent to 5.65g NMVOC/ $m^3$ landfill gas (Passant, 1993).

### 6.2.1.1.2 Activity data and parameters

SWDS include solid municipal waste (household, garden, commercial-services wastes) and industrial wastes.

#### *6.2.1.1.2.1 Municipal waste*

##### *6.2.1.1.2.1.1 Quantities of waste landfilled*

In 2015, the management of municipal solid waste (MSW) in Portuguese mainland was under the responsibility of 23 Municipal Waste Management Systems (12 multi-municipal and 11 inter-municipal entities).

Since 1999, data on MSW is available for the majority of these systems, including production amounts, final disposal and, to a less extent, waste composition.

For previous years, information on municipal waste was not collected on a regular basis, and most information was available from:

- PERSU II - "Plano Estratégico dos Resíduos Sólidos Urbanos" (Strategic Plan on Municipal Solid Waste), which was approved by the Government in 1997. This plan includes data from annual municipal registries;
- a study performed by Quercus (1995) – "Caracterização dos Resíduos Sólidos Urbanos e Inventariação dos Locais de Deposição em Portugal" (Characterization of Municipal Solid Waste and Survey of Disposal Sites in Portugal). The study of Quercus (1995) considered open dump sites, managed landfills, composting and incineration units, covering aspects as the quantities of waste treated or landfilled and other characteristics (opening and closure year of operation, waste composition, existence of flaring equipment, etc). Data was based on a survey performed in 1994, which enabled the calculation of per capita generation rates for 1994, based on the amounts of waste collected and the population served by waste collection.

The use of the FOD method requires building a data time series for several decades in the past concerning waste quantities, composition and disposal practices. According to IPCC (2000, 2006), it is good practice to estimate historical data if such data are not available, when this is a key source category (ANNEX A: COMPLETENESS AND KEY CATEGORIES). The extent of the time series has been set to 30 years, in order to follow the guidance from IPCC (2000, 2006) which recommends to consider data on solid waste disposal (amount, composition) for 3 to 5 half-lives (please see 6.2.1.1.2.1.3-Other parameters) of the waste deposited at SWDS.

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. These assumptions were based on scarce information for municipal solid wastes quantities in Portugal Mainland, which indicated a tendency of 3% in the period (1980-1985).

Therefore, for the period 1960-1994, municipal solid wastes production was estimated for each municipality as follows:

| |
|---|
| [Population (inhabitants) * Annual amount of municipal waste generated per capita (t/inhabitant/year)] |

Population data for resident population is available from periodical census made by the National Statistical Office (INE). Available years are: 1960, 1970, 1981, 1991, 2001, and 2011. Data for intermediate years were estimated, by interpolation, for each municipality.

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:

Waste disposed to SWDS = [Population * Annual amount of municipal waste generated per capita *

Percentage of Population served by waste collection]

– Quantity of incinerated waste – Quantity of composted/digested waste

At present the National legislation (Decree-Law no. 178/2006 amended and republished in the Decree-Law no. 73/2011) defines the legal obligations related to the Waste Registry for: waste producers, management waste operators (municipal and non-municipal), waste carriers, integrated schemes for management of specific waste streams, and waste brokers and dealers.

The National entity responsible for the definition, implementation and supervising the waste policies is APA, I.P. through its Waste Department, which is also responsible for the validation and treatment of the information collected via the Integrated System for Electronic Registry on Waste (SIRER) in the SILIAMB electronic platform.

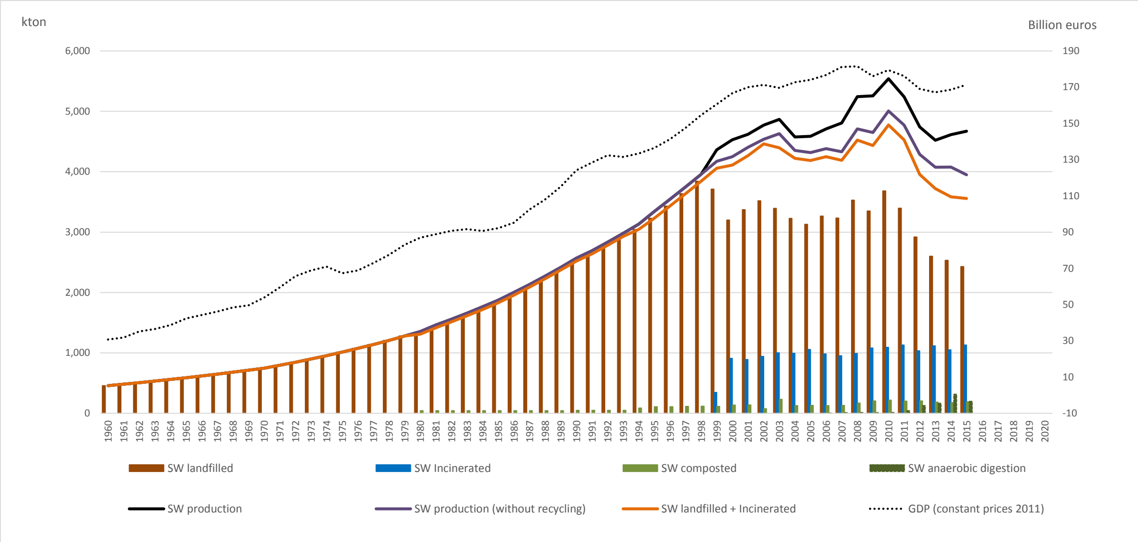
The operators should upload on different registration maps (MRRU, for municipal waste) the information regarding production, trade, recovery and disposal of waste, including the origin of the waste, the quantities generated and treated, the classification and the destiny of the waste.

It is  based on the data collected from the MRRU (Municipal Waste Registration Form), that APA, I.P. produces annual information referring to quantities of municipal waste generated in each municipality and their treatment (landfilling, incineration, composting, recycling). Information on waste composition is also collected (the Ordinance 851/2009 defines the methodology for municipal waste characterization).

Accordingly, for the more recent years (for 1994, and since 1999) the information refers to data effectively collected and reported by the waste management systems, which details the different treatments: landfilling, incineration, composting/anaerobic digestion, and material recycling. The inventory excludes the material recycling amounts.

Next figure presents the trends of SW generation amounts and the quantities of waste per type of final disposal.

Figure 6.2 – Municipal waste (excluding material recycling)




Source: APA, include estimates.

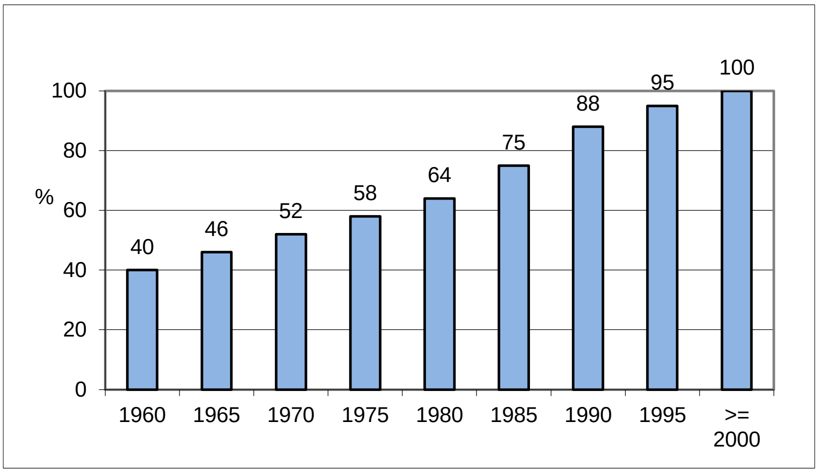
In the latest years, solid waste production presents a decreasing tendency, resulting from the policies on preventing, reducing and recycling of waste, but mainly due to the recent economic crisis effect on consumption.

In 2015 they were produced around 4.7 million tonnes (t) of the urban waste in Portugal, approximately 1.0% more than in 2014, reversing the downward trend started in 2010. This increase may be related to an improvement of the economic situation of Portugal which registered approximately 1.6% growth in 2015 as compared to 2014.

As presented in the figure, waste start to be diverted from SWDS after 1999 corresponding to the beginning of operation of two MSW incineration units in Mainland Portugal.

Despite the fact that landfilling remains the main destination for municipal waste, the final disposal of waste in landfills have been continuously decreasing since 2010. This trend has been accompanied by the growth of importance of Mechanical and Biological treatment as well as Screening units as foreseen in the Municipal Solid waste Strategic Plan (PERSU, PERSU II) and the National Plan for Waste Management (PGNR 2011-2020). The number of waste management infrastructures for organic recovery and biological treatment have grown expressively in the last decade, with the aim to increase the direct diversion of landfill waste and increase the quantity of recyclable waste recovered.

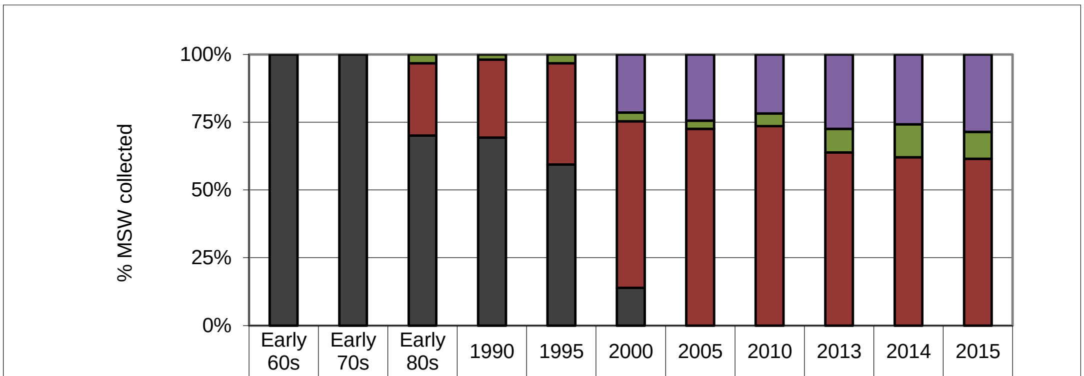
Figure 6.3 – Population served by waste collection systems




Source: APA

The share of treatment for the first years of the time series was calculated having as a basis the Quercus survey. Data for recent years (mainly since 1999) refer to data collected from management systems. As shown in the next figure there was a significant effort at national level to deactivate and closure all uncontrolled dumping sites. This effort was concluded in 2002 when all uncontrolled dumping sites had been closed. Another fact refers to the relatively reduction of waste disposal on land in favour of incineration, and more recently of organic treatment. As previously mentioned, in 1999 two MSW incineration units start operating, which was accompanied by a drop of waste disposal in SWDS (in 1998 disposal in SWDS represented 97% of total waste disposal; in 2015 this figure fall to 62%, and the percentage of waste incinerated represents 26%). Composting has been growing in importance and represents in 2015 approx. 10% of waste final disposal.

Figure 6.4 –Waste treatment




| | Early 60s | Early 70s | Early 80s | 1990 | 1995 | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Incinerated | 0 | 0 | 0 | 0 | 0 | 21 | 24 | 22 | 27 | 26 | 29 |
| Composted/ AD | 0 | 0 | 3 | 2 | 3 | 3 | 3 | 5 | 9 | 12 | 10 |
| Managed landfills | 0 | 0 | 27 | 29 | 37 | 61 | 72 | 74 | 64 | 62 | 62 |
| Open dump sites | 100 | 100 | 70 | 69 | 59 | 14 | 0 | 0 | 0 | 0 | 0 |

Source: APA estimates.

*6.2.1.1.2.1.2 Methane generation*

The parameters used in the calculation are mainly IPCC default values.

Table 6.1 – Parameters used in Lo calculation

| Parameter | Explanation | Value considered |
|---|---|---|
| MCF | IPCC defaults | Managed landfills = 1.0<br>Unmanaged/Uncategorised = 0.6 |
| DOC | National estimate | Variable on waste composition |
| DOCF | 2006 IPCC default (including lignin C) | 0.5 |
| F | 2006 IPCC default | 0.5 |

The estimation of Degradable Organic Carbon (DOC), presented in the following table, was based on national information on the waste composition.

Table 6.2 – Composition of waste disposed to SWDS

| Fermentable fractions | DOC content | Early 60s | Early 70s | Early 80s | Early 90s | Mid 90s | 2000 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percentage of wet weight | | | | | | | | | | | |
| Paper/cardboard | 40 | 17.0 | 17.0 | 17.0 | 21.1 | 22.7 | 26.4 | 13.7 | 12.9 | 12.3 | 13.6 | 13.7 | 13.3 |
| Glass | - | 2.5 | 2.5 | 2.5 | 4.4 | 5.1 | 7.4 | 3.7 | 3.6 | 4.0 | 4.5 | 4.4 | 4.3 |
| Plastics | - | 3.0 | 3.0 | 3.0 | 9.2 | 11.7 | 11.1 | 10.8 | 10.5 | 10.2 | 10.8 | 10.8 | 10.8 |
| Metal | - | 3.0 | 3.0 | 3.0 | 2.8 | 2.7 | 2.8 | 2.0 | 1.8 | 1.6 | 1.9 | 1.9 | 1.8 |
| Food waste | 15 | 59.9 | 59.9 | 59.9 | 42.0 | 34.8 | 26.5 | 42.8 | 43.0 | 40.9 | 36.6 | 37.5 | 36.7 |
| Textiles | 24 | 5.5 | 5.5 | 5.5 | 3.8 | 3.1 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |
| Non-food fermentable materials 1) | 20 | 0.0 | 0.0 | 0.0 | 13.4 | 18.7 | 17.4 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 | 14.3 |
| Wood | 43 | 0.0 | 0.0 | 0.0 | 0.2 | 0.3 | 0.5 | 1.5 | 1.0 | 1.1 | 1.1 | 1.0 | 1.2 |
| Other | - | 9.1 | 9.1 | 9.1 | 3.2 | 0.8 | 5.4 | 8.7 | 10.3 | 13.1 | 14.8 | 13.9 | 15.0 |
| **DOC** | **-** | **17.1** | **17.1** | **17.1** | **18.4** | **18.9** | **18.9** | **16.0** | **15.5** | **15.0** | **14.9** | **15.0** | **14.8** |

Notes:
Data on waste composition: Early 60s, 70s and 80s data refer to Fernandes, A Pastor (1982), "RSU do Continente - um Guia para Orientação e Inform. Das Autarquias", LNETI. Early 90s: estimates from interpolation. Mid 90s: data refer to 1994; DGA. 2000 and 2010-14: APA
DOC content: 2006 IPCC defaults.

*6.2.1.1.2.1.3 Other parameters*

The value of landfill gas generation rate constant (k) depends on several factors as the composition of the waste and the conditions of the SWDS (e.g. climatic conditions).

This parameter is related to the time taken for the DOCm (Degradable Organic Matter) in waste to decay to half its initial mass (´half life´ or $t_{1/2}$) as follows: $k = \ln2 / t_{1/2}$. The k value considered was 0.07 (half life of about 10 years), which represents a higher decay rate compared to the k default value proposed by the IPCC 2000 (0.05 - half life of about 14 years).

The k value used was estimated as a function of the national climatic conditions, using a Geographic Information System. A geographic database with the universe Landfill Sites (SWDS) licensed in Portugal was crossed with cartography on the following climatological variables: a) Annual Potential Evapotranspiration (PET); 2) Mean Annual Temperature (MAT); 3) Mean Annual Precipitation (MAP) (from IPMA). Each SWDS was classified according to the climatic conditions and a corresponding k value, based on the recommended default methane generation rate (k) values from 2006 IPCC (Table 3.3, Chapter 3: SWD).

The 0.07 refer to the average conditions of the overall SWDS.

#### 6.2.1.1.2.2 Industrial waste

##### 6.2.1.1.2.2.1 Quantities of waste landfilled

Industrial wastes considered refer only to the fermentable part of industrial waste.

Historical time series are based on 1999 data, which refer to the first set of data available on industrial waste disposal that was collected via an annual registry of industrial declarations received from the regional environment directorates (CCDR).

Data for the period 1960-1999 have been estimated based on expert judgment. For the years 1960-1990 a growth rate of 1.5% per year was considered, and for the following years (1990-1998), 2% per year. Data for the years 1999, 2002 and 2003 refer to the annual registries data. The years 2000 and 2001 refer to estimates based on the interpolation of 1999 and 2002 data, and the 2004-2007 period to an interpolation of 2003 and 2008 data.

Data from 2008 onwards refer to data collected via SIRER (Integrated System for Electronic Registry on Waste) in the SILIAMB electronic platform. After data collection and the respective validation at APA, I.P., data is handled by the INE (National Statistical Office) in order to extrapolate the information to the universe of enterprises for each economic branch, due to the different scope required by the national legislation on waste registration and the Waste Statistics Regulation (Regulation (EC) no. 2150/2002).

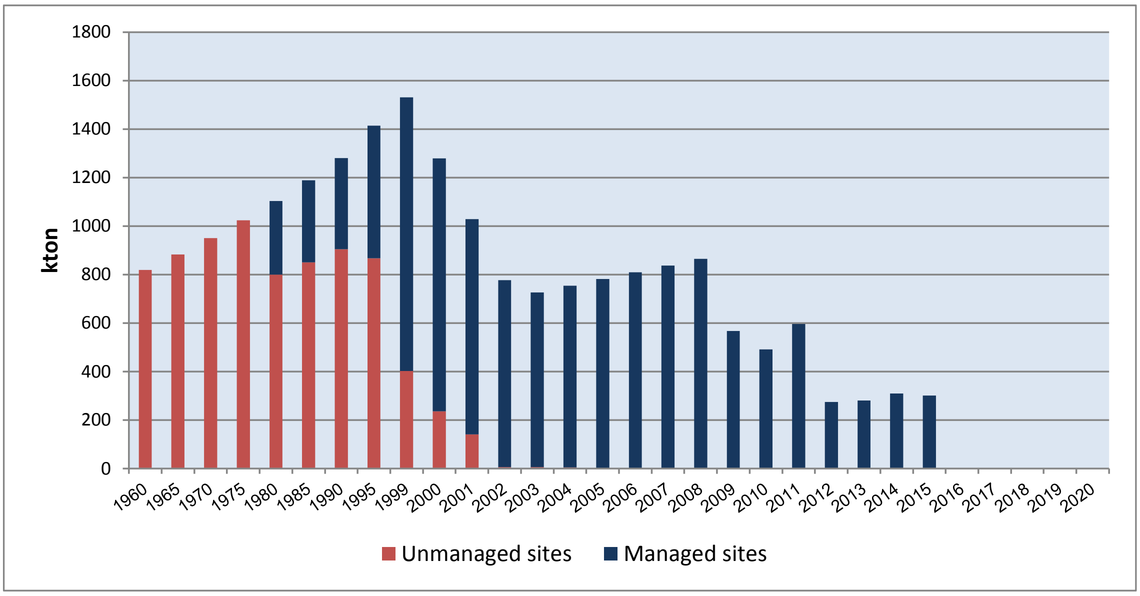
In 2012, the Statistical Office made a methodological change in the sectoral waste statistics, consisting in the harmonization of the sample used for these statistics with other statistical operations related to the Common Corporate Sector/ Business Sector, in which a set of statistical units, such as municipalities and other entities from public administrations, are excluded since 2012.

This revision is considered to have increase the quality of the waste statistics, as it was found to exist an overlap of content and double accounting between the sectoral and the municipal statistics, due to a double registry, in the MRRU and MIRR, of waste operations by many operators.

In order to make the time series more consistent, the data from 2008 has been revised to exclude the information from entities not considered from 2012 onwards. This double accounting phenomenon is more difficult to quantify for previous years.

As there is no available information concerning industrial waste treatment for the earlier years, it was assumed that all estimated waste produced have followed the municipal disposal pattern between uncontrolled and controlled SWDS.

Figure 6.5 – Quantities of fermentable industrial waste disposed to SWDS




Source: APA

The fluctuations of industrial waste amounts disposed in landfills, as shown in the figure above, results in part from the use of different data sets along the time. There are however other factors, that explain these differences, such as the landfill diversion. The treatment of industrial waste includes landfilling, incineration, shipping abroad and recycling. The differences result, at least partially, from the variation of fluxes to other treatments as a consequence of the annual waste market demand.

*6.2.1.1.2.2.2 Methane generation*

The parameters used in the calculations are basically the same as the ones presented for municipal waste, excepted for DOCm. Data for this parameter varies according to the available information on industrial waste composition and includes estimates based on interpolation and average of last available data for missing years.

Available data on industrial waste production is based on APA´s data which refer to annual registries from industrial units declarations. This information is classified according to the European Waste Catalogue list (EWC) and is disaggregated by type of treatment. From this database a selection was made (by expert judgment) in order to consider the EWC categories referring to organic origin. Each one of these categories was classified according to a group and was assigned with a DOC value, also defined by expert guess.

Until 2003 the inventory considered data from the waste registries at a disaggregated level of 6 digits of the European Waste List Decision - 2000/532/EC, by treatment/destiny type; no statistical treatment were made to consider the non-responses. Based on these categories, a selection was done in order to consider the categories containing fermentable waste, and each of the categories selected was classified according to a group/DOC value.

Since 2008, data refer to the National Waste Registry that collects data via the SIRER's MIRR registration map at SILIAMB electronic plataform. Data provided by waste operators under this registry are treated subsequently by the INE (National Statistical Institute) in order to extrapolate the information to the universe of enterprises for each economic branch. The extrapolation is made however at a more aggregated level.

Data considered for the years 2008 onwards, refer to the EWCStat 4.0 categories that are considered as organic waste. These data are presented in the next table.

Table 6.3 - Industrial organic waste composition and DOC

| waste groups | DOC (0...1) | 1960-98 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|
| | | ton | | | | | |
| paper and textiles | 0.40 | | 841,899 | | | 384,713 | 316,538 |
| garden waste, park waste or other non-food organic p | 0.17 | | 77,269 | | | 208,985 | 172,125 |
| food waste | 0.15 | | 19,209 | | | 56,455 | 158,286 |
| wood or straw | 0.30 | | 155,142 | | | 64,044 | 14,566 |
| Fuels | - | | 0 | | | 0 | 0 |
| Plastic | - | | 115,538 | | | 22,190 | 40,060 |
| Sludge from natural origin | 0.14 | | 236,250 | | | 39,759 | 22,687 |
| Sludge from non-natural origin or hydrocarbons | - | | 83,191 | | | 0 | 31 |
| Synthetic fibres | - | | 2,073 | | | 0 | 0 |
| Non-natural organic substances | - | | 52 | | | 1,410 | 2,643 |
| TOTAL | - | *estimates* | 1,530,854 | *1,279,815* | *1,028,576* | 777,337 | 728,946 |
| DOC (weighted average) | - | *0.282* | 0.282 | *0.284* | *0.285* | 0.288 | 0.257 |

| waste groups (EWC-Stat/Version 4) | DOC (0...1) | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ton | | | | | | | | | | | |
| 03.2 + 03.3 Sluge from industrial origin | 0.14 | | | | | 28,674 | 40,149 | 32,944 | 33,758 | 23,203 | 26,905 | 29,733 | 29,979 |
| 05 Health care and biological wastes a) | 0.15 | | | | | 9,791 | 9,790 | 9,759 | 10,698 | 9,916 | 3,588 | 808 | 2,395 |
| 07.2 Paper and cardboard wastes | 0.40 | | | | | 3,214 | 3,548 | 1,372 | 54,435 | 323 | 275 | 144 | 214 |
| 07.5 Wood wastes | 0.30 | | | | | 22,776 | 12,758 | 8,197 | 7,848 | 4,713 | 1,053 | 628 | 858 |
| 07.6 Textile wastes a) | 0.24 | | | | | 29,400 | 25,348 | 36,064 | 24,162 | 14,925 | 13,950 | 16,002 | 15,282 |
| 09.1 Animal waste of food preparation and products | 0.15 | | | | | 20,377 | 12,173 | 15,692 | 14,063 | 11,818 | 14,020 | 19,803 | 17,257 |
| 09.2 Vegetal waste | 0.15 | | | | | 24,531 | 13,715 | 9,994 | 15,216 | 3,405 | 2,611 | 4,112 | 3,430 |
| 09.3 Slurry and manure | 0.15 | | | | | 0 | 20 | 0 | 0 | 0 | 0 | 19,187 | 9,780 |
| 10.1 Household and similar wastes b) | 0.17 | | | | | 456,187 | 181,907 | 150,910 | 211,008 | 37,390 | 34,743 | 34,291 | 35,224 |
| 10.21 + 10.22 Mixed and undifferentiated materials | 0.26 | | | | | 129,327 | 127,318 | 90,989 | 99,042 | 45,971 | 42,461 | 54,849 | 49,849 |
| 11 Common sludges | 0.14 | | | | | 89,469 | 93,815 | 95,137 | 88,537 | 87,977 | 73,664 | 58,298 | 67,330 |
| TOTAL | - | *754,633* | *782,320* | *810,006* | *837,693* | 865,380 | 566,972 | 491,447 | 596,709 | 275,080 | 281,207 | 309,581 | *301,441* |
| DOC (weighted average) | - | *0.241* | *0.224* | *0.208* | *0.191* | 0.175 | 0.175 | 0.171 | 0.192 | 0.155 | 0.135 | 0.139 | *0.137* |

Notes:
a) IPCC 2006 table 2.6.
b) Regional default MSW composition data provided for Western Europe in table 2.3 of the 2006 IPCC Guidelines.
Data on italics: estimates.

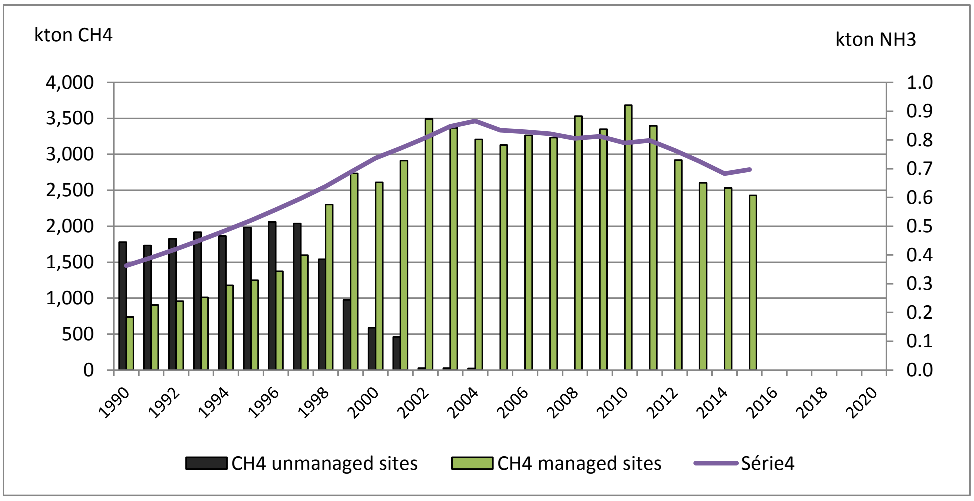
Total amounts of organic industrial waste and associated DOC values refer to estimates based on interpolation for the years: 2000, 2001 (interpolation of 1999 and 2002 data); and 2004-2007 (interpolation of 2003 and 2008 data). The amounts of waste for the previous decades (1960-1998) were calculated considering annual growth rates as explained previously, 2015 data were estimated on the basis of GDP variation, taking in account the average of 2013-2014 data.

DOC values used in the calculations resulted from weighted averages based on the quantities reported for each EWC category considered and the respective assigned DOC, and refer to disposal on land.

### 6.2.1.2 *NH3 emissions from Solid Waste Disposal Sites (SWDS)*

$NH_3$ emissions are calculated on the basis of $CH_4$ emission values (calculated under UNFCCC), using the $NH_3/CH_4$ ratio proposed by Eggleston (1992), i.e. 0.0073 kg $NH_3$/kg $CH_4$.

Figure 6.6 – Emissions of CH4 and NH3




## 6.2.2 NH3 emissions from Composting and Anaerobic Digestion (NFR 5 B 1)

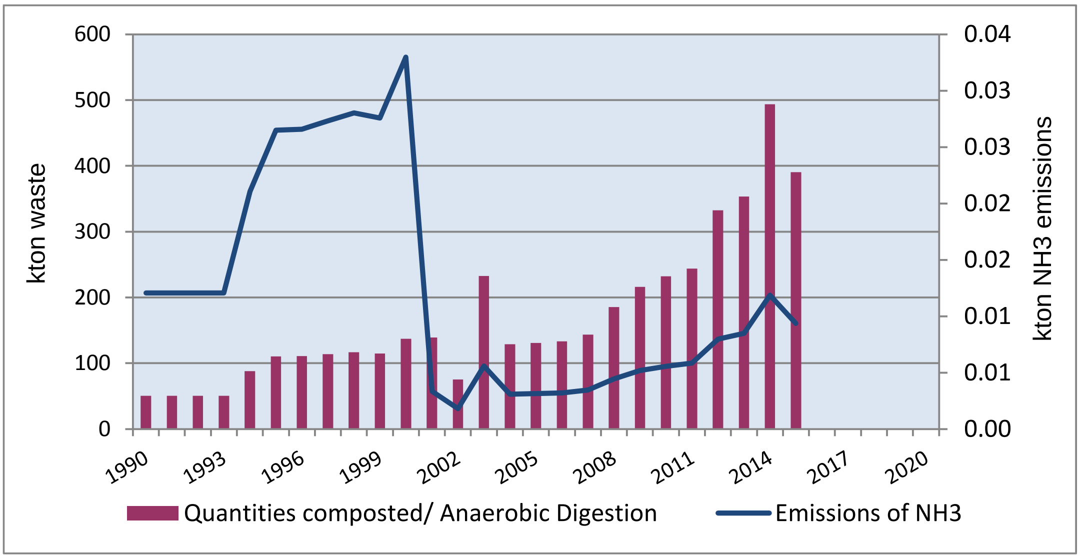
### 6.2.2.1 *Methodology*

Emission estimates follow Tier 2 approach for composting indicated in the 2016 Guidebook.

### 6.2.2.2 *Activity data*

The activity level for past years is based on estimated data as previously explained (section 6.2.1.1.2.1.1 - Quantities of waste landfilled). Data for recent years refer to data collected from management systems.

Figure 6.7 – Quantities of municipal waste composted/ Digested and related NH3 emissions




Source:APA

#### 6.2.2.3 *Emission factors*

Emission factors reflect change in treatment technology. Until 1999 NH3 emissions from domestic composting of organic waste were estimated to be without control; after 2000 it was assumed the existence of emission control with bio-filters.

Table 6.4 – Ammonia emission factors for compost production

| | EF g NH3/ton SW | Source |
|---|---|---|
| Uncontrolled | 240 | 2016 EEA Guidebook (Tier 2 default) |
| Biofilter | 24 | 2017 EEA Guidebook (Tier 2 default) |

### 6.2.3 Waste Incineration (NFR 5 C)

Waste incineration originates emissions of several pollutants. The inventory includes estimates for $SO_2$, $NO_x$, NMVOC, CO, $NH_3$, Particulates and Heavy Metals emissions from the incineration of solid wastes. Furthermore, these sources are also relevant in terms of Dioxins and Furans, PAHs, HCB and PCBs emissions.

The IPCC GPG determines that emissions from incineration with energy recovery should be reported in the energy sector (sub-category 1A(a) Public electricity and heat production).

Incineration of municipal solid wastes (MSW) in Portugal takes place in three modern units (two in Portugal Mainland) where energy is recovered, and thus these emissions are accounted for in the energy sector. The incineration of clinical waste occurs without energy recovery and is therefore allocated to the waste sector.

Nevertheless, as the methodology applies for both situations (with and without energy recover), in order to avoid a double description, it is presented only once in this sub-section.

This category includes also emissions from the incineration of industrial waste in industrial units. The emissions from cremation are also quantified.

#### 6.2.3.1 *Non-CO2 emissions*

##### 6.2.3.1.1 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.

$$\text{Non-CO}_2 \text{ emissions (Gg/yr)} = \Sigma_i \left( IW_i * EF_i \right) * 10^{-6}$$

where:

$IW_i$ = Amount of incinerated waste of type i (Gg/yr);

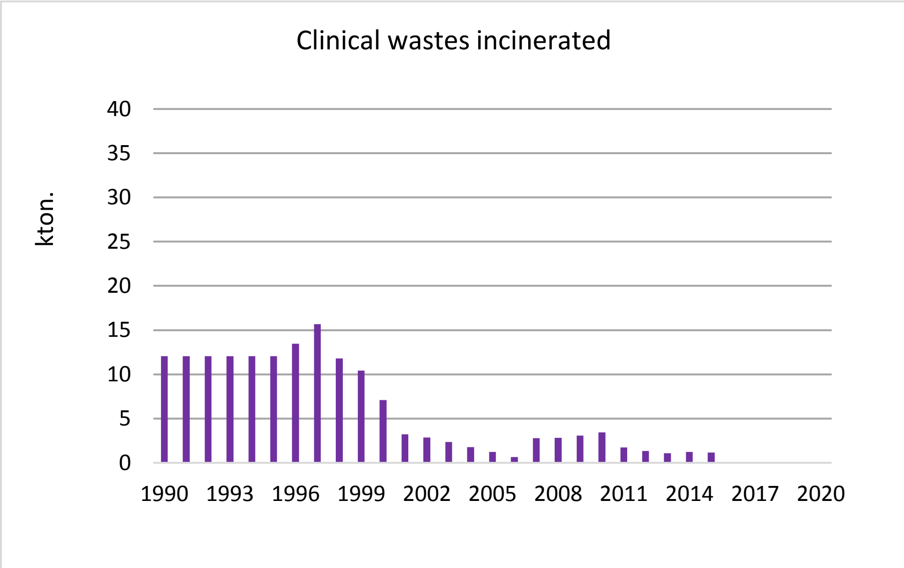
$EF_i$ = Aggregate pollutant emission factor for waste type i (kg pollutant/Gg)

##### 6.2.3.1.2 Activity data

###### *6.2.3.1.2.1 Clinical waste (NFR 5C1biii)*

Data on clinical waste incinerated refers to data declared in registry maps of public and private hospital units, research centers and other units (e.g. piercings, tattoos). The quantities of clinical waste incinerated decreased strongly in the years 2000s as shown in the next figure. Twenty-five incinerators were closed in recent years in Mainland Portugal, and only 1 remaining clinical waste incinerator is operating since 2004. Other clinical wastes receive alternative treatment or are sent abroad.

Figure 6.8 – Quantities of clinical waste incinerated




Sources: APA (include estimates); DGS.

The remaining clinical waste incinerator suffered two main requalification processes, the most significant occurred in 2004.

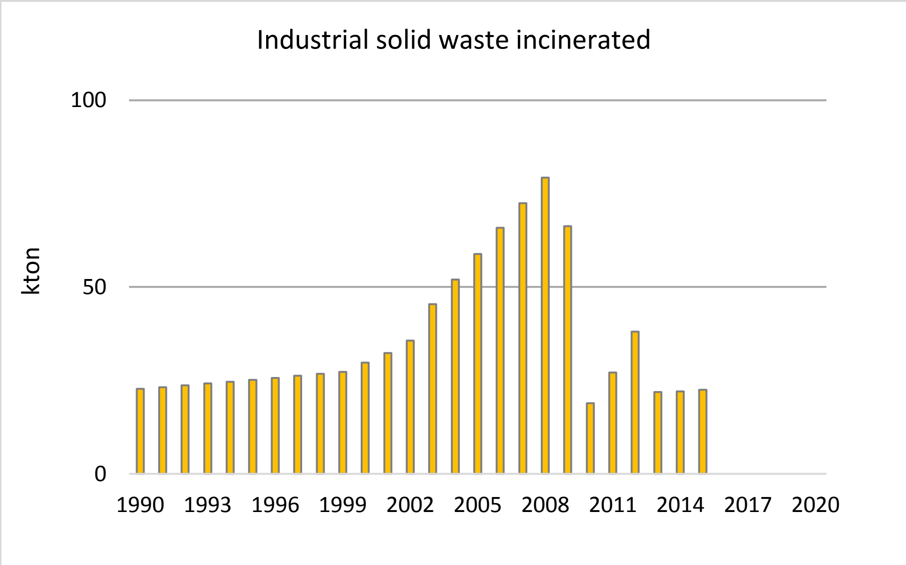
The plant type is a “controlled air incinerator”, which includes 2 combustion chambers. At a first stage, the waste is burnt in oxygen deficit conditions at temperatures from 850ºC to 950ºC. The resulting gases get into a second combustion chamber or thermal reactor where the gases suffer a new combustion reaching higher temperatures (1100ºC – 1200ºC) during 2 seconds. These gases are then conducted into a boiler where they are cooled. After that, the gases suffer a dry treatment chemical process, in a contact reactor, through the direct injection of sodium bicarbonate and activated carbon in the gas flux. At the end, the gas is conducted into a ceramic filter where the particulate matter is trapped.

#### *6.2.3.1.2.2 Industrial waste (NFR 5 C 1 b i)*

Data refer to incineration of industrial solid waste in industrial units collected in APA. Data for the years 1999, 2002 and 2003 refer to industrial units declarations. Data for the period 1990-98 are based on the same assumptions used for Industrial Solid Waste Disposed on Land: a per year growth rate of 2%.The figures for 2000 and 2001 are interpolated. Data from 2004 onwards refer to data collected under SIRER’s MIRR. Data provided by the different waste operators and industrials on the amounts of non-urban waste generated are statistical treated by the INE (Statistical Institute) in order to extrapolate the information for the universe of each economic branch.

As referred before, in late 2014, the INE revised the methodology resulting in a new time series (2008-2010) and provided data for 2011 and 2012 for the quantities of industrial waste incinerated. Data for 2013 and 2014 have been estimated based on the average of the last available years (2011 and 2012).

Figure 6.9 – Quantities of combusted industrial waste




Source: APA (include estimates).

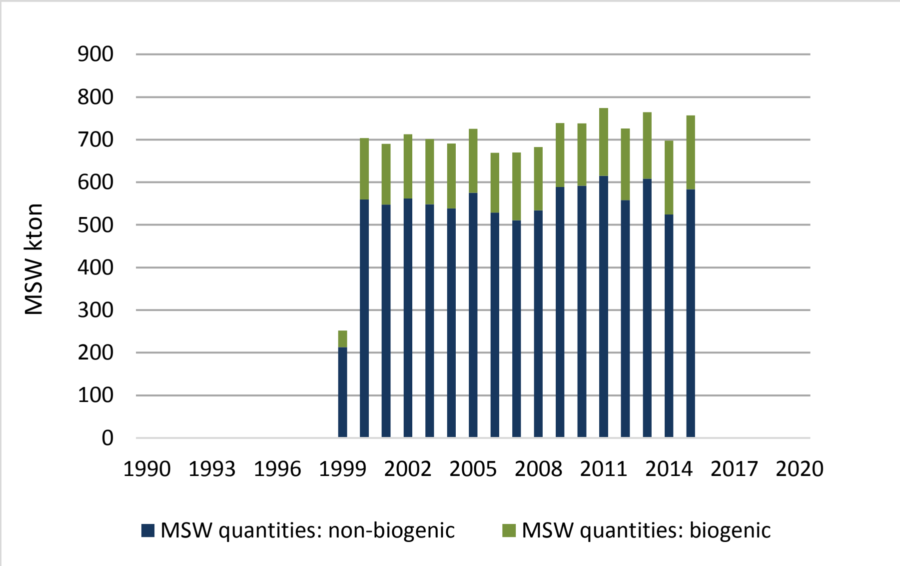
The fluctuations on the amounts of industrial waste incineration, as shown in the previous figure, results, at least partially, from the variation of fluxes to other treatments (landfilling, shipping abroad and recycling) as a consequence of the annual waste market demand.

#### *6.2.3.1.2.3 Municipal waste (accounted in NFR 1A1a)*

In 1999, two incineration units, Valorsul and Lipor started to operate in an experimental regime, respectively in April and August 1999. Their industrial exploration started at the end of the same year or early January 2000. These units are dedicated to the incineration of MSW which includes domestic and commercial waste. (Figure 6.10)

The emissions from MSW incineration occur with energy recovery and are therefore accounted in the energy sector (category 1A1a).

Figure 6.10 – Quantities of Municipal Solid Waste incinerated




The incineration units considered are modern units using best available technologies, either concerning the abatement technologies or the incineration techniques used, which aim at the optimization of the combustion process, and consequently the minimisation of atmospheric pollutants.

The incineration process used refers to mass burning with heat recovery for steam and electricity production. The waste is burnt in a combustion grate at approximately 1000ºC. During the waste incineration process, high temperature gases are released. These gases remain at least 2 seconds in the combustion chambers at a minimum temperature of 850ºC. After the passage in the recovery boiler, the produced steam is used for electric power generation; the cooled gases suffer several treatment processes to remove $NO_x$, acid gases, dioxins, furans, heavy metals and particulates.

Abatement technologies used include:

- NOx reduction system based on the ammonia or urea injection in the combustion chamber;
- semi-dry treatment process, consisting of a reactor, were spray fine droplets of an alkaline reagent (calcium hydroxide) are introduced to neutralise the acid gases;
- activated carbon injection to remove dioxins, furans and heavy metals;
- fabric filter for particulate removal.

#### 6.2.3.1.3 Emission factors

Emission factors applied are either country-specific, being obtained from monitoring data in incineration units, or obtained from references US/AP42 or EMEP/CORINAIR.

Table 6.5 – Emissions factors of CLRTAP gases from incineration of clinical wastes: until 2004

| Pollutants | Unit | EF | Source |
|---|---|---|---|
| SOx | kg/ton W | 1.09 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| NOx | kg/ton W | 1.78 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| COVNM | kg/ton W | 0.7 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| CO | kg/ton W | 1.48 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| NH3 | kg/ton W | 0.004 | Country measured data |
| Pb | kg/ton W | 0.036 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PST | kg/ton W | 2.33 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PM10 | % PST | 65 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PM2.5 | % PST | 43.3 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| BC | % PST | 2.3 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| Cd | kg/ton W | 0.00274 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| Hg | kg/ton W | 0.0537 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| As | kg/ton W | 0.000121 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| Cr | kg/ton W | 0.000388 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| Cu | kg/ton W | 0.0006 | 2007 guid CR, Plant type: controlled air; Abatem: uncontrolled; refª USEPA1998 |
| Ni | kg/ton W | 0.000295 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| DioxFur | g I-TEQ/ton W | 0.04 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PAH | g/ton W | 0.00004 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PCB | g/ton W | 0.0233 | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| HCB | g/ton W | 0.1 | 2016 EEA Guidebook (Tier 2, Uncontroled) |

Table 6.6 – Emissions factors of CLRTAP gases from incineration of clinical wastes: after 2005

| Pollutants | Unit | EF | Efficiency | Source |
|---|---|---|---|---|
| SOx | kg/ton W | 0.0872 | 92.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| NOx | kg/ton W | 1.78 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| COVNM | kg/ton W | 0.7 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| CO | kg/ton W | 1.48 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| NH3 | kg/ton W | 0.004 | - | Country measured data |
| Pb | kg/ton W | 0.002 | 94.5% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| PST | kg/ton W | 0.233 | 90.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| PM10 | % PST | 65 | - | - |
| PM2.5 | % PST | 43.3 | - | - |
| BC | % PST | 2.3 | - | - |
| Cd | kg/ton W | 0.0001096 | 96.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| Hg | kg/ton W | 0.001611 | 97.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| As | kg/ton W | 0.00000121 | 99.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| Cr | kg/ton W | 0.00001552 | 96.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| Cu | kg/ton W | 0.000246 | 59.0% | 2016 EEA Guidebook (Tier 2, Controled by various types of abatement) |
| Ni | kg/ton W | 0.000295 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| DioxFur | g I-TEQ/ton W | 0.04 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PAH | g/ton W | 0.00004 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| PCB | g/ton W | 0.0233 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |
| HCB | g/ton W | 0.1 | - | 2016 EEA Guidebook (Tier 2, Uncontroled) |

Table 6.9 – Emissions factors of CLRTAP gases for incineration of Industrial Waste

| Pollutants | Unit | EF | Source |
|---|---|---|---|
| SOx | kg/ton MSW | 0.05 | 2016 EEA Guidebook (Tier 1 default EF) |
| NOx | kg/ton MSW | 0.9 | 2016 EEA Guidebook (Tier 1 default EF) |
| NMVOC | kg/ton MSW | 7.4 | 2016 EEA Guidebook (Tier 1 default EF) |
| CO | kg/ton MSW | 0.1 | 2016 EEA Guidebook (Tier 1 default EF) |
| PST | kg/ton MSW | 0.01 | 2016 EEA Guidebook (Tier 1 default EF) |
| PM10 | kg/ton MSW | 0.01 | 2016 EEA Guidebook (Tier 1 default EF) |
| PM2.5 | kg/ton MSW | 0.004 | 2016 EEA Guidebook (Tier 1 default EF) |
| BC | % of PM2.5 | 3.50 | 2016 EEA Guidebook (Tier 1 default EF) |
| Pb | g/ton MSW | 1.30 | 2016 EEA Guidebook (Tier 1 default EF) |
| As | g/ton MSW | 0.016 | 2016 EEA Guidebook (Tier 1 default EF) |
| Cd | g/ton MSW | 0.100 | 2016 EEA Guidebook (Tier 1 default EF) |
| Cr | g/ton MSW | 0.13 | AP-42. Chp 2.1 (Refuse Combustion) a) |
| Hg | g/ton MSW | 0.056 | 2016 EEA Guidebook (Tier 1 default EF) |
| Ni | g/ton MSW | 0.140 | 2016 EEA Guidebook (Tier 1 default EF) |
| PCDD/ Fs | g TEQ/ton MSW | 0.0004 | 2016 EEA Guidebook (Tier 1 default EF) |
| Total PAHs b) | g/ton MSW | 0.02 | 2016 EEA Guidebook (Tier 1 default EF) |
| HCB | g/ton MSW | 0.002 | 2016 EEA Guidebook (Tier 1 default EF) |
| PCB | g/ton MSW | 2.595 | EIIP: chapter 16 Open burning municipal w aste; table 16.4-1; EF source: EPA, 1997 |

Notes:

a) Mass Burn Waterwall Combustor (MW/WW) with Eletrostatic Prec. And Semi-wet scrubber (same as Spray Dryier) SD/ESP

b) Total tetra- through octa- chlorinated dibenzo- p- dioxin/ chlorinated dibenzofurans

Table 6.7 – Emissions factors of CLRTAP gases from incineration of MSW

| Pollutants | Unit | EF | Source |
|---|---|---|---|
| SOx | kg/ton MSW | 0.0220 | Country measured data |
| NOx | kg/ton MSW | 0.7240 | Country measured data |
| COVNM | kg/ton MSW | 0.0059 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| CO | kg/ton MSW | 0.0360 | Country measured data |
| NH3 | kg/ton MSW | 0.0043 | Country measured data |
| Pb | kg/ton MSW | 0.000058 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| PST | kg/ton MSW | 0.0070 | Country measured data |
| Cd | kg/ton MSW | 0.0000046 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| Hg | kg/ton MSW | 0.0000188 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| As | g/ton MSW | 0.000001 | Country measured data |
| Cr | g/ton MSW | 0.000003 | Country measured data |
| Cu | g/ton MSW | 0.000026 | Country measured data |
| Ni | g/ton MSW | 0.000004 | Country measured data |
| Zn | g/ton MSW | 0.0245 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| DioxFur | g I-TEQ/ton MSW | 0.00000005 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| PAH | g/ton MSW | 0.0000474 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| HCB | g/ton MSW | 0.0000452 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |
| PCB | g/ton MSW | 0.0000000034 | 2016 EEA Guidebook (Tier 1); Nielsen et al. (2010) |

### 6.2.4 Cremation (NFR 5 C 1 b v)

The inventory covers the cremation of human corpses. The contribution of crematoria to national emissions is generally comparatively small for all pollutants except for heavy metals (HM). Other potential emissions are: dioxins and furans and polycyclic aromatic hydrocarbons (PAHs).

Emission estimates follow the simpler methodology (tier 1 default) indicated in 2016 EEA Guidebook, based on activity data multiplied by default emission factors.

#### 6.2.4.1 *Activity data*

The importance of cremation has been steadily growing and represents at present 14.1 per cent of funeral types.

Figure 6.11 – Number of human corpses cremated

| Year | Number of corpses | Year | Number of corpses | Year | Number of corpses |
|---|---|---|---|---|---|
| 1990 | 131 | 2000 | 1,706 | 2010 | 8,752 |
| 1991 | 250 | 2001 | 2,053 | 2011 | 9,849 |
| 1992 | 268 | 2002 | 2,446 | 2012 | 12,117 |
| 1993 | 517 | 2003 | 3,085 | 2013 | 12,589 |
| 1994 | 593 | 2004 | 3,441 | 2014 | 13,433 |
| 1995 | 677 | 2005 | 4,110 | 2015 | 14,853 |
| 1996 | 744 | 2006 | 4,492 | 2016 | - |
| 1997 | 912 | 2007 | 5,323 | 2017 | - |
| 1998 | 1,124 | 2008 | 6,889 | 2018 | - |
| 1999 | 1,541 | 2009 | 7,750 | 2019 | - |

Source: Servilusa/ Associação Portuguesa dos Profissionais do Sector Funerário

Table 6.10 – Emissions factors of CLRTAP gases for cremation

| Pollutants | Unit | EF | Source |
|---|---|---|---|
| SOx | kg/body | 0.113 | 2016 EEA Guidebook, Tier 1 default |
| NOx | kg/body | 0.825 | 2016 EEA Guidebook, Tier 1 default |
| COVNM | kg/body | 0.013 | 2016 EEA Guidebook, Tier 1 default |
| CO | kg/body | 0.14 | 2016 EEA Guidebook, Tier 1 default |
| Pb | mg/body | 30.03 | 2016 EEA Guidebook, Tier 1 default |
| PST | g/body | 38.56 | 2016 EEA Guidebook, Tier 1 default |
| Cd | mg/body | 5.03 | 2016 EEA Guidebook, Tier 1 default |
| Hg | g/body | 1.49 | 2016 EEA Guidebook, Tier 1 default |
| As | mg/body | 13.61 | 2016 EEA Guidebook, Tier 1 default |
| Cr | mg/body | 13.56 | 2016 EEA Guidebook, Tier 1 default |
| Cu | mg/body | 12.43 | 2016 EEA Guidebook, Tier 1 default |
| Ni | mg/body | 17.33 | 2016 EEA Guidebook, Tier 1 default |
| Se | mg/body | 19.78 | 2016 EEA Guidebook, Tier 1 default |
| Zn | mg/body | 160.12 | 2016 EEA Guidebook, Tier 1 default |
| PCDD/ PCDF (DioxFur) | µg/body | 0.027 | 2016 EEA Guidebook, Tier 1 default |
| benzo(a)pyrene | µg/body | 13.2 | 2016 EEA Guidebook, Tier 1 default |
| benzo(b)fluoranthene | µg/body | 7.21 | 2016 EEA Guidebook, Tier 1 default |
| benzo(k)fluoranthene | µg/body | 6.44 | 2016 EEA Guidebook, Tier 1 default |
| indeno(1,2,3-cd)pyrene | µg/body | 6.99 | 2016 EEA Guidebook, Tier 1 default |
| PCB | mg/body | 0.41 | 2016 EEA Guidebook, Tier 1 default |
| HCB | mg/body | 0.15 | 2016 EEA Guidebook, Tier 1 default |

## 6.2.5 Wastewater Handling (NFR 5 D)

### 6.2.5.1 *Domestic Wastewater*

Wastewater treatment systems types determine the level of air pollution emissions. Data trends on wastewater handling systems and types of treatment were compiled by ex-INAG/National Institute for Water (now integrated in the APA).

Table 6.8 – Percentage of population by wastewater handling system

| | Wastewater handling systems | 1990 | 1994 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009-2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % population | | | | | | | | | | | | |
| **Population without sewerage** | | | | | | | | | | | | | | |
| **1.1-** | **% Pop: without sewerage (latrines)** | 37.0 | 23.4 | 6.4 | 5.3 | 4.3 | 3.2 | 2.1 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **1.2-** | **% Pop: individual treatment (private septic tanks)** | 1.5 | 8.2 | 14.8 | 16.9 | 19.0 | 21.2 | 23.3 | 25.4 | 27.5 | 24.0 | 23.0 | 22.0 | 21.0 |
| **Population with sewerage** | | | | | | | | | | | | | | |
| **2.1-** | **% de Pop: with discharge into the ocean, without treatment** | 6.5 | 6.5 | 6.5 | 5.6 | 4.7 | 3.8 | 2.8 | 1.9 | 1.0 | 1.0 | 1.3 | 1.5 | 1.2 |
| **2.2-** | **% de Pop: with discharge into inland waters, without treatment** | 36.8 | 40.8 | 30.3 | 25.9 | 21.5 | 17.1 | 12.8 | 8.4 | 4.0 | 3.0 | 2.5 | 1.9 | 1.2 |
| **2.3-** | **% de Pop: with discharge into soil, without treatment** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| **2.4-** | **% de Pop: unknown disposal** | 0.0 | 0.0 | 0.0 | 0.4 | 0.8 | 1.2 | 1.6 | 2.0 | 2.4 | 2.0 | 3.3 | 4.6 | 5.6 |
| **3-** | **% Pop: with treatment** | 18.2 | 21.1 | 42.0 | 45.8 | 49.7 | 53.5 | 57.3 | 61.2 | 65.0 | 70.0 | 70.0 | 70.0 | 71.0 |
| **3.1-** | **% Pop: colective septic tanks** | 2.2 | 2.3 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 7.0 | 5.1 | 3.3 | 3.0 |
| **3.2-** | **% Pop: with preliminary treatment** | 0.0 | 0.0 | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 7.0 | 7.5 | 8.0 | 7.6 |
| **3.3-** | **% Pop: with primary treatment** | 5.2 | 5.2 | 9.0 | 8.5 | 8.0 | 7.5 | 7.0 | 6.5 | 6.0 | 3.0 | 4.4 | 5.9 | 1.9 |
| **3.4-** | **% Pop: with secondary and tertiary treatment** | 10.8 | 13.6 | 28.0 | 31.8 | 35.7 | 39.5 | 43.3 | 47.2 | 51.0 | 53.0 | 52.9 | 52.9 | 58.5 |
| 3.4.1- | Biodisks with anaerobic sludge digestion | 1.1 | 1.4 | 2.0 | 1.7 | 1.4 | 1.1 | 0.8 | 0.5 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 |
| 3.4.2- | Biodisks without anaerobic sludge digestion | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.4 | 0.5 | 0.7 | 0.8 | 0.8 | 0.6 | 0.3 | 0.2 |
| 3.4.3- | Activated sludge with anaerobic sludge digestion | 1.4 | 2.0 | 4.6 | 6.9 | 9.2 | 11.5 | 13.9 | 16.2 | 18.5 | 18.9 | 18.2 | 17.5 | 16.7 |
| 3.4.4- | Activated sludge without anaerobic sludge digestion | 1.4 | 2.0 | 4.6 | 5.8 | 7.0 | 8.1 | 9.3 | 10.5 | 11.7 | 11.9 | 11.6 | 11.3 | 14.0 |
| 3.4.5- | Laguning, with anaerobic pond | 1.7 | 1.9 | 3.6 | 3.0 | 2.4 | 1.9 | 1.3 | 0.8 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| 3.4.6- | Laguning, without anaerobic pond | 0.6 | 0.6 | 1.2 | 1.9 | 2.6 | 3.2 | 3.9 | 4.6 | 5.3 | 5.5 | 5.3 | 5.1 | 4.4 |
| 3.4.7- | Percolation beds with anaerobic sludge digestion | 3.6 | 4.6 | 8.8 | 8.0 | 7.1 | 6.3 | 5.4 | 4.6 | 3.7 | 3.7 | 3.4 | 3.1 | 2.9 |
| 3.4.8- | Percolation beds without anaerobic sludge digestion | 0.0 | 0.0 | 0.0 | 0.7 | 1.3 | 2.0 | 2.6 | 3.3 | 3.9 | 4.0 | 3.2 | 2.4 | 1.8 |
| 3.4.9- | Imhoff Tank | 0.6 | 0.3 | 0.1 | 0.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.3 | 1.3 | 1.2 | 1.0 | 0.8 |
| 3.4.10- | Oxidation ponds with anaerobic sludge digestion | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 |
| 3.4.11- | Oxidation ponds without anaerobic sludge digestion | 0.3 | 0.4 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.6 | 1.5 | 1.4 | 1.4 |
| 3.4.12- | Other treatment with anaerobic sludge digestion | 0.0 | 0.0 | 0.0 | 0.4 | 0.8 | 1.2 | 1.5 | 1.9 | 2.3 | 2.3 | 2.2 | 2.0 | 2.5 |
| 3.4.13- | Other treatment without anaerobic sludge digestion | 0.0 | 0.3 | 1.6 | 1.4 | 1.1 | 0.9 | 0.7 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 3.4.14- | With unspecified treatment | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.4 | 0.5 | 0.7 | 0.8 | 1.7 | 4.7 | 7.7 | 12.8 |

Source: ex-INAG.

Until 1999, data for wastewater handling systems are based on a compilation study, performed by ex-INAG, of all surveys and inventories done in the past concerning sanitation and wastewater treatment infrastructures. Data from this study refer to 1990, 1994 and 1999. More recent data (from 2005 onwards) is based on a database (INSAAR – Inventário Nacional de Sistemas de Abastecimento de Água e de Águas Residuais/ National survey on water supply and wastewater treatment systems) which was implemented and was managed by ex-INAG. From 2000 to 2004, data used in the calculations are interpolations based on the 1999 and 2005 figures.

Since the restructuration of the National Water Authority the referred "Inventário Nacional de Sistemas de Abastecimento de Água e Águas Residuais (INSAAR)", the national data base for wastewater treatment systems, has been deactivated. As a consequence, data considered since 2010 refer to INSAAR latest available year (2009).

#### 6.2.5.1.1 NMVOC emissions from wastewater (Human Sewage)

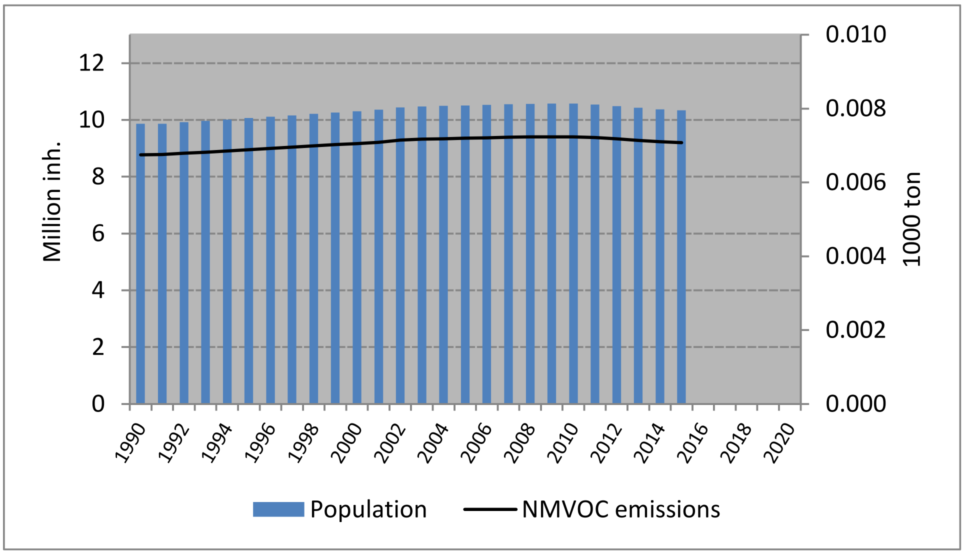
##### *6.2.5.1.1.1 Methodology, activity data and parameters*

Total population for each year was multiplied by a default emission factor for NMVOC of 15 mg/m3 waste water proposed by the 2016 EEA Guidebook:

NMVOC = Population * 15 mg/10³ l wastewater * 125 l/inhabitant.day * 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” (Decree-law 23/95 23rd August).

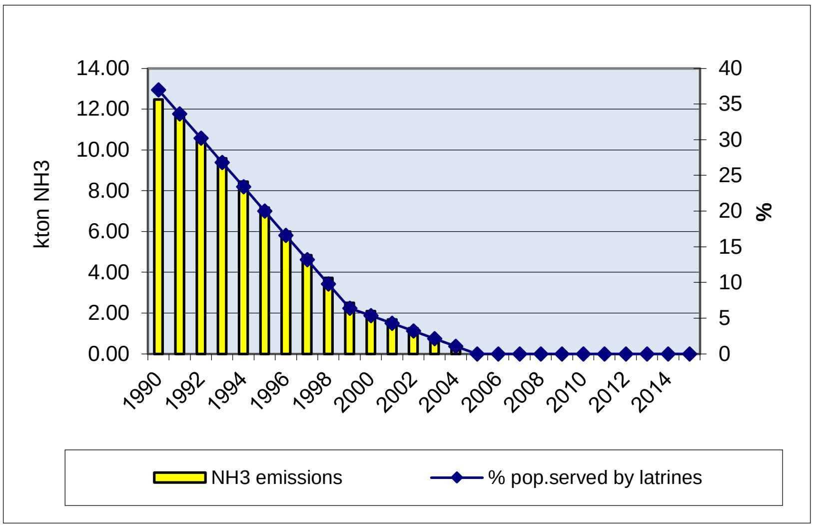
Figure 6.12 – NMVOC emissions




### 6.2.5.1.2 NH3 emissions from Wastewater Handling (WWH)

NH3 emissions result mainly from the decomposition of urea and uric acid contained in human excreta. The estimates considered the population served by latrines.

Figure 6.13 – $NH_3$ emissions and % population served by latrines




#### *6.2.5.1.2.1 Methodology*

Emissions were calculated, as follows:

$$NH_3(S) = (Protein * F_{NPR} * F_{NON\text{-}CON} * EF * Pop - N_{SLUDGE}) * Stor * 17/14$$

where:

$NH3_{(s)}$ - NH3 emissions from human sewage (kg $NH_3$-N/yr);

Protein - annual per capita protein intake (kg/person/yr);

$F_{NPR}$ - fraction of nitrogen in protein (0.16 kg N/kg protein - IPCC default);

$F_{NON\text{-}CON}$ - Fraction of non-consumed protein added to the wastewater (0.2)

EF - emissions factor (0.3 kg $NH_3$-N/kg sewage-N produced);

Pop - number of inhabitants in country;

$N_{SLUDGE}$ – nitrogen applied in agriculture soils, kg N/yr

Stor - % population served by latrines;

17/14 is the molecular weight ratio of $NH_3$ to N.

###### *6.2.5.1.2.2 Activity data*

Activity data results of protein intake, according to national data from National Statistical Office (INE) (please see next table), multiplied by total population, from the INE Census for the years 1981, 1991, 2001, and 2011; intermediate years have been estimated by interpolation. Data on annual per capita protein intake refer to the “Balança Alimentar Portuguesa - BAP” which is updated every five years. The latest data available refer to the 2013 enquiry that considers the 2008-2012 period. Data for 2013 refer to the latest available year (2012). Other parameters used in the estimations are based on the 2006 IPCC defaults.

Table 6.9 – Data and parameters used calculation of NH3 emissions from wastewater

| Parameter | Year | INE data (kg/person/year) |
|---|---|---|
| Annual per capita protein intake | 1990 | 39.2 |
| | 1991 | 40.2 |
| | 1992 | 40.5 |
| | 1993 | 41.2 |
| | 1994 | 41.4 |
| | 1995 | 40.9 |
| | 1996 | 41.1 |
| | 1997 | 41.4 |
| | 1998 | 42.7 |
| | 1999 | 43.8 |
| | 2000 | 43.5 |
| | 2001 | 43.6 |
| | 2002 | 43.9 |
| | 2003 | 43.7 |
| | 2004 | 43.7 |
| | 2005 | 43.2 |
| | 2006 | 44.0 |
| | 2007 | 45.2 |
| | 2008 | 46.0 |
| | 2009 | 46.0 |
| | 2010 | 45.7 |
| | 2011 | 44.8 |
| | 2012 | 43.9 |
| | *2013* | *43.9* |
| | *2014* | *43.9* |
| | *2015* | *43.9* |
| Fraction of nitrogen in protein | 16% | 2006 IPCC default |
| Fraction of non-consumed | 20% | Expert judgement |

Note:
2013 -2015: data refer to 2012.

##### *6.2.5.1.2.3 Emission factors*

The EF proposed by EMEP/CORINAIR (EEA, 2002) was used: 0.3 kg $NH_3$-N/kg sewage-N produced, which is based on the assumption that during storage for one year, approximately 30% of nitrogen is emitted as $NH_3$ in an evaporation process.

### 6.2.5.2 ***Industrial Wastewater***

#### 6.2.5.2.1 NMVOC emissions

##### *6.2.5.2.1.1 Methodology, activity data and parameters*

Emissions were calculated on the basis of an emission factor value of 0.15 mg NMVOC/m3 wastewater, and the quantities of wastewater discharged in m3 for each industry sector considered.

$$EF = 0.15\ mg/m^3\ \text{wastewater} * \text{volumes of wastewater produced}$$

Data on industrial discharges and handling systems types are scattered and difficult to obtain. The approach used in the Portuguese inventory estimates the volumes of industrial wastewater production using statistical production data on industries (IndPROD, t product/yr) multiplied by discharge coefficients (m3/t product).

For each industrial sector identified, several statistical information sources - although obtained from the same institution - had to be used to establish the full time series from 1990 to 2015. Nevertheless, efforts were made to guarantee that the consistency in time series was not impaired by the use of different origins of information.

As regards the sources of information:

- Preference was given to statistical information publicly available from the webpage of the National Statistical Institute (INE) - http://www.ine.pt/prodserv. The use of these data guarantees the absence of confidential issues and usually comprehends the full time-series. It was not possible to use this data for all sectors because the level of disaggregation was seldom compatible with the needs of the inventory;

- The National Statistical Institute (INE) makes periodical annual surveys on industrial production. Unfortunately the survey that was executed until 1991, the IAIT survey, uses a different methodology, than the one that was used in the IAPI survey, that is being used since 1992.

- The IAIT survey was based on an inquiry to each industrial facility, used the Economic Activity Class code rev.1 (CAE rev 1) and a set of specific codes for products and materials. The IAPI survey uses the new revision of the CAE system (CAE rev2), and products and materials use a common code system (PRODCOM) in connection with CAE code. In opposition to the IAIT survey, the IAPI collected data for each company (headquarters). These two surveys are delivered to the APA for inventory purposes, but with the compromise that confidential data could not be published;

- Refining of crude oil and petroleum products was establish from the DGEG's Energy Balance, which data is available annually from 1990 till 2015;

- Production of paper pulp was available directly from the individual industrial plants, for the all period.

Next tables present the building blocks of the activity data time series from the available information. Gaps in mid years were estimated by linear interpolation. In a similar mode, linear extrapolation was used to estimate data for years 1990-1991 and 2001 till 2009, whenever they were not available. All constructed time series were checked against the occurrence of inconsistencies that could appear due to the use of different sources of information76. The checking of the time series was based on graph plotting of the data, and basically the aim was to detected unexpected sudden changes in the magnitude of the time series from 1991 till 1992, when IAIT was changed to IAPI. In some situations the beginning years when IAPI was started had to be discarded, because a sudden and temporary drop from IAIT values was observable and after some years they rise again and continue with a trend compatible with that that existed in IAIT. It was assumed that an adaptation period to the new industrial survey lead to a temporary underestimation of industrial production statistics.

[76] It must be stressed though, that all information sources were produced by the National Statistical Institute (INE). Only methodological procedures for data collection change according to years.

Table 6.10 – Sources of Information used to define the time-series of industrial production (1/2)

| Industry | IAIT<br>CAE rev1 | IAPI<br>PRODCOM | Infoline | Note |
|---|---|---|---|---|
| Slaughter House | | | 1990-2015 | Cattle, sheep, goats and horses |
| Slaughter House, sw ine | | | 1990-2015 | |
| Slaughter House, Poultry | | | 1990-2015 | Broilers, Turkeys, ducks, quails, ostrich, guinea-fow l, geese, pheasants, partridge and pigeons |
| Meat Packing | 311120 | 15130-1513013-151301190200 | - | |
| Milk processing | 3112 | | 1994-2015 | |
| Cheese | 3112 | 15510 | - | |
| Other dairy products | 3112 | | 1994-2015 | Cream, yugurt, pow der milk, ice-creams |
| Fruit and vegetables conservation | 3114 | | 1994-2015 | |
| Tomato juice | | | 1994-2015 | |
| Fruit Juices | 3131+3132 | | 1994-2015 | |
| Fish processing and canning | 3114 | 15200 | - | |
| Olive oil production | | 15412 | - | |
| Olive oil processing | 31152 | 15420113 | - | |
| Edible oils | 31152 | 1541; 1542 | - | Only Olive oil |
| Margarine | 31154 | 1543 | - | |
| Grains milling and processing | 3116 | 156; 15860 | - | |
| Sugar processing | 3118 | 15830 | - | |
| Yeast | | | 1993-2015 | |
| Ethanol | 313110 | 159101070; 1592011 | - | |
| Spirits Distillation | 3131+3132 | 1591010-159101070+1592012 | - | |
| Wine Cellars | 3131+3132 | 15930; 15950 | 2001-2015 | |
| Beer | 3133 | 1596010 | - | |
| Mineral w ater and similars | | | 1993-2015 | |

Table 6.11 – Sources of Information used to define the time-series of industrial production (2/2)

| Industry | IAIT CAE rev1 | IAPI PRODCOM | Infoline | Note |
|---|---|---|---|---|
| Wool production | | 171002021 | - | |
| Wool processing | | 171002027;1710042; 1710053 | - | |
| Synthetic fibres processing | 321130 | 171003031; 171003039;1710052 31/32/33/39/91/92/93 /99;1710055 | 171003039+17 1005231/32/33/ 39/91/92/93/99 +1710055 | |
| Artificial fibres processing | 321130 | 171003050;1710054/ 55 | - | |
| Cotton fibres processing | 321130 | 1710043; 171004553; 171004555; 171004557; 1720020; 173001023 | - | |
| Leather industry | | 19101; 19102 | - | |
| Cork processing | | 2010 | - | AD is cork consumption in all industrial activities |
| Cork granulation | | 2052213; 2052214 | - | |
| Kraft pulping | | | - | LPS Data |
| Acid sulphite pulping | | | - | LPS Data |
| Kraft paper | 3412 | 2112022; 2112023 | - | |
| Wafer board and Strand board | 33 (code 15460) | 20202 | - | |
| Chorine and alkalis | | 241301111; 2413015; 2413022 | - | |
| Inorganic acids | | 2413014-241301453-241301475-241301477 | - | |
| Cyclic Hydrocarbons | | 2414312; 2414314 | - | |
| Aliphatic Hydrocarbons | | 2414311 | - | |
| Synthetic fertilizers | | 2415 | - | Original units is kg N, kg P2O5 and K2O and w ere converted to ton of fertilizer |
| Pesticides | 3512 | 242 | - | |
| Polymers | 351312 | 24160-2416058 | - | |
| Synthetic rubber | | 2417 | - | |
| Artificial fibres production | | 2470023; 247003070 | - | |
| Polyester fibres production | | 247001130; 247001315; 247001350 | - | |
| Acrylic fibres production | | 247001150 | - | |
| Paints, varnishes and lacquers | 3521 | 24301 | - | |
| Pharmaceutical products | | | 1998-2015 | |
| Soaps | | 2451131 | - | |
| detergents | | 2451120/32 | - | |
| Petroleum refining | | | - | Energy Balance (DGGE): 1990-2015 |

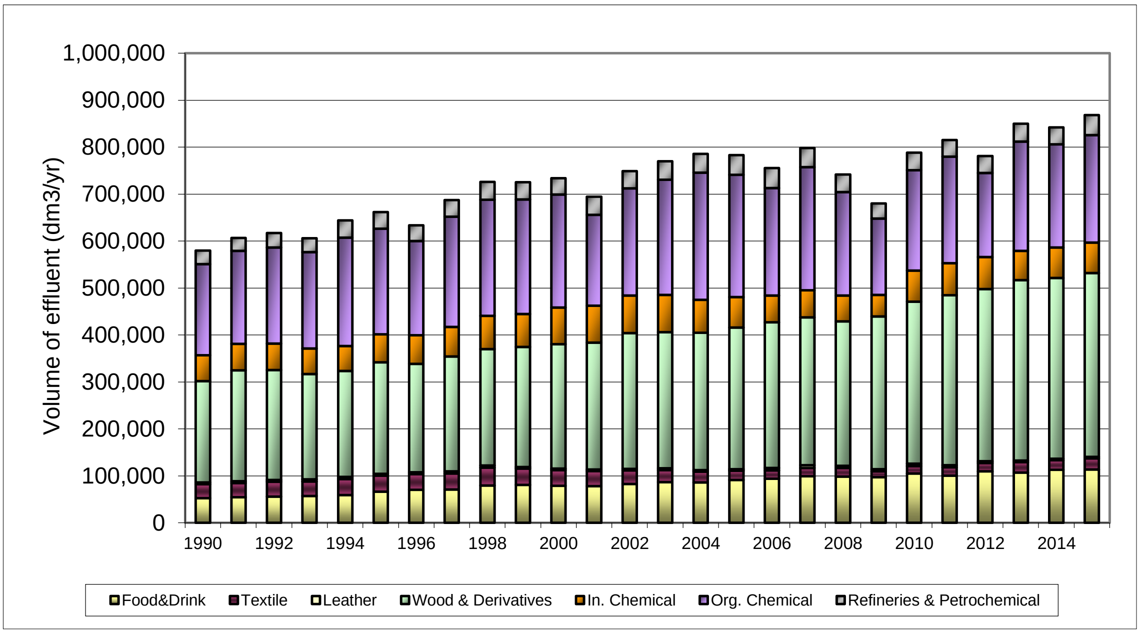
The following table shows the discharge coefficients that were used to estimate the volumes of wastewater produced by industrial sector, having as a basis the coefficients available in Cartaxo et al (1985).

Table 6.12 – Coefficients used to estimate volumes of industrial wastewater production

| Portuguese classification | IPCC industrial branches | Unit prod (PU) | Discharge (m3/PU) |
|---|---|---|---|
| Slaughter House | Meat & Poultry | ton | 6 |
| Slaughter House, swine | Meat & Poultry | ton | 6 |
| Slaughter House, Poultry | Meat & Poultry | ton | 9 |
| Meat Packing | Meat & Poultry | ton | 10 |
| Milk processing | Dairy Products | m3 | 1 |
| Cheese | Dairy Products | m3 milk | 8 |
| Other dairy products | Dairy Products | m3 milk | 5 |
| Fruit and vegetables conservat | Vegetables, Fruits & Juices | ton | 15 |
| Tomato juice | Vegetables, Fruits & Juices | ton | 100 |
| Fruit Juices | Vegetables, Fruits & Juices | ton | 9 |
| Fish processing and canning | Fish Processing | ton | 35 |
| Olive oil production | - | ton olives | 1 |
| Olive oil processing | - | ton | 6 |
| Edible oils | Vegetable Oils | ton | 3 |
| Margarine | Dairy Products | ton | 25 |
| Grains milling and processing | Starch Production | ton | 3 |
| Sugar processing | Sugar Refining | ton | 8 |
| Yeast | - | ton | 120 |
| Ethanol | Alcohol Refining | m3 | 17 |
| Spirits Distillation | Wine & Vinegar | m3 | 8 |
| Wine Cellars | Wine & Vinegar | ton grapes | 2 |
| Beer | Beer & Malt | m3 | 5 |
| Mineral water and similars | Vegetables, Fruits & Juices | ton | 8 |
| Wool production | Textiles (Natural) | ton | 44 |
| Wool processing | Textiles (Natural) | ton | 537 |
| Synthetic fibres processing | Textiles (Natural) | ton | 155 |
| Artificial fibres processing | Textiles (Natural) | ton | 42 |
| Cotton fibres processing | Textiles (Natural) | ton | 317 |
| Leather industry | - | ton | 85 |
| Cork processing | - | ton | 1 |
| Cork granulation | - | m3 | 1 |
| Kraft pulping | Pulp & Paper (Combined) | ton | 140 |
| Acid sulphite pulping | Pulp & Paper (Combined) | ton | 270 |
| Kraft paper | Pulp & Paper (Combined) | ton | 14 |
| Wafer board and Strand board | - | ton | 1 |
| Chorine and alkalis | - | ton ClNa | 28 |
| Inorganic acids | - | ton | 100 |
| Cyclic Hydrocarbons | Organic Chemicals | ton | 190 |
| Aliphatic Hydrocarbons | Organic Chemicals | ton | 190 |
| Synthetic fertilizers | - | ton | 15 |
| Pesticides | Drugs & Medicines | ton | 4 |
| Polymers | Plastics & Resins | ton | 15 |
| Synthetic rubber | Plastics & Resins | ton | 15 |
| Artificial fibres production | Plastics & Resins | ton | 300 |
| Polyester fibres production | Plastics & Resins | ton | 348 |
| Acrylic fibres production | Plastics & Resins | ton | 65 |
| Paints, varnishes and lacquers | Paints | ton | 0 |
| Pharmaceutical products | - | employe | 0 |
| Soaps | Soap & Detergents | ton | 4 |
| Detergents | Soap & Detergents | ton | 3 |
| Petroleum refining | Petroleum Refineries | ton | 2 |

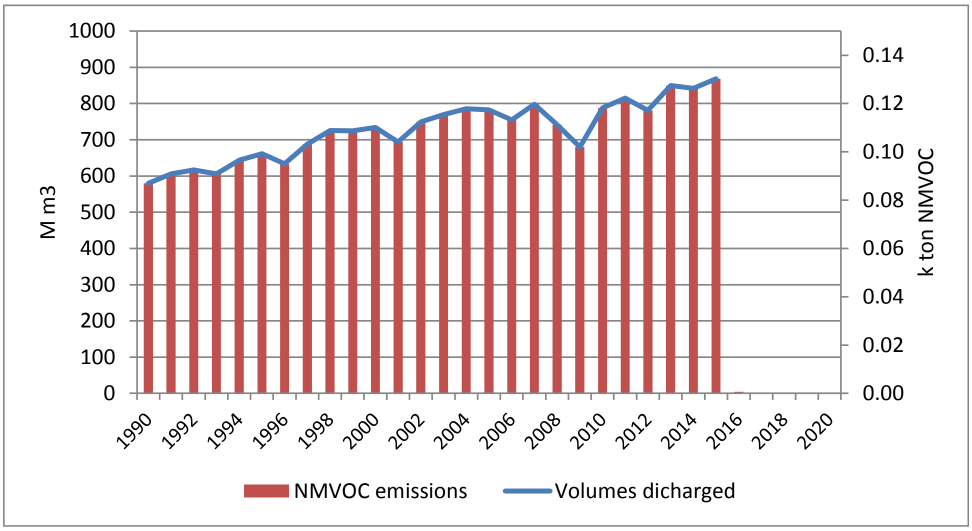
Total wastewater load aggregated per industrial group is presented in the Figure below, from where it is evident the predominant importance of wastewater loads from the industry of wood and wood derivatives and from the organic industry.

Figure 6.14 – Industrial Wastewater discharges, expressed in 1000 m³, from major groups of industrial activity




Next Figure presents the estimated total volumes of industrial wastewater produced and the related NMVOC emissions during the period analysed.

Figure 6.15 – Total industrial wastewater discharge and NMVOC emissions




### 6.2.6 Emissions from other waste: landfill gas and other biogas burning (NFR5 E)

The capture and burning of landfill gas and biogas (e.g. from sewage sludge) is used for energy purposes or flaring (without energy recovery). Emissions from the combustion of landfill gas and biogas captured should be included in the energy sector when there is energy recovery, or in the waste sector when is flared.

For practical reasons all information related to the estimates of emissions from biogas combustion (with and without energy recovery) is presented here. However, the emissions related to energy recovery situations are accounted in sector 1A1a, and the emissions resulting from flaring are considered in category 5E.

#### 6.2.6.1 *Methodology*

Emissions from the combustion of landfill gas and biogas with and without energy recovery have been estimated using emission factors based on the energy or the mass of the biogas consumed (combusted).

### 6.2.6.2 *Activity data and parameters*

Table 6.13 – Activity data, emission factors and emissions resulting from landfill gas and biogas combusted

| ***Quantities of landfill gas and biogas combusted*** | | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Electrical production a) | GJ | 38,031 | 28,056 | 30,216 | 24,647 | 146,555 | 342,822 | 317,318 | 536,868 | 787,149 | 968,432 | 1,261,021 | 1,668,286 | 2,051,425 | 2,335,114 | 2,575,738 | 2,354,043 |
| | Flaring b) | GJ | - | - | - | - | - | 266,085 | 440,544 | 420,404 | 416,178 | 356,085 | 287,131 | 60,069 | not available | not available | not available | 30,104 |

| ***Emission factors*** | | | |
|---|---|---|---|
| | NOx | g/GJ | 74 |
| | NMVOC | g/GJ | 23 |
| | CO | g/GJ | 29 |
| | SOx | g/GJ | 0.67 |
| | TSP | g/GJ | 0.78 |
| | PM10 | g/GJ | 0.78 |
| | PM2.5 | g/GJ | 0.78 |
| | BC | % PM2.5 | 4 |
| | Pb | mg/GJ | 0.011 |
| | Cd | mg/GJ | 0.0009 |
| | Hg | mg/GJ | 0.54 |
| | As | mg/GJ | 0.1 |
| | Cr | mg/GJ | 0.013 |
| | Cu | mg/GJ | 0.0026 |
| | Ni | mg/GJ | 0.013 |
| | Se | mg/GJ | 0.058 |
| | Zn | mg/GJ | 0.73 |
| | DioxFur | nano g TEQ/GJ | 0.52 |
| | PAHs | microg/GJ | 5.8 |

(cont.)

| *Emissions with energy recovery (CRF 1A1a)* | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOx | ton | 2.8 | 2.1 | 2.2 | 1.8 | 10.8 | 25.4 | 21.8 | 43.1 | 61.1 | 65.1 | 84.8 | 128.2 | 164.0 | 191.3 | 215.7 | 218.6 |
| NMVOC | ton | 0.875 | 0.645 | 0.695 | 0.567 | 3.371 | 7.885 | 6.786 | 13.386 | 18.998 | 20.240 | 26.358 | 39.857 | 50.963 | 59.458 | 67.053 | 67.952 |
| CO | ton | 1.103 | 0.814 | 0.876 | 0.715 | 4.250 | 9.942 | 8.556 | 16.878 | 23.954 | 25.519 | 33.234 | 50.255 | 64.258 | 74.969 | 84.545 | 85.678 |
| SOx | ton | 0.025 | 0.019 | 0.020 | 0.017 | 0.098 | 0.230 | 0.198 | 0.390 | 0.553 | 0.590 | 0.768 | 1.161 | 1.485 | 1.732 | 1.953 | 1.979 |
| TSP | ton | 0.030 | 0.022 | 0.024 | 0.019 | 0.114 | 0.267 | 0.230 | 0.454 | 0.644 | 0.686 | 0.894 | 1.352 | 1.728 | 2.016 | 2.274 | 2.304 |
| PM10 | ton | 0.030 | 0.022 | 0.024 | 0.019 | 0.114 | 0.267 | 0.230 | 0.454 | 0.644 | 0.686 | 0.894 | 1.352 | 1.728 | 2.016 | 2.274 | 2.304 |
| PM2.5 | ton | 0.030 | 0.022 | 0.024 | 0.019 | 0.114 | 0.267 | 0.230 | 0.454 | 0.644 | 0.686 | 0.894 | 1.352 | 1.728 | 2.016 | 2.274 | 2.304 |
| BC | ton | 0.001 | 0.001 | 0.001 | 0.001 | 0.005 | 0.011 | 0.009 | 0.018 | 0.026 | 0.027 | 0.036 | 0.054 | 0.069 | 0.081 | 0.091 | 0.092 |
| Pb | ton | 0.0000004 | 0.0000003 | 0.0000003 | 0.0000003 | 0.0000016 | 0.0000038 | 0.0000035 | 0.0000059 | 0.0000087 | 0.0000107 | 0.0000139 | 0.0000184 | 0.0000226 | 0.0000257 | 0.0000283 | 0.0000259 |
| Cd | ton | 0.00000003 | 0.00000003 | 0.00000003 | 0.00000002 | 0.00000013 | 0.00000031 | 0.00000029 | 0.00000048 | 0.00000071 | 0.00000087 | 0.00000113 | 0.00000150 | 0.00000185 | 0.00000210 | 0.00000232 | 0.00000212 |
| Hg | ton | 0.0000205 | 0.0000152 | 0.0000163 | 0.0000133 | 0.0000791 | 0.0001851 | 0.0001714 | 0.0002899 | 0.0004251 | 0.0005230 | 0.0006810 | 0.0009009 | 0.0011078 | 0.0012610 | 0.0013909 | 0.0012712 |
| As | ton | 0.0000038 | 0.0000028 | 0.0000030 | 0.0000025 | 0.0000147 | 0.0000343 | 0.0000317 | 0.0000537 | 0.0000787 | 0.0000968 | 0.0001261 | 0.0001668 | 0.0002051 | 0.0002335 | 0.0002576 | 0.0002354 |
| Cr | ton | 0.0000005 | 0.0000004 | 0.0000004 | 0.0000003 | 0.0000019 | 0.0000045 | 0.0000041 | 0.0000070 | 0.0000102 | 0.0000126 | 0.0000164 | 0.0000217 | 0.0000267 | 0.0000304 | 0.0000335 | 0.0000306 |
| Cu | ton | 0.0000001 | 0.0000001 | 0.0000001 | 0.0000001 | 0.0000004 | 0.0000009 | 0.0000008 | 0.0000014 | 0.0000020 | 0.0000025 | 0.0000033 | 0.0000043 | 0.0000053 | 0.0000061 | 0.0000067 | 0.0000061 |
| Ni | ton | 0.0000005 | 0.0000004 | 0.0000004 | 0.0000003 | 0.0000019 | 0.0000045 | 0.0000041 | 0.0000070 | 0.0000102 | 0.0000126 | 0.0000164 | 0.0000217 | 0.0000267 | 0.0000304 | 0.0000335 | 0.0000306 |
| Se | ton | 0.0000022 | 0.0000016 | 0.0000018 | 0.0000014 | 0.0000085 | 0.0000199 | 0.0000184 | 0.0000311 | 0.0000457 | 0.0000562 | 0.0000731 | 0.0000968 | 0.0001190 | 0.0001354 | 0.0001494 | 0.0001365 |
| Zn | ton | 0.0000278 | 0.0000205 | 0.0000221 | 0.0000180 | 0.0001070 | 0.0002503 | 0.0002316 | 0.0003919 | 0.0005746 | 0.0007070 | 0.0009205 | 0.0012178 | 0.0014975 | 0.0017046 | 0.0018803 | 0.0017185 |
| DioxFur | g I-TEQ | 0.00002 | 0.00001 | 0.00002 | 0.00001 | 0.00008 | 0.00018 | 0.00017 | 0.00028 | 0.00041 | 0.00050 | 0.00066 | 0.00087 | 0.00107 | 0.00121 | 0.00134 | 0.00122 |
| PAHs | ton | 0.0000002 | 0.0000002 | 0.0000002 | 0.0000001 | 0.0000009 | 0.0000020 | 0.0000018 | 0.0000031 | 0.0000046 | 0.0000056 | 0.0000073 | 0.0000097 | 0.0000119 | 0.0000135 | 0.0000149 | 0.0000137 |
| *Emissions without energy recovery (CRF 6D)* | | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** |
| NOx | ton | - | - | - | - | - | 19.7 | 32.6 | 31.1 | 30.8 | 26.4 | 21.2 | 4.4 | 0.0 | 0.0 | 0.0 | 2.2 |
| NMVOC | ton | - | - | - | - | - | 6.1 | 10.1 | 9.7 | 9.6 | 8.2 | 6.6 | 1.4 | 0.0 | 0.0 | 0.0 | 0.7 |
| CO | ton | - | - | - | - | - | 7.7 | 12.8 | 12.2 | 12.1 | 10.3 | 8.3 | 1.7 | 0.0 | 0.0 | 0.0 | 0.9 |
| SOx | ton | - | - | - | - | - | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TSP | ton | - | - | - | - | - | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PM10 | ton | - | - | - | - | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PM2.5 | ton | - | - | - | - | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BC | ton | - | - | - | - | - | 0.00006 | 0.00011 | 0.00010 | 0.00010 | 0.00009 | 0.00007 | 0.00001 | 0.00000 | 0.00000 | 0.00000 | 0.00001 |
| Pb | ton | - | - | - | - | - | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Cd | ton | - | - | - | - | - | 0.0000002 | 0.0000004 | 0.0000004 | 0.0000004 | 0.0000003 | 0.0000003 | 0.0000001 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| Hg | ton | - | - | - | - | - | 0.0001437 | 0.0002379 | 0.0002270 | 0.0002247 | 0.0001923 | 0.0001551 | 0.0000324 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000163 |
| As | ton | - | - | - | - | - | 0.0000266 | 0.0000441 | 0.0000420 | 0.0000416 | 0.0000356 | 0.0000287 | 0.0000060 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000030 |
| Cr | ton | - | - | - | - | - | 0.0000035 | 0.0000057 | 0.0000055 | 0.0000054 | 0.0000046 | 0.0000037 | 0.0000008 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000004 |
| Cu | ton | - | - | - | - | - | 0.0000007 | 0.0000011 | 0.0000011 | 0.0000011 | 0.0000009 | 0.0000007 | 0.0000002 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000001 |
| Ni | ton | - | - | - | - | - | 0.0000035 | 0.0000057 | 0.0000055 | 0.0000054 | 0.0000046 | 0.0000037 | 0.0000008 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000004 |
| Se | ton | - | - | - | - | - | 0.0000154 | 0.0000256 | 0.0000244 | 0.0000241 | 0.0000207 | 0.0000167 | 0.0000035 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000017 |
| Zn | ton | - | - | - | - | - | 0.0001942 | 0.0003216 | 0.0003069 | 0.0003038 | 0.0002599 | 0.0002096 | 0.0000439 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000220 |
| DioxFur | g I-TEQ | - | - | - | - | - | 0.0001384 | 0.0002291 | 0.0002186 | 0.0002164 | 0.0001852 | 0.0001493 | 0.0000312 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000157 |
| PAHs | | | | | | | 0.0000015 | 0.0000026 | 0.0000024 | 0.0000024 | 0.0000021 | 0.0000017 | 0.0000003 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000002 |

Notes:

a) DGEG data
b) APA´s questionnaires.

### 6.2.7 Emissions from other waste: car and house fires. (NFR 5E)

This category includes mostly unwanted fires in cars and various types of houses.

Emissions from fires include emissions of particulates, heavy metals and main pollutants such as NOx, SO2, CO and non-methane volatile organic compounds (NMVOC).

#### 6.2.7.1 *Methodology, activity data and emission factors*

Emissions were calculated on the basis of an emission factor porposed in the 2016 EEAGuidebook, for occurences referring to car fires, and residential and industrial buildings.

## 6.3 Recalculations

The recalculations made since last submission result mainly from updates of EF proposed by the latestest EEA Guidebook and 2006 IPCC Guidelines..

## 6.4 Further improvements

Since the restructuration of the National Water Authority (ex-INAG), the referred "Inventário Nacional de Sistemas de Abastecimento de Água e Águas Residuais (INSAAR)", the national data base for wastewater treatment systems, has been deactivated. Alternative data sources have to be developed or a new methodological approach should be followed in order to update the time series for the whole period in a consistent way.

Considering the limitations in the time trend in load and the share of each treatment system concerning industrial wastewater handling, efforts will continue in order to improve the assessment of the situation concerning industrial wastewater. These should include the development of a data base aggregating information collected under different schemes: IPPC, PRTR and information from the discharge permits.

# 7 MEMO ITEMS

## 7.1 Wildfires (NFR 11.B)

Forest fires are the main disturbance to forests in Portugal and have a substantial impact on the Portuguese forest. The level of disturbances on a forest varies with the type and severity of the fire, the conditions under which they occur and the characteristics of the ecosystem. Different tree species have different strategies to cope with the effects of fire and the actual mortality caused by fires depend on the ecosystem types or climatic zones.

Forest fires are highly correlated to weather conditions, both within each year (about 90% of the fires take place during period June-September, usually the hotter and drier months of the year), and between years (years with hot and dry summers have much higher burnt areas than years with mild and wet summers).

### 7.1.1 Activity data and parameters

#### 7.1.1.1 *Estimation of Burnt Areas*

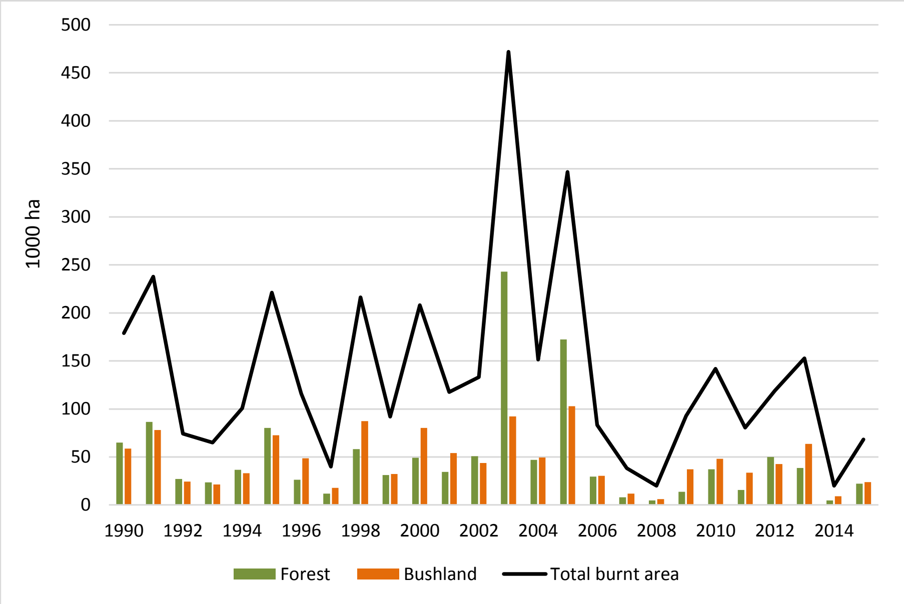
The main source of burnt areas are the fire reports issued every year by the National Forest Authority, currently the Institute for Nature Conservation and Forestry. The reports are derived from satellite imagery and the results cover all burnt areas, divided by forest, shrubland and agriculture.

ICNF reports provide also annual burnt area per forest type, comparing annual forest fire cartography with the NFI plots. For other land uses only the total aggregated area is presented. To estimate the burnt areas per other land use type the following assumptions were made:

1. No burnt areas in the categories: irrigated crops, rice paddies

2. Agriculture burnt area reported in fire statistics distributed proportionally to reported area per land-use type, for all other cropland and grassland types

Figure 7.1 – Wildfires: annual area burnt (1000 hectares)




Source: ICNF.

#### 7.1.1.2 *Estimation of Biomass Loss due to Fires*

The estimates consider the above ground biomass for forest trees, the undergrowth cover, and biomass from litter existing in forest land.

Schrubland ("matos") is also considered in the inventory, despite the fact that it is generally non-managed land. This submission considers also the biomass burning in croplands and grasslands.

The loss of biomass during forest fires was estimated by multiplying the above ground biomass in each land-use with its combustion factor.

According to Rosa (2009) forest fire emissions are much more related to biomass of smaller sizes than to total biomass, as they tend to present much higher combustion factors.

An estimation of the finer particles present in forest was made identifying the following components: leaves, small branches, litter and understory shrubs (woody vegetation under the canopy of species that do not reach 5m at maturity). The basis for this calculation is the biomass values presented in next table.

As there were no values on combustion factors for these land-use types, a conservative approach was taken and the combustion factor was assumed to be 100%, which is very likely an overestimation.

A summary of the values used in estimating biomass loss due to fires is presented in next Table.

Table 7.1 – Combustion Factors per Biomass Component used in the Estimation of Fire Emissions

| | Share of AG Tree Biomass | | Combustion Factor | | | | |
|---|---|---|---|---|---|---|---|
| Land-use Type | Leaves % | Small branches % | Leaves % | Small branches % | Litter % | Shrubs % | AG Biomass % |
| Pinus pinaster | 7% | 11% | 88% | 58% | 75% | 72% | - |
| Quercus suber | 13% | 21% | 88% | 58% | 75% | 72% | - |
| Eucalyptus spp. | 9% | 7% | 88% | 58% | 75% | 72% | - |
| Quercus rotundifolia | 16% | 27% | 88% | 58% | 75% | 72% | - |
| Quercus spp. | 21% | 54% | 88% | 58% | 75% | 72% | - |
| Other broadleaves | 21% | 54% | 88% | 58% | 75% | 72% | - |
| Pinus pinea | 5% | 8% | 88% | 58% | 75% | 72% | - |
| Other coniferous | 8% | 12% | 88% | 58% | 75% | 72% | - |
| Rainfed annual crops | - | - | - | - | - | - | 100% |
| Irrigated annual crops | - | - | - | - | - | - | - |
| Rice padies | - | - | - | - | - | - | - |
| Vineyards | - | - | - | - | - | - | 100% |
| Olive groves | - | - | - | - | - | - | 100% |
| Other permanent crops | - | - | - | - | - | - | 100% |
| All grasslands | - | - | - | - | - | - | 100% |
| Wetlands | - | - | - | - | - | - | - |
| Settlements | - | - | - | - | - | - | - |
| Shrubland | - | - | - | - | 75% | 72% | - |
| Other | - | - | - | - | - | - | - |

### 7.1.2 Methodology

The estimates of non-$CO_2$ gas emissions are based on the IPCC 1996 Revised Guidelines (IPCC,1997) methodology, which are based on ratios to carbon released during combustion ($L_{Direct}$).

The carbon trace gas emissions (CO and NMVOC) are calculated using direct ratios to total carbon. Total suspended particles (TSP) have also been estimated applying a direct ratios to total carbon. To estimate nitrogen trace gas releases ($NO_x$), the total carbon released is first multiplied by the N/C ration (0.01) to get the total nitrogen released; the emissions of $NO_x$ are then calculated multiplying the total N released by the $NO_x$ emissions ratios to the total N released.

Emissions ratios:

IPCC 1996 - CO: 0.06; NOx: 0.121

AP-42 - NMVOC: 0.0068, TSP: 0.0085

Emissions estimation:

Emissions NMVOC (expressed as CH4) = $L_{Direct}$ * emission ratio * 16/12

Emissions CO = $L_{Direct}$ * emission ratio * 28/12

Emissions TSP = $L_{Direct}$ * emission ratio

Emissions NOx = $L_{Direct}$ * ratio N/C (0.01) * emission ratio * 46/14

#### 7.1.2.1 *Carbon losses due to wildfires*

The annual carbon loss in living biomass resulting from wildfires was estimated based on direct carbon loss, and was calculated as follows:

$$L_{Direct} = \sum A_{burnt,j} \times B_{ABG,j} \times (B_{leafs,j} \times BCF_{leafs,j} + B_{branches,j} \times BCF_{branches,j})$$

where:

$L_{Direct}$ = annual carbon loss, Gg C

$j$ = corresponds to forest type *j* or crop type or grassland or scrubland

$A_{burnt,j}$ = Area burnt, kha

$B_{ABG}$ = Average C stock in above ground biomass, Gg C.kha$^{-1}$

$B_{leafs}$ = Percentage of leaf's biomass in above ground biomass, %

$BCF_{leafs}$ = Combustion factor of leafs, %

$B_{branches}$ = Percentage of small branches' biomass in above ground biomass, %

$BCF_{branches}$ = Combustion factor of small branches, %

In the case of cropland, grassland the combustion factor for above ground biomass is considered to be 100%, assuming that all the biomass is burnt. For schrubland the combustion factor considered is 72%.

Other carbon losses, called here indirect, can be estimated on the basis of tree mortality, as a consequence of fires. However, as the accounting of these losses only affects $CO_2$ emissions from non-salvaged wood, they have not been considered in this submission (only in UNFCCC submission).

Emissions of air pollutants depend on the fuel type and fuel loading, among other factors.

In this submission, the estimates consider the tree species burnt and their respective biomass volumes and dry matter content.

Table 7.2 – Average Carbon Stocks ($B_{ABG}$) in Above Ground Living Biomass and Litter per Land Use Type

| Average Carbon Stocks per Landuse Type | Above Ground Biomass | | | Litter | Notes |
|---|---|---|---|---|---|
| | 1995 GgC/1.000ha | 2005 GgC/1.000ha | 2010 GgC/1.000ha | All years GgC/1.000ha | |
| Pinus pinaster | 28.29 | 26.74 | 26.74 | 2.96 | (1); (8) |
| Quercus suber | 20.67 | 20.04 | 20.04 | 2.04 | (1); (8) |
| Eucalyptus spp. | 16.72 | 17.97 | 17.97 | 1.85 | (1); (8) |
| Quercus rotundifolia | 9.47 | 8.37 | 8.37 | 2.04 | (1); (8) |
| Quercus spp. | 15.45 | 15.87 | 15.87 | 1.85 | (1); (8) |
| Other broadleaves | 20.40 | 30.79 | 30.79 | 1.85 | (1); (8) |
| Pinus pinea | 25.40 | 18.79 | 18.79 | 2.41 | (1); (8) |
| Other coniferous | 8.70 | 14.51 | 14.51 | 2.96 | (1); (8) |
| Rainfed annual crops | 0.31 | 0.31 | 0.31 | 0.33 | (4) |
| Irrigated annual crops (except rice) | 0.31 | 0.31 | 0.31 | 0.33 | (4) |
| Rice padies | 0.31 | 0.31 | 0.31 | 0.33 | (4) |
| Vineyards | 3.34 | 3.34 | 3.34 | 0.33 | (5); (6) |
| Olive groves | 7.85 | 7.85 | 7.85 | 0.33 | (5); (6) |
| Other permanent crops | 8.46 | 8.46 | 8.46 | 0.33 | (5); (6) |
| All grasslands | 0.53 | 0.53 | 0.53 | 0.41 | (2) |
| Wetlands | 0.00 | 0.00 | 0.00 | 0.00 | (9) |
| Settlements | 0.00 | 0.00 | 0.00 | 0.00 | (9) |
| Shrubland | 8.78 | 8.78 | 8.78 | 4.96 | (3) |
| Other | 1.05 | 1.05 | 1.05 | 2.07 | (7) |

*(1) Living biomass calculated from NFI4 (1995), NFI5 (2005) and NFI6 (2010). NFI6 data will be available in 2013; NIR 2013*
*(2) Calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Grassland vegetated*
*(3) Calculated from Rosa 2009 "Estimativa das emissões de gases com efeito de estufa"*
*(4) Calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Grassland vegetated*
*(5) Litter calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Non-forest class*
*(6) Living biomass from NIR Spain 2012, Tabla 7.3.3, page 7.59*
*(7) Calculated from EMEP/EEA emission inventory guidebook 2009, Chapter 11b Forest fires, Table 2-1 "Sparsely vegetated ar*
*(8) Litter values from expert judgement based on Rosa 2009 "Estimativa das emissões de gases com efeito de estufa", Quad*
*(9) No values were found in literature; assumed = 0*

## 7.2 NMVOC Biogenic Emissions (NFR 11.C)

### 7.2.1 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 1, 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.

### 7.2.2 Methodology

#### 7.2.2.1 *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:

$$Emi\_NMVOC_{(s,t)} = \Sigma_n [(EF\_Iso_{(s,n)} + EF\_Mono_{(s,n)} + EF\_OVOC_{(s,n)}) * Veget_{AREA(s,n)}] * 10^{-6}$$

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.

#### 7.2.2.2 *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):

$$Resin\_NMVOC_{(s)} = \Sigma_n [(EF\_tapping_{(n)} * N_{tappedtrees(n)}] * 10^{-3}$$

where,

$Resin\_NMVOC_{(s)}$ - Emissions of NMVOC resulting from resin tapping in Maritime pine, added over all national territory, in year t (t/yr);

$EF\_Tapping_{(n)}$ - VOC emission factor for resin tapping at territorial unit n (mg/tree/yr);

$N_{tappedtrees(n)}$ - Number of trees (millions) subjected to resin-tapping in territorial unit n;

### 7.2.3 Emission Factors

Two different situations exist in what concern the determination of emission factors.

#### 7.2.3.1 *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:

$$EF_{(s,n,t,c)} = D_{(s)} * \varepsilon_{(s,c)} * \gamma_{(n,t,c)} * 10 / CC_{(s)}$$

where,

$EF_{(s,n,t,c)}$ - Emission factor (g/ha/yr) for compound c;

$CC_{(s)}$ - Carbon content of compound c;

$D_{(s)}$ - Foliar density (kg dm/m$^2$) for each specific species, averaged over the vegetation period;

$\varepsilon_{(s,c)}$ - specie or ecosystem dependent emission factor (µgC/g dm/yr) at standard conditions (PAR flux of 1000 µgmol/m2/s and leaf temperature of 303.15 K). Varies with each specific compound;

$\gamma_{(n,t,c)}$ - non-dimensional adjustment factor accounting for the influence of light (PAR) and leaf temperature. This parameter changes in time, according to meteorological conditions, and it is function of each particular compound;

PAR - Photosynthetically active radiation (400-700 nm), typically about 45-50% of total global radiation (mmol-photons/m$^2$/s).

Values for D and $\varepsilon$ where set from available bibliographic references and are presented in next Table 7.3. For deciduous species D is zero during the coldest period, which is also presented in Table 7.3 [77]:

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.

[77] During this period emissions from foliage are obviously zero.

Table 7.3 – Meteorological independent parameters used to determine foliage emission factors

| **Tree Specie** | | **D** | | **Vegetation Period** | **□** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **kd dm/m2** | | | **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 | |
| 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, P. 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 7.4 | | 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 | Guenther et al, 1994 |
| 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 | |

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/m²/s)

$C_T$, the temperature dependence is described by:

$$C_T = \frac{\exp\left[\frac{95\,000 * (T - Ts)}{R * T * Ts}\right]}{1 + \exp\left[\frac{230\,000 * (T - 314)}{R * T * Ts}\right]}$$

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:

$$\gamma = \exp\left[\beta * (T - T_s)\right]$$

Where

$\beta$ is a constant, assumed 0.09 $K^{-1}$ (Guenther et al, 1993),

T is leaf temperature (K) and

$T_s$ is standard temperature (303 K)

This same equation was used for OVOC following recommendations in Geron et al (1999) and in the EMEP/CORINAIR (Chapter B1101) (EEA,2002).

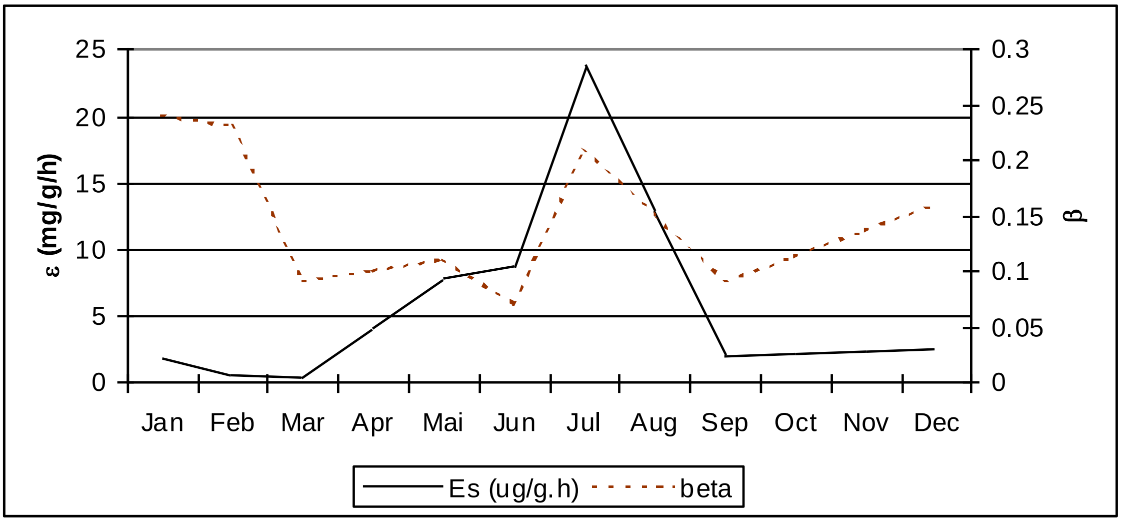
For some species however, this general formulation was not used but it is replaced by country specific equations. This is particularly the case for cork and Holm oaks, where monoterpene emissions are also function of light[78]. These equations are summarized in table 9.2.

[78] 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 7.4 – Specie and country specific equations for γ

| Specie | Compound | Equation | Reference |
|---|---|---|---|
| P. Pinaster | Monoterpernes | $\gamma = \exp[0.138 * (T-30)]$ | Pio et al (1999) |
| Eucalyptus | Monoterpenes | $\gamma = \exp[0.07 * (T-30)]$ | Nunes (1996) |
| Cork Oak | Isoprene | $\gamma = \{CL*CT + \exp[\beta* (T-Ts)]\}$ | 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 | $\gamma = \{CL*CT + \exp[0.09* (T-Ts)]\}$ | |

Figure 7.2 - Time variable ε for Cork Oak (adapted from Silva et al (1999))




The γ parameter was determined for each tree specie (s) for each territorial unit, n (nut 3 level) from climatic data for a typical day of 12 hours for each month of the year according to the following equation:

$$\gamma_{(n,s)} = \Sigma_{m,h} \{\gamma[PAR_{(n,m,h)},T_{(n,m,h)},s]\}$$

where,

$\gamma[PAR_{(n,m,h)},T_{(n,m,h)},s]$ - γ estimate for a specific hour h of a typical day a particular month m, calculated according to the specific equation for tree specie s;

$PAR_{(n,m,h)},T_{(n,m,h)}$ - Photosynthetically active radiation of hour h of month m in territorial unit n;

$T_{(n,m,h)}$ - Leaf temperature of hour h of month m in territorial unit n.

#### 7.2.3.2 *Other agricultural areas and grasslands*

For other agricultural areas and grasslands, the emission factor is simply a constant value, that is not a function of climatic conditions and hence not specific of each territorial area., and that is expressed in mg C/m²h. The considered values in the Portuguese inventory, from (Veldt,1991; Veldt,1998), are presented in table 9.3.

Table 7.5 – Emission Factors of NMVOC for biogenic emissions from agricultural areas, except olives, orchards and vine

| Crop | Isoprene | Monoterpene | OVOC | NMVOC |
|---|---|---|---|---|
| | µgC/m2/h | | | µg/m2/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

#### 7.2.3.3 *Resin-tapping*

The emission factor for resin-tapping, per tree in extraction, follows the equation proposed by Pio & Valente (1998), for each particular condition:

$$\log10[EF\_tapping_{(m,h)}] = 0.631 + 0.06 * T$$

where,

$EF\_tapping_{(m,h)}$ - VOC emission rate from resin-tapping (mg VOC/hr/tree) for a specific time;

T - Air temperature (ºC).

The annual emission factor for each territorial unit was obtained by the addition of the emission factors for each hourly period in a year:

$$EF\_tapping_{(n)} = \Sigma_{m,h} \{EF\_Tapping_{(m,h)}\}$$

### 7.2.4 Activity Data

Basic activity data is the area for each crop or plant species. This information was available from AFN for years 1990 and 1995 and was interpolated and extrapolated[79] for the remaining time-series. Foliage areas for each tree specie were obtained according to the following equation:

$$Foliage\_Area_{(n,s)} = Pure_{(n,s)} + 0.75 * Dominant_{(n,s)} + 0.25 * Dominated_{(n,s)} + Dispersed_{(n,s)}$$

where,

$Foliage\_Area_{(n,s)}$ - total area covered by foliage of tree specie s in territorial unit n (ha);

$Pure_{(n,s)}$ - Land area occupied by pure strands of specie s in territorial unit n (ha);

$Dominant_{(n,s)}$ - Land area occupied by mixed strands where specie s is dominant, in territorial unit n (ha);

[79] Linear interpolation

Dominated$_{(n,s)}$ - Land area occupied by mixed strands where specie s is non-dominant, in territorial unit n (ha);

Dispersed$_{(n,s)}$ - Dispersed arboreal areas inter-mixed in non-forest areas forming small woodland areas (Bosquetes) (ha).

Table 7.6 – Forest Area per tree species (ha)

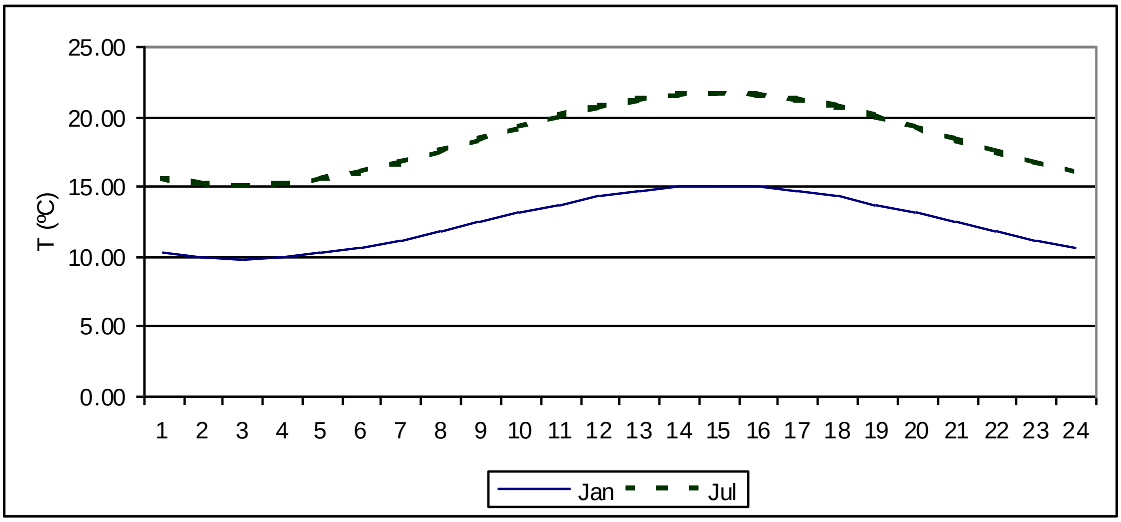
| specie | 1990 | 1995 | 2000 | 2005 | Last year |
|---|---|---|---|---|---|
| Pinus pinaster | 1,069,000 | 976,069 | 974,015 | 741,741 | 741,741 |
| P. Pinea | 35,000 | 77,650 | 83,559 | 102,143 | 77,650 |
| Other conifer | 69,000 | 27,358 | 29,440 | 46,499 | 70,992 |
| Quercus suber | 693,000 | 712,813 | 728,693 | 851,958 | 851,958 |
| Q. Rotundifolia | 462,000 | 461,577 | 465,295 | 420,244 | 420,244 |
| Other oaks | 123,000 | 130,899 | 130,078 | 117,900 | 117,900 |
| Castanea sativa | 37,000 | 40,579 | 40,324 | 28,200 | 28,200 |
| Eucalyptus sp. | 554,000 | 672,149 | 677,599 | 678,741 | 678,741 |
| Other broadleaves | 98,000 | 102,037 | 106,994 | 131,373 | 131,373 |
| Mixed, other | 0 | 0 | 0 | 0 | 0 |
| Bushlands (Matos) | 1,734,822 | 2,054,571 | 2,054,571 | 2,054,571 | 2,054,571 |
| Olive groves | 337,189 | 333,144 | 369,162 | 376,524 | 343,219 |
| Orchards and vineyards | 428,506 | 406,712 | 378,054 | 379,680 | 307,578 |
| Arable land | 2,349,298 | 2,140,174 | 1,692,107 | 1,240,701 | 833,209 |
| Rice | 33,824 | 21,726 | 23,859 | 21,938 | 29,120 |
| Pasture | 857,733 | 1,024,373 | 1,389,845 | 1,768,616 | 1,786,434 |
| Market gardening | 31,980 | 27,825 | 21,608 | 21,408 | 16,943 |
| Resin tapping (Mtree) | 35 | 35 | 35 | 35 | 35 |

For the determination of emissions from resin-tapping the number of pine trees under extraction must be known. Pio & Valente (1998) estimated that this number is about 35 million trees in the 1980-1990 period. After 1990 the same authors believe that there has been a decrease in the number of trees explored, but no statistical information is available

For the calculation of the emission factors it is necessary, as mentioned before, the knowledge of PAR and leaf temperature. These were set for each hour of the day and each month according to the following information.

A time series of 30 years (1951-1980) of average minimum and maximum air temperature, for each month and territorial unit, were used to establish a typical evolution of daily temperature, for each month of the year and each territorial unit. A cosine function was considered with a peak of air temperature occurring at 15.00 (2 PM). In the following figure there is an example for the daily evolution of air temperatures in January and July for Madeira Island.

Figure 7.3 – Cosine modelling of daily evolution of air temperatures in January and July in Madeira Island region. Obtained for average minimum and maximum monthly temperatures in 1951-1980 (INMG)

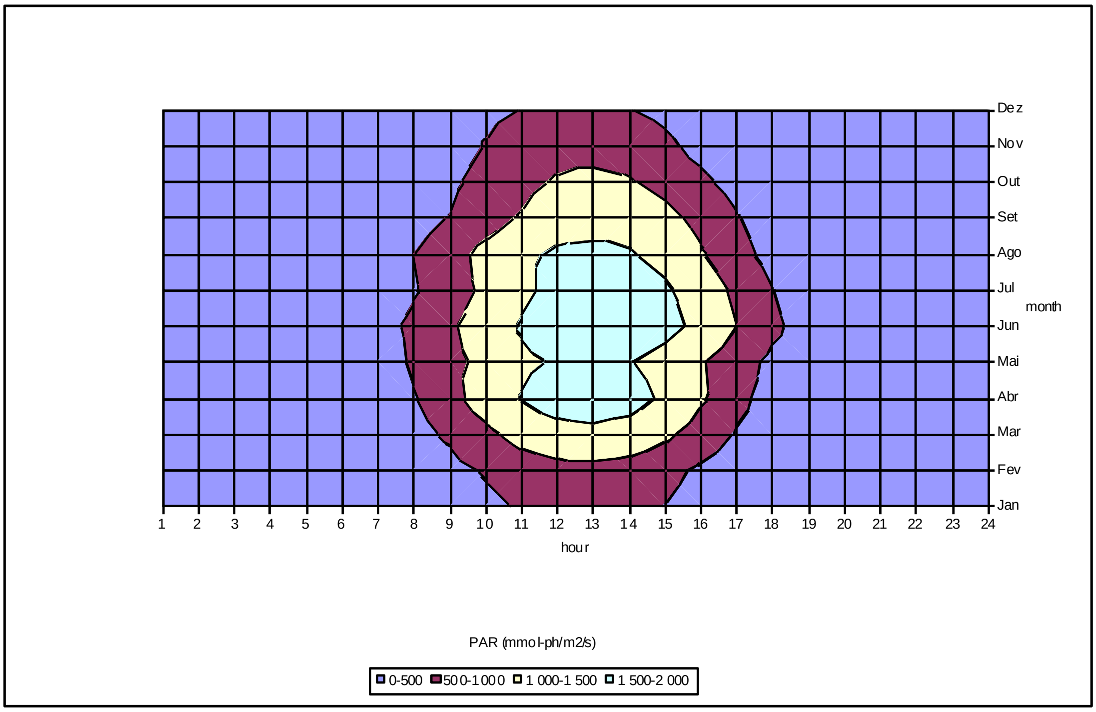



Source: INMG

However the information concerning PAR is scarce and some simplifications and assumptions had to be made. The pattern of monthly and daily variation of PAR was set by UA (Nunes, 1996) in Aveiro region, in central coastal Portugal, from a full year of measurements of total radiation (W/m2) in the meteorology monitoring station of Cacia. Average hourly total radiation was converted in PAR (mmol-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 7.4 – Pattern of evolution of PAR (mmol/m2/s) according to month and hour of day (Nunes, 1996)




### 7.2.5 Recalculations

No changes were made to this category since the submission of last year.

### 7.2.6 Further Improvements

This category is foreseen to be revised in the near future in order to better harmonise and reflect the developments made in the last years related to the quantification of Land Use categories, and improvements in the methologies.

An improvement in information concerning resin extraction may ameliorate the estimates of VOC emissions from resin-tapping in Maritime pine.

# 8 RECALCULATIONS

The 2017 Portuguese submission was compiled to the extent of possible according to the most recent methodological guidance – the 2016 EMEP/EEA air pollutant emission inventory guidebook and the 2006 IPCC Guidelines.

Other recalculations refer to updates of background information and to revisions aiming to follow the recommendations issued during the CLRTAP inventory reviews and other inventory review processes under the UNFCCC and the EC.

The recalculations performed are summarized as follows:

**Energy Combustion**

Energy Industries (NFR 1.A.1)

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

Manufacturing industries and construction (NFR 1.A.2)

Review of the time series of activity data and emission factors for the two main installations in the Chemical sector.

Transports (NFR 1.A.3)

Recalculations for Road Transportation (NFR 1.A.3.b) comprise:

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

Recalculations for Water Borne Navigation (NFR 1.A.3.d) comprise:

- Update and correction of the 2014 data due to a compilation error detected during the QA/QC procedure.

**Industrial Processes**

Chemical industry: Other (2B10a)

Revision of the vinyl chloride monomer activity data for all the period 1990-2014.

Review of the time series of activity data and emission factors for the Carbon Black sector. For all period 1990-2013

**Agriculture**

The major changes between last year submission and this year submission result from the following actions:

- revision of 2013 and 2014 values of N inorganic fertilizers updated by INE;

- revision of 2013 and 2014 data of sewage sludge applied to agricultural soils, updated by the waste sector;
- implementation of the tier 2 methodology of EMEP/EEA Guidebook 2016 to estimate NH3 emissions from N inorganic ferilizers applied to soil;
- insertion of the N fraction leached during solid manure storage in the Nflow calculations. N leached was calculated using IPCCC 2006 Guidelines and this revision assure the complete coherence of N flow in both inventories submissions, UNFCCC and UNECE/CLRTAP;
- minor corrections as a result of internal QA/QC procedures.

**Waste**

Solid waste disposal (NFR 5A)

A significant revision of activity data for municipal waste was made since last submission. The time series were revised based on the availability of more detailed information for the more recent years which enables a better split between the quantities that entered directly in the systems and the ones that refer to an indirect disposal.

The revisions made also include the non-urban waste (sectoral waste) following a methodological change made by INE in 2012. In this revision, the sample used for the statistics of sectoral waste was harmonized with the other statistical operations related to the Common Corporate Sector/ Business Sector, in which a set of statistical units, such as municipalities and other entities from public administrations, are excluded since 2012.

Biological treatment of solid waste (NFR 5B)

The time series on the quantities of composted municipal waste has been revised in order to quantify the amounts that are effectively subject to composting, separating the quantities that are forwarded to biological treatment but are rejected afterwards.

Biological treatment of solid waste (NFR 5C)

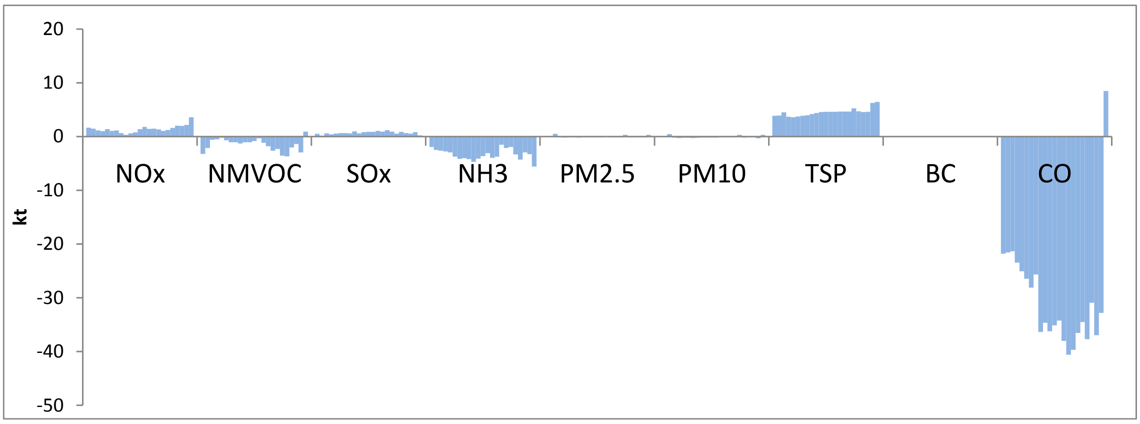
The recalculations made refer to changes of activity data for the non-urban waste (sectoral waste) in result of the methodological revision made by INE in 2012.

Other Waste (NFR 5E)

EF for combustion of biogas has been revised according to latest Guidance from 2016 EEA and 2006 IPCC.

The recalculations of emission levels are presented in the following figures which show the absolute differences between the latest submission (2017) and the previous submission (2016).

Figure 8.1 – Recalculations for main pollutants and particulate matter for 1990-2014 (absolute difference between 2016 and 2017 submissions)




The impact of the recalculation in each sector for the 2014 year and for every pollutant is presented in the next figures, which show the impact of the recalculation of the categories in total recalculation of each pollutant, calculated as: 100 x [(LS-PS)/Total recalculation (LS)], where LS = latest submission and PS = previous submission).

Figure 8.2 – Sectoral contribution in recalculations: Main pollutants and particulate matter (% contribution to the total recalculation of each pollutant in 2014)

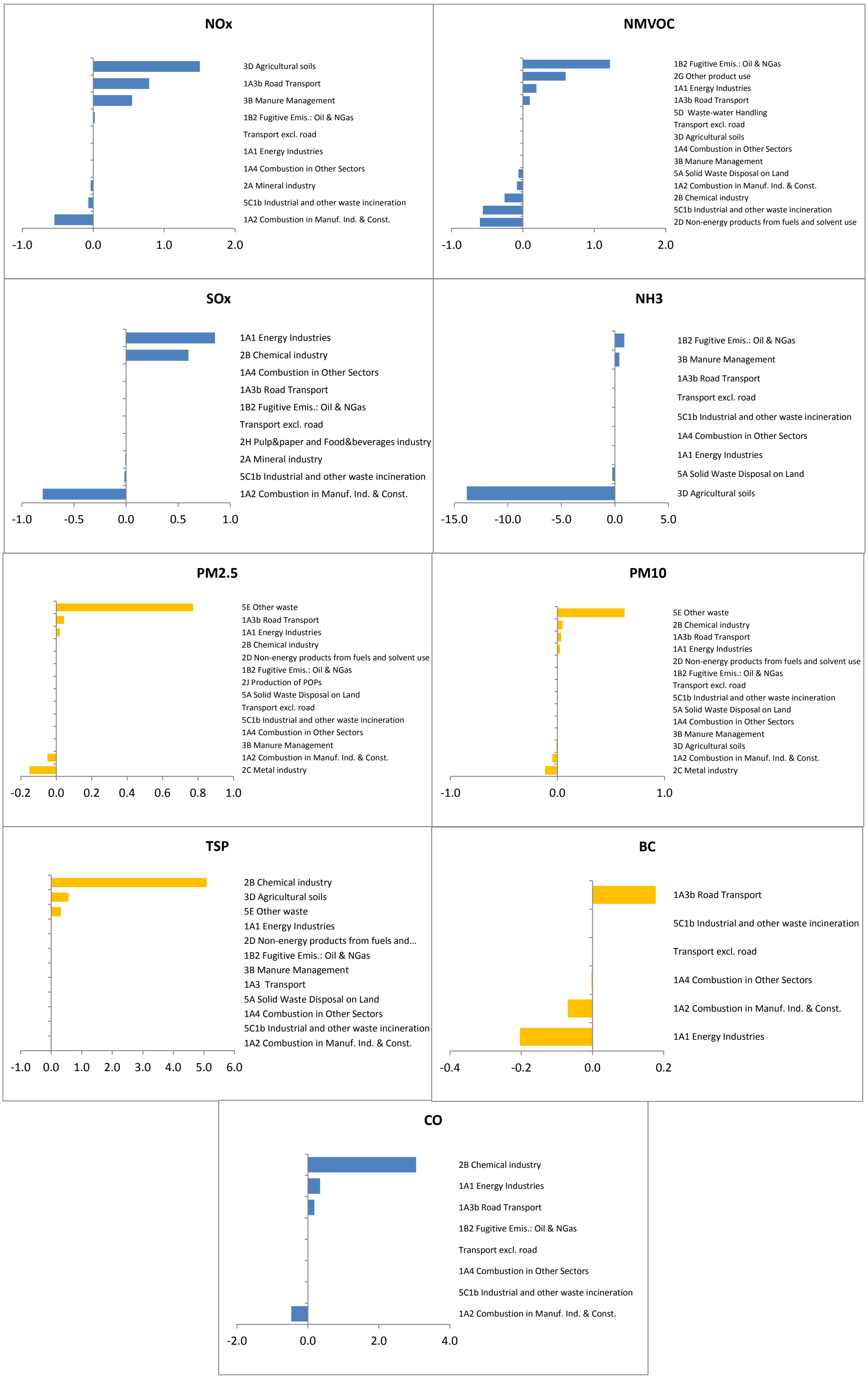


Figure 8.3 – Recalculations for heavy metals for 1990-2014 (absolute difference between 2016 and 2017 submissions)

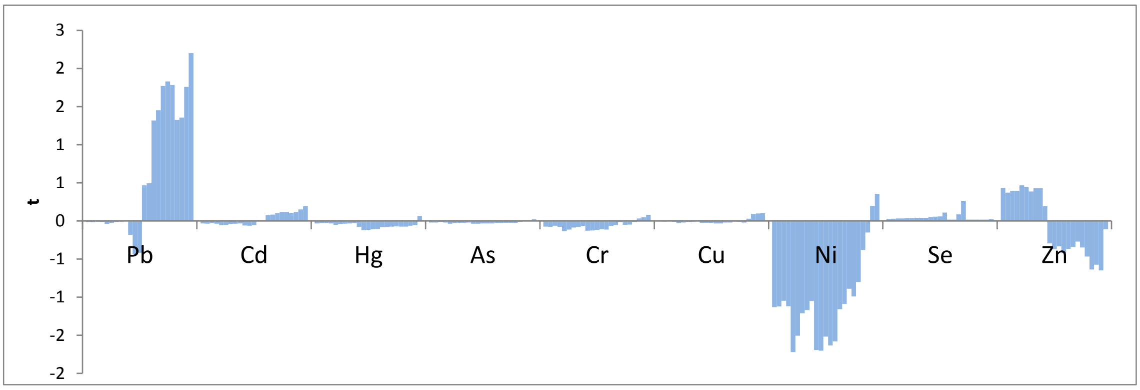


Figure 8.4 – Sectoral contribution in recalculations: Heavy Metals (% contribution to the total recalculation of each pollutant in 2014)

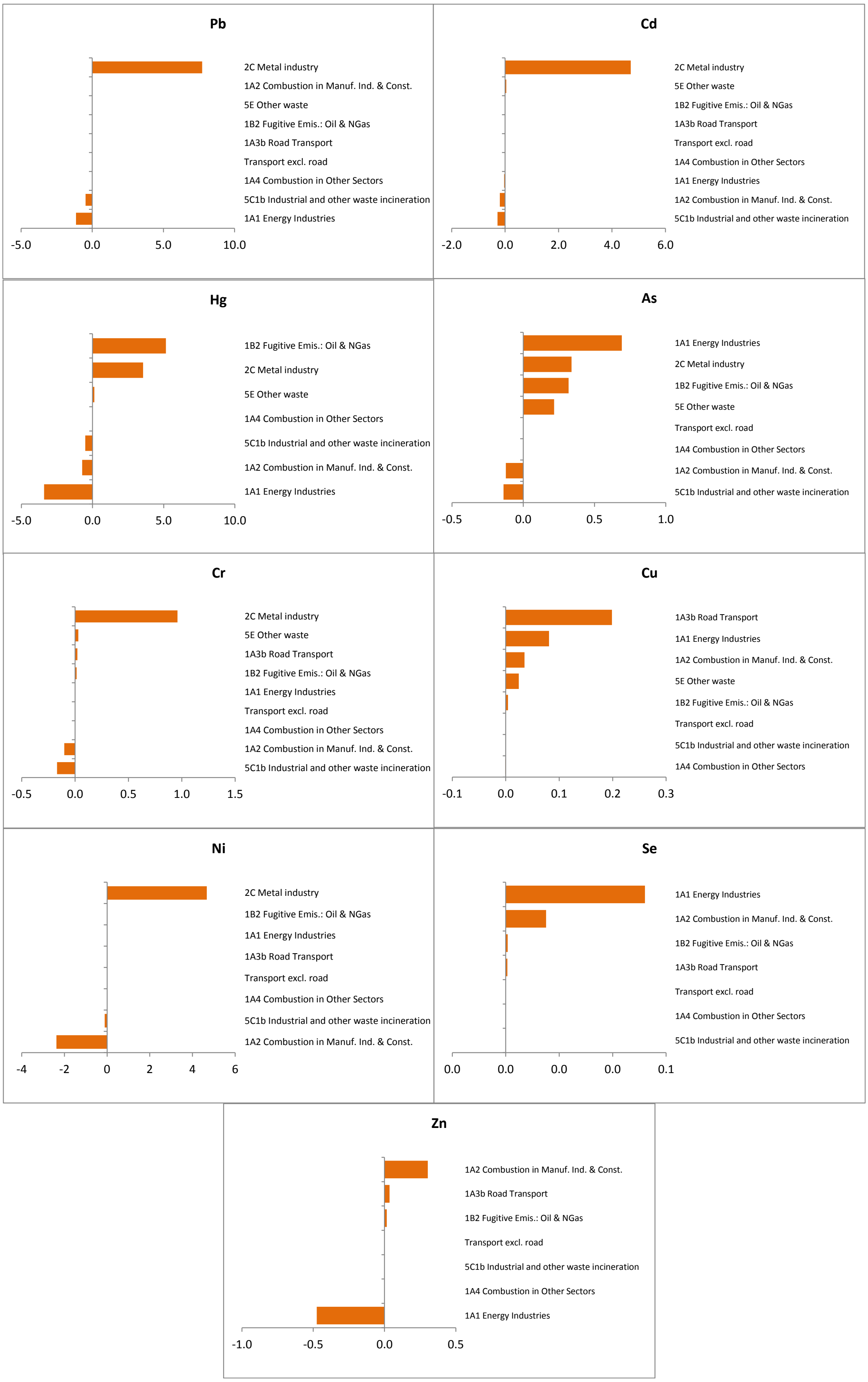


Figure 8.5 – Recalculations for Dioxines, PAHs, HCB and PCB for 1990-2014 (absolute difference between 2016 and 2017 submissions)

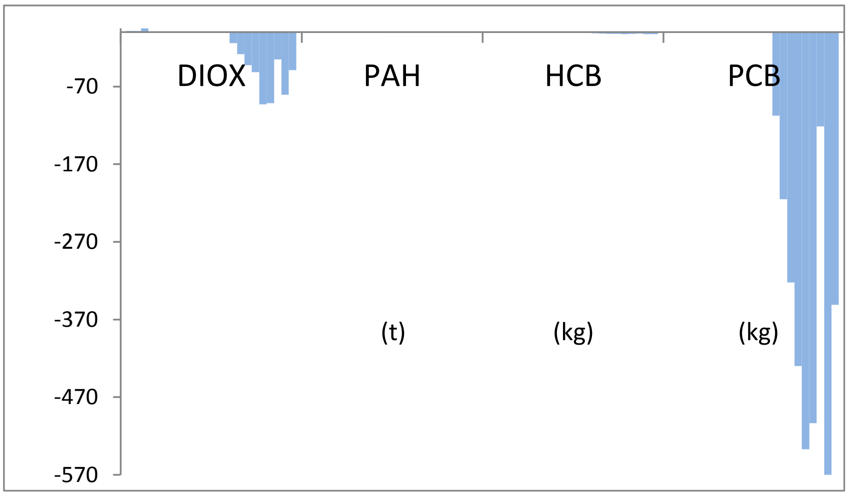
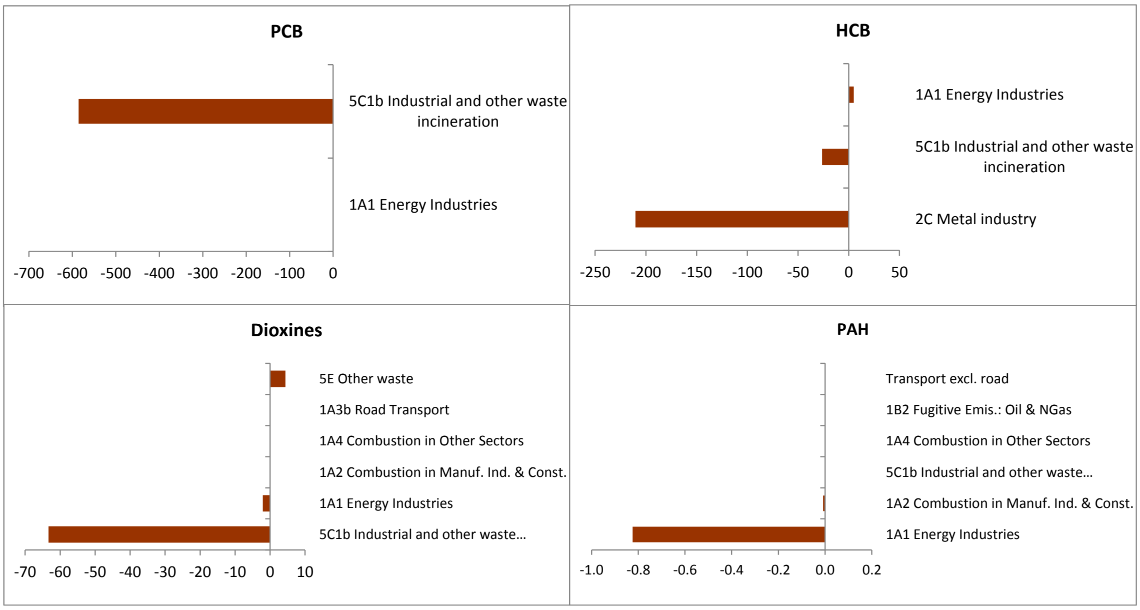



Figure 8.6 – Sectoral contribution in recalculations: PCB, Dioxines and PAHs (% contribution to the total recalculation of each pollutant in 2014)



# 9 List of Acronyms

| | | |
|---|---|---|
| ABS | Acrylonitrile Butadiene Styrene | Acrilo Nitrilo Butadieno Estireno |
| AC | Air Conditioning | Ar condicionado |
| ACAP | Portuguese Association of Automobile Business | Associação do Comércio Automóvel de Portugal |
| ADP | ADP fertilizers (national fertilizer industry) | ADP fertilizantes |
| AVG | Aviation Gasoline | Gasolina de Aviação |
| AN | Ammonium Nitrate | Nitrato de Amónio |
| ANA | Airports and Air Navigation | Aeroportos e Navegação Aérea |
| ANAC | Portuguesa Civil Aviation Authority | Autoridade Nacional da Aviação Civil |
| ANAM | Madeira Island Airports and Air Navigation | Aeroportos e Navegação Aérea da Madeira |
| ANECRA | National Association of Companies of Automobile Business and Reparation | Associação Nacional das Empresas do Comércio e da Reparação Automóvel |
| APED | Portuguese Association of Distribution Companies | Associação Portuguesa de Empresas de Distribuição |
| APIRAC | National Association of Industry of Refrigeration and Air Conditioning | Associação Portuguesa dos Industriais da Refrigeração e Ar Condicionado |
| APORBET | Portuguese Association of Betuminous Mixes Producers | Associação Portuguesa de Fabricantes de Misturas Betuminosas |
| AS | Ammonium Sulphate | Sulfato de Amónia |
| ASN | Ammonium Sulphate Nitrate | Sulfonitrato de Amónia |
| BAT | Best Available Technologies | - |
| BOD | Biochemical Oxygen Demand | Carência Bioquímica de Oxigénio |
| BOF | Basic Oxygen Furnace | - |
| CAFE | Clean Air For Europe | - |
| CAN | Calcium Ammonium Nitrate | Nitrato de Cálcio-amônio |
| CCDR-LVT | Lisbon and Tagus Valley Coordination and Regional Development Comission | Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo |
| CELPA | Portuguese Paper Industry Association | Associação da Indústria Papeleira |
| CFC | Clorofluorcarbons | Clorofluorcarbonetos |
| CH4 | Methane | Metano |
| CITEPA | Interprofessional Technical Center of Studies of Atmospheric Pollution | Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique |
| CKD | Cement Kiln Dust | - |
| CMN | Calcium Magnesium Nitrate | - |
| CN | Calcium Nitrate | Nitrato de 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 |

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| DGADR | General Directorate for Agriculture and Rural Development | Direção Geral de Agricultura e do Desenvolvimento Rural |
| DGAE (ex DGE) | General Directorate for Economic Activities | Direcção Geral das Actividades Económicas |
| DGAV | General Directorate  for Food and Veterenary | Direção geral de Alimentação e Veterinária |
| DGEG (ex DGGE) | General Directorate for Energy and Geology | Direcção Geral de Energia e Geologia |
| DGF | General Directorate of Forests | Direcção-Geral das Florestas |
| AFN | National Forestry Authority | Autoridade Florestal Nacional |
| DGTT | General Directorate of Terrestrial Transportation | Direcção Geral dos Transportes Terrestres |
| Distrito | Portuguese territorial unit comprehending several concelhos but not coincident with a region which is NUT II. | - |
| DOC | Degradable Organic Carbon | Carbono Orgânico Degradável |
| DOCF | Degradable Organic Carbon Dissimilated | - |
| DRAOT | Regional Directorate of Environment and Land Use Planning | Direcção Regional do Ambiente e Ordenamento do Território |
| EAF | Electric Arc Furnace | Forno Arco Eléctrico |
| EAPA | European Asphalt Pavement Association | - |
| EF | Emission Factors | Factores de Emissão |
| EMEP | Cooperative Programme for Monitoring and Evaluation of the Longrange Transmission of Air Pollutants in Europe | - |
| EPER | European Pollutant Emission Register | Registo Europeu de Emissões Poluentes |
| E-PRTR | European Pollutant Release and Transfer Register | - |
| FAEED | Federal Aviation Administration Aircraft Engine Emission Database | - |
| FAM | Animal Manure Nitrogen Applied to Soils | - |
| FAO | Food and Agriculture Organization of the United Nations | - |
| FCC | Fluidized-bed Catalytic Cracking | Cracking catalítico de leito fluidizado |
| FCR | Fixation in Crop Residues | - |
| FCT-UNL | Faculty of Science and Technology of New University of Lisbon | Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa |
| FGR | Annual amount of nitrogen in animal excreta (faeces and urine) deposited directly in soil during grazing in pasture and adjusted to account for the amount that volatilises as NH3 | - |
| FOD | First Order Decay | Decaimento de Primeira Ordem |
| FSN | Nitrogen in Synthetic Fertilizers | - |
| GASA | Analysis Group of Ambiental Systems | Grupo de Análises de Sistemas Ambientais |
| GCV | Gross Calorific Value | - |
| GHG | Green House Gases | Gases Com Efeito de Estufa |
| GHV | Gross Heating Value | Poder Calorífico Superior |
| GIC | Large Combustion Plants (LCP) | Grandes Instalações de Combustão |
| GPG | Good Practice Guidance | - |
| GPP | Planning and Policies Office | Gabinete de Planeamento e Políticas |
| GPPAA | Agricultre and Food Planning and Policies Office (changed to GPP) | Gabinete de Planeamento e Política Agro-Alimentar |
| GWP | Global Warming Potential | - |
| H2S | Hydrogen Sulfide | Sulfureto de Hidrogénio |
| HCFC | Hydroclorofluorcarbons | - |
| HDPE | High Density Poly Ethylene | - |
| HDV | Heavy Duty Vehicles | Veículos Pesados de Mercadorias |

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|---|---|---|
| HFC | Hydrofluorcarbons | - |
| IA | Institute for The Environment | Instituto do Ambiente |
| IAIT | Annual Survey to Manufacturing Industry | Inquérito Anual à Indústria Transformadora |
| IAPI | Annual Survey to Industrial Production | Inquérito Anual à Produção Industrial |
| ICAO | International Civil Aviation Organization | |
| ICNF (ex-AFN) | National Institute for Nature conservation and Forests | Instituto da Conservação da Natureza e das Florestas |
| IEF | Implied Emission Factors | Factores de Emissão Implícitos |
| IEP | Portuguese Road Institute | Instituto de Estradas de Portugal |
| IFA | International Fertilizer Industry Association | |
| IFADAP | Institute for Financing and Support of Development of Agriculture and Fisheries | Instituto de Financiamento e Apoio ao Desenvolvimento da Agricultura e das Pescas |
| IMT (ex.IMTT, DGV) | Institute for Mobility and Transportation | Instituto da Mobilidade e dos Transportes |
| INAG | National Water Institute | Instituto da Água |
| INE | National Statistics Institute | Instituto Nacional de Estatística |
| INIAV | National Institute for Agriculture and Veterinary Research | Instituto Nacional de Investigação Agrária e Veterinária |
| INR | National Wastes Institute | Instituto Nacional de Resíduos |
| INRA | National Institute for Agronomic Investigation (France) | Institut National de la Recherche Agronomique (França) |
| INRB | National Institute of Biological Resources (changed to INIAV) | Instituto Nacional de Recursos Biológicos |
| IPCC | Intergovernmental Panel on Climate Change | - |
| IPMA | Portuguese Sea and Atmosphere Institute | Instituto Português do Mar e da Atmosfera |
| ISP | Portuguese Insurance Institute | Instituto de Seguros de Portugal |
| IST-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 | - |
| LQARS | Agriculture Quimical Laboratoy Rebelo da Silva (integrated in INIAV) | Laboratório Químico Agrícola Rebelo da Silva |
| LPS | Large Point Sources (Corinair definition) | Grandes Fontes Poluidoras |
| LRTAP | Long-range Transboundary Air Pollution | Poluição Atmosférica Transfronteiras a Longa Distância |
| LTO | Landing and Take-off | Aterragens e Descolagens |
| LUCF | Land-use Change and Forestry | Alteração do Uso do Solo e Florestas |
| LULUCF | Land Use, Land-use Change and Forestry | Uso do Solo, Alteração do Uso do Solo e Florestas |
| MA | Ministry of Environment | Ministério do Ambiente |
| MAC | Mobile Air-conditioning systems | - |
| MADRP | Ministry of Agriculture, Rural Development and Fisheries | Ministério da Agricultura, Desenvolvimento Rural e Pescas |
| MAM | Ministry of Agriculture and Sea | Ministério da Agricultura e do Mar |
| MAMAOT | Ministry for Agriculture, Sea, Environment and Land Use Planning (changed to MAM) | Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território |
| MAOT | Ministry of Environment and Land Use Planning | 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 |

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| MDI | Metered Dose Inhalers | - |
| MEET | Methodologies For Estimating Air Pollutant Emissions From Transport | - |
| MMS | Manure Management Systems | Sistema de Gestão de Estrumes |
| MSW | Municipal Solid Wastes | Resíduos Sólidos Municipais |
| MTBE | Methyl Tertiary Butyl Ether | Metil-Ter-Butil-Éter |
| Na2S | Sodium Sulphide | Sulfureto de Sódio |
| NaOH | Sodium Hydroxide | Hidróxido de Sódio |
| NAPFUE | CORINAIR Fuel Nomenclature | |
| NATO | North Atlantic Treaty Organisation | Organização do Tratado do Atlântico Norte |
| NAVE | National Entity responsible for air traffic | Navegação Aérea |
| NCV | Net Calorific Value | - |
| NFI | National Forestry Inventories | Inventário Florestal Nacional |
| NFR | New Format Reporting | - |
| NH3 | Ammoniac | Amoníaco |
| NMVOC | Non Methane Volatile Organic Compounds | Compostos Orgânicos Voláteis Não Metânicos (COVNM) |
| NOx | Nitrogen Oxides (NO + NO2) | Óxidos de Azoto (NO+NO2) |
| NPK | Nitrogen, Phosphorus and Potassium | Nitrogénio, Fósforo e Potássio |
| NSS | Normal Super Phosphates | Superfosfatos simples |
| NUTS (0..III) | Nomenclature of Territorial Units for Statistics | Nomenclatura de Unidades Territoriais para fins estatísticos |
| OD | Origin - Destiny | Origem - Destino |
| ODS | Ozone Depleting Substances | - |
| OECD | Organization for Economic Co-operation and Development | Organização para a Cooperação e Desenvolvimento Económico (OCDE) |
| OX | Oxidation Factor | Factor de Oxidação |
| PAF | Florestal Action Program | Programa de Acção Florestal |
| PAH | Polycyclic Aromatic Hydrocarbons | Hidrocarbonetos Aromáticos Policíclicos |
| PCI | Low Heating Value (LHV) | Poder Calorífico Inferior |
| PEN | National Energetic Program | Plano Energético Nacional |
| PER | Perchloro-ethylene | Percloroetileno |
| PERSU | Strategic Plan on Municipal Solid Wastes | Plano Estratégico dos Resíduos Sólidos Urbanos |
| PETROGAL | Portuguese Petroleum Company | Empresa de Petróleos de Portugal |
| PFC | Perfluorinated Hidrocarbons | - |
| PM1 | Particles with Aerodynamic Diameter smaller than 1 micrometer | Partículas cujo diâmetro aerodinâmico é inferior a 1 micrómetro |
| PM10 | Particles with Aerodynamic Diameter smaller than 10 micrometers | Partículas cujo diâmetro aerodinâmico é inferior a 10 micrómetros |
| PM2.5 | Particles with Aerodynamic Diameter smaller than 2.5 micrometers | Partículas cujo diâmetro aerodinâmico é inferior a 2.5 micrómetros |
| PNAC | National Climate Change Program | Programa Nacional para as Alterações Climáticas |
| PNPA | National Plan for Environmental Policy | Plano Nacional da Política de Ambiente |
| PP | Poly Propylene | Polipropileno |
| PS | Poly Styrene | Poliestireno |
| PTEN | National Emission Ceilings Program | Programa para os Tectos de Emissão Nacional |
| PVC | Poly Vinyl Chloride | Cloreto de Polivinil |
| RA | Agricultural Region | Região Agrária |
| REN | National Electric System | Rede Eléctrica Nacional |
| RVP | Reid Vapour Pressure | Pressão de Vapor de Reid |

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|---|---|---|
| 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 Resíduais |
| ZA | Agricultural Zone | Zona Agrária |

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# ANNEX A: COMPLETENESS AND KEY CATEGORIES

## Annex Table 1 – Completeness table

| NFR Code | Longname | Main Pollutants | | | | Particulate Matter | | | | Other | Priority Heavy Metals | | | Additional Heavy Metals | | | | | | POPs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NOx (as $NO_2$) | NMVOC | SOx (as $SO_2$) | $NH_3$ | $PM_{2.5}$ | $PM_{10}$ | TSP | BC | CO | Pb | Cd | Hg | As | Cr | Cu | Ni | Se | Zn | Dioxines /furans | PAHs/ Total | HCB | PCBs |
| 1A1b | Petroleum refining | | | | NE | | | | | | | | | | | | | | | | | | |
| 1A2a | Stationary combustion in manufacturing industries and construction: Iron and steel | | | | NE | NE | NE | NE | NE | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | | | | NE | | | | | | | | | | | | | | | | | | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | | | | NE | | | | | | | | | | | | | | | | | | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | | | | NE | | | | | | | | | | | | | | | | | | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | | | | NE | | | | | | | | | | | | | | | | | | |
| 1A3bi | Road transport: Passenger cars | | | | | | | NE | | | | | NE | NE | | | | | | | NE | | |
| 1A3bii | Road transport: Light duty vehicles | | | | | | | NE | | | | | NE | NE | | | | | | | NE | | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | | | | | | | NE | | | | | NE | NE | | | | | | | NE | | |
| 1A3biv | Road transport: Mopeds & motorcycles | | | | | | | NE | | | | | NE | NE | | | | | | | NE | | |
| 1A3bvi | Road transport: Automobile tyre and brake wear | | | | | | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | | | | |
| 1A3bvii | Road transport: Automobile road abrasion | | | | | | | NE | | NE | NE | NE | NE | NE | NE | NE | NE | NE | | | | | |
| 1A3c | Railways | | | | | | | | | | | | NE | | | | | | | NE | | | |
| 1A3dii | National navigation (shipping) | | | | | | | | | | | | | | | | | | | NE | | | |
| 1A3ei | Pipeline transport | | | | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | |
| 1A3eii | Other (please specify in the IIR) | NE | NE | NE | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | |
| 1A4aii | Commercial/institutional: Mobile | NE | NE | NE | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 1A4bi | Residential: Stationary | | | | | | | | | | | | | | | | | | | | | | NE |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | | | | | | | | | | | | | | | | | | | | | NE | NE |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | | | | | | | | | | | | NE | | | | | | | NE | | | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | | | | | | | | | | | | | | | | | | | NE | | | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | | | | | NE | NE | NE | NE | | | | NE | NE | | | | | | NE | NE | | |
| 1B1a | Fugitive emission from solid fuels: Coal mining and handling | | | | | | | | | NE | NE | NE | NE | NE | NE | NE | NE | NE | | | | | |
| 1B1b | Fugitive emission from solid fuels: Solid fuel transformation | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | NE | NE | | |
| 1B1c | Other fugitive emissions from solid fuels | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | | | |
| 1B2ai | Fugitive emissions oil: Exploration, production, transport | | | NE | | | | | | | | | | | | | | | NE | | | | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | | | | | | | | NE | | | | | | | | | | NE | | | | |
| 1B2av | Distribution of oil products | | | NE | | | | | | | | | | | | | | | NE | | | | |
| 1B2b | Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution ar | | NE | NE | | | | | | | | | | | | | | | NE | | | | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | | | | NE | | | | NE | | | | | | | | | | | NE | | | |
| 1B2d | Other fugitive emissions from energy production | NE | NE | NE | | NE | NE | NE | NE | NE | NE | NE | | | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 2A1 | Cement production | | | | | | | | | | | | | | | | | | | NE | NE | | |
| 2A2 | Lime production | | | | | | | | | | NE | NE | | | | | | | | | | | |
| 2A3 | Glass production | | | | | | | | NE | | | | | | | | | | | NE | NE | | |
| 2A5a | Quarrying and mining of minerals other than coal | | | | | NE | NE | NE | | | | | | | | | | | | | | | |
| 2A5b | Construction and demolition | | NE | | | NE | NE | NE | | | | | | | | | | | | | | | |
| 2A5c | Storage, handling and transport of mineral products | | | | | NE | NE | NE | | | | | | | | | | | | | | | |
| 2A6 | Other mineral products (please specify in the IIR) | NE | | NE | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | | |
| 2B1 | Ammonia production | | | | | NE | | | | | | | | | | | | | | | | | |
| 2B2 | Nitric acid production | | | | | NE | | | | | | | | | | | | | | | | | |
| 2B7 | Soda ash production | | | | | NE | NE | NE | | | | | | | | | | | | | | | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | | | | | | | | NE | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |

(cont.)

| NFR Code | Longname | Main Pollutants | | | | Particulate Matter | | | | Other | Priority Heavy Metals | | | Additional Heavy Metals | | | | | | POPs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NOx (as $NO_2$) | NMVOC | SOx (as $SO_2$) | $NH_3$ | $PM_{2.5}$ | $PM_{10}$ | TSP | BC | CO | Pb | Cd | Hg | As | Cr | Cu | Ni | Se | Zn | Dioxines /furans | PAHs/ Total | HCB | PCBs |
| 2C1 | Iron and steel production | | | | NE | | | | NE | | | | | | | | | NE | | | | | |
| 2D3a | Domestic solvent use including fungicides | | | | | NE | NE | NE | NE | | | | | | | | | | | | | | |
| 2D3b | Road paving with asphalt | NE | | NE | | | | | NE | | | | | | | | | | NE | NE | NE | | |
| 2D3c | Asphalt roofing | | NE | | | NE | NE | NE | NE | NE | NE | NE | | | | | | | NE | NE | NE | | |
| 2D3d | Coating applications | | | | | NE | NE | NE | NE | | | | | | | | | | | | | | |
| 2D3e | Degreasing | | | | | NE | NE | NE | NE | | | | | | | | | | | | | | |
| 2D3f | Dry cleaning | | | | | NE | NE | NE | NE | | | | | | | | | | | | | | |
| 2D3g | Chemical products | | | | | | | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 2D3h | Printing | | | | | NE | NE | NE | NE | | | | | | | | | | | | | | |
| 2H1 | Pulp and paper industry | | | | NE | | | | NE | | | | | | | | | | | NE | NE | | |
| 2H2 | Food and beverages industry | | | | | NE | NE | NE | | | | | | | | | | | | | | | |
| 2I | Wood processing | NE | | NE | NE | NE | NE | NE | NE | | | | NE | | NE | | | | | | | | |
| 2J | Production of POPs | NE | NE | NE | NE | NE | NE | NE | NE | | | | | | | | | | | | | NE | NE |
| 2K | Consumption of POPs and heavy metals (e.g. electrical and scientific equipment) | | | | | | | | | NE | NE | NE | NE | NE | NE | NE | NE | NE | | | | NE | NE |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | NE | NE | NE | NE | | | | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| 3B1a | Manure management - Dairy cattle | | NE | | | | | | | | | | | | | | | | | | | | |
| 3B1b | Manure management - Non-dairy cattle | | NE | | | | | | | | | | | | | | | | | | | | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | | | | NE | | | | | | | | | | | | | | | | | | |
| 5B2 | Biological treatment of waste - Anaerobic digestion at biogas facilities | NE | | | | | | | | | | | | | | | | | | | | | |
| 5C1bii | Hazardous waste incineration | | | | NE | | | | | | | | | | | | | | | | | | |
| 5C1biv | Sewage sludge incineration | | | | NE | | | | | | | | | | | | | | | | | | |

Annex Table 2 – Key category analysis of 2015 inventory

**NOx Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A3biii | Road transport: Heavy duty vehicles and buses | 20.59 | 20.6 | x |
| 1A3bi | Road transport: Passenger cars | 14.15 | 34.7 | x |
| 1A1a | Public electricity and heat production | 12.35 | 47.1 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 10.31 | 57.4 | x |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 8.57 | 66.0 | x |
| 1A3bii | Road transport: Light duty vehicles | 5.35 | 71.3 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 3.42 | 74.7 | x |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 3.14 | 77.9 | x |
| 2H1 | Pulp and paper industry | 2.95 | 80.8 | x |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 2.29 | 83.1 | |
| 1A4bi | Residential: Stationary | 2.24 | 85.3 | |
| 1A1b | Petroleum refining | 1.90 | 87.2 | |
| 1A3dii | National navigation (shipping) | 1.83 | 89.1 | |
| 1A3ai(i) | International aviation LTO (civil) | 1.74 | 90.8 | |
| 1A4ai | Commercial/institutional: Stationary | 1.34 | 92.2 | |
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | 1.11 | 93.3 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 1.00 | 94.3 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.83 | 95.1 | |
| 3Da3 | Urine and dung deposited by grazing animals | 0.69 | 95.8 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.60 | 96.4 | |
| 3F | Field burning of agricultural residues | 0.47 | 96.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.45 | 97.3 | |
| 1A3c | Railways | 0.34 | 97.6 | |
| 2C1 | Iron and steel production | 0.28 | 97.9 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.27 | 98.2 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.27 | 98.4 | |
| 3Da2a | Animal manure applied to soils | 0.24 | 98.7 | |
| 3B4h | Manure management - Other animals (please specify in IIR) | 0.21 | 98.9 | |
| 3B4gii | Manure mangement - Broilers | 0.15 | 99.1 | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 0.14 | 99.2 | |
| 3B1a | Manure management - Dairy cattle | 0.12 | 99.3 | |
| 3B4gi | Manure mangement - Laying hens | 0.11 | 99.4 | |
| 3B1b | Manure management - Non-dairy cattle | 0.09 | 99.5 | |
| 3Da2c | Other organic fertilisers applied to soils (including compost) | 0.08 | 99.6 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.07 | 99.7 | |
| 2B2 | Nitric acid production | 0.07 | 99.7 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.05 | 99.8 | |
| 3B2 | Manure management - Sheep | 0.05 | 99.8 | |
| 1A2a | Stationary combustion in manufacturing industries and construction: Iron and steel | 0.04 | 99.9 | |
| 3Da2b | Sewage sludge applied to soils | 0.04 | 99.9 | |
| 3B4giii | Manure mangement - Turkeys | 0.02 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.01 | 100.0 | |
| 3B3 | Manure management - Swine | 0.01 | 100.0 | |
| 3B4e | Manure management - Horses | 0.01 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.01 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.01 | 100.0 | |
| 3B4d | Manure management - Goats | 0.01 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |

**NOx Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 66.48 | 20.95 | 0.11 | 33.82 | 33.8 | x |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 23.63 | 34.94 | 0.08 | 23.21 | 57.0 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 15.10 | 17.50 | 0.03 | 8.64 | 65.7 | x |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 10.17 | 3.88 | 0.01 | 4.31 | 70.0 | x |
| 2H1 | Pulp and paper industry | 2.50 | 5.00 | 0.01 | 4.13 | 74.1 | x |
| 1A3bi | Road transport: Passenger cars | 38.21 | 24.01 | 0.01 | 4.10 | 78.2 | x |
| 1A2d | Stationary combustion in manufacturing industries and | 3.10 | 5.33 | 0.01 | 4.01 | 82.2 | x |
| 1A3ai(i) | International aviation LTO (civil) | 1.15 | 2.94 | 0.01 | 2.72 | 84.9 | |
| 1A2a | Stationary combustion in manufacturing industries and | 2.47 | 0.08 | 0.01 | 2.16 | 87.1 | |
| 1A3c | Railways | 3.12 | 0.58 | 0.01 | 2.11 | 89.2 | |
| 1A1b | Petroleum refining | 2.80 | 3.22 | 0.01 | 1.57 | 90.8 | |
| 1A4ai | Commercial/institutional: Stationary | 4.52 | 2.28 | 0.00 | 1.20 | 92.0 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 7.06 | 5.80 | 0.00 | 0.99 | 93.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 21.31 | 14.54 | 0.00 | 0.82 | 93.8 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.53 | 1.01 | 0.00 | 0.81 | 94.6 | |
| 1A3dii | National navigation (shipping) | 3.70 | 3.11 | 0.00 | 0.60 | 95.2 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.00 | 0.45 | 0.00 | 0.58 | 95.8 | |
| 3Da3 | Urine and dung deposited by grazing animals | 1.01 | 1.17 | 0.00 | 0.58 | 96.4 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.52 | 0.76 | 0.00 | 0.50 | 96.9 | |
| 3B4h | Manure management - Other animals (please specify ir | 1.04 | 0.36 | 0.00 | 0.48 | 97.3 | |
| 1A3bii | Road transport: Light duty vehicles | 13.27 | 9.08 | 0.00 | 0.47 | 97.8 | |
| 1A2e | Stationary combustion in manufacturing industries and | 1.90 | 1.70 | 0.00 | 0.44 | 98.3 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.31 | 0.45 | 0.00 | 0.30 | 98.6 | |
| 2C1 | Iron and steel production | 0.35 | 0.47 | 0.00 | 0.28 | 98.8 | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 0.13 | 0.23 | 0.00 | 0.18 | 99.0 | |
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | 2.48 | 1.89 | 0.00 | 0.16 | 99.2 | |
| 3Da2a | Animal manure applied to soils | 0.67 | 0.41 | 0.00 | 0.09 | 99.3 | |
| 3B1a | Manure management - Dairy cattle | 0.18 | 0.20 | 0.00 | 0.09 | 99.4 | |
| 3F | Field burning of agricultural residues | 1.02 | 0.80 | 0.00 | 0.09 | 99.4 | |
| 1A4bi | Residential: Stationary | 5.25 | 3.80 | 0.00 | 0.08 | 99.5 | |
| 2B2 | Nitric acid production | 0.25 | 0.12 | 0.00 | 0.08 | 99.6 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.20 | 0.09 | 0.00 | 0.07 | 99.7 | |
| 3B4gii | Manure mangement - Broilers | 0.29 | 0.25 | 0.00 | 0.06 | 99.7 | |
| 1A2c | Stationary combustion in manufacturing industries and | 2.04 | 1.41 | 0.00 | 0.06 | 99.8 | |
| 3B4gi | Manure mangement - Laying hens | 0.20 | 0.18 | 0.00 | 0.05 | 99.8 | |
| 3Da2b | Sewage sludge applied to soils | 0.04 | 0.07 | 0.00 | 0.05 | 99.9 | |
| 5C1biii | Clinical waste incineration | 0.02 | 0.00 | 0.00 | 0.02 | 99.9 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.16 | 0.13 | 0.00 | 0.02 | 99.9 | |
| 5C1bv | Cremation | 0.00 | 0.01 | 0.00 | 0.02 | 99.9 | |
| 3B2 | Manure management - Sheep | 0.12 | 0.08 | 0.00 | 0.01 | 100.0 | |
| 3B4e | Manure management - Horses | 0.01 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 3B4d | Manure management - Goats | 0.02 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 3B3 | Manure management - Swine | 0.03 | 0.02 | 0.00 | 0.01 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.02 | 0.02 | 0.00 | 0.01 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.01 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.02 | 0.01 | 0.00 | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.22 | 0.16 | 0.00 | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.05 | 0.03 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

NMVOC **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 2D3a | Domestic solvent use including fungicides | 15.08 | 15.1 | x |
| 2D3g | Chemical products | 11.77 | 26.9 | x |
| 2D3d | Coating applications | 9.50 | 36.3 | x |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 8.39 | 44.7 | x |
| 1A4bi | Residential: Stationary | 7.52 | 52.3 | x |
| 2H2 | Food and beverages industry | 7.18 | 59.4 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 5.14 | 64.6 | x |
| 2H1 | Pulp and paper industry | 3.99 | 68.6 | x |
| 2D3i | Other solvent use (please specify in the IIR) | 3.90 | 72.5 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 3.74 | 76.2 | x |
| 1A3bi | Road transport: Passenger cars | 3.13 | 79.3 | x |
| 1B2av | Distribution of oil products | 2.55 | 81.9 | x |
| 2D3h | Printing | 2.41 | 84.3 | |
| 2G | Other product use (please specify in the IIR) | 2.34 | 86.6 | |
| 1B2ai | Fugitive emissions oil: Exploration, production, transport | 1.49 | 88.1 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 1.36 | 89.5 | |
| 3F | Field burning of agricultural residues | 1.27 | 90.7 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 1.22 | 92.0 | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 1.15 | 93.1 | |
| 5A | Biological treatment of waste - Solid waste disposal on land | 1.12 | 94.2 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.94 | 95.2 | |
| 1A1a | Public electricity and heat production | 0.90 | 96.1 | |
| 2D3e | Degreasing | 0.84 | 96.9 | |
| 2D3f | Dry cleaning | 0.46 | 97.4 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.38 | 97.8 | |
| 2D3b | Road paving with asphalt | 0.34 | 98.1 | |
| 1A3bii | Road transport: Light duty vehicles | 0.31 | 98.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.18 | 98.6 | |
| 3De | Cultivated crops | 0.17 | 98.8 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.17 | 98.9 | |
| 2I | Wood processing | 0.17 | 99.1 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.15 | 99.2 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.13 | 99.4 | |
| 5C1bi | Industrial waste incineration | 0.09 | 99.5 | |
| 2C1 | Iron and steel production | 0.09 | 99.6 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.08 | 99.6 | |
| 5D2 | Industrial wastewater handling | 0.07 | 99.7 | |
| 1A1b | Petroleum refining | 0.06 | 99.8 | |
| 1A3dii | National navigation (shipping) | 0.06 | 99.8 | |
| 1A2a | Stationary combustion in manufacturing industries and construction: Iron and steel | 0.04 | 99.9 | |
| 1A3c | Railways | 0.03 | 99.9 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.03 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.03 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.03 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.01 | 100.0 | |
| 5D1 | Domestic wastewater handling | 0.00 | 100.0 | |
| 3Da2a | Animal manure applied to soils | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |
| 3Da3 | Urine and dung deposited by grazing animals | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify in IIR) | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 100.0 | |

NMVOC **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A3bi | Road transport: Passenger cars | 55.13 | 5.51 | 0.12 | 25.62 | 25.6 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 45.31 | 6.58 | 0.09 | 19.35 | 45.0 | x |
| 2D3a | Domestic solvent use including fungicides | 25.33 | 26.56 | 0.04 | 8.17 | 53.1 | x |
| 2D3g | Chemical products | 16.88 | 20.72 | 0.04 | 7.96 | 61.1 | x |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 11.05 | 14.77 | 0.03 | 6.21 | 67.3 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 3.35 | 9.05 | 0.03 | 5.67 | 73.0 | x |
| 2H1 | Pulp and paper industry | 3.51 | 7.03 | 0.02 | 3.92 | 76.9 | x |
| 2H2 | Food and beverages industry | 12.31 | 12.64 | 0.02 | 3.75 | 80.7 | x |
| 2D3h | Printing | 2.56 | 4.24 | 0.01 | 2.12 | 82.8 | |
| 2D3i | Other solvent use (please specify in the IIR) | 6.66 | 6.86 | 0.01 | 2.05 | 84.8 | |
| 2D3d | Coating applications | 28.77 | 16.72 | 0.01 | 1.88 | 86.7 | |
| 2G | Other product use (please specify in the IIR) | 3.01 | 4.12 | 0.01 | 1.77 | 88.5 | |
| 1A4bi | Residential: Stationary | 22.40 | 13.24 | 0.01 | 1.28 | 89.7 | |
| 1A2d | Stationary combustion in manufacturing industries and | 1.30 | 2.40 | 0.01 | 1.28 | 91.0 | |
| 1B2av | Distribution of oil products | 4.63 | 4.50 | 0.01 | 1.20 | 92.2 | |
| 1B2ai | Fugitive emissions oil: Exploration, production, transpo | 1.87 | 2.62 | 0.01 | 1.15 | 93.4 | |
| 1A1a | Public electricity and heat production | 0.36 | 1.59 | 0.01 | 1.13 | 94.5 | |
| 5A | Biological treatment of waste - Solid waste disposal on | 1.07 | 1.98 | 0.00 | 1.06 | 95.6 | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 1.52 | 2.02 | 0.00 | 0.85 | 96.4 | |
| 2D3f | Dry cleaning | 2.07 | 0.80 | 0.00 | 0.47 | 96.9 | |
| 3F | Field burning of agricultural residues | 2.67 | 2.25 | 0.00 | 0.40 | 97.3 | |
| 2D3e | Degreasing | 1.55 | 1.48 | 0.00 | 0.38 | 97.7 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 1.82 | 1.65 | 0.00 | 0.38 | 98.0 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.80 | 0.26 | 0.00 | 0.22 | 98.3 | |
| 3De | Cultivated crops | 0.87 | 0.31 | 0.00 | 0.22 | 98.5 | |
| 1A3bii | Road transport: Light duty vehicles | 1.19 | 0.55 | 0.00 | 0.20 | 98.7 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.78 | 0.29 | 0.00 | 0.18 | 98.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.62 | 0.23 | 0.00 | 0.15 | 99.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.22 | 0.31 | 0.00 | 0.14 | 99.1 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.32 | 0.05 | 0.00 | 0.14 | 99.3 | |
| 1A3c | Railways | 0.28 | 0.05 | 0.00 | 0.11 | 99.4 | |
| 2C1 | Iron and steel production | 0.10 | 0.17 | 0.00 | 0.09 | 99.5 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.06 | 0.14 | 0.00 | 0.08 | 99.6 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 3.16 | 2.16 | 0.00 | 0.06 | 99.6 | |
| 5D2 | Industrial wastewater handling | 0.08 | 0.12 | 0.00 | 0.06 | 99.7 | |
| 1A1b | Petroleum refining | 0.06 | 0.11 | 0.00 | 0.05 | 99.7 | |
| 2D3b | Road paving with asphalt | 0.81 | 0.60 | 0.00 | 0.05 | 99.8 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.16 | 0.05 | 0.00 | 0.05 | 99.8 | |
| 5C1bi | Industrial waste incineration | 0.17 | 0.17 | 0.00 | 0.05 | 99.9 | |
| 2I | Wood processing | 0.51 | 0.29 | 0.00 | 0.04 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.03 | 0.05 | 0.00 | 0.03 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.12 | 0.10 | 0.00 | 0.02 | 100.0 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 1.04 | 0.67 | 0.00 | 0.02 | 100.0 | |
| 1A2a | Stationary combustion in manufacturing industries and | 0.12 | 0.07 | 0.00 | 0.01 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.01 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.03 | 0.02 | 0.00 | 0.00 | 100.0 | |
| 5D1 | Domestic wastewater handling | 0.01 | 0.01 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3Da3 | Urine and dung deposited by grazing animals | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify ir | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3Da2a | Animal manure applied to soils | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**SOx Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 25.87 | 25.9 | x |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 17.79 | 43.7 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 14.23 | 57.9 | x |
| 2H1 | Pulp and paper industry | 11.58 | 69.5 | x |
| 1A1a | Public electricity and heat production | 8.60 | 78.1 | x |
| 1A3dii | National navigation (shipping) | 4.59 | 82.7 | x |
| 1A4bi | Residential: Stationary | 4.20 | 86.9 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 2.82 | 89.7 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 2.37 | 92.1 | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 2.14 | 94.2 | |
| 1A4ai | Commercial/institutional: Stationary | 1.96 | 96.1 | |
| 2C1 | Iron and steel production | 0.75 | 96.9 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.70 | 97.6 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.51 | 98.1 | |
| 3F | Field burning of agricultural residues | 0.33 | 98.4 | |
| 1A1b | Petroleum refining | 0.29 | 98.7 | |
| 1A2a | Stationary combustion in manufacturing industries and construction: Iron and steel | 0.25 | 99.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.23 | 99.2 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.23 | 99.4 | |
| 1A3bi | Road transport: Passenger cars | 0.15 | 99.6 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.13 | 99.7 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.06 | 99.8 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.06 | 99.8 | |
| 1A3c | Railways | 0.05 | 99.9 | |
| 1A3bii | Road transport: Light duty vehicles | 0.04 | 99.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.04 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.02 | 100.0 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |

**SOx Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 174.63 | 3.16 | 0.05 | 33.57 | 33.6 | x |
| 1A2d | Stationary combustion in manufacturing industries and | 16.64 | 9.51 | 0.02 | 14.80 | 48.4 | x |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.48 | 6.54 | 0.02 | 12.67 | 61.0 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 6.70 | 5.23 | 0.01 | 8.70 | 69.7 | x |
| 2H1 | Pulp and paper industry | 4.55 | 4.26 | 0.01 | 7.28 | 77.0 | x |
| 1A1b | Petroleum refining | 18.80 | 0.11 | 0.01 | 4.07 | 81.1 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 26.35 | 1.04 | 0.01 | 3.97 | 85.1 | |
| 1A3dii | National navigation (shipping) | 2.05 | 1.69 | 0.00 | 2.83 | 87.9 | |
| 1A2c | Stationary combustion in manufacturing industries and | 13.81 | 0.26 | 0.00 | 2.64 | 90.5 | |
| 1A4bi | Residential: Stationary | 2.75 | 1.55 | 0.00 | 2.39 | 92.9 | |
| 1A2e | Stationary combustion in manufacturing industries and | 12.99 | 0.87 | 0.00 | 1.25 | 94.2 | |
| 1A3bii | Road transport: Light duty vehicles | 4.36 | 0.01 | 0.00 | 0.97 | 95.2 | |
| 1A2a | Stationary combustion in manufacturing industries and | 4.93 | 0.09 | 0.00 | 0.94 | 96.1 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 3.85 | 0.02 | 0.00 | 0.84 | 96.9 | |
| 1A3bi | Road transport: Passenger cars | 3.37 | 0.06 | 0.00 | 0.66 | 97.6 | |
| 2C1 | Iron and steel production | 0.32 | 0.28 | 0.00 | 0.47 | 98.1 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 2.25 | 0.02 | 0.00 | 0.47 | 98.5 | |
| 1A4ai | Commercial/institutional: Stationary | 4.20 | 0.72 | 0.00 | 0.45 | 99.0 | |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 7.96 | 0.79 | 0.00 | 0.28 | 99.3 | |
| 3F | Field burning of agricultural residues | 0.16 | 0.12 | 0.00 | 0.20 | 99.5 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.76 | 0.19 | 0.00 | 0.19 | 99.6 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.03 | 0.08 | 0.00 | 0.16 | 99.8 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.33 | 0.00 | 0.00 | 0.07 | 99.9 | |
| 1A3c | Railways | 0.34 | 0.02 | 0.00 | 0.04 | 99.9 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.54 | 0.05 | 0.00 | 0.03 | 99.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.01 | 0.01 | 0.00 | 0.02 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.79 | 0.09 | 0.00 | 0.01 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.01 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.01 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

NH3 **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | 20.64 | 20.6 | x |
| 3Da2a | Animal manure applied to soils | 17.40 | 38.0 | x |
| 3B3 | Manure management - Swine | 12.92 | 51.0 | x |
| 3Da3 | Urine and dung deposited by grazing animals | 8.73 | 59.7 | x |
| 3B1a | Manure management - Dairy cattle | 7.69 | 67.4 | x |
| 3B4gi | Manure mangement - Laying hens | 5.83 | 73.2 | x |
| 3B4gii | Manure mangement - Broilers | 5.43 | 78.7 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 4.09 | 82.7 | x |
| 3B1b | Manure management - Non-dairy cattle | 3.86 | 86.6 | |
| 5A | Biological treatment of waste - Solid waste disposal on land | 2.78 | 89.4 | |
| 3B2 | Manure management - Sheep | 1.82 | 91.2 | |
| 1A3bi | Road transport: Passenger cars | 1.64 | 92.8 | |
| 3F | Field burning of agricultural residues | 1.55 | 94.4 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 1.22 | 95.6 | |
| 3B4giii | Manure mangement - Turkeys | 1.03 | 96.6 | |
| 1B2d | Other fugitive emissions from energy production | 0.85 | 97.5 | |
| 3B4h | Manure management - Other animals (please specify in IIR) | 0.81 | 98.3 | |
| 3B4giv | Manure management - Other poultry | 0.41 | 98.7 | |
| 3B4e | Manure management - Horses | 0.37 | 99.1 | |
| 3B4d | Manure management - Goats | 0.27 | 99.4 | |
| 3Da2c | Other organic fertilisers applied to soils (including compost) | 0.19 | 99.6 | |
| 3B4f | Manure management - Mules and asses | 0.19 | 99.7 | |
| 3Da2b | Sewage sludge applied to soils | 0.14 | 99.9 | |
| 1A3bii | Road transport: Light duty vehicles | 0.03 | 99.9 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.03 | 99.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.02 | 100.0 | |
| 2B2 | Nitric acid production | 0.01 | 100.0 | |
| 5B2 | Biological treatment of waste - Anaerobic digestion at biogas facilities | 0.01 | 100.0 | |
| 1A1a | Public electricity and heat production | 0.01 | 100.0 | |
| 5B1 | Biological treatment of waste - Composting | 0.01 | 100.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.00 | 100.0 | |
| 1A3c | Railways | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |

NH3 **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | 10.82 | 9.27 | 0.03 | 22.77 | 22.8 | x |
| 3Da3 | Urine and dung deposited by grazing animals | 3.78 | 3.92 | 0.02 | 14.74 | 37.5 | x |
| 3B4gi | Manure mangement - Laying hens | 2.90 | 2.62 | 0.01 | 7.44 | 45.0 | x |
| 3B3 | Manure management - Swine | 7.89 | 5.80 | 0.01 | 7.14 | 52.1 | x |
| 1A3bi | Road transport: Passenger cars | 0.04 | 0.74 | 0.01 | 7.04 | 59.1 | x |
| 3B4gii | Manure mangement - Broilers | 2.75 | 2.44 | 0.01 | 6.63 | 65.8 | x |
| 5A | Biological treatment of waste - Solid waste disposal on | 0.98 | 1.25 | 0.01 | 6.12 | 71.9 | x |
| 3Da2a | Animal manure applied to soils | 13.10 | 7.81 | 0.01 | 6.10 | 78.0 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 2.01 | 1.84 | 0.01 | 5.39 | 83.4 | x |
| 1B2d | Other fugitive emissions from energy production | 0.01 | 0.38 | 0.01 | 3.73 | 87.1 | |
| 3B4h | Manure management - Other animals (please specify ir | 1.03 | 0.36 | 0.00 | 2.97 | 90.1 | |
| 3B4f | Manure management - Mules and asses | 0.54 | 0.08 | 0.00 | 2.62 | 92.7 | |
| 1A2f | Stationary combustion in manufacturing industries and | 0.56 | 0.55 | 0.00 | 1.83 | 94.5 | |
| 3F | Field burning of agricultural residues | 0.89 | 0.70 | 0.00 | 1.25 | 95.8 | |
| 3B1b | Manure management - Non-dairy cattle | 2.55 | 1.73 | 0.00 | 0.86 | 96.6 | |
| 3B1a | Manure management - Dairy cattle | 5.24 | 3.45 | 0.00 | 0.83 | 97.5 | |
| 3B4e | Manure management - Horses | 0.14 | 0.17 | 0.00 | 0.78 | 98.2 | |
| 3B4d | Manure management - Goats | 0.26 | 0.12 | 0.00 | 0.44 | 98.7 | |
| 3Da2b | Sewage sludge applied to soils | 0.04 | 0.06 | 0.00 | 0.37 | 99.1 | |
| 3B4giv | Manure management - Other poultry | 0.33 | 0.18 | 0.00 | 0.28 | 99.3 | |
| 3B2 | Manure management - Sheep | 1.30 | 0.82 | 0.00 | 0.21 | 99.6 | |
| 3B4giii | Manure mangement - Turkeys | 0.69 | 0.46 | 0.00 | 0.17 | 99.7 | |
| 1A3bii | Road transport: Light duty vehicles | 0.01 | 0.01 | 0.00 | 0.08 | 99.8 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.01 | 0.01 | 0.00 | 0.07 | 99.9 | |
| 5B2 | Biological treatment of waste - Anaerobic digestion at b | NO | 0.00 | 0.00 | 0.05 | 99.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.01 | 0.01 | 0.00 | 0.04 | 99.9 | |
| 5B1 | Biological treatment of waste - Composting | 0.01 | 0.00 | 0.00 | 0.03 | 100.0 | |
| 2B2 | Nitric acid production | 0.01 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 1A3c | Railways | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**PM2.5 Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 35.28 | 35.3 | x |
| 2H1 | Pulp and paper industry | 14.53 | 49.8 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 10.04 | 59.9 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 7.44 | 67.3 | x |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | 3.67 | 71.0 | x |
| 3F | Field burning of agricultural residues | 3.51 | 74.5 | x |
| 2D3b | Road paving with asphalt | 3.45 | 77.9 | x |
| 2A3 | Glass production | 3.02 | 81.0 | x |
| 1A3bi | Road transport: Passenger cars | 3.01 | 84.0 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 2.25 | 86.2 | |
| 1A3ai(i) | International aviation LTO (civil) | 2.24 | 88.5 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 1.90 | 90.4 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 1.62 | 92.0 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 1.45 | 93.4 | |
| 1A3bii | Road transport: Light duty vehicles | 1.21 | 94.6 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.98 | 95.6 | |
| 5E | Other waste (please specify in IIR) | 0.96 | 96.6 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.65 | 97.2 | |
| 1A3dii | National navigation (shipping) | 0.56 | 97.8 | |
| 1A1a | Public electricity and heat production | 0.51 | 98.3 | |
| 1A4ai | Commercial/institutional: Stationary | 0.40 | 98.7 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.36 | 99.0 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.24 | 99.3 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.16 | 99.4 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.11 | 99.6 | |
| 2C1 | Iron and steel production | 0.09 | 99.7 | |
| 1A1b | Petroleum refining | 0.09 | 99.7 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.09 | 99.8 | |
| 2A2 | Lime production | 0.05 | 99.9 | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | 0.05 | 99.9 | |
| 2D3g | Chemical products | 0.03 | 100.0 | |
| 1A3c | Railways | 0.03 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5A | Biological treatment of waste - Solid waste disposal on land | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 100.0 | |
| 3B1a | Manure management - Dairy cattle | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify in IIR) | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |

**PM2.5 Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 26.96 | 15.92 | 0.10 | 26.35 | 26.4 | x |
| 2H1 | Pulp and paper industry | 3.27 | 6.56 | 0.07 | 17.64 | 44.0 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 2.83 | 4.53 | 0.04 | 10.11 | 54.1 | x |
| 1A3bii | Road transport: Light duty vehicles | 3.11 | 0.54 | 0.04 | 8.87 | 63.0 | x |
| 1A1a | Public electricity and heat production | 1.56 | 0.23 | 0.02 | 4.64 | 67.6 | x |
| 2A3 | Glass production | 0.53 | 1.36 | 0.02 | 4.21 | 71.8 | x |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.00 | 0.86 | 0.02 | 3.86 | 75.7 | x |
| 1A3ai(i) | International aviation LTO (civil) | 0.36 | 1.01 | 0.01 | 3.25 | 78.9 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 3.27 | 3.36 | 0.01 | 3.23 | 82.2 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.96 | 0.11 | 0.01 | 3.02 | 85.2 | |
| 1A3bi | Road transport: Passenger cars | 0.93 | 1.36 | 0.01 | 2.74 | 87.9 | |
| 2L | Other production, consumption, storage, transportation | 1.41 | 1.66 | 0.01 | 2.33 | 90.2 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.84 | 0.29 | 0.01 | 1.73 | 92.0 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 1.24 | 0.65 | 0.01 | 1.56 | 93.5 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.41 | 0.05 | 0.00 | 1.26 | 94.8 | |
| 2D3b | Road paving with asphalt | 1.62 | 1.56 | 0.00 | 1.13 | 95.9 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.99 | 1.01 | 0.00 | 0.97 | 96.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.10 | 0.16 | 0.00 | 0.39 | 97.3 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.65 | 0.44 | 0.00 | 0.37 | 97.6 | |
| 5E | Other waste (please specify in IIR) | 0.63 | 0.43 | 0.00 | 0.36 | 98.0 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.18 | 0.07 | 0.00 | 0.32 | 98.3 | |
| 1A1b | Petroleum refining | 0.13 | 0.04 | 0.00 | 0.29 | 98.6 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.83 | 0.73 | 0.00 | 0.27 | 98.9 | |
| 1A3c | Railways | 0.08 | 0.01 | 0.00 | 0.22 | 99.1 | |
| 3F | Field burning of agricultural residues | 2.02 | 1.59 | 0.00 | 0.19 | 99.3 | |
| 1A4ai | Commercial/institutional: Stationary | 0.17 | 0.18 | 0.00 | 0.17 | 99.5 | |
| 2C1 | Iron and steel production | 0.02 | 0.04 | 0.00 | 0.13 | 99.6 | |
| 3Dc | Farm-level agricultural operations including storage, har | 0.06 | 0.02 | 0.00 | 0.13 | 99.7 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.02 | 0.04 | 0.00 | 0.10 | 99.8 | |
| 2A2 | Lime production | 0.01 | 0.02 | 0.00 | 0.06 | 99.9 | |
| 5C1biii | Clinical waste incineration | 0.01 | 0.00 | 0.00 | 0.04 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.30 | 0.25 | 0.00 | 0.04 | 100.0 | |
| 2D3g | Chemical products | 0.01 | 0.01 | 0.00 | 0.02 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B1a | Manure management - Dairy cattle | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5A | Biological treatment of waste - Solid waste disposal on | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify ir | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**PM10 Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 28.43 | 28.4 | x |
| 2D3b | Road paving with asphalt | 17.15 | 45.6 | x |
| 2H1 | Pulp and paper industry | 13.85 | 59.4 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 7.89 | 67.3 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 5.92 | 73.3 | x |
| 1A3bi | Road transport: Passenger cars | 3.08 | 76.3 | x |
| 3F | Field burning of agricultural residues | 2.91 | 79.2 | x |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | 2.88 | 82.1 | x |
| 2A3 | Glass production | 2.48 | 84.6 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 2.02 | 86.6 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 2.01 | 88.6 | |
| 1A3ai(i) | International aviation LTO (civil) | 1.76 | 90.4 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 1.50 | 91.9 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 1.26 | 93.2 | |
| 1A3bii | Road transport: Light duty vehicles | 1.16 | 94.3 | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | 0.97 | 95.3 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.77 | 96.1 | |
| 5E | Other waste (please specify in IIR) | 0.75 | 96.8 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.60 | 97.4 | |
| 1A1a | Public electricity and heat production | 0.59 | 98.0 | |
| 1A3dii | National navigation (shipping) | 0.44 | 98.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.32 | 98.8 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.29 | 99.0 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.22 | 99.3 | |
| 2A2 | Lime production | 0.21 | 99.5 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.14 | 99.6 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.11 | 99.7 | |
| 2C1 | Iron and steel production | 0.08 | 99.8 | |
| 1A1b | Petroleum refining | 0.07 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.07 | 99.9 | |
| 2D3g | Chemical products | 0.03 | 100.0 | |
| 1A3c | Railways | 0.03 | 100.0 | |
| 5A | Biological treatment of waste - Solid waste disposal on land | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 100.0 | |
| 3B1a | Manure management - Dairy cattle | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify in IIR) | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |

**PM10 Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 27.63 | 16.32 | 0.09 | 22.30 | 22.3 | x |
| 2H1 | Pulp and paper industry | 3.97 | 7.95 | 0.07 | 17.44 | 39.7 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 2.84 | 4.53 | 0.03 | 8.23 | 48.0 | x |
| 1A1a | Public electricity and heat production | 2.98 | 0.34 | 0.03 | 7.63 | 55.6 | x |
| 1A3bii | Road transport: Light duty vehicles | 3.22 | 0.67 | 0.03 | 7.14 | 62.7 | x |
| 2D3b | Road paving with asphalt | 10.23 | 9.85 | 0.02 | 5.76 | 68.5 | x |
| 2A3 | Glass production | 0.55 | 1.42 | 0.01 | 3.58 | 72.1 | x |
| 1A3bi | Road transport: Passenger cars | 1.10 | 1.77 | 0.01 | 3.23 | 75.3 | x |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.00 | 0.86 | 0.01 | 3.16 | 78.5 | x |
| 3Dc | Farm-level agricultural operations including storage, har | 1.58 | 0.56 | 0.01 | 2.67 | 81.1 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 3.30 | 3.40 | 0.01 | 2.66 | 83.8 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.36 | 1.01 | 0.01 | 2.65 | 86.4 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.99 | 0.13 | 0.01 | 2.48 | 88.9 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 1.55 | 0.72 | 0.01 | 1.97 | 90.9 | |
| 1A2e | Stationary combustion in manufacturing industries and | 1.06 | 0.34 | 0.01 | 1.90 | 92.8 | |
| 2L | Other production, consumption, storage, transportation | 1.41 | 1.66 | 0.01 | 1.89 | 94.7 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.55 | 0.06 | 0.01 | 1.43 | 96.1 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 1.08 | 1.15 | 0.00 | 1.04 | 97.2 | |
| 1A1b | Petroleum refining | 0.21 | 0.04 | 0.00 | 0.46 | 97.6 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.10 | 0.16 | 0.00 | 0.32 | 97.9 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.65 | 0.44 | 0.00 | 0.31 | 98.2 | |
| 5E | Other waste (please specify in IIR) | 0.63 | 0.43 | 0.00 | 0.30 | 98.5 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.19 | 0.08 | 0.00 | 0.28 | 98.8 | |
| 2A2 | Lime production | 0.06 | 0.12 | 0.00 | 0.25 | 99.1 | |
| 1A3c | Railways | 0.08 | 0.01 | 0.00 | 0.19 | 99.3 | |
| 3F | Field burning of agricultural residues | 2.13 | 1.67 | 0.00 | 0.18 | 99.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.17 | 0.18 | 0.00 | 0.15 | 99.6 | |
| 1A2d | Stationary combustion in manufacturing industries and | 1.39 | 1.16 | 0.00 | 0.11 | 99.7 | |
| 2C1 | Iron and steel production | 0.02 | 0.05 | 0.00 | 0.11 | 99.8 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.02 | 0.04 | 0.00 | 0.08 | 99.9 | |
| 5C1biii | Clinical waste incineration | 0.02 | 0.00 | 0.00 | 0.05 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.30 | 0.25 | 0.00 | 0.03 | 100.0 | |
| 2D3g | Chemical products | 0.01 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5A | Biological treatment of waste - Solid waste disposal on | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B1a | Manure management - Dairy cattle | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify ir | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**TSP** **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 2D3b | Road paving with asphalt | 45.47 | 45.5 | x |
| 1A4bi | Residential: Stationary | 14.11 | 59.6 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 13.00 | 72.6 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 7.84 | 80.4 | x |
| 2H1 | Pulp and paper industry | 7.40 | 87.8 | |
| 2L | Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR) | 3.36 | 91.2 | |
| 3F | Field burning of agricultural residues | 1.39 | 92.6 | |
| 2A3 | Glass production | 1.23 | 93.8 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 1.06 | 94.9 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.83 | 95.7 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.71 | 96.4 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.65 | 97.0 | |
| 3Dc | Farm-level agricultural operations including storage, handling and transport of agricultural products | 0.46 | 97.5 | |
| 1A1a | Public electricity and heat production | 0.39 | 97.9 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.37 | 98.3 | |
| 5E | Other waste (please specify in IIR) | 0.36 | 98.6 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.31 | 98.9 | |
| 2A2 | Lime production | 0.24 | 99.2 | |
| 1A3dii | National navigation (shipping) | 0.21 | 99.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.15 | 99.5 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.14 | 99.7 | |
| 2C1 | Iron and steel production | 0.12 | 99.8 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.06 | 99.8 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.06 | 99.9 | |
| 1A1b | Petroleum refining | 0.03 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.03 | 100.0 | |
| 1A3c | Railways | 0.01 | 100.0 | |
| 2D3g | Chemical products | 0.01 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 100.0 | |
| 5A | Biological treatment of waste - Solid waste disposal on land | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 100.0 | |
| 3B1a | Manure management - Dairy cattle | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify in IIR) | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 100.0 | |

**TSP** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 28.99 | 17.12 | 0.08 | 26.82 | 26.8 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 9.21 | 15.77 | 0.06 | 19.08 | 45.9 | x |
| 2H1 | Pulp and paper industry | 4.48 | 8.98 | 0.04 | 12.77 | 58.7 | x |
| 1A1a | Public electricity and heat production | 4.53 | 0.47 | 0.03 | 10.08 | 68.8 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 7.90 | 9.51 | 0.02 | 5.63 | 74.4 | x |
| 2D3b | Road paving with asphalt | 57.30 | 55.18 | 0.01 | 3.98 | 78.4 | x |
| 2A3 | Glass production | 0.58 | 1.50 | 0.01 | 2.54 | 80.9 | x |
| 3Dc | Farm-level agricultural operations including storage, hai | 1.58 | 0.56 | 0.01 | 2.48 | 83.4 | |
| 2L | Other production, consumption, storage, transportation | 3.41 | 4.07 | 0.01 | 2.34 | 85.7 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.00 | 0.86 | 0.01 | 2.29 | 88.0 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 1.75 | 0.78 | 0.01 | 2.29 | 90.3 | |
| 1A2e | Stationary combustion in manufacturing industries and | 1.20 | 0.38 | 0.01 | 1.98 | 92.3 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.36 | 1.01 | 0.01 | 1.80 | 94.1 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.67 | 0.07 | 0.00 | 1.49 | 95.6 | |
| 3F | Field burning of agricultural residues | 2.15 | 1.69 | 0.00 | 0.87 | 96.4 | |
| 1A2d | Stationary combustion in manufacturing industries and | 1.60 | 1.29 | 0.00 | 0.57 | 97.0 | |
| 1A1b | Petroleum refining | 0.27 | 0.04 | 0.00 | 0.56 | 97.6 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.65 | 0.44 | 0.00 | 0.44 | 98.0 | |
| 5E | Other waste (please specify in IIR) | 0.63 | 0.43 | 0.00 | 0.43 | 98.5 | |
| 2A2 | Lime production | 0.16 | 0.29 | 0.00 | 0.39 | 98.8 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.19 | 0.08 | 0.00 | 0.27 | 99.1 | |
| 2C1 | Iron and steel production | 0.05 | 0.14 | 0.00 | 0.25 | 99.4 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.10 | 0.16 | 0.00 | 0.20 | 99.6 | |
| 1A3c | Railways | 0.09 | 0.02 | 0.00 | 0.17 | 99.7 | |
| 1A3dii | National navigation (shipping) | 0.30 | 0.25 | 0.00 | 0.08 | 99.8 | |
| 5C1biii | Clinical waste incineration | 0.03 | 0.00 | 0.00 | 0.07 | 99.9 | |
| 1A4ai | Commercial/institutional: Stationary | 0.17 | 0.19 | 0.00 | 0.07 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.02 | 0.04 | 0.00 | 0.05 | 100.0 | |
| 2D3g | Chemical products | 0.01 | 0.01 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5A | Biological treatment of waste - Solid waste disposal on | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B3 | Manure management - Swine | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giii | Manure mangement - Turkeys | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B1a | Manure management - Dairy cattle | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gi | Manure mangement - Laying hens | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4giv | Manure management - Other poultry | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4gii | Manure mangement - Broilers | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B1b | Manure management - Non-dairy cattle | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B2 | Manure management - Sheep | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4f | Manure management - Mules and asses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4h | Manure management - Other animals (please specify ir | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4d | Manure management - Goats | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 3B4e | Manure management - Horses | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**BC** **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 16.51 | 16.5 | x |
| 1A3bi | Road transport: Passenger cars | 14.89 | 31.4 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 14.14 | 45.5 | x |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 11.49 | 57.0 | x |
| 1A3ai(i) | International aviation LTO (civil) | 10.39 | 67.4 | x |
| 1A3bii | Road transport: Light duty vehicles | 6.42 | 73.8 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 5.85 | 79.7 | x |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 5.42 | 85.1 | x |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 3.86 | 89.0 | |
| 3F | Field burning of agricultural residues | 3.17 | 92.1 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 2.49 | 94.6 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 1.69 | 96.3 | |
| 1A4ai | Commercial/institutional: Stationary | 1.24 | 97.6 | |
| 1A3dii | National navigation (shipping) | 0.71 | 98.3 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.46 | 98.7 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.44 | 99.2 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.25 | 99.4 | |
| 1A3c | Railways | 0.20 | 99.6 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.18 | 99.8 | |
| 1A1a | Public electricity and heat production | 0.10 | 99.9 | |
| 1A1b | Petroleum refining | 0.10 | 100.0 | |
| 2A2 | Lime production | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |

**BC** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A3bii | Road transport: Light duty vehicles | 1.71 | 0.30 | 0.13 | 29.94 | 29.9 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 0.26 | 0.66 | 0.07 | 15.99 | 45.9 | x |
| 1A3bi | Road transport: Passenger cars | 0.43 | 0.70 | 0.06 | 13.27 | 59.2 | x |
| 1A3ai(i) | International aviation LTO (civil) | 0.17 | 0.48 | 0.05 | 12.23 | 71.4 | x |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.52 | 0.54 | 0.03 | 5.75 | 77.2 | x |
| 1A4bi | Residential: Stationary | 1.30 | 0.77 | 0.02 | 4.64 | 81.8 | x |
| 1A2e | Stationary combustion in manufacturing industries and | 0.32 | 0.12 | 0.02 | 3.62 | 85.4 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.15 | 0.01 | 0.01 | 3.27 | 88.7 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.53 | 0.27 | 0.01 | 3.15 | 91.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.11 | 0.01 | 0.01 | 2.08 | 93.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.05 | 0.08 | 0.01 | 1.56 | 95.5 | |
| 1A3c | Railways | 0.05 | 0.01 | 0.00 | 0.86 | 96.4 | |
| 1A1a | Public electricity and heat production | 0.04 | 0.00 | 0.00 | 0.85 | 97.2 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.05 | 0.02 | 0.00 | 0.59 | 97.8 | |
| 3F | Field burning of agricultural residues | 0.19 | 0.15 | 0.00 | 0.57 | 98.4 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.01 | 0.02 | 0.00 | 0.46 | 98.8 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.28 | 0.18 | 0.00 | 0.39 | 99.2 | |
| 1A4ai | Commercial/institutional: Stationary | 0.10 | 0.06 | 0.00 | 0.33 | 99.6 | |
| 1A3dii | National navigation (shipping) | 0.04 | 0.03 | 0.00 | 0.19 | 99.7 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.37 | 0.25 | 0.00 | 0.18 | 99.9 | |
| 1A1b | Petroleum refining | 0.01 | 0.00 | 0.00 | 0.06 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 2A2 | Lime production | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

CO Level Assessment

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 48.60 | 48.6 | x |
| 1A3bi | Road transport: Passenger cars | 11.68 | 60.3 | x |
| 3F | Field burning of agricultural residues | 9.61 | 69.9 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 8.77 | 78.7 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 3.15 | 81.8 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 3.11 | 84.9 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 3.04 | 88.0 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 2.26 | 90.2 | |
| 1A1a | Public electricity and heat production | 2.07 | 92.3 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 1.99 | 94.3 | |
| 1A3bii | Road transport: Light duty vehicles | 0.99 | 95.2 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.91 | 96.2 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.76 | 96.9 | |
| 1A1b | Petroleum refining | 0.63 | 97.6 | |
| 1A4ai | Commercial/institutional: Stationary | 0.47 | 98.0 | |
| 2C1 | Iron and steel production | 0.42 | 98.4 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.34 | 98.8 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.27 | 99.1 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.25 | 99.3 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.18 | 99.5 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.14 | 99.6 | |
| 1A3dii | National navigation (shipping) | 0.12 | 99.7 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.09 | 99.8 | |
| 1A3c | Railways | 0.08 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.05 | 100.0 | |
| 1A2a | Stationary combustion in manufacturing industries and construction: Iron and steel | 0.02 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.02 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |

CO Trend Assessment (1990-2015)

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A3bi | Road transport: Passenger cars | 346.80 | 31.10 | 0.11 | 42.13 | 42.1 | x |
| 1A4bi | Residential: Stationary | 218.76 | 129.35 | 0.07 | 26.51 | 68.6 | x |
| 3F | Field burning of agricultural residues | 33.11 | 25.58 | 0.02 | 6.92 | 75.6 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 94.28 | 23.34 | 0.01 | 4.25 | 79.8 | x |
| 2B10a | Chemical industry: Other (please specify in the IIR) | 5.46 | 8.37 | 0.01 | 3.15 | 83.0 | x |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 5.93 | 8.08 | 0.01 | 2.93 | 85.9 | |
| 1A1a | Public electricity and heat production | 2.03 | 5.50 | 0.01 | 2.33 | 88.2 | |
| 1A2d | Stationary combustion in manufacturing industries and | 5.67 | 6.01 | 0.01 | 1.97 | 90.2 | |
| 1A2a | Stationary combustion in manufacturing industries and | 11.16 | 0.06 | 0.00 | 1.81 | 92.0 | |
| 1A2f | Stationary combustion in manufacturing industries and | 13.82 | 8.28 | 0.00 | 1.73 | 93.7 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 7.75 | 5.29 | 0.00 | 1.28 | 95.0 | |
| 1A3ai(i) | International aviation LTO (civil) | 2.16 | 2.42 | 0.00 | 0.81 | 95.8 | |
| 2C1 | Iron and steel production | 8.12 | 1.13 | 0.00 | 0.79 | 96.6 | |
| 1A1b | Petroleum refining | 0.75 | 1.68 | 0.00 | 0.69 | 97.3 | |
| 1A3bii | Road transport: Light duty vehicles | 11.17 | 2.63 | 0.00 | 0.57 | 97.9 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 2.76 | 2.02 | 0.00 | 0.52 | 98.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.62 | 1.24 | 0.00 | 0.50 | 98.9 | |
| 1B2aiv | Fugitive emissions oil: Refining / storage | 0.00 | 0.73 | 0.00 | 0.35 | 99.3 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.28 | 0.37 | 0.00 | 0.13 | 99.4 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.68 | 0.48 | 0.00 | 0.12 | 99.5 | |
| 1A2c | Stationary combustion in manufacturing industries and | 1.29 | 0.66 | 0.00 | 0.11 | 99.6 | |
| 1A3dii | National navigation (shipping) | 0.38 | 0.32 | 0.00 | 0.09 | 99.7 | |
| 1A3c | Railways | 1.10 | 0.20 | 0.00 | 0.08 | 99.8 | |
| 1A2e | Stationary combustion in manufacturing industries and | 2.19 | 0.91 | 0.00 | 0.08 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 1.08 | 0.24 | 0.00 | 0.06 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.08 | 0.14 | 0.00 | 0.06 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.05 | 0.04 | 0.00 | 0.01 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.02 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

**Pb** **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 2A3 | Glass production | 56.79 | 56.8 | x |
| 1A3bi | Road transport: Passenger cars | 12.49 | 69.3 | x |
| 2C1 | Iron and steel production | 10.62 | 79.9 | x |
| 1A1a | Public electricity and heat production | 8.60 | 88.5 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 4.85 | 93.4 | |
| 1A4bi | Residential: Stationary | 2.42 | 95.8 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 2.06 | 97.8 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.73 | 98.6 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.25 | 98.8 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.17 | 99.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.14 | 99.1 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.13 | 99.3 | |
| 1A1b | Petroleum refining | 0.12 | 99.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.10 | 99.5 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.09 | 99.6 | |
| 5C1bi | Industrial waste incineration | 0.08 | 99.7 | |
| 3F | Field burning of agricultural residues | 0.08 | 99.7 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.07 | 99.8 | |
| 1A3dii | National navigation (shipping) | 0.06 | 99.9 | |
| 1A3bii | Road transport: Light duty vehicles | 0.05 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.03 | 99.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.02 | 100.0 | |
| 1A3c | Railways | 0.02 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.01 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.01 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |

**Pb** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A3bi | Road transport: Passenger cars | 462.54 | 4.48 | 0.05 | 43.88 | 43.9 | x |
| 2A3 | Glass production | 7.35 | 20.39 | 0.04 | 33.83 | 77.7 | x |
| 2C1 | Iron and steel production | 1.57 | 3.81 | 0.01 | 6.31 | 84.0 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 65.54 | 0.74 | 0.01 | 6.04 | 90.1 | |
| 1A1a | Public electricity and heat production | 3.50 | 3.09 | 0.01 | 4.86 | 94.9 | |
| 1A2f | Stationary combustion in manufacturing industries and | 2.19 | 1.74 | 0.00 | 2.72 | 97.6 | |
| 1A4bi | Residential: Stationary | 1.47 | 0.87 | 0.00 | 1.31 | 98.9 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.36 | 0.26 | 0.00 | 0.41 | 99.4 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.07 | 0.05 | 0.00 | 0.08 | 99.4 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.02 | 0.05 | 0.00 | 0.08 | 99.5 | |
| 1A1b | Petroleum refining | 0.09 | 0.04 | 0.00 | 0.07 | 99.6 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.04 | 0.00 | 0.06 | 99.6 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.45 | 0.06 | 0.00 | 0.06 | 99.7 | |
| 5C1bi | Industrial waste incineration | 0.03 | 0.03 | 0.00 | 0.05 | 99.7 | |
| 5C1biii | Clinical waste incineration | 0.44 | 0.00 | 0.00 | 0.04 | 99.8 | |
| 3F | Field burning of agricultural residues | 0.04 | 0.03 | 0.00 | 0.04 | 99.8 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.02 | 0.02 | 0.00 | 0.04 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.03 | 0.02 | 0.00 | 0.03 | 99.9 | |
| 1A3bii | Road transport: Light duty vehicles | 0.02 | 0.02 | 0.00 | 0.03 | 99.9 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.31 | 0.03 | 0.00 | 0.02 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.03 | 0.01 | 0.00 | 0.02 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.00 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 1.27 | 0.09 | 0.00 | 0.01 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.01 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A3c | Railways | 0.03 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

Cd **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 63.60 | 63.6 | x |
| 1A4bi | Residential: Stationary | 9.89 | 73.5 | x |
| 2C1 | Iron and steel production | 6.92 | 80.4 | x |
| 2A3 | Glass production | 6.05 | 86.5 | |
| 3F | Field burning of agricultural residues | 4.16 | 90.6 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 2.58 | 93.2 | |
| 1A1a | Public electricity and heat production | 1.84 | 95.0 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.81 | 95.8 | |
| 1A3bi | Road transport: Passenger cars | 0.79 | 96.6 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.66 | 97.3 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.63 | 97.9 | |
| 1A1b | Petroleum refining | 0.41 | 98.3 | |
| 1A4ai | Commercial/institutional: Stationary | 0.40 | 98.7 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.36 | 99.1 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.28 | 99.4 | |
| 1A3bii | Road transport: Light duty vehicles | 0.20 | 99.6 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.10 | 99.7 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.06 | 99.7 | |
| 5E | Other waste (please specify in IIR) | 0.06 | 99.8 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.06 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.05 | 99.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.04 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.03 | 100.0 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 1A3c | Railways | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |

Cd **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 1.35 | 0.08 | 0.13 | 32.99 | 33.0 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 2.92 | 2.69 | 0.11 | 28.20 | 61.2 | x |
| 2C1 | Iron and steel production | 0.03 | 0.29 | 0.04 | 10.77 | 72.0 | x |
| 2A3 | Glass production | 0.09 | 0.26 | 0.03 | 7.64 | 79.6 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.29 | 0.03 | 0.03 | 6.76 | 86.4 | x |
| 1A2c | Stationary combustion in manufacturing industries and | 0.13 | 0.02 | 0.01 | 2.98 | 89.3 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.16 | 0.03 | 0.01 | 2.89 | 92.2 | |
| 1A4bi | Residential: Stationary | 0.71 | 0.42 | 0.01 | 2.44 | 94.7 | |
| 1A3bi | Road transport: Passenger cars | 0.02 | 0.03 | 0.00 | 0.90 | 95.6 | |
| 5C1biii | Clinical waste incineration | 0.03 | 0.00 | 0.00 | 0.88 | 96.4 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.19 | 0.11 | 0.00 | 0.85 | 97.3 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.01 | 0.03 | 0.00 | 0.79 | 98.1 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.02 | 0.00 | 0.67 | 98.8 | |
| 3F | Field burning of agricultural residues | 0.24 | 0.18 | 0.00 | 0.63 | 99.4 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.01 | 0.01 | 0.00 | 0.27 | 99.7 | |
| 1A3bii | Road transport: Light duty vehicles | 0.01 | 0.01 | 0.00 | 0.11 | 99.8 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.00 | 0.00 | 0.00 | 0.10 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.03 | 99.9 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.03 | 99.9 | |
| 1A1b | Petroleum refining | 0.03 | 0.02 | 0.00 | 0.02 | 99.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.00 | 0.00 | 0.00 | 0.02 | 99.9 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A3c | Railways | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A3dii | National navigation (shipping) | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**Hg** **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 47.03 | 47.0 | x |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 25.65 | 72.7 | x |
| 2A3 | Glass production | 5.11 | 77.8 | x |
| 1B2d | Other fugitive emissions from energy production | 4.80 | 82.6 | x |
| 2C1 | Iron and steel production | 4.16 | 86.7 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 3.86 | 90.6 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 2.02 | 92.6 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 1.84 | 94.5 | |
| 3F | Field burning of agricultural residues | 1.74 | 96.2 | |
| 5C1bv | Cremation | 1.31 | 97.5 | |
| 1A4bi | Residential: Stationary | 1.26 | 98.8 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.27 | 99.0 | |
| 1A1b | Petroleum refining | 0.24 | 99.3 | |
| 1A4ai | Commercial/institutional: Stationary | 0.16 | 99.4 | |
| 5E | Other waste (please specify in IIR) | 0.15 | 99.6 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.14 | 99.7 | |
| 5C1biii | Clinical waste incineration | 0.11 | 99.8 | |
| 5C1bi | Industrial waste incineration | 0.08 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.07 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.02 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |

**Hg** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 5C1biii | Clinical waste incineration | 0.65 | 0.00 | 0.10 | 29.56 | 29.6 | x |
| 1A2d | Stationary combustion in manufacturing industries and | 0.33 | 0.43 | 0.08 | 22.40 | 52.0 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.24 | 0.03 | 0.03 | 8.08 | 60.0 | x |
| 1B2d | Other fugitive emissions from energy production | 0.00 | 0.08 | 0.02 | 6.98 | 67.0 | x |
| 2A3 | Glass production | 0.03 | 0.09 | 0.02 | 6.11 | 73.1 | x |
| 1A1a | Public electricity and heat production | 1.38 | 0.78 | 0.02 | 6.08 | 79.2 | x |
| 2C1 | Iron and steel production | 0.02 | 0.07 | 0.02 | 5.12 | 84.3 | x |
| 1A2c | Stationary combustion in manufacturing industries and | 0.10 | 0.00 | 0.02 | 4.31 | 88.6 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.15 | 0.03 | 0.01 | 3.95 | 92.6 | |
| 1A2f | Stationary combustion in manufacturing industries and | 0.21 | 0.06 | 0.01 | 3.83 | 96.4 | |
| 5C1bv | Cremation | 0.00 | 0.02 | 0.01 | 1.91 | 98.3 | |
| 3F | Field burning of agricultural residues | 0.04 | 0.03 | 0.00 | 0.78 | 99.1 | |
| 1A4bi | Residential: Stationary | 0.03 | 0.02 | 0.00 | 0.33 | 99.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.00 | 0.00 | 0.18 | 99.6 | |
| 1A1b | Petroleum refining | 0.01 | 0.00 | 0.00 | 0.12 | 99.7 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 0.00 | 0.00 | 0.09 | 99.8 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 0.00 | 0.00 | 0.05 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.05 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.00 | 0.00 | 0.00 | 0.04 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.02 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**As Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 55.43 | 55.4 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 19.87 | 75.3 | x |
| 2A3 | Glass production | 12.26 | 87.6 | x |
| 2C1 | Iron and steel production | 3.54 | 91.1 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 1.73 | 92.8 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 1.72 | 94.5 | |
| 1A3dii | National navigation (shipping) | 0.98 | 95.5 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.77 | 96.3 | |
| 1A1b | Petroleum refining | 0.68 | 97.0 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.66 | 97.6 | |
| 3F | Field burning of agricultural residues | 0.62 | 98.3 | |
| 1A4bi | Residential: Stationary | 0.56 | 98.8 | |
| 1B2d | Other fugitive emissions from energy production | 0.27 | 99.1 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.26 | 99.3 | |
| 5E | Other waste (please specify in IIR) | 0.24 | 99.6 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.19 | 99.8 | |
| 1A4ai | Commercial/institutional: Stationary | 0.13 | 99.9 | |
| 1A3c | Railways | 0.03 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.02 | 100.0 | |
| 5C1bv | Cremation | 0.01 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.01 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |

**As Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 2A3 | Glass production | 0.07 | 0.20 | 0.06 | 26.02 | 26.0 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.26 | 0.03 | 0.04 | 19.78 | 45.8 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 0.41 | 0.33 | 0.03 | 14.53 | 60.3 | x |
| 1A2c | Stationary combustion in manufacturing industries and | 0.12 | 0.01 | 0.02 | 10.07 | 70.4 | x |
| 1A2e | Stationary combustion in manufacturing industries and | 0.14 | 0.03 | 0.02 | 8.69 | 79.1 | x |
| 2C1 | Iron and steel production | 0.03 | 0.06 | 0.02 | 7.02 | 86.1 | x |
| 1A2d | Stationary combustion in manufacturing industries and | 0.05 | 0.00 | 0.01 | 4.44 | 90.6 | |
| 1A1b | Petroleum refining | 0.06 | 0.01 | 0.01 | 3.57 | 94.1 | |
| 1A1a | Public electricity and heat production | 1.59 | 0.92 | 0.01 | 2.39 | 96.5 | |
| 1A3dii | National navigation (shipping) | 0.02 | 0.02 | 0.00 | 0.78 | 97.3 | |
| 1B2d | Other fugitive emissions from energy production | 0.00 | 0.00 | 0.00 | 0.73 | 98.0 | |
| 3F | Field burning of agricultural residues | 0.01 | 0.01 | 0.00 | 0.53 | 98.6 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.00 | 0.00 | 0.32 | 98.9 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.02 | 0.01 | 0.00 | 0.28 | 99.2 | |
| 1A4bi | Residential: Stationary | 0.01 | 0.01 | 0.00 | 0.23 | 99.4 | |
| 1A3c | Railways | 0.00 | 0.00 | 0.00 | 0.18 | 99.6 | |
| 5C1biii | Clinical waste incineration | 0.00 | 0.00 | 0.00 | 0.14 | 99.7 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 0.00 | 0.00 | 0.09 | 99.8 | |
| 5E | Other waste (please specify in IIR) | 0.01 | 0.00 | 0.00 | 0.09 | 99.9 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.04 | 99.9 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.03 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.02 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |

**Cr** **Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 2A3 | Glass production | 39.13 | 39.1 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 30.29 | 69.4 | x |
| 1A4bi | Residential: Stationary | 7.07 | 76.5 | x |
| 1A1a | Public electricity and heat production | 6.44 | 82.9 | x |
| 1A3bi | Road transport: Passenger cars | 5.41 | 88.3 | |
| 2C1 | Iron and steel production | 3.50 | 91.8 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 1.79 | 93.6 | |
| 1A3bii | Road transport: Light duty vehicles | 1.50 | 95.1 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 1.15 | 96.3 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.78 | 97.0 | |
| 1A1b | Petroleum refining | 0.66 | 97.7 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.66 | 98.4 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.44 | 98.8 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.30 | 99.1 | |
| 1A4ai | Commercial/institutional: Stationary | 0.29 | 99.4 | |
| 3F | Field burning of agricultural residues | 0.24 | 99.6 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.12 | 99.8 | |
| 1A3dii | National navigation (shipping) | 0.06 | 99.8 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.05 | 99.9 | |
| 5E | Other waste (please specify in IIR) | 0.04 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.03 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.02 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.01 | 100.0 | |
| 1A3c | Railways | 0.00 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |

**Cr** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 2A3 | Glass production | 1.48 | 4.10 | 0.23 | 33.82 | 33.8 | x |
| 1A1a | Public electricity and heat production | 3.67 | 0.67 | 0.18 | 27.25 | 61.1 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 2.79 | 3.17 | 0.07 | 10.40 | 71.5 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.74 | 0.07 | 0.04 | 6.22 | 77.7 | x |
| 1A3bi | Road transport: Passenger cars | 0.26 | 0.57 | 0.03 | 4.18 | 81.9 | x |
| 2C1 | Iron and steel production | 0.82 | 0.37 | 0.02 | 3.53 | 85.4 | |
| 1A4bi | Residential: Stationary | 1.25 | 0.74 | 0.02 | 3.33 | 88.7 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.34 | 0.05 | 0.02 | 2.75 | 91.5 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.39 | 0.08 | 0.02 | 2.74 | 94.2 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.40 | 0.12 | 0.02 | 2.44 | 96.7 | |
| 1A1b | Petroleum refining | 0.23 | 0.07 | 0.01 | 1.42 | 98.1 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.13 | 0.19 | 0.01 | 0.91 | 99.0 | |
| 1A3bii | Road transport: Light duty vehicles | 0.15 | 0.16 | 0.00 | 0.42 | 99.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.03 | 0.00 | 0.34 | 99.7 | |
| 5C1biii | Clinical waste incineration | 0.00 | 0.00 | 0.00 | 0.04 | 99.8 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.00 | 0.01 | 0.00 | 0.04 | 99.8 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 0.00 | 0.00 | 0.04 | 99.9 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.02 | 0.01 | 0.00 | 0.03 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 0.00 | 0.00 | 0.02 | 99.9 | |
| 1A3c | Railways | 0.00 | 0.00 | 0.00 | 0.02 | 99.9 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.04 | 0.03 | 0.00 | 0.02 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.01 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 3F | Field burning of agricultural residues | 0.03 | 0.03 | 0.00 | 0.01 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A3dii | National navigation (shipping) | 0.01 | 0.01 | 0.00 | 0.00 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**Cu** **Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A3bi | Road transport: Passenger cars | 47.73 | 47.7 | x |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 15.94 | 63.7 | x |
| 1A3bii | Road transport: Light duty vehicles | 13.04 | 76.7 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 6.85 | 83.6 | x |
| 1A1a | Public electricity and heat production | 4.07 | 87.6 | |
| 2A3 | Glass production | 3.45 | 91.1 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 2.65 | 93.7 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 1.52 | 95.2 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 1.47 | 96.7 | |
| 2C1 | Iron and steel production | 1.02 | 97.7 | |
| 1A4bi | Residential: Stationary | 0.65 | 98.4 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.39 | 98.8 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.32 | 99.1 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.21 | 99.3 | |
| 1A1b | Petroleum refining | 0.19 | 99.5 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.13 | 99.6 | |
| 3F | Field burning of agricultural residues | 0.08 | 99.7 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.06 | 99.8 | |
| 1A3c | Railways | 0.06 | 99.8 | |
| 1A3dii | National navigation (shipping) | 0.06 | 99.9 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.04 | 99.9 | |
| 5E | Other waste (please specify in IIR) | 0.03 | 100.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.03 | 100.0 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |

**Cu** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A3bi | Road transport: Passenger cars | 6.42 | 14.10 | 0.25 | 42.74 | 42.7 | x |
| 1A1a | Public electricity and heat production | 2.06 | 1.20 | 0.07 | 12.80 | 55.5 | x |
| 1A3bii | Road transport: Light duty vehicles | 3.68 | 3.85 | 0.05 | 9.20 | 64.7 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 2.16 | 2.02 | 0.04 | 7.32 | 72.1 | x |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.99 | 0.78 | 0.03 | 4.53 | 76.6 | x |
| 2A3 | Glass production | 0.37 | 1.02 | 0.02 | 4.14 | 80.7 | x |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.64 | 0.43 | 0.02 | 3.45 | 84.2 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.38 | 0.10 | 0.02 | 3.38 | 87.6 | |
| 1A4bi | Residential: Stationary | 0.33 | 0.19 | 0.01 | 2.01 | 89.6 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.21 | 0.06 | 0.01 | 1.83 | 91.4 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.19 | 0.04 | 0.01 | 1.73 | 93.1 | |
| 1A1b | Petroleum refining | 0.19 | 0.06 | 0.01 | 1.59 | 94.7 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 3.32 | 4.71 | 0.01 | 1.48 | 96.2 | |
| 2C1 | Iron and steel production | 0.11 | 0.30 | 0.01 | 1.18 | 97.4 | |
| 1A3c | Railways | 0.10 | 0.02 | 0.01 | 0.90 | 98.3 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.39 | 0.45 | 0.00 | 0.67 | 99.0 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.04 | 0.11 | 0.00 | 0.47 | 99.4 | |
| 3F | Field burning of agricultural residues | 0.03 | 0.02 | 0.00 | 0.13 | 99.5 | |
| 1A3dii | National navigation (shipping) | 0.02 | 0.02 | 0.00 | 0.08 | 99.6 | |
| 5C1biii | Clinical waste incineration | 0.01 | 0.00 | 0.00 | 0.08 | 99.7 | |
| 5E | Other waste (please specify in IIR) | 0.01 | 0.01 | 0.00 | 0.07 | 99.8 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.01 | 0.01 | 0.00 | 0.06 | 99.8 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.01 | 0.00 | 0.05 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 0.00 | 0.00 | 0.04 | 99.9 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.04 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.01 | 0.02 | 0.00 | 0.03 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**Ni** **Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 28.35 | 28.3 | x |
| 2A3 | Glass production | 20.49 | 48.8 | x |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 11.02 | 59.9 | x |
| 1A1a | Public electricity and heat production | 8.69 | 68.5 | x |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 6.76 | 75.3 | x |
| 2C1 | Iron and steel production | 6.63 | 81.9 | x |
| 1A3dii | National navigation (shipping) | 5.94 | 87.9 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 3.65 | 91.5 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 2.53 | 94.0 | |
| 1A1b | Petroleum refining | 1.90 | 95.9 | |
| 1A3bi | Road transport: Passenger cars | 1.67 | 97.6 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.59 | 98.2 | |
| 1A3bii | Road transport: Light duty vehicles | 0.43 | 98.6 | |
| 1A4bi | Residential: Stationary | 0.41 | 99.0 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.37 | 99.4 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.19 | 99.6 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.11 | 99.7 | |
| 3F | Field burning of agricultural residues | 0.09 | 99.8 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.09 | 99.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.03 | 99.9 | |
| 5C1bi | Industrial waste incineration | 0.02 | 99.9 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.02 | 100.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.02 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 100.0 | |
| 1A3c | Railways | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |

**Ni** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 52.92 | 1.38 | 0.06 | 33.37 | 33.4 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 6.00 | 4.49 | 0.03 | 18.02 | 51.4 | x |
| 2A3 | Glass production | 1.17 | 3.24 | 0.03 | 15.44 | 66.8 | x |
| 1A1b | Petroleum refining | 13.30 | 0.30 | 0.02 | 8.61 | 75.4 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 11.26 | 0.58 | 0.01 | 5.67 | 81.1 | x |
| 2C1 | Iron and steel production | 0.14 | 1.05 | 0.01 | 5.18 | 86.3 | |
| 1A2d | Stationary combustion in manufacturing industries and | 6.35 | 1.74 | 0.01 | 3.95 | 90.2 | |
| 1A3dii | National navigation (shipping) | 1.12 | 0.94 | 0.01 | 3.88 | 94.1 | |
| 1A2c | Stationary combustion in manufacturing industries and | 5.52 | 0.40 | 0.00 | 2.19 | 96.3 | |
| 1A3bi | Road transport: Passenger cars | 0.12 | 0.26 | 0.00 | 1.23 | 97.5 | |
| 1A2e | Stationary combustion in manufacturing industries and | 5.99 | 1.07 | 0.00 | 0.82 | 98.4 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.06 | 0.09 | 0.00 | 0.42 | 98.8 | |
| 1A3bii | Road transport: Light duty vehicles | 0.07 | 0.07 | 0.00 | 0.29 | 99.1 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.01 | 0.06 | 0.00 | 0.29 | 99.4 | |
| 1A4bi | Residential: Stationary | 0.11 | 0.06 | 0.00 | 0.24 | 99.6 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.01 | 0.03 | 0.00 | 0.14 | 99.7 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.03 | 0.02 | 0.00 | 0.07 | 99.8 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.02 | 0.01 | 0.00 | 0.06 | 99.9 | |
| 3F | Field burning of agricultural residues | 0.02 | 0.01 | 0.00 | 0.06 | 99.9 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.00 | 0.00 | 0.00 | 0.02 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A3c | Railways | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

**Se** **Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 2A3 | Glass production | 97.09 | 97.1 | x |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 1.68 | 98.8 | |
| 1A1a | Public electricity and heat production | 0.44 | 99.2 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.30 | 99.5 | |
| 1A3bi | Road transport: Passenger cars | 0.12 | 99.6 | |
| 1A4bi | Residential: Stationary | 0.05 | 99.7 | |
| 1A3dii | National navigation (shipping) | 0.05 | 99.7 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.04 | 99.8 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.03 | 99.8 | |
| 1A1b | Petroleum refining | 0.03 | 99.8 | |
| 1A3bii | Road transport: Light duty vehicles | 0.03 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.03 | 99.9 | |
| 3F | Field burning of agricultural residues | 0.03 | 99.9 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.02 | 99.9 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.02 | 100.0 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.01 | 100.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.01 | 100.0 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.01 | 100.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.00 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 1A3c | Railways | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |

**Se** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 2A3 | Glass production | 11.11 | 30.77 | 0.16 | 50.02 | 50.0 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 0.60 | 0.53 | 0.08 | 26.15 | 76.2 | x |
| 1A1a | Public electricity and heat production | 0.19 | 0.14 | 0.03 | 9.11 | 85.3 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.04 | 0.01 | 0.01 | 2.50 | 87.8 | |
| 1A1b | Petroleum refining | 0.03 | 0.01 | 0.01 | 1.93 | 89.7 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.07 | 0.10 | 0.01 | 1.90 | 91.6 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.03 | 0.01 | 0.01 | 1.68 | 93.3 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.03 | 0.01 | 0.00 | 1.42 | 94.7 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.02 | 0.01 | 0.00 | 1.40 | 96.1 | |
| 1A4bi | Residential: Stationary | 0.03 | 0.02 | 0.00 | 1.39 | 97.5 | |
| 1A3dii | National navigation (shipping) | 0.02 | 0.01 | 0.00 | 0.79 | 98.3 | |
| 3F | Field burning of agricultural residues | 0.01 | 0.01 | 0.00 | 0.48 | 98.8 | |
| 1A3bii | Road transport: Light duty vehicles | 0.01 | 0.01 | 0.00 | 0.39 | 99.2 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.01 | 0.01 | 0.00 | 0.21 | 99.4 | |
| 1A3bi | Road transport: Passenger cars | 0.02 | 0.04 | 0.00 | 0.20 | 99.6 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.00 | 0.00 | 0.00 | 0.18 | 99.7 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.00 | 0.00 | 0.00 | 0.10 | 99.8 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.05 | 99.9 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.00 | 0.00 | 0.03 | 99.9 | |
| 1A3c | Railways | 0.00 | 0.00 | 0.00 | 0.03 | 100.0 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.00 | 0.00 | 0.00 | 0.02 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

**Zn** **Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 2C1 | Iron and steel production | 30.45 | 30.4 | x |
| 2A3 | Glass production | 19.89 | 50.3 | x |
| 1A4bi | Residential: Stationary | 17.50 | 67.8 | x |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 8.72 | 76.5 | x |
| 1A3bi | Road transport: Passenger cars | 6.81 | 83.4 | x |
| 1A1a | Public electricity and heat production | 6.35 | 89.7 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 2.39 | 92.1 | |
| 1A3bii | Road transport: Light duty vehicles | 1.88 | 94.0 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 1.43 | 95.4 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.82 | 96.2 | |
| 1A4ai | Commercial/institutional: Stationary | 0.80 | 97.0 | |
| 1A1b | Petroleum refining | 0.67 | 97.7 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.50 | 98.2 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.42 | 98.6 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.35 | 99.0 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.33 | 99.3 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.27 | 99.6 | |
| 3F | Field burning of agricultural residues | 0.21 | 99.8 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.06 | 99.8 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.05 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.04 | 99.9 | |
| 1A5b | Other, Mobile (including military, land based and recreational boats) | 0.03 | 99.9 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.03 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.01 | 100.0 | |
| 1A3c | Railways | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |

**Zn** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A4bi | Residential: Stationary | 27.92 | 16.47 | 0.28 | 33.35 | 33.3 | x |
| 2C1 | Iron and steel production | 10.49 | 28.66 | 0.21 | 24.58 | 57.9 | x |
| 2A3 | Glass production | 6.75 | 18.72 | 0.14 | 16.28 | 74.2 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 3.60 | 1.34 | 0.05 | 5.58 | 79.8 | x |
| 1A3bi | Road transport: Passenger cars | 2.93 | 6.41 | 0.04 | 4.23 | 84.0 | x |
| 1A2d | Stationary combustion in manufacturing industries and | 4.75 | 8.21 | 0.03 | 3.25 | 87.3 | |
| 1A1a | Public electricity and heat production | 5.71 | 5.98 | 0.02 | 2.52 | 89.8 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 1.55 | 0.77 | 0.02 | 2.08 | 91.9 | |
| 1A2e | Stationary combustion in manufacturing industries and | 1.08 | 0.40 | 0.01 | 1.69 | 93.6 | |
| 1A2c | Stationary combustion in manufacturing industries and | 1.04 | 0.47 | 0.01 | 1.47 | 95.0 | |
| 1A1b | Petroleum refining | 1.03 | 0.63 | 0.01 | 1.20 | 96.2 | |
| 1A3bii | Road transport: Light duty vehicles | 1.70 | 1.77 | 0.01 | 0.78 | 97.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.25 | 0.75 | 0.01 | 0.70 | 97.7 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 1.39 | 2.25 | 0.01 | 0.70 | 98.4 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 0.37 | 0.26 | 0.00 | 0.39 | 98.8 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.40 | 0.33 | 0.00 | 0.32 | 99.1 | |
| 1A3ai(i) | International aviation LTO (civil) | 0.11 | 0.31 | 0.00 | 0.27 | 99.4 | |
| 3F | Field burning of agricultural residues | 0.25 | 0.20 | 0.00 | 0.21 | 99.6 | |
| 1A3c | Railways | 0.06 | 0.01 | 0.00 | 0.10 | 99.7 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.06 | 0.02 | 0.00 | 0.10 | 99.8 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.05 | 0.01 | 0.00 | 0.09 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.04 | 0.03 | 0.00 | 0.03 | 99.9 | |
| 1A5b | Other, Mobile (including military, land based and recrea | 0.04 | 0.03 | 0.00 | 0.03 | 99.9 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.03 | 0.06 | 0.00 | 0.03 | 100.0 | |
| 1A3aii(i) | Domestic aviation LTO (civil) | 0.03 | 0.05 | 0.00 | 0.02 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

**Diox Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 5C1biii | Clinical waste incineration | 59.48 | 59.5 | x |
| 1A4bi | Residential: Stationary | 18.02 | 77.5 | x |
| 5C1bi | Industrial waste incineration | 10.23 | 87.7 | x |
| 5E | Other waste (please specify in IIR) | 5.64 | 93.4 | |
| 1A1a | Public electricity and heat production | 2.29 | 95.7 | |
| 1A3bi | Road transport: Passenger cars | 1.82 | 97.5 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.67 | 98.1 | |
| 1A3bii | Road transport: Light duty vehicles | 0.46 | 98.6 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.42 | 99.0 | |
| 3F | Field burning of agricultural residues | 0.19 | 99.2 | |
| 1A4ai | Commercial/institutional: Stationary | 0.18 | 99.4 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.17 | 99.6 | |
| 2C1 | Iron and steel production | 0.17 | 99.7 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.09 | 99.8 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.09 | 99.9 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 0.06 | 100.0 | |
| 1A1b | Petroleum refining | 0.01 | 100.0 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.01 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |

**Diox Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 5C1biii | Clinical waste incineration | 482.30 | 45.80 | 0.05 | 49.54 | 49.5 | x |
| 1A4bi | Residential: Stationary | 23.49 | 13.88 | 0.02 | 20.87 | 70.4 | x |
| 5C1bi | Industrial waste incineration | 7.96 | 7.88 | 0.01 | 13.42 | 83.8 | x |
| 5E | Other waste (please specify in IIR) | 6.38 | 4.34 | 0.01 | 6.82 | 90.6 | |
| 1A1a | Public electricity and heat production | 1.04 | 1.76 | 0.00 | 3.22 | 93.9 | |
| 1A3bi | Road transport: Passenger cars | 0.61 | 1.40 | 0.00 | 2.63 | 96.5 | |
| 1A3biii | Road transport: Heavy duty vehicles and buses | 0.29 | 0.52 | 0.00 | 0.95 | 97.4 | |
| 1A3bii | Road transport: Light duty vehicles | 0.33 | 0.35 | 0.00 | 0.61 | 98.1 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.28 | 0.32 | 0.00 | 0.56 | 98.6 | |
| 2C1 | Iron and steel production | 2.11 | 0.13 | 0.00 | 0.36 | 99.0 | |
| 1A4ai | Commercial/institutional: Stationary | 0.01 | 0.14 | 0.00 | 0.28 | 99.3 | |
| 3F | Field burning of agricultural residues | 0.18 | 0.15 | 0.00 | 0.24 | 99.5 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.20 | 0.13 | 0.00 | 0.20 | 99.7 | |
| 1A3biv | Road transport: Mopeds & motorcycles | 0.08 | 0.07 | 0.00 | 0.12 | 99.8 | |
| 1A2f | Stationary combustion in manufacturing industries and | 0.64 | 0.05 | 0.00 | 0.10 | 99.9 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.22 | 0.07 | 0.00 | 0.07 | 100.0 | |
| 1A1b | Petroleum refining | 0.03 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.07 | 0.01 | 0.00 | 0.01 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |

**Total PAH Level Assessment**

| NFR | Sectors | % total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 3F | Field burning of agricultural residues | 88.06 | 88.1 | x |
| 1A4bi | Residential: Stationary | 9.81 | 97.9 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and other machinery | 0.75 | 98.6 | |
| 2C1 | Iron and steel production | 0.52 | 99.1 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.26 | 99.4 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.14 | 99.5 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 0.11 | 99.7 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.08 | 99.7 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.08 | 99.8 | |
| 1A3dii | National navigation (shipping) | 0.08 | 99.9 | |
| 1A4ai | Commercial/institutional: Stationary | 0.04 | 99.9 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.04 | 100.0 | |
| 1A3c | Railways | 0.03 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 100.0 | |
| 1A1b | Petroleum refining | 0.00 | 100.0 | |
| 1A1a | Public electricity and heat production | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 100.0 | |

**Total PAH Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | % cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 3F | Field burning of agricultural residues | 125.30 | 99.62 | 0.05 | 49.43 | 49.4 | x |
| 2C1 | Iron and steel production | 6.11 | 0.59 | 0.03 | 25.75 | 75.2 | x |
| 1A4bi | Residential: Stationary | 18.81 | 11.10 | 0.02 | 18.00 | 93.2 | x |
| 1A2f | Stationary combustion in manufacturing industries and | 0.59 | 0.12 | 0.00 | 2.05 | 95.2 | |
| 1A2c | Stationary combustion in manufacturing industries and | 0.24 | 0.04 | 0.00 | 0.90 | 96.1 | |
| 1A2gviii | Stationary combustion in manufacturing industries and | 0.58 | 0.29 | 0.00 | 0.88 | 97.0 | |
| 1A3c | Railways | 0.19 | 0.03 | 0.00 | 0.69 | 97.7 | |
| 1A2e | Stationary combustion in manufacturing industries and | 0.35 | 0.16 | 0.00 | 0.64 | 98.3 | |
| 1A4ciii | Agriculture/Forestry/Fishing: National fishing | 0.25 | 0.09 | 0.00 | 0.62 | 99.0 | |
| 1A4cii | Agriculture/Forestry/Fishing: Off-road vehicles and othe | 1.24 | 0.85 | 0.00 | 0.43 | 99.4 | |
| 1A4ai | Commercial/institutional: Stationary | 0.00 | 0.05 | 0.00 | 0.30 | 99.7 | |
| 1A2d | Stationary combustion in manufacturing industries and | 0.09 | 0.10 | 0.00 | 0.20 | 99.9 | |
| 1A3dii | National navigation (shipping) | 0.10 | 0.09 | 0.00 | 0.07 | 100.0 | |
| 1A1a | Public electricity and heat production | 0.01 | 0.00 | 0.00 | 0.03 | 100.0 | |
| 5C1bi | Industrial waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A1b | Petroleum refining | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1A4ci | Agriculture/Forestry/Fishing: Stationary | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 1B2c | Venting and flaring (oil, gas, combined oil and gas) | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5C1biii | Clinical waste incineration | 0.00 | 0.00 | 0.00 | 0.00 | 100.0 | |
| 5E | Other waste (please specify in IIR) | NO | 0.00 | 0.00 | 0.00 | 100.0 | |

**HCB** **Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 81.61 | 81.6 | x |
| 5C1biii | Clinical waste incineration | 9.66 | 91.3 | |
| 5C1bi | Industrial waste incineration | 3.80 | 95.1 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 2.28 | 97.4 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.96 | 98.3 | |
| 1A4ai | Commercial/institutional: Stationary | 0.55 | 98.9 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.49 | 99.4 | |
| 2C1 | Iron and steel production | 0.43 | 99.8 | |
| 5C1bv | Cremation | 0.19 | 100.0 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.02 | 100.0 | |
| 1A4bi | Residential: Stationary | 0.01 | 100.0 | |
| 1A1b | Petroleum refining | 0.00 | 100.0 | |

**HCB** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 1A1a | Public electricity and heat production | 0.57 | 0.97 | 0.21 | 46.35 | 46.4 | x |
| 2C1 | Iron and steel production | 1.86 | 0.01 | 0.15 | 33.13 | 79.5 | x |
| 5C1biii | Clinical waste incineration | 1.21 | 0.11 | 0.07 | 14.97 | 94.4 | x |
| 1A4bi | Residential: Stationary | 0.11 | 0.00 | 0.01 | 1.99 | 96.4 | |
| 5C1bi | Industrial waste incineration | 0.05 | 0.05 | 0.01 | 1.81 | 98.3 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.03 | 0.03 | 0.00 | 1.12 | 99.4 | |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.02 | 0.01 | 0.00 | 0.39 | 99.8 | |
| 5C1bv | Cremation | 0.00 | 0.00 | 0.00 | 0.13 | 99.9 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.01 | 0.00 | 0.00 | 0.09 | 100.0 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.02 | 0.01 | 0.00 | 0.02 | 100.0 | |

**PCBs** **Level Assessment**

| NFR | Sectors | %total 2015 | Cumulative total | Key category |
|---|---|---|---|---|
| 5C1bi | Industrial waste incineration | 99.83 | 99.8 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.07 | 99.9 | |
| 5C1biii | Clinical waste incineration | 0.04 | 99.9 | |
| 1A1a | Public electricity and heat production | 0.04 | 100.0 | |
| 5C1bv | Cremation | 0.01 | 100.0 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.00 | 100.0 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.00 | 100.0 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 0.00 | 100.0 | |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.00 | 100.0 | |
| 1A1b | Petroleum refining | 0.00 | 100.0 | |

**PCBs** **Trend Assessment (1990-2015)**

| NFR | Sectors | 1990 | Last year | Trend assess. | %cont. to trend | Cumulative total | Key category |
|---|---|---|---|---|---|---|---|
| 5C1bi | Industrial waste incineration | 62.29 | 60.71 | 0.01 | 45.70 | 45.7 | x |
| 5C1biii | Clinical waste incineration | 0.28 | 0.03 | 0.00 | 33.00 | 78.7 | x |
| 1A2c | Stationary combustion in manufacturing industries and construction: Chemicals | 0.07 | 0.00 | 0.00 | 9.15 | 87.9 | x |
| 1A2gviii | Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR) | 0.10 | 0.04 | 0.00 | 7.31 | 95.2 | |
| 1A1a | Public electricity and heat production | 0.00 | 0.03 | 0.00 | 3.48 | 98.6 | |
| 5C1bv | Cremation | 0.00 | 0.01 | 0.00 | 0.81 | 99.5 | |
| 1A2e | Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco | 0.00 | 0.00 | 0.00 | 0.30 | 99.8 | |
| 1A2f | Stationary combustion in manufacturing industries and construction: Non-metallic minerals | 0.00 | 0.00 | 0.00 | 0.24 | 100.0 | |
| 1A2d | Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print | 0.00 | 0.00 | 0.00 | 0.01 | 100.0 | |

# ANNEX B: ENERGY BALANCE SHEET FOR 2015

## Annex Table 3 – Energy Balance Sheet for 2015

| BALANÇO ENERGÉTICO tep 2015 (provisório) | | Hulha e Antracite | Coque de Carvão | **Total de Carvão** | Petróleo Bruto | Refugos e Produtos Intermédios | GPL | Gasolinas | Petróleos | Jets | Gasóleo | Fuelóleo | Nafta | Coque de Petróleo | **Total de Petróleo Energético** | Lubrificantes | Asfaltos | Parafinas | Solventes | Outros | **Total de Petróleo Não Energético** | **Total de Petróleo** | **Gás Natural** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 = 1+ 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 = 4 a 13 | 15 | 16 | 17 | 18 | 19 | 20 = 15 a 19 | 21= 14 + 20 | 22 |
| **IMPORTAÇÕES** | 1. | 3 313 150 | 5 586 | **3 318 736** | 14 360 476 | 1 258 229 | 814 275 | 143 752 | 948 | 10 796 | 795 950 | 260 748 | 64 141 | 296 791 | **18 006 106** | 42 800 | 115 859 | 4 394 | 128 | | **163 181** | **18 169 287** | **4 081 859** |
| **PRODUÇÃO DOMÉSTICA** | 2. | | | | | | | | | | | | | | | | | | | | | | |
| **VARIAÇÃO DE "STOCKS"** | 3. | - 49 958 | - 29 | **- 49 987** | 125 016 | 106 950 | - 1 099 | 1 051 | | | 71 225 | - 70 700 | | - 53 032 | **179 411** | - 19 061 | 4 482 | - 913 | 990 | - 18 479 | **- 32 981** | **146 430** | **- 15 428** |
| **SAÍDAS** | 4. | 110 032 | 41 | **110 073** | | 151 843 | 79 347 | 1 876 984 | | 1 048 263 | 2 434 858 | 2 136 441 | 430 521 | | **8 158 257** | 122 780 | 89 628 | 6 137 | 16 462 | 182 476 | **417 483** | **8 575 740** | |
| *Exportações* | *4.1* | *110 032* | *41* | *110 073* | | *151 843* | *79 347* | *1 876 984* | | *1 867* | *2 323 761* | *1 608 181* | *430 521* | | *6 472 504* | *122 182* | *89 628* | *6 137* | *16 462* | *182 476* | *416 885* | *6 889 389* | |
| *Transportes Marítimos Internacionais* | *4.2* | | | | | | | | | | *111 097* | *528 260* | | | *639 357* | *598* | | | | | *598* | *639 955* | |
| *Aviação Internacional* | *4.3* | | | | | | | | | *1 046 396* | | | | | *1 046 396* | | | | | | | *1 046 396* | |
| **CONSUMO DE ENERGIA PRIMÁRIA** | 5. | 3 253 076 | 5 574 | **3 258 650** | 14 235 460 | 999 436 | 736 027 | -1 734 283 | 948 | -1 037 467 | -1 710 133 | -1 804 993 | - 366 380 | 349 823 | **9 668 438** | - 60 919 | 21 749 | - 830 | - 17 324 | - 163 997 | **- 221 321** | **9 447 117** | **4 097 287** |
| **PARA NOVAS FORMAS DE ENERGIA** | 6. | 3 245 793 | | **3 245 793** | 14 229 583 | 328 487 | - 191 901 | -2 860 762 | - 357 | -1 191 797 | -6 538 354 | -2 112 740 | -1 057 454 | | **604 705** | - 111 775 | - 155 993 | - 12 478 | - 26 656 | - 203 047 | **- 509 949** | **94 757** | **2 375 600** |
| *Briquetes* | *6.1* | | | | | | | | | | | | | | | | | | | | | | |
| *Coque* | *6.2* | | | | | | | | | | | | | | | | | | | | | | |
| *Produtos de Petróleo* | *6.3* | | | | *14 229 583* | *470 191* | *- 191 901* | *-2 860 762* | *- 357* | *-1 191 797* | *-6 562 879* | *-2 385 838* | *-1 303 056* | | *203 184* | *- 111 775* | *- 155 993* | *- 12 478* | *- 26 656* | *- 203 047* | *- 509 948* | *- 306 764* | |
| *Hidrogénio* | *6.4* | | | | | | | | | | | | | | | | | | | | | | *244 500* |
| *Petroquímica* | *6.5* | | | | | *- 173 530* | | | | | | | *245 602* | | *72 072* | | | | | | | *72 072* | |
| *Eletricidade* | *6.6* | *3 245 793* | | *3 245 793* | | | | | | | *24 446* | *152 965* | | | *177 411* | | | | | | | *177 411* | *900 039* |
| *Cogeração* | *6.7* | | | | | *31 826* | | | | | *79* | *120 133* | | | *152 038* | | | | | | | *152 038* | *1 231 061* |
| *Produção de Eletricidade* | *6.7.1* | | | | | | | | | | *53* | *45 986* | | | *46 039* | | | | | | | *46 039* | |
| *Refinação de Petróleo* | *6.7.2* | | | | | *31826* | | | | | | | | | *31826* | | | | | | | *31826* | *406 532* |
| *Gás de Cidade* | *6.7.3* | | | | | | | | | | | | | | | | | | | | | | |
| *Agricultura* | *6.7.4* | | | | | | | | | | | | | | | | | | | | | | *4 020* |
| *Alimentação, bebidas e tabaco* | *6.7.5* | | | | | | | | | | | *9 735* | | | *9 735* | | | | | | | *9 735* | *84 193* |
| *Têxteis* | *6.7.6* | | | | | | | | | | *5* | | | | *5* | | | | | | | *5* | *117 749* |
| *Papel e Artigos de Papel* | *6.7.7* | | | | | | | | | | *3* | *28 551* | | | *28 554* | | | | | | | *28 554* | *396 306* |
| *Químicas e Plásticos* | *6.7.8* | | | | | | | | | | | *23 136* | | | *23 136* | | | | | | | *23 136* | *63 735* |
| *Cerâmicas* | *6.7.9* | | | | | | | | | | | | | | | | | | | | | | *30 963* |
| *Vidro e Artigos de Vidro* | *6.7.10* | | | | | | | | | | | | | | | | | | | | | | |
| *Cimento e Cal* | *6.7.11* | | | | | | | | | | | | | | | | | | | | | | *3 244* |
| *Metalúrgicas* | *6.7.12* | | | | | | | | | | | | | | | | | | | | | | |
| *Siderurgia* | *6.7.13* | | | | | | | | | | | | | | | | | | | | | | |
| *Vestuário, Calçado e Curtumes* | *6.7.14* | | | | | | | | | | | | | | | | | | | | | | *7 941* |
| *Madeira e Artigos de Madeira* | *6.7.15* | | | | | | | | | | *18* | *12 725* | | | *12 743* | | | | | | | *12 743* | |
| *Borracha* | *6.7.16* | | | | | | | | | | | | | | | | | | | | | | *15 518* |
| *Metalo-eletro-mecânicas* | *6.7.17* | | | | | | | | | | | | | | | | | | | | | | *2 516* |
| *Outras Indústrias Transformadoras* | *6.7.18* | | | | | | | | | | | | | | | | | | | | | | *1844* |
| *Indústrias Extrativas* | *6.7.19* | | | | | | | | | | | | | | | | | | | | | | *23 868* |
| *Serviços* | *6.7.20* | | | | | | | | | | | | | | | | | | | | | | *72 632* |

| BALANÇO ENERGÉTICO tep 2015 (provisório) | | Hulha e Antracite | Coque de Carvão | Total de Carvão | Petróleo Bruto | Refugos e Produtos Intermédios | GPL | Gasolinas | Petróleos | Jets | Gasóleo | Fuelóleo | Nafta | Coque de Petróleo | Total de Petróleo Energético | Lubrificantes | Asfaltos | Parafinas | Solventes | Outros | Total de Petróleo Não Energético | Total de Petróleo | Gás Natural |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 = 1 + 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 = 4 a 13 | 15 | 16 | 17 | 18 | 19 | 20 = 15 a 19 | 21= 14 + 20 | 22 |
| **CONSUMO DO SECTOR ENERGÉTICO** | 7. | | | | 5 877 | 670 949 | 1 527 | | 215 | | 56 | 120 195 | 353 | | **799 172** | 1 887 | - 386 | 67 | 50 | 21 | **1 639** | **800 811** | **133 589** |
| *Consumo Próprio da Refinação* | *7.1* | | | | | *658 300* | *1 264* | | | | *40* | *120 195* | | | *779 799* | *26* | | | | | *26* | *779 825* | *125 430* |
| *Perdas da Refinação* | *7.2* | | | | *5 877* | *12 649* | *258* | | *215* | | | | *353* | | *19 352* | *242* | *- 386* | *67* | *50* | | *- 27* | *19 325* | |
| *Coquerie e outras não especificadas* | *7.3* | | | | | | | | | | | | | | | | | | | | | | |
| *Centrais Elétricas* | *7.4* | | | | | | | | | | | | | | | *1 617* | | | | | *1 617* | *1 617* | |
| *Bombagem Hidroelétrica* | *7.5* | | | | | | | | | | | | | | | | | | | | | | |
| *Extração de Carvão, Petróleo e Gás Natural* | *7.6* | | | | | | | | | | | | | | | *2* | | | | | *2* | *2* | *6* |
| *Perdas de Transporte e Distribuição* | *7.7* | | | | | | *5* | | | | *16* | | | | *21* | | | | | *21* | *21* | *42* | *8 153* |
| **CONSUMO COMO MATÉRIA PRIMA** | 8. | | | | | | *354 928* | | | | | | *690 721* | | *1 045 649* | | | | | | | *1 045 649* | |
| **DISPONÍVEL PARA CONSUMO FINAL** | 9. | 7 283 | 5 574 | **12 857** | | | 571 473 | 1 126 479 | 1 090 | 154 330 | 4 828 165 | 187 552 | | 349 823 | **7 218 912** | 48 969 | 178 128 | 11 581 | 9 282 | 39 029 | **286 989** | **7 505 900** | **1 588 098** |
| ACERTOS | | - 352 | - 358 | - 710 | | | 851 | - 9 956 | 197 | 4 948 | - 31 150 | 25 635 | | 1 350 | - 8 125 | 2 257 | 553 | 135 | 391 | 3 103 | 6 439 | - 1 687 | - 29 750 |
| **CONSUMO FINAL** | 10. | 7 635 | 5 932 | **13 567** | | | 570 622 | 1 136 435 | 893 | 149 382 | 4 859 315 | 161 917 | | 348 473 | **7 227 037** | 46 712 | 177 575 | 11 446 | 8 891 | 35 926 | **280 550** | **7 507 587** | **1 617 848** |
| **AGRICULTURA E PESCAS** | 10.1 | | | | | | 5 317 | 779 | 610 | | 345 078 | 3 931 | | | **355 715** | 242 | | | | | **242** | **355 957** | 4 336 |
| *Agricultura* | *10.1.1* | | | | | | *5 310* | *662* | *610* | | *257 316* | *1 282* | | | *265 180* | *93* | | | | | *93* | *265 273* | *3 800* |
| *Pescas* | *10.1.2* | | | | | | *7* | *117* | | | *87 762* | *2 649* | | | *90 535* | *149* | | | | | *149* | *90 684* | *536* |
| **INDÚSTRIAS EXTRATIVAS** | 10.2 | 41 | | **41** | | | 1 308 | | | | 33 429 | 525 | | | **35 262** | 1 066 | | | | | **1 066** | **36 328** | **4 057** |
| **INDÚSTRIAS TRANSFORMADORAS** | 10.3 | 7 594 | 5 932 | **13 526** | | | 56 121 | 27 | 35 | | 113 265 | 65 993 | | 348 473 | **583 914** | 10 071 | 3 748 | 11 399 | 8 837 | 35 926 | **69 981** | **653 895** | **1 093 825** |
| *Alimentação, bebidas e tabaco* | *10.3.1* | | | | | | *17 747* | | *6* | | *31 756* | *27 837* | | | *77 346* | *362* | | | | | *362* | *77 708* | *145 649* |
| *Têxteis* | *10.3.2* | | | | | | *2 751* | | | | *1 761* | *2 124* | | | *6 636* | *849* | | | | | *849* | *7 485* | *115 997* |
| *Papel e Artigos de Papel* | *10.3.3* | | | | | | *2 008* | | *7* | | *4 790* | *27 851* | | | *34 656* | *310* | | | | *11 646* | *11 956* | *46 612* | *101 904* |
| *Químicas e Plásticos* | *10.3.4* | | | | | | *2 424* | | *2* | | *2 338* | *3 802* | | | *8 566* | *1 559* | *3 748* | *7 398* | *8 588* | *24 280* | *45 573* | *54 139* | *137 143* |
| *Cerâmicas* | *10.3.5* | | | | | | *3 563* | | *2* | | *3 852* | | | *10 680* | *18 097* | *102* | | | | | *102* | *18 199* | *194 943* |
| *Vidro e Artigos de Vidro* | *10.3.6* | | | | | | *117* | | | | *1 109* | *47* | | | *1 273* | *176* | | | | | *176* | *1 449* | *208 503* |
| *Cimento e Cal* | *10.3.7* | | | | | | *624* | | *2* | | *20 086* | *117* | | *337 793* | *358 622* | *223* | | | | | *223* | *358 845* | *33 275* |
| *Metalúrgicas* | *10.3.8* | | *4 414* | *4 414* | | | *2 413* | | | | *1 041* | | | | *3 454* | *388* | | | *1* | | *389* | *3 843* | *20 098* |
| *Siderurgia* | *10.3.9* | *7 425* | *1 371* | *8 796* | | | *76* | | | | *1 644* | | | | *1 720* | *352* | | | *1* | | *353* | *2 073* | *51 348* |
| *Vestuário, Calçado e Curtumes* | *10.3.10* | | | | | | *2 998* | | *1* | | *3 427* | *2 050* | | | *8 476* | *41* | | | *2* | | *43* | *8 519* | *13 197* |
| *Madeira e Artigos de Madeira* | *10.3.11* | | | | | | *1 677* | | | | *7 076* | *444* | | | *9 197* | *372* | | *3 473* | | | *3 845* | *13 042* | *7 834* |
| *Borracha* | *10.3.12* | | | | | | *146* | | | | *107* | | | | *253* | *2 024* | | *456* | *1* | | *2 481* | *2 734* | *3 796* |
| *Metalo-eletro-mecânicas* | *10.3.13* | *26* | *106* | *132* | | | *17 083* | *27* | *13* | | *8 050* | *370* | | | *25 543* | *2 856* | | *46* | *80* | | *2 982* | *28 525* | *54 379* |
| *Outras Indústrias Transformadoras* | *10.3.14* | *143* | *41* | *184* | | | *2 494* | | *2* | | *26 228* | *1 351* | | | *30 075* | *457* | | *26* | *164* | | *647* | *30 722* | *5 759* |
| **CONSTRUÇÃO E OBRAS PÚBLICAS** | 10.4 | | | | | | 8 208 | | 3 | | 84 534 | 14 235 | | | **106 980** | 1 542 | 173 827 | | 44 | | **175 413** | **282 393** | **14 533** |
| **TRANSPORTES** | 10.5 | | | | | | 39 338 | 1 135 629 | | 123 938 | 4 187 000 | 48 128 | | | **5 534 033** | 31 763 | | | | | **31 763** | **5 565 796** | **13 090** |
| *Aviação Nacional* | *10.5.1* | | | | | | | *1 321* | | *123 938* | | | | | *125 259* | *2* | | | | | *2* | *125 261* | |
| *Transportes Marítimos Nacionais* | *10.5.2* | | | | | | | *44* | | | *49 904* | *48 128* | | | *98 076* | *292* | | | | | *292* | *98 368* | |
| *Caminho de Ferro* | *10.5.3* | | | | | | | | | | *10 431* | | | | *10 431* | | | | | | | *10 431* | |
| *Rodoviários* | *10.5.4* | | | | | | *39 338* | *1 134 264* | | | *4 126 665* | | | | *5 300 267* | *31 469* | | | | | *31 469* | *5 331 736* | *13 090* |
| **SETOR DOMÉSTICO** | 10.6 | | | | | | 379 514 | | 188 | | 54 268 | | | | **433 970** | | | | | | | **433 970** | **263 908** |
| **SERVIÇOS** | 10.7 | | | | | | 80 816 | | 57 | 25 444 | 41 741 | 29 105 | | | **177 163** | 2 028 | | 47 | 10 | | **2 085** | **179 248** | **224 099** |

| BALANÇO ENERGÉTICO tep | | Gases Incond. de Petroquímica | Hidrogénio | **Outros Gases Derivados** | Hidro-eletricidade | Eólica | Foto-voltaica | Geo-térmica | Termo-eletricidade | **Total de Eletricidade** | **Calor** | Resíduos Não Renováveis | Solar Térmico | Lenhas e Resíduos Vegetais | Resíduos Sólidos Urbanos | Licores Sulfitivos | Outros Renováveis | Biogás | Biocombus-tíveis | **Renováveis Sem Eletricidade** | **TOTAL GERAL** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2015 (provisório)** | | 23 | 24 | 25 = 23 + 24 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41= 34 a 40 | 42=3+21+22+25+31+32+33+41 |
| **IMPORTAÇÕES** | 1. | | | | | | | | | **694 664** | | 33 609 | | 58 349 | | | 18 036 | | 67 675 | **144 060** | 26 442 215 |
| **PRODUÇÃO DOMÉSTICA** | 2. | | | | 842 760 | 998 257 | 68 469 | 17 507 | | **1 926 993** | | 132 917 | 80 267 | 1 595 773 | 97 388 | 983 554 | 22 563 | 82 580 | 320 678 | **3 182 803** | **5 242 713** |
| **VARIAÇÃO DE "STOCKS"** | 3. | | | | | | | | | | | | | | | | | | 6 955 | **6 955** | **87 970** |
| **SAÍDAS** | 4. | | | | | | | | | **499 781** | | | | 317 265 | | | | | 34 529 | **351 794** | **9 537 388** |
| *Exportações* | *4.1* | | | | | | | | | *499 781* | | | | *317 265* | | | | | *34 529* | *351 794* | *7 851 037* |
| *Transportes Marítimos Internacionais* | *4.2* | | | | | | | | | | | | | | | | | | | | *639 955* |
| *Aviação Internacional* | *4.3* | | | | | | | | | | | | | | | | | | | | *1 046 396* |
| **CONSUMO DE ENERGIA PRIMÁRIA** | 5. | | | | *842 760* | *998 257* | *68 469* | *17 507* | | **2 121 876** | | 166 526 | 80 267 | 1 336 857 | 97 388 | 983 554 | 40 599 | 82 580 | 346 869 | **2 968 114** | **22 059 570** |
| **PARA NOVAS FORMAS DE ENERGIA** | 6. | | | | *842 760* | *998 257* | *68 469* | *17 507* | -2 581 188 | **-2 581 188** | **-1 397 727** | 111 462 | | 437 270 | 97 388 | 983 554 | | 74 556 | 342 954 | **1 935 722** | **3 784 419** |
| *Briquetes* | *6.1* | | | | | | | | | | | | | | | | | | | | |
| *Coque* | *6.2* | | | | | | | | | | | | | | | | | | | | |
| *Produtos de Petróleo* | *6.3* | | *201 918* | *201 918* | | | | | | | | | | | | | | | *342 954* | *342 954* | *238 108* |
| *Hidrogénio* | *6.4* | | *- 201 918* | *- 201 918* | | | | | | | | | | | | | | | | | *42 582* |
| *Petroquímica* | *6.5* | *- 72 072* | | *- 72 072* | | | | | | | | | | | | | | | | | |
| *Eletricidade* | *6.6* | | | | *842 760* | *998 257* | *68 469* | *17 507* | *-1 963 936* | *-1 963 936* | | *97 388* | | *298 276* | *97 388* | | | *70 565* | | *466 229* | *2 922 924* |
| *Cogeração* | *6.7* | *72 072* | | *72 072* | | | | | *- 617 252* | *- 617 252* | *-1 397 727* | *14 074* | | *138 994* | | *983 554* | | *3 991* | | *1 126 539* | *580 805* |
| *Produção de Eletricidade* | *6.7.1* | | | | | | | | *- 16 591* | *- 16 591* | *- 836* | | | | | | | | | | *28 612* |
| *Refinação de Petróleo* | *6.7.2* | | | | | | | | *- 129 293* | *- 129 293* | *- 211 409* | | | | | | | | | | *97 656* |
| *Gás de Cidade* | *6.7.3* | | | | | | | | | | | | | | | | | | | | |
| *Agricultura* | *6.7.4* | | | | | | | | *- 1 772* | *- 1 772* | *- 1 599* | | | | | | | *309* | | *309* | *958* |
| *Alimentação, bebidas e tabaco* | *6.7.5* | | | | | | | | *- 26 383* | *- 26 383* | *- 47 493* | | | | | | | | | | *20 052* |
| *Têxteis* | *6.7.6* | | | | | | | | *- 47 309* | *- 47 309* | *- 39 927* | | | | | | | | | | *30 518* |
| *Papel e Artigos de Papel* | *6.7.7* | | | | | | | | *- 304 423* | *- 304 423* | *- 935 962* | | | *114 309* | | *983 554* | | | | *1 097 863* | *282 338* |
| *Químicas e Plásticos* | *6.7.8* | *72 072* | | *72 072* | | | | | *- 28 373* | *- 28 373* | *- 77 534* | *11 724* | | | | | | | | | *64 760* |
| *Cerâmicas* | *6.7.9* | | | | | | | | *- 10 116* | *- 10 116* | *- 15 675* | | | | | | | | | | *5 172* |
| *Vidro e Artigos de Vidro* | *6.7.10* | | | | | | | | | | | | | | | | | | | | |
| *Cimento e Cal* | *6.7.11* | | | | | | | | *- 1 360* | *- 1 360* | *- 1 016* | | | | | | | | | | *868* |
| *Metalúrgicas* | *6.7.12* | | | | | | | | | | | | | | | | | | | | |
| *Siderurgia* | *6.7.13* | | | | | | | | | | | | | | | | | | | | |
| *Vestuário, Calçado e Curtumes* | *6.7.14* | | | | | | | | *- 2 926* | *- 2 926* | *- 2 429* | | | | | | | | | | *2 586* |
| *Madeira e Artigos de Madeira* | *6.7.15* | | | | | | | | *- 6 882* | *- 6 882* | *- 12 340* | | | *24 685* | | | | | | *24 685* | *18 206* |
| *Borracha* | *6.7.16* | | | | | | | | *- 3 935* | *- 3 935* | *- 10 521* | *2 350* | | | | | | | | | *3 412* |
| *Metalo-eletro-mecânicas* | *6.7.17* | | | | | | | | *- 1 073* | *- 1 073* | *- 666* | | | | | | | | | | *777* |
| *Outras Indústrias Transformadoras* | *6.7.18* | | | | | | | | *- 1 617* | *- 1 617* | *- 865* | | | | | | | *2 695* | | *2 695* | *2 057* |
| *Indústrias Extrativas* | *6.7.19* | | | | | | | | *- 8 022* | *- 8 022* | *- 11 738* | | | | | | | | | | *4 108* |
| *Serviços* | *6.7.20* | | | | | | | | *- 27 177* | *- 27 177* | *- 27 717* | | | | | | | *987* | | *987* | *18 725* |

| BALANÇO ENERGÉTICO<br>tep<br><br>2015 (provisório) | | Gases Incond. de Petroquímica<br>23 | Hidrogénio<br>24 | **Outros Gases Derivados**<br>25 = 23 + 24 | Hidro-eletricidade<br>26 | Eólica<br>27 | Foto-voltaica<br>28 | Geo-térmica<br>29 | Termo-eletricidade<br>30 | **Total de Eletricidade**<br>31 | **Calor**<br>32 | Resíduos Não Renováveis<br>33 | Solar Térmico<br>34 | Lenhas e Resíduos Vegetais<br>35 | Resíduos Sólidos Urbanos<br>36 | Licores Sulfitivos<br>37 | Outros Renováveis<br>38 | Biogás<br>39 | Biocombus-tíveis<br>40 | **Renováveis Sem Eletricidade**<br>41= 34 a 40 | **TOTAL GERAL**<br>42=3+21+22+25+31+32+33+41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CONSUMO DO SECTOR ENERGÉTICO** | 7. | | | | | | | | | **763 057** | **211 409** | | | | | | | | | | **1 908 866** |
| *Consumo Próprio da Refinação* | *7.1* | | | | | | | | | *75 026* | *211 409* | | | | | | | | | | *1 191 690* |
| *Perdas da Refinação* | *7.2* | | | | | | | | | | | | | | | | | | | | *19 325* |
| *Coquerie e outras não especificadas* | *7.3* | | | | | | | | | *4* | | | | | | | | | | | *4* |
| *Centrais Elétricas* | *7.4* | | | | | | | | | *139 947* | | | | | | | | | | | *141 564* |
| *Bombagem Hidroelétrica* | *7.5* | | | | | | | | | *126 316* | | | | | | | | | | | *126 316* |
| *Extração de Carvão, Petróleo e Gás Natural* | *7.6* | | | | | | | | | *610* | | | | | | | | | | | *618* |
| *Perdas de Transporte e Distribuição* | *7.7* | | | | | | | | | *421 154* | | | | | | | | | | | *429 349* |
| **CONSUMO COMO MATÉRIA PRIMA** | 8. | | | | | | | | | | | | | | | | | | | | *1 045 649* |
| **DISPONÍVEL PARA CONSUMO FINAL** | 9. | | | | | | | | | **3 940 007** | **1 186 318** | 55 064 | 80 267 | 899 587 | | | 40 599 | 8 024 | 3 915 | **1 032 392** | **15 320 636** |
| ACERTOS | | | | | | | | | | 20 | | | | | | | | | 303 | 303 | - 31 824 |
| **CONSUMO FINAL** | 10. | | | | | | | | | **3 939 987** | **1 186 318** | 55 064 | 80 267 | 899 587 | | | 40 599 | 8 024 | 3 612 | **1 032 089** | **15 352 460** |
| **AGRICULTURA E PESCAS** | 10.1 | | | | | | | | | **73 597** | **1 599** | | | 2 667 | | | | | **3** | **2 670** | **438 159** |
| *Agricultura* | *10.1.1* | | | | | | | | | *69 749* | *1 599* | | | *2 667* | | | | | *1* | *2 668* | *343 089* |
| *Pescas* | *10.1.2* | | | | | | | | | *3 848* | | | | | | | | | *2* | *2* | *95 070* |
| **INDÚSTRIAS EXTRATIVAS** | 10.2 | | | | | | | | | **54 297** | **11 738** | | | | | | | | | | **106 461** |
| **INDÚSTRIAS TRANSFORMADORAS** | 10.3 | | | | | | | | | **1 262 978** | **1 145 264** | **55 064** | | **102 679** | | | **39 082** | 8 024 | **278** | **150 063** | **4 374 615** |
| *Alimentação, bebidas e tabaco* | *10.3.1* | | | | | | | | | *159 404* | *47 493* | | | *27 572* | | | | *1 258* | | *28 830* | *459 084* |
| *Têxteis* | *10.3.2* | | | | | | | | | *90 921* | *39 927* | | | *2 099* | | | | | | *2 099* | *256 429* |
| *Papel e Artigos de Papel* | *10.3.3* | | | | | | | | | *261 989* | *935 962* | | | *19 930* | | | *455* | *6 766* | | *27 151* | *1 373 618* |
| *Químicas e Plásticos* | *10.3.4* | | | | | | | | | *182 214* | *77 534* | *54* | | *1 075* | | | | | *278* | *1 353* | *452 437* |
| *Cerâmicas* | *10.3.5* | | | | | | | | | *33 414* | *15 675* | | | *17 887* | | | | | | *17 887* | *280 118* |
| *Vidro e Artigos de Vidro* | *10.3.6* | | | | | | | | | *44 326* | | | | | | | | | | | *254 278* |
| *Cimento e Cal* | *10.3.7* | | | | | | | | | *72 841* | *1 016* | *55 010* | | *7 395* | | | *38 627* | | | *46 022* | *567 009* |
| *Metalúrgicas* | *10.3.8* | | | | | | | | | *20 583* | | | | *2* | | | | | | *2* | *48 940* |
| *Siderurgia* | *10.3.9* | | | | | | | | | *108 652* | | | | | | | | | | | *170 869* |
| *Vestuário, Calçado e Curtumes* | *10.3.10* | | | | | | | | | *23 578* | *2 429* | | | *1 870* | | | | | | *1 870* | *49 593* |
| *Madeira e Artigos de Madeira* | *10.3.11* | | | | | | | | | *44 920* | *12 340* | | | *23 662* | | | | | | *23 662* | *101 798* |
| *Borracha* | *10.3.12* | | | | | | | | | *18 639* | *10 521* | | | *467* | | | | | | *467* | *36 157* |
| *Metalo-eletro-mecânicas* | *10.3.13* | | | | | | | | | *169 382* | *666* | | | *548* | | | | | | *548* | *253 632* |
| *Outras Indústrias Transformadoras* | *10.3.14* | | | | | | | | | *32 115* | *1 701* | | | *172* | | | | | | *172* | *70 653* |
| **CONSTRUÇÃO E OBRAS PÚBLICAS** | 10.4 | | | | | | | | | 26 384 | | | | 154 | | | | | | **154** | **323 464** |
| **TRANSPORTES** | 10.5 | | | | | | | | | 25 884 | | | | | | | | | 3 331 | **3 331** | **5 608 101** |
| *Aviação Nacional* | *10.5.1* | | | | | | | | | | | | | | | | | | | | *125 261* |
| *Transportes Marítimos Nacionais* | *10.5.2* | | | | | | | | | | | | | | | | | | | | *98 368* |
| *Caminho de Ferro* | *10.5.3* | | | | | | | | | *25 828* | | | | | | | | | | | *36 259* |
| *Rodoviários* | *10.5.4* | | | | | | | | | *56* | | | | | | | | | *3 331* | *3 331* | *5 348 213* |
| **SETOR DOMÉSTICO** | 10.6 | | | | | | | | | 1 029 809 | | | 37 571 | *762 949* | | | | | | **800 520** | **2 528 207** |
| **SERVIÇOS** | 10.7 | | | | | | | | | **1 467 038** | **27 717** | | 42 696 | 31 138 | | | 1 517 | | | **75 351** | **1 973 453** |

# ANNEX C: ENERGY (NFR 1)

## Transport (NFR 1.A.3)

Annex Table 4- Activity data for NFR 1.A.3.a: Fuel consumption from aviation sector (t)

| Fuel Sales | | NAPFUE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aviation Gasoline | L | 209 | 1,893 | 1,751 | 1,560 | 1,212 | 1,435 | 1,914 | 1,540 | 1,876 | 1,925 | 1,964 | 2,353 | 2,304 | 2,334 |
| Jet Fuel | L | 207 | 554,471 | 564,264 | 596,977 | 565,406 | 572,457 | 599,465 | 595,172 | 613,723 | 654,021 | 720,960 | 752,932 | 741,541 | 715,095 |
| | | | | | | | | | | | | | | | |
| **Fuel Sales** | | **NAPFUE** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** |
| Aviation Gasoline | L | 209 | 1,985 | 1,847 | 2,192 | 2,179 | 2,086 | 2,280 | 2,280 | 2,869 | 2,258 | 1,268 | 1,168 | 1,333 | 1,257 |
| Jet Fuel | L | 207 | 770,040 | 835,208 | 865,857 | 907,189 | 949,650 | 969,349 | 907,530 | 985,343 | 1,006,836 | 1,015,897 | 1,027,228 | 1,086,001 | 1,139,566 |

Annex Table 5- Aircraft type and representative aircraft for LTO and cruise emission factors.

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| 100 | Fokker 100 | L JeK | L2J | 100 | 100 |
| 146 | BAe 146 all pax models | L JeK | L4J | 146 | 146 |
| 310 | Airbus A310 all pax models | L JeK | L2J | 310 | 310 |
| 321 | Airbus A321-100/200 | L JeK | L2J | 321 | 320 |
| 330 | Airbus A330 all models | L JeK | L2J | 330 | 330 |
| 340 | Airbus A340 all models | L JeK | L4J | 342 | 340 |
| 707 | Boeing 707/720 all pax models | L JeK | L4J | 707 | 340 |
| 717 | Boeing 717 | L JeK | L2J | 717 | NA |
| 727 | Boeing 727 all pax models | L JeK | L3J | 727 | 727 |
| 737 | Boeing 737 all pax models | L JeK | L2J | 731 | 731 |
| 747 | Boeing 747 all pax models | L JeK | L4J | 747 | 741 |
| 757 | Boeing 757 all pax models | L JeK | L2J | 752 | 757 |
| 767 | Boeing 767 all pax models | L JeK | L2J | 767 | 767 |
| 777 | Boeing 777 all pax models | L JeK | L2J | 772 | 777 |
| 14F | BAe 146 Freighter (-100/200/300QT & QC) | L JeK | L4J | 146 | 146 |
| 31F | Airbus A310 Freighter | L JeK | L2J | 310 | 310 |
| 32S | Airbus A318/319/320/321 | L JeK | L2J | 320 | 320 |
| 70F | Boeing 707 Freighter | L JeK | L4J | 70F | 340 |
| 70M | Boeing 707 Combi | L JeK | L4J | 707 | 340 |
| 72F | Boeing 727 Freighter (-100/200) | L JeK | L3J | 72F | 727 |
| 72M | Boeing 727 Combi | L JeK | L3J | 727 | 727 |
| 73F | Boeing 737 all Freighter models | L JeK | L2J | 731 | 731 |
| 73W | Boeing 737-700 (winglets) pax | L JeK | L2J | 73W | 734 |
| 74F | Boeing 747 all Freighter models | L JeK | L4J | 74F | 741 |
| 74M | Boeing 747 all Combi models | L JeK | L4J | 747 | 741 |
| 75F | Boeing 757 Freighter | L JeK | L2J | 75F | 757 |
| 76F | Boeing 767 all Freighter models | L JeK | L2J | 767 | 767 |
| A109 | Agusta A-109 | L JeK | H2T | S61 | NA |
| A4F | Antonov AN-124 Ruslan | L JeK | L4J | A4F | 340 |
| AB6 | Airbus Industrie A300-600 pax | L JeK | L2J | AB6 | 310 |
| AB4 | Airbus Industrie A300B2/B4/C4 pax | L JeK | L2J | AB4 | 310 |
| 31X | Airbus A310-200 Freighter | L JeK | L2J | 312 | 310 |
| 319 | Airbus A319 | L JeK | L2J | 319 | 320 |
| A32 | Antonov AN-32 | L JeK | L2T | A32 | NA |
| 320 | Airbus A320-100/200 | L JeK | L2J | 321 | 320 |
| 321 | Airbus A321-100/200 | L JeK | L2J | 321 | 320 |
| 332 | Airbus A330-200 | L JeK | L2J | 330 | 330 |
| 333 | Airbus A330-300 | L JeK | L2J | 330 | 330 |
| 342 | Airbus A340-200 | L JeK | L4J | 342 | 340 |
| 343 | Airbus A340-300 | L JeK | L4J | 343 | 340 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| 346 | Airbus A340-600 | L JeK | L4J | 346 | 340 |
| A4F | Antonov AN-124 Ruslan | L JeK | L4J | A4F | 340 |
| A660 | Ayres Turbo Thrush (S-2R-T660) | L JeK | L1T | C208 | C208 |
| AA5 | Gulfstream American AA-5 Traveler | L AvG | L1P | AA5 | DHO |
| AB3 | Airbus Industrie A300 pax | L JeK | L2J | AB3 | 310 |
| AB6 | Airbus Industrie A300-600 pax | L JeK | L2J | AB6 | 310 |
| ABB | Airbus Industrie A300-600ST Beluga Freighter | L JeK | L2J | AB6 | 310 |
| ABF | Airbus Industrie A300 Freighter | L JeK | L2J | AB3 | 310 |
| AC11 | Rockwell Commander | L AvG | L1P | C150 | DHO |
| ACT | Gulfstream/Rockwell (Aero) Turbo Commander | L JeK | L2T | ACT | NA |
| ACD | Gulfstream/Rockwell (Aero) Commander/Turbo Commander | L JeK | L2T | ACD | NA |
| AEST | Aerostar 600 | L AvG | L2P | AEST | DHO |
| AJET | Dassault Alpha Jet | L JeK | L2J | FA10 | S20 |
| ALO3 | Aerospatiale Alouette 3 | L JeK | H1T | ALO3 | NA |
| ANF | Antonov AN-12 | L JeK | L4T | ANF | NA |
| A26 | Antonov AN-26 | L JeK | L2T | A26 | AN6 |
| AN4 | Antonov AN-24 | L JeK | L2T | AN4 | NA |
| AN6 | Antonov AN-26 / AN-30 /AN-32 | L JeK | L2T | A26 | AN6 |
| AN7 | Antonov AN-72 / AN-74 | L JeK | L2J | AN7 | F27 |
| AN7 | Antonov AN-72 / AN-74 | L JeK | L2J | AN7 | F27 |
| ANF | Antonov AN-12 | L JeK | L4T | ANF | NA |
| APH | Eurocopter (Aerospatiale) SA330 Puma / AS332 Super Puma | L JeK | H2T | S61 | NA |
| ARJ | Avro RJ70 / RJ85 / RJ100 Avroliner | L JeK | L4J | ARJ | 146 |
| AS32 | Aerospatiale Super Puma | L JeK | H2T | S61 | NA |
| AS50 | Aerospatiale Fennec (AS-550) | L JeK | H1T | S61 | NA |
| AS65 | Aerospatiale Dolphin (AS-366) | L JeK | H2T | AS65 | NA |
| ASTR | IAI Gulfstream G100 | L JeK | L2J | WWP | S20 |
| AT3 | AIDC AT-3 Tzu-Chung | L JeK | L2J | AT3 | NA |
| AT43 | Aerospatiale/Alenia ATR 42-300 / 320 | L JeK | L2T | ATR | AT42 |
| AT5 | Aerospatiale/Alenia ATR 42-500 | L JeK | L2T | ATR | AT42 |
| AT5 | Aerospatiale/Alenia ATR 42-500 | L JeK | L2T | ATR | AT42 |
| AT5T | Air Tractor AT-502 | L JeK | L1T | C208 | C208 |
| AT7 | Aerospatiale/Alenia ATR 72 | L JeK | L2T | ATR | AT7 |
| AT7 | Aerospatiale/Alenia ATR 72 | L JeK | L2T | ATR | AT7 |
| AT8T | Air Tractor AT-802 Fire Boss | L JeK | L1T | C208 | NA |
| ATP | British Aerospace ATP | L JeK | L2T | ATR | AT42 |
| ATR | Aerospatiale/Alenia ATR 42/ ATR 72 | L JeK | L2T | ATR | AT42 |
| B06 | Agusta AB-206 LongRanger | L JeK | H1T | S61 | NA |
| MBH | Eurocopter (MBB) Bo.105 | L JeK | H2T | S61 | NA |
| B11 | British Aerospace (BAC) One Eleven / RomBAC One Eleven | L JeK | L2J | B11 | B11 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| B12 | British Aerospace (BAC) One Eleven 200 | L JeK | L2J | B12 | B11 |
| BES | Beechcfrat 1900/1900C | L JeK | L2T | BE1 | BE1 |
| B200 | Beech 200 Super King Air | L JeK | L2T | BE20 | BE20 |
| B350 | Beech Super King Air 350 | L JeK | L2T | BE30 | B350 |
| B412 | Bell 412 | LJeK | H1T | BH2 | NA |
| B36T | Allison 36 Turbine Bonanza | L JeK | L1T | C208 | C208 |
| 70M | Boeing 707 Combi | L JeK | L4J | 707 | 340 |
| 717 | Boeing 717 | L JeK | L2J | 717 | NA |
| B72 | Boeing 720B pax | L JeK | L4J | B72 | NA |
| 72X | Boeing 727-100 Freighter | L JeK | L3J | 721 | 727 |
| 72S | Boeing 727-200 Advanced pax | L JeK | L3J | 722 | 727 |
| 731 | Boeing 737-100 pax | L JeK | L2J | 731 | 731 |
| 73M | Boeing 737-200 Combi | L JeK | L2J | 732 | 731 |
| 73Y | Boeing 737-300 Freighter | L JeK | L2J | 733 | 731 |
| 735 | Boeing 737-500 pax | L JeK | L2J | 735 | 734 |
| B735 | Boeing 737-500 | L JeK | L2J | 735 | 734 |
| 736 | Boeing 737-600 pax | L JeK | L2J | 736 | 734 |
| 73W | Boeing 737-700 (winglets) pax | L JeK | L2J | 73W | 734 |
| 73H | Boeing 737-800 (winglets) pax | L JeK | L2J | 73H | 734 |
| 739 | Boeing 737-900 pax | L JeK | L2J | 739 | 734 |
| 741 | Boeing 747-100 pax | L JeK | L4J | 741 | 741 |
| 74C | Boeing 747-200 Combi | L JeK | L4J | 742 | 741 |
| 74U | Boeing 747-300 / 747-200 SUD Freighter | L JeK | L4J | 743 | 741 |
| 74J | Boeing 747-400 (Domestic) pax | L JeK | L4J | 744 | 74J |
| B74S | Boeing 747SP | L JeK | L4J | B74S | 741 |
| B74R | Boeing 747SR | LJeK | L4J | 74V | 741 |
| 75M | Boeing 757 Mixed Configuration | L JeK | L2J | 752 | 757 |
| 753 | Boeing 757-300 pax | L JeK | L2J | 752 | 757 |
| 76X | Boeing 767-200 Freighter | L JeK | L2J | 762 | 767 |
| 76Y | Boeing 767-300 Freighter | L JeK | L2J | 763 | 767 |
| 764 | Boeing 767-400 pax | L JeK | L2J | 764 | 767 |
| 772 | Boeing 777-200 pax | L JeK | L2J | 772 | 777 |
| 773 | Boeing 777-300 pax | L JeK | L2J | 773 | 777 |
| B11 | British Aerospace (BAC) One Eleven / RomBAC One Eleven | L JeK | L2J | B11 | B11 |
| BE1 | Beechcraft 1900/1900C/1900D | L JeK | L2T | BE1 | BE1 |
| BE10 | Beech King Air 100 | L JeK | L2T | BE10 | B350 |
| BE18 | Beech 18 | L AvG | L2P | BE18 | DHO |
| BE19 | Beech 19 Sport | L AvG | L1P | BE19 | DHO |
| BE2 | Beechcraft twin piston engines | L AvG | L2P | BE55 | DHO |
| BE20 | Beech Huron | L JeK | L2T | BE20 | BE20 |
| BE30 | Beech Super King Air 300 | L JeK | L2T | BE30 | B350 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| BE33 | Beech Bonanza 33 | L AvG | L1P | BE33 | DHO |
| BE35 | Beech Bonanza 35 | L AvG | L1P | BE33 | DHO |
| BE36 | Beech Bonanza 36 | L AvG | L1P | BE33 | DHO |
| BE4 | Beech Beechjet | L JeK | L2J | BE40 | LOH |
| BE40 | Beech Beechjet | L JeK | L2J | BE40 | LOH |
| BE55 | Beech Baron | L AvG | L2P | BE55 | DHO |
| BE58 | Beech Baron 58 | L AvG | L2P | BE55 | DHO |
| BE76 | Beech Duchess | L AvG | L2P | BE55 | DHO |
| BE95 | Beech 95 Travel Air | LJeK | L2T | BE10 | B350 |
| BE9L | Beech King Air 90 | L JeK | L2T | BE10 | B350 |
| BEC | Beechcraft light aircraft | L AvG | L1P | BE19 | DHO |
| BEH | Beechcraft 1900D | L JeK | L2T | BE1 | BE1 |
| BEP | Beechcraft light aircraft - single engine | L AvG | L1P | BE19 | DHO |
| BET | Beechcraft light aircraft - twin turboprop engine | L JeK | L2T | BE20 | BE1 |
| BH2 | Bell Helicopters | L JeK | H1T | BH2 | NA |
| BNI | Pilatus Britten-Norman BN-2A/B Islander | L AvG | L2P | BNI | DHO |
| BNI | Pilatus Britten-Norman BN-2A/B Islander | L AvG | L2P | BNI | DHO |
| C130 | Lockheed Hercules | L JeK | L4T | C130 | LOH |
| C150 | Cessna 150 | L AvG | L1P | C150 | DHO |
| C160 | Transall C-160 | L JeK | L2T | C160 | NA |
| C17 | Boeing Globemaster 3 | L JeK | L4J | C17 | NA |
| C172 | Cessna 172 Mescalero | L AvG | L1P | C150 | DHO |
| C177 | Cessna 177 Cardinal | L AvG | L1P | C150 | DHO |
| C182 | Cessna 182 Skylane | L AvG | L1P | C150 | DHO |
| C185 | Cessna 185 Skywagon | L AvG | L1P | C150 | DHO |
| C206 | Cessna 206 Stationair | L AvG | L1P | C150 | DHO |
| C208 | Cessna 208 Caravan | L JeK | L1T | C208 | C208 |
| C210 | Cessna 210 Centurion | L AvG | L1P | C150 | DHO |
| CS2 | CASA / IPTN 212 Aviocar | L JeK | L2T | CS2 | NA |
| C303 | Cessna T303 Crusader | L AvG | L2P | C404 | DHO |
| C310 | Cessna 310 | L AvG | L2P | C337 | DHO |
| C337 | Cessna 337 Super Skymaster | L AvG | L2P | C337 | DHO |
| C402 | Cessna 402 Businessliner | L AvG | L2P | C404 | DHO |
| C404 | Cessna 402 Titan | L AvG | L2P | C404 | DHO |
| C414 | Cessna 414 Chancellor | L AvG | L2P | C404 | DHO |
| C421 | Cessna 421 Executive Commuter | L AvG | L2P | C404 | DHO |
| C425 | Cessna 425 Conquest | L JeK | L2T | C425 | NA |
| C441 | Cessna 441 Conquest | L JeK | L2T | C441 | NA |
| C500 | Cessna 500 Citation | L JeK | L2J | C500 | DHO |
| C501 | Cessna 501 Citation 1SP | L JeK | L2J | C500 | DHO |
| C510 | Cessna Citation Muatang | LJeK | L2J | C500 | DHO |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| C525 | Cessna 525 Citation | L JeK | L2J | C500 | DHO |
| C550 | Cessna 550 Citation 2 | L JeK | L2J | C550 | DHO |
| C551 | Cessna 551 Citation 2SP | L JeK | L2J | C551 | DHO |
| C560 | Cessna 560 Citation 5 | L JeK | L2J | C560 | S20 |
| C56X | Cessna 560XL Citation Excel | L JeK | L2J | C560 | S20 |
| C650 | Cessna 650 Citation 3 | L JeK | L2J | C680 | SH6 |
| C680 | Cessna 680 Citation Sovereign | L JeK | L2J | C680 | SH6 |
| C750 | Cessna 750 Citation 10 | L JeK | L2J | C750 | F50 |
| CCJ | Canadair Challenger | L JeK | L2J | CCJ | AN6 |
| CCX | Canadair Global Express | L JeK | L2J | CR7 | FRJ |
| CL4 | Canadair CL-44 | L JeK | L4T | CL4 | F28 |
| CL4 | Canadair CL-44 | L JeK | L4T | CL4 | F28 |
| CL30 | BD-100 Challenge | LJeK | L2J | CL30 | NA |
| CCJ | Canadair Challenger | L JeK | L2J | CCJ | AN6 |
| CN2 | Cessna light aircraft - twin piston engines | L AvG | L2P | C404 | DHO |
| CS5 | CASA / IPTN CN-235 | L JeK | L2T | CS5 | NA |
| CNA | Cessna light aircraft | 0 | 0 | C150 | DHO |
| CNJ | Cessna Citation | L JeK | L2J | C500 | DHO |
| CNT | Cessna light aircraft - twin turboprop engines | L JeK | L2T | CNT | NA |
| CRJ | Canadair Regional Jet | L JeK | L2J | CR1 | FRJ |
| CRV | Aerospatiale (Sud Aviation) Se.210 Caravelle | L JeK | L2J | CRV | D94 |
| CS2 | CASA / IPTN 212 Aviocar | L JeK | L2T | CS2 | NA |
| CS5 | CASA / IPTN CN-235 | L JeK | L2T | CS5 | NA |
| CVF | Convair CV-240 / 440 / 580 / 600 / 640 Freighter | L JeK | L2T | CVF | NA |
| CVY | Convair CV-580 / 600 / 640 Freighter | L JeK | L2T | CVY | BE1 |
| CVR | Convair CV-240 / 440 / 580 / 600 / 640 pax | L JeK | L2T | CVR | NA |
| D10 | Douglas DC-10 pax | L JeK | L3J | D10 | D10 |
| D1F | Douglas DC-10 all Freighters | L JeK | L3J | D10 | D10 |
| D28 | Fairchild Dornier Do.228 | L JeK | L2T | D28 | BE20 |
| D28 | Fairchild Dornier Do.228 | L JeK | L2T | D28 | BE20 |
| D38 | Fairchild Dornier Do.328 | L JeK | L2T | FRJ | FRJ |
| D38 | Fairchild Dornier Do.328 | L JeK | L2T | FRJ | FRJ |
| D8F | Douglas DC-8 all Freighters | L JeK | L4J | D8T | 340 |
| D8M | Douglas DC-8 all Combi models | L JeK | L4J | DC8 | 340 |
| D9F | Douglas DC-9 all Freighters | L JeK | L2J | D9F | D91 |
| D1X | Douglas DC-10-10 Freighter | L JeK | L3J | D11 | D10 |
| DC3T | Douglas DC-3 | L JeK | L2T | DC3T | NA |
| DC8 | Douglas DC-8 all pax models | L JeK | L4J | DC8 | 340 |
| D8T | Douglas DC-8-50 Freighter | L JeK | L4J | D8T | 340 |
| D8L | Douglas DC-8-62 pax | L JeK | L4J | D8X | 340 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| D8Y | Douglas DC-8-71 / 72 / 73 Freighters | L JeK | L4J | D8Y | 340 |
| DC9 | Douglas DC-9 all pax models | L JeK | L2J | DC9 | D91 |
| DF3 | Dassault (Breguet Mystere) Falcon 50 / 900 | L JeK | L3J | FA50 | F50 |
| DFL | Dassault (Breguet Mystere) Falcon | 0 | 0 | FA10 | S20 |
| DHR | De Havilland Canada DHC-2 Turbo-Beaver | L AvG | L1P | DHB | DHO |
| DH7 | De Havilland Canada DHC-7 Dash 7 | L JeK | L4T | DH7 | DH7 |
| DH8 | De Havilland Canada DHC-8 Dash 8 all models | L JeK | L2T | DH8 | DH8 |
| DH1 | De Havilland Canada DHC-8-100 Dash 8 / 8Q | L JeK | L2T | DH8 | DH8 |
| DH3 | De Havilland Canada DHC-8-300 Dash 8 / 8Q | L JeK | L2T | DH8 | DH8 |
| DH4 | De Havilland Canada DHC-8-400 Dash 8Q | L JeK | L2T | DH8 | DH8 |
| DHB | De Havilland Canada DHC-2 Beaver / Turbo Beaver | L AvG | L1P | DHB | DHO |
| DHP | De Havilland Canada DHC-2 Beaver | L AvG | L1P | DHB | DHO |
| DHS | De Havilland Canada DHC-3 Otter | L AvG | L1P | DHB | DHO |
| DHT | De Havilland Canada DHC-6 Twin Otter | L JeK | L2T | DHT | B350 |
| DH7 | De Havilland Canada DHC-7 Dash 7 | L JeK | L4T | DH7 | DH7 |
| DHO | De Havilland Canada DHC-3 Otter / Turbo Otter | L AvG | L1P | DHB | DHO |
| DHT | De Havilland Canada DHC-6 Twin Otter | L JeK | L2T | DHT | B350 |
| DR40 | Robin DN-400 | L AvG | L1P | C150 | DHO |
| EMB | Embraer EMB.110 Bandeirnate | L JeK | L2T | EMB | EMB |
| EM2 | Embraer EMB.120 Brasilia | L JeK | L2T | EM2 | NA |
| E121 | Embraer 121 Xingu | L JeK | L2T | E121 | B350 |
| ER3 | Embraer RJ135 | L JeK | L2J | ERJ | ERJ |
| ER4 | Embraer RJ145 Amazon | L JeK | L2J | ERJ | ERJ |
| E70 | Embraer 170 | L JeK | L2J | EMJ | FRJ |
| E3CF | Boeing Sentry | L JeK | L4J | E3CF | NA |
| EM2 | Embraer EMB.120 Brasilia | L JeK | L2T | EM2 | NA |
| EMB | Embraer EMB.110 Bandeirnate | L JeK | L2T | EMB | EMB |
| EMJ | Embraer 170/190 | L JeK | L2J | EMJ | FRJ |
| ERJ | Embraer RJ135 / RJ140 / RJ145 | L JeK | L2J | ERJ | ERJ |
| 100 | Fokker 100 | L JeK | L2J | 100 | 100 |
| F16 | Lockheed F-16 Fighting Falcon | L JeK | L1J | F16 | NA |
| F27 | Fairchild FH.227 | L JeK | L2T | FK7 | NA |
| F28 | Fokker F.28 Fellowship 3000 | L JeK | L2J | F24 | F28 |
| F2TH | Dassault Falcon 2000 | L JeK | L2J | F2TH | NA |
| F406 | Cessna F406 Caravan 2 | L JeK | L2T | F406 | F406 |
| F50 | Fokker 50 | L JeK | L2T | F50 | F50 |
| F70 | Fokker 70 | L JeK | L2J | F70 | NA |
| F900 | Dassault Falcon 900 | L JeK | L3J | F900 | F50 |
| FA10 | Dassault Falcon 10 | L JeK | L2J | FA10 | S20 |
| FA20 | Dassault Falcon 20 | L JeK | L2J | FA20 | S20 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| FA50 | Dassault Falcon 50 | L JeK | L3J | FA50 | F50 |
| FRJ | Fairchild Dornier 328JET | L JeK | L2J | FRJ | FRJ |
| GRS | Gulfstream Aerospace G-159 Gulfstream I | L JeK | L2T | GRS | NA |
| GALX | IAI Galaxi | L JeK | L2J | WWP | S20 |
| CCX | Canadair Global Express | L JeK | L2J | CR7 | FRJ |
| GLF2 | Grumman Gulfstream 2 | L JeK | L2J | GLF3 | NA |
| GLF3 | Grumman Gulfstream 3 | L JeK | L2J | GLF3 | NA |
| GLF4 | Grumman Gulfstream 4 | L JeK | L2J | GLF4 | NA |
| GLF5 | Grumman Gulfstream 5 | L JeK | L2J | GLF5 | NA |
| GRG | Grumman G.21 Goose | L AvG | A2P | GRG | B350 |
| GRJ | Gulfstream Aerospace G-1159 Gulfstream II / III / IV / V | L JeK | L2J | GLF3 | NA |
| GRS | Gulfstream Aerospace G-159 Gulfstream I | L JeK | L2T | GRS | NA |
| H25 | British Aerospace (Hawker Siddeley) HS-125 | L JeK | L2J | H25 | S20 |
| H25 | British Aerospace (Hawker Siddeley) HS-125 | L JeK | L2J | H25 | S20 |
| H25B | British Aerospace (Hawker Siddeley) HS-125 | L JeK | L2J | H25 | S20 |
| H60 | Sikorsky Black Hawk | L JeK | H2T | S61 | NA |
| HS7 | Hawker Siddeley HS.748 | L JeK | L2T | HS7 | FRJ |
| IL6 | Ilyushin IL62 | L JeK | L4J | IL6 | 340 |
| IL6 | Ilyushin IL62 | L JeK | L4J | IL6 | 340 |
| IL7 | Ilyushin IL76 | L JeK | L4J | IL7 | 340 |
| IL7 | Ilyushin IL76 | L JeK | L4J | IL7 | 340 |
| IL8 | Ilyushin IL18 | L JeK | L4T | IL8 | NA |
| IL9 | Ilyushin IL96 pax | L JeK | L4J | IL9 | 340 |
| IL9 | Ilyushin IL96 pax | L JeK | L4J | IL9 | 340 |
| ILW | Ilyushin IL86 | L JeK | L4J | ILW | 340 |
| J31 | British Aerospace Jetstream 31 | L JeK | L2T | J31 | J31 |
| FRJ | Fairchild Dornier 328JET | L JeK | L2J | FRJ | FRJ |
| J41 | British Aerospace Jetstream 41 | L JeK | L2T | J41 | J41 |
| J31 | British Aerospace Jetstream 31 | L JeK | L2T | J31 | J31 |
| L10 | Lockheed L-1011 Tristar pax | L JeK | L3J | L10 | D10 |
| L11 | Lockheed L-1011 1 / 50 / 100 / 150 / 200 / 250 Tristar pax | L JeK | L3J | L10 | D10 |
| LOF | Lockheed L-188 Electra Freighter | L JeK | L4T | LOF | NA |
| L1F | Lockheed L-1011 Tristar Freighter | L JeK | L3J | L10 | D10 |
| L29 | Aero (2) L-29 Delfin | L JeK | L1J | F16 | NA |
| L4T | LET 410 | L JeK | L2T | L4T | NA |
| LJ31 | Learjet 31 | L JeK | L2J | LJ31 | S20 |
| LJ35 | Learjet 35 | L JeK | L2J | LJ35 | S20 |
| LJ40 | Learjet 40 | LJeK | L2J | LJ35 | S20 |
| LJ45 | Learjet 45 | L JeK | L2J | LJ35 | S20 |
| LJ60 | Learjet 60 | L JeK | L2J | LJ35 | S20 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| LOE | Lockheed L-188 Electra pax | L JeK | L4T | LOE | NA |
| LOF | Lockheed L-188 Electra Freighter | L JeK | L4T | LOF | NA |
| LOH | Lockheed L-182 / 282 / 382 (L-100) Hercules | L JeK | L4T | C130 | LOH |
| LOM | Lockheed L-188 Electra Mixed Configuration | L JeK | L4T | LOM | NA |
| LRJ | Gates Learjet | L JeK | L2J | LJ23 | S20 |
| LYNX | Westland Lynx | L JeK | H2T | S61 | NA |
| M11 | McDonnell Douglas MD11 pax | L JeK | L3J | M11 | D10 |
| M1F | McDonnell Douglas MD11 Freighter | L JeK | L3J | M11 | D10 |
| M1M | McDonnell Douglas MD11 Mixed Configuration | L JeK | L3J | M11 | D10 |
| M20P | Mooney M-20 | L AvG | L1P | M20P | DHO |
| M20T | Mooney TLS | L AvG | L1P | M20P | DHO |
| M80 | McDonnell Douglas MD80 | L JeK | L2J | M81 | M82 |
| M90 | McDonnell Douglas MD90 | L JeK | L2J | M90 | M82 |
| M1F | McDonnell Douglas MD11 Freighter | L JeK | L3J | M11 | D10 |
| M82 | McDonnell Douglas MD82 | L JeK | L2J | M82 | M82 |
| M83 | McDonnell Douglas MD83 | L JeK | L2J | M83 | M82 |
| M88 | McDonnell Douglas MD88 | L JeK | L2J | M88 | M82 |
| M90 | McDonnell Douglas MD90 | L JeK | L2J | M90 | M82 |
| MIH | MIL Mi-8 / Mi-17 / Mi-171 / Mil-172 | L JeK | H2T | S61 | NA |
| MIH | MIL Mi-8 / Mi-17 / Mi-171 / Mil-172 | L JeK | H2T | S61 | NA |
| MU2 | Mitsubishi Mu-2 | L JeK | L2T | MU2 | NA |
| ND2 | Aerospatiale (Nord) 262 | L JeK | L2T | ND2 | NA |
| ND2 | Aerospatiale (Nord) 262 | L JeK | L2T | ND2 | NA |
| NDC | Aerospatiale SN.601 Corvette | L JeK | L2J | NDC | DHO |
| P180 | Piaggio P-180 Avanti | L JeK | L2T | P180 | B350 |
| P28A | Piper Archer 2 | L AvG | L1P | P28A | DHO |
| PN6 | Partenavia P.68 | L AvG | L2P | PN6 | DHO |
| PA18 | Piper Super Club | L AvG | L1P | PA18 | DHO |
| PA2 | Piper light aircraft - twin piston engines | L AvG | L2P | PA31 | DHO |
| PA24 | Piper Comanche | L AvG | L1P | PA24 | DHO |
| PA27 | Piper Aztec | L AvG | L1P | PA27 | DHO |
| PA3 | Piper Twin Comanche | L AvG | L2P | PA31 | DHO |
| PA3 | Piper Twin Comanche | L AvG | L2P | PA31 | DHO |
| PA31 | Piper Navajo | L AvG | L2P | PA31 | DHO |
| PA32 | Piper Saratoga | L AvG | L1P | PA32 | DHO |
| PA34 | Piper Seneca | L AvG | L2P | PA44 | DHO |
| PA44 | Piper Seminole | L AvG | L2P | PA44 | DHO |
| PA46 | Piper Malibu | L AvG | L1P | PA46 | DHO |
| PAG | Piper light aircraft | L AvG | L1P | P28A | DHO |
| PAT4 | Piper T-1040 | L JeK | L2T | PAT4 | SWM |
| PL2 | Pilatus PC-12 | L JeK | L1T | PL2 | C208 |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| PL6 | Pilatus PC-6 Turbo Porter | L JeK | L1T | PL6 | C208 |
| PL2 | Pilatus PC-12 | L JeK | L1T | PL2 | C208 |
| PL6 | Pilatus PC-6 Turbo Porter | L JeK | L1T | PL6 | C208 |
| PN6 | Partenavia P.68 | L AvG | L2P | PN6 | DHO |
| PUMA | Aerospatile Puma | L JeK | H2T | S61 | NA |
| S05F | Siai-Marchetti S-205-20F | L AvG | L1P | C150 | DHO |
| S20 | Saab 2000 | L JeK | L2T | S20 | S20 |
| S58 | Sikorsky S-58T | L JeK | H1T | S58 | NA |
| S58P | Sikorsky S-58 | L AvG | H1P | S61 | NA |
| NDC | Aerospatiale SN.601 Corvette | L JeK | L2J | NDC | DHO |
| S61 | Sikorsky S-61 | L JeK | H2T | S61 | NA |
| S76 | Sikorsky S-76 | L JeK | H2T | S61 | NA |
| SA3 | Stits Playboy | L AvG | L1P | SA3 | DHO |
| S20 | Saab 2000 | L JeK | L2T | S20 | S20 |
| SBR1 | North American Sabreliner | L JeK | L2J | SBR1 | NA |
| SF3 | Saab SF340A/B | L JeK | L2T | SF3 | SF3 |
| SF3 | Saab SF340A/B | L JeK | L2T | SF3 | SF3 |
| SH3 | Shorts SD.330 | L JeK | L2T | SH3 | SH3 |
| SH3 | Shorts SD.330 | L JeK | L2T | SH3 | SH3 |
| SH6 | Shorts SD.360 | L JeK | L2T | SH6 | SH6 |
| SH6 | Shorts SD.360 | L JeK | L2T | SH6 | SH6 |
| SHB | Shorts SC-5 Belfast | L JeK | L4T | SHB | NA |
| SR20 | Cirrus SR-20 | L AvG | L1P | C150 | DHO |
| SR22 | Cirrus SR-22 | L AvG | L1P | C150 | DHO |
| SSC | Aerospatiale/BAC Concorde | L JeK | L4J | SSC | NA |
| SW2 | Swearingen Merlin 2 | L JeK | L2T | SW2 | NA |
| SW3 | Swearingen Merlin 3 | L JeK | L2T | SW3 | SHS |
| SW4 | Swearingen Merlin 4 | L JeK | L2T | SW4 | NA |
| SWM | Fairchild (Swearingen) SA26 / SA226 / SA227 Metro / Merlin / Expediter | L JeK | L2T | PA31 | SWM |
| TU3 | Tupolev Tu134 | L JeK | L2J | TU3 | NA |
| TU5 | Tupolev Tu154 | L JeK | L3J | TU5 | 727 |
| T20 | Tupolev Tu-204 / Tu-214 | L JeK | L2J | T20 | NA |
| T20 | Tupolev Tu-204 / Tu-214 | L JeK | L2J | T20 | NA |
| TBM | Grumman Avenger | L AvG | L1P | C150 | NA |
| TBM7 | Socata TBM-700 | L JeK | L1T | TBM7 | C208 |
| TOBA | Socata Tobago | L AvG | L1P | C150 | DHO |
| TRIN | Scata Pashosh | L AvG | L1P | C150 | DHO |
| TU3 | Tupolev Tu134 | L JeK | L2J | TU3 | NA |
| TU5 | Tupolev Tu154 | L JeK | L3J | TU5 | 727 |
| VC10 | Bac VC-10 | L JeK | L4J | VC10 | NA |
| VCV | Vickers Viscount | L JeK | L4T | VCV | NA |

| Code | Aircraft Name | Fuel Type | Description | LTO Representative | Cruise Representative |
|---|---|---|---|---|---|
| WG30 | Westland WG-30 | L JeK | H2T | S61 | NA |
| WWP | Israel Aircraft Industries 1124 Westwind | L JeK | L2J | WWP | S20 |
| WWP | Israel Aircraft Industries 1124 Westwind | L JeK | L2J | WWP | S20 |
| YK2 | Yakovlev Yak 42 | L JeK | L3J | YK2 | NA |
| YK4 | Yakovlev Yak 40 | L JeK | L3J | YK4 | NA |
| YK4 | Yakovlev Yak 40 | L JeK | L3J | YK4 | NA |
| YK2 | Yakovlev Yak 42 | L JeK | L3J | YK2 | NA |
| YK5 | Yakovlev Yak 50 | L AvG | L1P | C150 | DHO |

Annex Table 6 - Activity data for NFR 1.A.3.b: Fuel consumption from road transport sector (t)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | L | 208 | 1,376,217 | 1,513,827 | 1,690,627 | 1,781,289 | 1,828,767 | 1,885,861 | 1,935,188 | 1,923,621 | 1,990,008 | 2,013,486 | 2,052,007 | 1,932,893 | 2,029,090 |
| Diesel | L | 205 | 1,603,658 | 1,665,579 | 1,769,092 | 1,822,672 | 1,965,847 | 2,110,210 | 2,269,116 | 2,513,347 | 2,998,556 | 3,240,566 | 3,759,009 | 3,976,418 | 4,029,320 |
| LPG | L | 303 | 21 | 56 | 98 | 109 | 117 | 289 | 1,799 | 17,321 | 19,794 | 23,862 | 22,329 | 21,653 | 21,213 |
| CNG | G | 302 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 648 | 4,287 | 6,616 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gasoline | L | 208 | 1,967,402 | 1,889,720 | 1,791,425 | 1,669,150 | 1,562,258 | 1,483,025 | 1,454,631 | 1,379,957 | 1,243,253 | 1,132,122 | 1,091,901 | 1,091,475 | 1,079,326 |
| Diesel | L | 205 | 4,065,129 | 4,121,935 | 4,147,187 | 4,290,841 | 4,272,991 | 4,270,954 | 4,281,060 | 4,287,166 | 4,022,401 | 3,691,647 | 3,622,111 | 3,721,710 | 3,779,888 |
| LPG | L | 303 | 20,484 | 18,869 | 20,935 | 22,356 | 23,218 | 25,865 | 30,309 | 28,950 | 30,127 | 31,856 | 33,421 | 33,519 | 35,804 |
| CNG | G | 302 | 8,643 | 8,517 | 9,572 | 9,508 | 10,527 | 11,004 | 10,934 | 11,459 | 11,493 | 10,946 | 11,315 | 11,058 | 11,923 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 65,776 | 128,777 | 127,573 | 218,216 | 321,397 | 313,020 | 286,604 | 275,214 | 276,123 | 321,320 |

Annex Table 7 - Activity data for NFR 1.A.3.c: Fuel consumption from railways (GJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | S | 102 | 845 | 456 | 583 | 482 | 502 | 185 | 255 | 0 | 0 | 0 | 0 | 0 | 77 |
| Coke | S | 108 | 252 | 168 | 168 | 84 | 84 | 28 | 56 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diesel-oil | L | 204 | 2,389,791 | 2,501,912 | 2,507,433 | 2,292,868 | 2,275,613 | 2,326,174 | 2,119,240 | 2,035,611 | 1,889,302 | 1,858,765 | 1,828,984 | 1,630,079 | 1,522,420 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | S | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coke | S | 108 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diesel-oil | L | 204 | 1,316,850 | 1,192,991 | 1,110,181 | 1,020,949 | 1,029,964 | 1,088,146 | 746,675 | 634,969 | 553,578 | 451,450 | 407,744 | 428,733 | 407,020 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 13,593 | 26,433 | 27,117 | 32,394 | 40,730 | 36,878 | 29,941 | 26,464 | 27,078 | 29,700 |

## Small combustion (NFR 1.A.4)

Annex Table 8 - Activity data for NFR 1.A.4.a: Fuel consumption in the commercial, services and institutional sector (GJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 2,377,775 | 2,082,473 | 1,987,019 | 4,274,308 | 3,304,671 | 1,388,428 | 2,838,261 | 3,440,598 | 3,314,158 | 3,449,183 | 3,534,234 |
| Diesel/Gas Oil | L | 204 | 5,639,815 | 6,917,498 | 8,280,078 | 7,888,815 | 8,726,269 | 13,105,635 | 16,719,028 | 18,351,231 | 18,391,384 | 21,956,952 | 24,194,942 |
| Kerosene | L | 206 | 74,919 | 33,396 | 64,201 | 13,467 | 12,685 | 25,068 | 27,142 | 17,200 | 6,137 | 7,572 | 9,494 |
| Gasoline | L | 208 | 579,621 | 638,690 | 617,687 | 1,174,935 | 1,419,347 | 2,593,860 | 3,262,569 | 3,219,051 | 2,217,473 | 2,854,812 | 2,486,947 |
| LPG | L | 303 | 1,198,048 | 1,373,765 | 1,580,371 | 1,268,113 | 2,562,028 | 3,836,555 | 4,010,705 | 4,233,884 | 4,414,101 | 5,206,806 | 5,113,787 |
| City Gas | L | 308 | 504,399 | 556,773 | 528,075 | 732,803 | 785,507 | 777,866 | 908,944 | 1,044,085 | 732,238 | 69,195 | 0 |
| Natural Gas | G | 301 | 0 | 0 | 0 | 0 | 0 | 15,786 | 563,881 | 1,593,080 | 2,579,983 | 4,042,999 | 5,152,623 |
| Wood | B | 111 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Biogas | B | 309 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37,572 | 76,912 | 41,033 | 45,650 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 2,907,217 | 3,152,344 | 3,182,777 | 2,220,557 | 1,905,882 | 2,672,347 | 1,385,221 | 1,030,689 | 850,701 | 768,683 | 1,218,547 |
| Diesel/Gas Oil | L | 204 | 29,771,236 | 33,061,615 | 28,690,066 | 12,587,334 | 12,101,443 | 4,807,532 | 3,312,792 | 2,680,918 | 2,454,310 | 2,659,231 | 1,720,719 |
| Kerosene | L | 206 | 7,344 | 7,216 | 6,334 | 1,298 | 5,191 | 879 | 2,219 | 2,177 | 4,103 | 84 | 2,386 |
| Gasoline | L | 208 | 2,364,277 | 2,426,561 | 1,637,165 | 28,471 | 27,801 | 37,473 | 2,177 | 0 | 0 | 0 | 0 |
| LPG | L | 303 | 5,287,262 | 5,413,453 | 4,806,060 | 5,143,317 | 4,804,021 | 2,146,848 | 1,927,378 | 1,919,549 | 1,958,653 | 3,135,595 | 3,383,577 |
| City Gas | L | 308 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural Gas | G | 301 | 6,020,765 | 6,592,309 | 6,494,120 | 8,545,510 | 10,053,470 | 10,731,187 | 11,091,210 | 12,311,704 | 12,384,387 | 12,315,682 | 12,423,534 |
| Wood | B | 111 | 0 | 0 | 0 | 0 | 0 | 0 | 2,532,762 | 1,463,891 | 1,462,176 | 1,679,456 | 1,302,845 |
| Biogas | B | 309 | 36,551 | 76,039 | 102,253 | 130,750 | 135,839 | 157,677 | 166,930 | 146,480 | 170,539 | 104,655 | 91,330 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 128,950 | 190,896 | 51,132 | 52,967 | 39,371 | 51,243 | 72,825 | 26,866 |

Annex Table 9 - Activity data for NFR 1.A.4.b: Fuel consumption in the residential sector (GJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 63,570 | 62,136 | 55,570 | 42,592 | 43,339 | 40,296 | 10,922 | 3,883 | 2,596 | 0 | 0 |
| Diesel/Gas Oil | L | 204 | 158,313 | 210,952 | 285,685 | 201,062 | 132,690 | 91,954 | 106,045 | 144,312 | 90,483 | 82,460 | 120,375 |
| Kerosene | L | 206 | 793,847 | 753,503 | 626,435 | 356,029 | 416,128 | 728,737 | 761,963 | 705,693 | 365,545 | 194,522 | 147,927 |
| Gasoline | L | 208 | 6,189 | 7,791 | 5,904 | 9,584 | 13,758 | 14,908 | 14,701 | 6,081 | 773 | 93 | 24,864 |
| LPG | L | 303 | 23,458,865 | 24,712,407 | 26,379,429 | 28,700,786 | 30,988,266 | 30,036,100 | 31,626,170 | 33,487,398 | 34,345,777 | 31,576,352 | 31,565,739 |
| City Gas | L | 308 | 1,923,876 | 1,950,110 | 1,984,435 | 1,929,958 | 1,977,160 | 1,991,632 | 2,106,088 | 2,039,388 | 1,212,913 | 156,763 | 0 |
| Natural Gas | G | 301 | 0 | 0 | 0 | 0 | 0 | 35,408 | 400,760 | 1,506,342 | 3,192,297 | 4,927,459 | 6,165,244 |
| Wood | B | 111 | 53,770,921 | 51,344,184 | 49,611,501 | 48,033,473 | 48,172,943 | 46,841,627 | 45,510,311 | 44,178,995 | 42,847,679 | 41,516,363 | 40,185,047 |
| Charcoal | B | 112 | 749,950 | 738,791 | 727,632 | 694,155 | 682,996 | 671,837 | 660,678 | 626,132 | 591,586 | 557,041 | 522,495 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Diesel/Gas Oil | L | 204 | 380,360 | 667,243 | 600,226 | 332,928 | 395,815 | 5,191,318 | 3,670,468 | 2,726,117 | 2,516,862 | 2,407,177 | 2,269,440 |
| Kerosene | L | 206 | 89,834 | 88,654 | 50,117 | 28,678 | 22,398 | 27,213 | 26,711 | 18,463 | 19,803 | 11,178 | 7,871 |
| Gasoline | L | 208 | 36,183 | 37,371 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LPG | L | 303 | 30,542,812 | 30,029,737 | 29,312,438 | 22,777,808 | 21,795,551 | 23,214,739 | 20,873,374 | 19,522,514 | 18,948,048 | 17,170,849 | 15,889,364 |
| City Gas | L | 308 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural Gas | G | 301 | 6,647,494 | 7,618,313 | 8,394,267 | 11,924,258 | 11,103,017 | 12,571,537 | 10,851,181 | 10,839,207 | 10,415,042 | 10,852,311 | 11,049,300 |
| Wood | B | 111 | 38,853,731 | 37,522,415 | 36,191,099 | 32,197,151 | 30,865,835 | 29,534,519 | 31,507,615 | 31,522,887 | 32,256,276 | 32,080,962 | 31,922,552 |
| Charcoal | B | 112 | 487,949 | 453,404 | 418,858 | 315,221 | 280,675 | 246,130 | 246,130 | 246,130 | 246,130 | 246,130 | 246,130 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 1 | 41 | 26,859 | 710 | 2,921 | 76 | 69 | 2,616 |

Annex Table 10 - Activity data for NFR 1.A.4.c.i: Fuel consumption in agriculture and forestry sector (GJ) (excluding mobile sources)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 524,617 | 376,193 | 286,335 | 426,845 | 511,483 | 547,071 | 474,723 | 677,941 | 889,643 | 799,840 | 1,207,470 |
| Kerosene | L | 206 | 350,338 | 311,043 | 272,158 | 191,157 | 183,421 | 427,000 | 494,010 | 24,166 | 44,397 | 47,082 | 50,284 |
| Gasoline | L | 208 | 33,650 | 35,681 | 47,407 | 129,648 | 162,646 | 197,586 | 174,417 | 159,737 | 42,723 | 119,538 | 106,820 |
| LPG | L | 303 | 329,856 | 405,427 | 478,962 | 572,444 | 826,953 | 560,179 | 713,861 | 674,638 | 496,882 | 673,259 | 639,651 |
| Natural Gas | G | 301 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 174 | 4,897 | 213,356 | 284,851 |
| Biogas | B | 309 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9,294 | 7,773 | 5,939 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 1,083,548 | 405,069 | 858,912 | 199,621 | 99,477 | 153,402 | 172,535 | 46,849 | 33,703 | 36,048 | 53,674 |
| Kerosene | L | 206 | 47,237 | 48,915 | 54,581 | 38,935 | 45,173 | 39,019 | 30,395 | 33,493 | 29,516 | 24,785 | 25,538 |
| Gasoline | L | 208 | 116,977 | 117,435 | 208,555 | 36,091 | 32,407 | 24,033 | 13,147 | 16,203 | 24,619 | 14,780 | 27,717 |
| LPG | L | 303 | 532,506 | 523,451 | 541,228 | 362,700 | 296,549 | 308,858 | 271,637 | 267,660 | 214,446 | 194,350 | 222,317 |
| Natural Gas | G | 301 | 292,066 | 295,599 | 325,872 | 305,260 | 370,699 | 423,872 | 486,213 | 516,693 | 570,870 | 305,385 | 327,408 |
| Biogas | B | 309 | 6,344 | 11,122 | 29,039 | 13,766 | 19,833 | 23,013 | 24,686 | 18,787 | 16,527 | 15,774 | 12,929 |

Annex Table 11 - Activity data for NFR 1.A.4.c.i: Fuels consumed in fisheries (excluding consumption in fishing vessels) (GJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 4,004 | 5,415 | 7,458 | 12,145 | 5,132 | 8,888 | 6,383 | 49,680 | 6,483 | 18,055 | 28,129 |
| Diesel/Gas Oil | L | 204 | 99,086 | 95,355 | 84,795 | 84,915 | 64,556 | 209,384 | 597,882 | 0 | 1,081,354 | 2,179,005 | 1,097,824 |
| Kerosene | L | 206 | 7 | 0 | 7 | 0 | 0 | 0 | 2,652 | 74,960 | 10,079 | 94 | 47 |
| Gasoline | L | 208 | 1,406 | 0 | 214 | 707 | 985 | 728 | 4,040 | 61,587 | 279,165 | 286,314 | 280,882 |
| LPG | L | 303 | 2,847 | 5,792 | 4,077 | 0 | 110 | 3,902 | 2,531 | 8,434 | 20,809 | 32,648 | 21,140 |
| Natural Gas | G | 301 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual Oil | L | 203 | 25,341 | 0 | 0 | 48,147 | 0 | 91,830 | 47,735 | 84,842 | 44,785 | 95,603 | 35,958 |
| Diesel/Gas Oil | L | 204 | 596,445 | 568,387 | 587,681 | 519,123 | 0 | 649,478 | 913,983 | 932,934 | 1,059,745 | 1,116,035 | 1,539,689 |
| Kerosene | L | 206 | 47 | 320 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gasoline | L | 208 | 278,706 | 260,910 | 29,919 | 5,569 | 30,062 | 21,060 | 18,255 | 4,145 | 11,305 | 5,317 | 4,899 |
| LPG | L | 303 | 20,708 | 91,294 | 5,903 | 5,778 | 3,014 | 1,675 | 461 | 209 | 0 | 0 | 293 |
| Natural Gas | G | 301 | 0 | 0 | 0 | 2,010 | 3,098 | 4,396 | 4,145 | 2,219 | 16,789 | 23,739 | 22,441 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 70,531 | 112,475 | 195,569 | 218,127 | 221,762 | 228,854 | 195,612 | 242,260 |

Annex Table 12 - Activity data for NFR 1.A.4.c.ii: Fuels consumption in machines and other off-road vehicles (GJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel/Gas Oil | L | 204 | 15,954,739 | 16,738,690 | 16,949,965 | 17,675,330 | 17,825,456 | 17,289,762 | 19,142,892 | 15,029,333 | 8,912,769 | 9,042,482 | 9,950,538 | 10,757,924 | 11,433,231 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel/Gas Oil | L | 204 | 9,133,707 | 8,703,013 | 12,775,956 | 12,053,442 | 11,905,304 | 11,241,230 | 10,005,353 | 9,649,630 | 9,487,624 | 9,624,560 | 9,945,778 | 10,013,090 | 10,040,638 |
| Biodiesel | B | 223 | 0 | 0 | 0 | 159,969 | 307,367 | 280,546 | 433,071 | 618,948 | 631,782 | 637,571 | 644,970 | 632,545 | 732,572 |

Annex Table 13 - Activity data for NFR 1.A.4.c.iii: Fuels consumed in fishing bunkers (GJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thin Fuel-oil | L | 203 | 0 | 6,000 | 0 | 81,600 | 552,240 | 53,520 | 32,000 | 19,520 | 21,760 | 12,880 | 4,000 | 0 | 0 |
| Thick Fuel-oil | L | 204 | 0 | 0 | 0 | 0 | 413,200 | 96,000 | 24,000 | 22,400 | 42,240 | 21,120 | 0 | 0 | 0 |
| Diesel/Gas Oil | L | 206 | 10,783,849 | 11,035,700 | 9,752,418 | 8,671,656 | 8,912,346 | 7,898,551 | 7,321,406 | 6,789,503 | 6,794,700 | 8,072,743 | 9,350,785 | 7,398,427 | 6,446,147 |
| NATO's Nafta | L | 208 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thin Fuel-oil | L | 203 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22,014 | 18,018 | 52,026 | 66,026 | 149,898 |
| Thick Fuel-oil | L | 204 | 0 | 0 | 0 | 0 | 0 | 0 | 714,669 | 765,555 | 717,098 | 9,158 | 0 | 0 | 0 |
| Diesel/Gas Oil | L | 206 | 5,591,932 | 6,630,905 | 5,496,620 | 5,749,321 | 4,798,240 | 4,694,265 | 5,765,758 | 5,916,129 | 5,142,046 | 5,082,892 | 5,192,645 | 4,236,519 | 3,785,012 |
| NATO's Nafta | L | 208 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Other Mobile (NFR 1.A.5)

Annex Table 14 - Activity data for NFR 1.A.5.b: Energy Consumption in Military aviation (TJ)

| Fuel | | NAPFUE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jet Fuel | L | 207 | 1,344 | 1,504 | 1,127 | 1,065 | 1,188 | 1,149 | 1,471 | 1,413 | 1,474 | 1,127 | 1,338 | 1,338 | 939 |

| Fuel | | NAPFUE | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jet Fuel | L | 207 | 749 | 570 | 1,025 | 1,064 | 1,026 | 1,200 | 1,205 | 1,208 | 1,086 | 683 | 822 | 961 | 1,065 |

# ANNEX D: AGRICULTURE (NFR 3)

Annex Table 15- Livestock numbers (thousands) – time series

| Animal | Sub-class | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy-Cattle | Dairy cows | 394 | 388 | 381 | 383 | 382 | 383 | 380 | 379 | 375 | 369 | 353 | 331 | 311 | 297 |
| Non-dairy cattle | Beef calfs (<1 yr) | 46 | 52 | 53 | 53 | 58 | 60 | 64 | 64 | 65 | 66 | 67 | 72 | 75 | 82 |
| | Calfs M.Rep. (<1 yr) | 186 | 185 | 182 | 176 | 167 | 162 | 155 | 151 | 149 | 149 | 144 | 140 | 137 | 141 |
| | Calfs F Rep. (<1 yr) | 177 | 178 | 178 | 174 | 164 | 158 | 152 | 152 | 155 | 165 | 174 | 180 | 186 | 186 |
| | Males 1-2 yrs | 112 | 114 | 114 | 108 | 103 | 103 | 105 | 101 | 95 | 86 | 82 | 81 | 80 | 80 |
| | Beef Fem. 1-2 yrs | 18 | 19 | 20 | 22 | 22 | 22 | 24 | 24 | 24 | 20 | 17 | 14 | 14 | 15 |
| | Females rep. 1-2 yrs | 111 | 115 | 112 | 109 | 106 | 109 | 112 | 109 | 108 | 116 | 127 | 135 | 136 | 133 |
| | Steers (>2 yrs) | 38 | 38 | 36 | 37 | 35 | 33 | 33 | 31 | 31 | 29 | 26 | 24 | 23 | 23 |
| | Heifers Beef (>2 yrs) | 4 | 5 | 7 | 9 | 10 | 10 | 9 | 9 | 9 | 7 | 6 | 6 | 8 | 8 |
| | Heifers rep. (>2 yrs) | 45 | 46 | 45 | 48 | 50 | 52 | 51 | 50 | 52 | 60 | 67 | 77 | 80 | 86 |
| | non-dairy cows | 242 | 245 | 238 | 241 | 252 | 273 | 296 | 316 | 332 | 338 | 345 | 352 | 362 | 371 |
| Swine | Piglets (<20 kg) | 727 | 756 | 756 | 750 | 735 | 726 | 703 | 701 | 695 | 691 | 663 | 626 | 591 | 571 |
| | Fatt. Pigs (20-50 kg) | 662 | 675 | 660 | 671 | 668 | 660 | 633 | 631 | 633 | 623 | 585 | 535 | 493 | 471 |
| | Fatt. Pigs (50-80 kg) | 525 | 545 | 544 | 539 | 532 | 525 | 505 | 496 | 492 | 498 | 483 | 446 | 402 | 374 |
| | Fatt. Pigs (80-110 kg) | 218 | 227 | 226 | 225 | 210 | 198 | 179 | 177 | 174 | 176 | 174 | 184 | 197 | 208 |
| | Fatt. Pigs (> 110 kg) | 44 | 46 | 46 | 47 | 45 | 44 | 40 | 39 | 38 | 38 | 38 | 43 | 42 | 43 |
| | Boars (>50 kg) | 26 | 28 | 27 | 28 | 28 | 26 | 24 | 23 | 23 | 22 | 20 | 19 | 17 | 16 |
| | Sows, pregnant | 210 | 219 | 218 | 220 | 216 | 211 | 204 | 204 | 202 | 201 | 195 | 197 | 196 | 198 |
| | Sows, non-pregnant | 124 | 131 | 135 | 136 | 134 | 132 | 127 | 128 | 127 | 127 | 124 | 111 | 91 | 73 |
| Sheep | Ewes | 2 292 | 2 293 | 2 257 | 2 268 | 2 303 | 2 339 | 2 376 | 2 368 | 2 367 | 2 388 | 2 410 | 2 388 | 2 328 | 2 282 |
| | Other Ovine | 663 | 725 | 789 | 794 | 811 | 817 | 813 | 802 | 834 | 840 | 733 | 506 | 299 | 204 |
| | Lambs | 307 | 326 | 320 | 300 | 279 | 278 | 292 | 297 | 301 | 307 | 319 | 320 | 330 | 324 |
| Goats | Does | 614 | 588 | 556 | 538 | 528 | 517 | 509 | 498 | 485 | 472 | 460 | 440 | 417 | 392 |
| | Other Caprine | 149 | 156 | 166 | 160 | 153 | 151 | 147 | 151 | 154 | 151 | 129 | 91 | 62 | 48 |
| | kids | 47 | 49 | 47 | 44 | 45 | 41 | 41 | 36 | 37 | 36 | 33 | 30 | 29 | 28 |
| Equidae | Horses | 33 | 38 | 40 | 42 | 44 | 48 | 52 | 54 | 56 | 57 | 58 | 59 | 59 | 58 |
| | Asses and Mules. | 118 | 116 | 114 | 114 | 109 | 103 | 96 | 90 | 82 | 75 | 69 | 63 | 57 | 51 |
| Poultry | Hens, reproductive | 3 421 | 3 300 | 3 116 | 2 941 | 2 947 | 3 271 | 3 477 | 3 390 | 2 982 | 2 636 | 2 644 | 2 780 | 3 019 | 3 206 |
| | Hens eggs | 7 539 | 7 695 | 7 932 | 8 159 | 8 143 | 7 745 | 7 392 | 7 322 | 7 859 | 8 627 | 9 060 | 9 089 | 8 739 | 8 440 |
| | Broilers | 18 524 | 18 812 | 19 243 | 19 674 | 19 530 | 18 813 | 18 355 | 18 733 | 20 538 | 22 936 | 24 374 | 24 259 | 22 590 | 20 921 |
| | Turkeys | 1 149 | 1 122 | 1 082 | 1 041 | 996 | 945 | 936 | 972 | 1 061 | 1 158 | 1 208 | 1 201 | 1 139 | 1 077 |
| | Other poultry | 1 667 | 1 656 | 1 639 | 1 622 | 1 625 | 1 648 | 1 648 | 1 606 | 1 591 | 1 648 | 1 707 | 1 695 | 1 613 | 1 531 |
| Other | Rabbits[1] | 475 | 464 | 447 | 430 | 415 | 401 | 384 | 363 | 346 | 338 | 336 | 332 | 325 | 318 |

1 Reproductive females

Livestock numbers (thousands) – time series (continuation)

| Animal | Sub-class | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy-Cattle | Dairy cows | 294 | 290 | 284 | 275 | 269 | 263 | 255 | 247 | 241 | 236 | 233 | 235 |
| Non-dairy cattle | Beef calfs (<1 yr) | 91 | 104 | 108 | 108 | 108 | 109 | 114 | 120 | 125 | 119 | 113 | 112 |
| | Calfs M.Rep. (<1 yr) | 140 | 136 | 131 | 129 | 127 | 123 | 123 | 128 | 136 | 136 | 142 | 152 |
| | Calfs F Rep. (<1 yr) | 187 | 183 | 180 | 178 | 174 | 169 | 171 | 179 | 190 | 191 | 198 | 209 |
| | Males 1-2 yrs | 79 | 81 | 77 | 75 | 73 | 72 | 66 | 60 | 55 | 54 | 53 | 58 |
| | Beef Fem. 1-2 yrs | 16 | 17 | 17 | 16 | 17 | 18 | 20 | 19 | 20 | 19 | 17 | 15 |
| | Females rep. 1-2 yrs | 135 | 135 | 139 | 139 | 141 | 142 | 137 | 132 | 131 | 135 | 139 | 148 |
| | Steers (>2 yrs) | 23 | 25 | 28 | 31 | 33 | 34 | 38 | 41 | 44 | 42 | 39 | 37 |
| | Heifers Beef (>2 yrs) | 8 | 9 | 9 | 9 | 9 | 10 | 12 | 13 | 14 | 14 | 15 | 15 |
| | Heifers rep. (>2 yrs) | 90 | 94 | 96 | 96 | 97 | 102 | 110 | 111 | 110 | 105 | 103 | 96 |
| | non-dairy cows | 382 | 397 | 411 | 425 | 432 | 436 | 438 | 440 | 442 | 443 | 450 | 461 |
| Swine | Piglets (<20 kg) | 570 | 574 | 583 | 590 | 592 | 602 | 597 | 614 | 634 | 658 | 681 | 713 |
| | Fatt. Pigs (20-50 kg) | 467 | 467 | 466 | 468 | 464 | 460 | 448 | 446 | 455 | 464 | 472 | 485 |
| | Fatt. Pigs (50-80 kg) | 373 | 368 | 362 | 356 | 357 | 362 | 360 | 362 | 366 | 366 | 369 | 380 |
| | Fatt. Pigs (80-110 kg) | 213 | 214 | 221 | 222 | 227 | 237 | 244 | 251 | 255 | 263 | 273 | 285 |
| | Fatt. Pigs (> 110 kg) | 40 | 41 | 43 | 44 | 44 | 40 | 36 | 30 | 27 | 25 | 28 | 30 |
| | Boars (>50 kg) | 14 | 12 | 12 | 11 | 10 | 8 | 7 | 6 | 5 | 5 | 5 | 6 |
| | Sows, pregnant | 194 | 191 | 189 | 185 | 183 | 181 | 179 | 172 | 166 | 159 | 159 | 162 |
| | Sows, non-pregnant | 67 | 68 | 70 | 71 | 70 | 69 | 66 | 66 | 66 | 68 | 69 | 71 |
| Sheep | Ewes | 2 273 | 2 293 | 2 275 | 2 225 | 2 137 | 2 030 | 1 915 | 1 811 | 1 735 | 1 683 | 1 638 | 1,620 |
| | Other Ovine | 216 | 234 | 267 | 250 | 225 | 206 | 191 | 179 | 160 | 167 | 162 | 155 |
| | Lambs | 329 | 322 | 328 | 340 | 337 | 307 | 277 | 264 | 267 | 263 | 267 | 275 |
| Goats | Does | 382 | 380 | 380 | 373 | 365 | 358 | 356 | 353 | 349 | 342 | 333 | 324 |
| | Other Caprine | 52 | 57 | 65 | 59 | 52 | 44 | 40 | 38 | 35 | 36 | 35 | 37 |
| | kids | 28 | 26 | 25 | 28 | 30 | 31 | 29 | 29 | 28 | 27 | 25 | 23 |
| Equidae | Horses | 56 | 52 | 49 | 47 | 46 | 42 | 38 | 33 | 30 | 27 | 26 | 26 |
| | Asses and Mules. | 45 | 40 | 36 | 33 | 29 | 26 | 22 | 20 | 18 | 15 | 14 | 13 |
| Poultry | Hens, reproductive | 3 253 | 3 056 | 2 800 | 2 717 | 2 877 | 3 218 | 3 453 | 3 542 | 3 396 | 3 179 | 3 060 | 2,960 |
| | Hens eggs | 7 942 | 7 349 | 6 830 | 6 490 | 6 758 | 7 341 | 7 867 | 7 883 | 7 475 | 7 138 | 6 887 | 6,803 |
| | Broilers | 19 620 | 18 686 | 17 885 | 16 848 | 16 780 | 17 915 | 19 207 | 19 452 | 18 650 | 17 847 | 17 313 | 17,045 |
| | Turkeys | 963 | 798 | 799 | 1 017 | 1 318 | 1 485 | 1 445 | 1 331 | 1 144 | 956 | 831 | 769 |
| | Other poultry | 1 445 | 1 353 | 1 314 | 1 332 | 1 414 | 1 504 | 1 522 | 1 460 | 1 319 | 1 178 | 1 084 | 1,038 |
| Other | Rabbits[1] | 306 | 289 | 270 | 254 | 251 | 255 | 255 | 243 | 218 | 193 | 177 | 169 |

1 Reproductive females

Annex Table 16- Total Nitrogen in manure produced by livestock (t N / yr)

| Animal Type | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy | 33 850 | 33 196 | 32 476 | 31 322 | 32 165 | 33 282 | 33 824 | 34 052 | 34 384 | 36 952 | 37 590 | 36 125 | 35 826 |
| Non-Dairy | 43 438 | 44 308 | 43 599 | 43 602 | 43 888 | 45 511 | 47 217 | 48 392 | 49 477 | 50 316 | 51 394 | 52 693 | 53 869 |
| Sheep | 25 391 | 25 809 | 25 910 | 26 037 | 26 474 | 26 837 | 27 154 | 27 006 | 27 213 | 27 444 | 26 943 | 25 237 | 23 319 |
| Goats | 5 279 | 5 149 | 4 983 | 4 824 | 4 703 | 4 614 | 4 535 | 4 480 | 4 409 | 4 301 | 4 077 | 3 678 | 3 327 |
| Horses | 1 447 | 1 666 | 1 750 | 1 842 | 1 953 | 2 094 | 2 272 | 2 396 | 2 485 | 2 527 | 2 563 | 2 582 | 2 596 |
| Mules and Asses | 2 599 | 2 560 | 2 513 | 2 499 | 2 393 | 2 273 | 2 104 | 1 969 | 1 812 | 1 658 | 1 517 | 1 383 | 1 247 |
| Swine | 26 055 | 27 093 | 27 064 | 27 217 | 26 701 | 26 132 | 24 977 | 24 816 | 24 653 | 24 618 | 23 786 | 22 485 | 20 858 |
| Poultry | 17 889 | 18 060 | 18 316 | 18 568 | 18 430 | 17 839 | 17 407 | 17 523 | 18 745 | 20 483 | 21 574 | 21 577 | 20 503 |
| Rabbits[1] | 4 273 | 4 172 | 4 022 | 3 872 | 3 733 | 3 605 | 3 452 | 3 263 | 3 113 | 3 041 | 3 023 | 2 984 | 2 923 |
| Total | 160 219 | 162 013 | 160 634 | 159 783 | 160 441 | 162 188 | 162 942 | 163 899 | 166 291 | 171 340 | 172 468 | 168 744 | 164 467 |

| Animal Type | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy | 33 363 | 33 086 | 33 467 | 32 919 | 31 822 | 31 289 | 30 783 | 29 845 | 28 894 | 28 329 | 27 683 | 27 664 | 27 760 |
| Non-Dairy | 55 201 | 56 592 | 58 318 | 59 523 | 60 536 | 61 211 | 61 741 | 62 388 | 62 835 | 63 410 | 63 203 | 63 778 | 65 181 |
| Sheep | 22 270 | 22 274 | 22 565 | 22 621 | 22 054 | 21 087 | 19 975 | 18 824 | 17 793 | 16 970 | 16 529 | 16 090 | 15 878 |
| Goats | 3 060 | 3 016 | 3 041 | 3 094 | 3 004 | 2 898 | 2 793 | 2 758 | 2 717 | 2 670 | 2 631 | 2 570 | 2 513 |
| Horses | 2 567 | 2 449 | 2 273 | 2 141 | 2 083 | 2 009 | 1 833 | 1 672 | 1 467 | 1 320 | 1 173 | 1 144 | 1,144 |
| Mules and Asses | 1 115 | 983 | 880 | 785 | 726 | 645 | 565 | 491 | 433 | 396 | 337 | 308 | 286 |
| Swine | 19 650 | 19 285 | 19 190 | 19 248 | 19 183 | 19 131 | 19 114 | 18 836 | 18 696 | 18 703 | 18 820 | 19 133 | 19 739 |
| Poultry | 19 454 | 18 288 | 17 053 | 16 174 | 15 721 | 16 417 | 17 785 | 18 818 | 18 784 | 17 721 | 16 691 | 15 993 | 15 662 |
| Rabbits[1] | 2 862 | 2 754 | 2 599 | 2 429 | 2 290 | 2 256 | 2 294 | 2 295 | 2 184 | 1 962 | 1 741 | 1 593 | 1 519 |
| Total | 159 541 | 158 726 | 159 387 | 158 934 | 157 419 | 156 944 | 156 882 | 155 927 | 153 802 | 151 482 | 148 815 | 148 273 | 149 682 |

1 Reproductive females

Annex Table 17- Gross feed intake (Mj/hd/yr), cattle

| Animal type | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 82 918 | 82 763 | 82 450 | 80 091 | 81 665 | 83 465 | 84 941 | 85 473 | 86 801 | 92 826 | 96 905 | 98 852 | 103 401 |
| Other cattle | 55 221 | 55 194 | 55 014 | 55 201 | 55 624 | 56 213 | 56 880 | 57 312 | 57 501 | 57 162 | 57 008 | 56 843 | 56 834 |

| Animal type | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dairy cattle | 101,235 | 101,480 | 105,142 | 105,478 | 105,708 | 107,871 | 109,437 | 109,817 | 110,276 | 112,278 | 111,341 | 115,441 | 112,978 |
| Other cattle | 56,856 | 56,873 | 57,097 | 57,411 | 57,726 | 57,937 | 58,099 | 58,019 | 57,747 | 57,387 | 57,432 | 57,387 | 57,255 |

Annex Table 18- Volatile solid excreted (kg dm/hd/yr) – all other animal categories than cattle

| Animal type | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sows | 230.62 | 231.20 | 232.76 | 232.66 | 232.77 | 232.95 | 233.09 | 233.18 | 233.37 | 233.55 | 233.82 | 228.58 | 221.25 |
| Other swine | 83.47 | 83.43 | 83.35 | 83.46 | 83.21 | 82.81 | 82.14 | 81.82 | 81.75 | 82.01 | 82.32 | 83.13 | 83.64 |
| Sheep | 183.64 | 183.94 | 185.14 | 185.89 | 186.86 | 186.93 | 186.36 | 186.07 | 186.36 | 186.24 | 184.31 | 180.66 | 176.39 |
| Goats | 170.48 | 169.24 | 168.13 | 168.29 | 168.34 | 168.62 | 168.70 | 168.90 | 168.20 | 168.04 | 169.66 | 172.52 | 174.64 |
| Horses | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 |
| Mules & asses | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 |
| Hens | 14.99 | 14.99 | 15.00 | 15.00 | 15.00 | 14.99 | 14.99 | 14.99 | 15.00 | 15.02 | 15.02 | 15.01 | 15.01 |
| Broilers | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 |
| Turkeys | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 |
| Other poultry | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 |
| Rabbits | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 |

| Animal type | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sows | 212.66 | 210.59 | 211.33 | 212.76 | 214.11 | 214.22 | 213.93 | 212.77 | 214.16 | 215.61 | 218.01 | 218.55 | 219.17 |
| Other swine | 84.00 | 84.00 | 83.70 | 83.54 | 83.15 | 83.22 | 83.12 | 83.25 | 82.57 | 81.87 | 81.28 | 81.11 | 80.93 |
| Sheep | 174.49 | 174.55 | 175.23 | 175.65 | 174.68 | 173.94 | 174.29 | 174.77 | 174.64 | 173.60 | 173.74 | 173.18 | 172.45 |
| Goats | 175.44 | 174.67 | 174.68 | 173.88 | 173.61 | 173.66 | 173.95 | 174.74 | 175.06 | 175.35 | 175.41 | 175.59 | 178.36 |
| Horses | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 | 627.80 |
| Mules & asses | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 | 343.10 |
| Hens | 15.00 | 15.00 | 14.99 | 15.00 | 14.99 | 14.99 | 14.99 | 14.99 | 14.99 | 14.99 | 14.99 | 14.99 | 14.99 |
| Broilers | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 | 6.30 |
| Turkeys | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 | 29.28 |
| Other poultry | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 | 14.76 |
| Rabbits | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 | 52.79 |

Annex Table 19 - Annual Nitrogen consumption (kt N/yr) by type of N inorganic fertilizer - time series activity data

| Type of N fertilizer | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonium nitrate (AN) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ammonium phosphate (MAP&DAP) | 13.28 | 13.28 | 13.28 | 13.28 | 13.28 | 16.75 | 15.74 | 12.40 | 12.60 | 14.34 | 11.83 | 10.52 | 12.04 |
| Ammonium sulphate (AS) | 17.72 | 17.72 | 17.72 | 17.72 | 17.72 | 25.40 | 26.70 | 20.43 | 19.84 | 12.45 | 14.47 | 10.92 | 11.58 |
| Calcium ammonia nitrate (CAN) | 46.13 | 46.13 | 46.13 | 46.13 | 46.13 | 40.67 | 52.91 | 52.45 | 53.21 | 42.77 | 45.72 | 38.78 | 42.50 |
| Urea | 13.35 | 13.35 | 13.35 | 13.35 | 13.35 | 7.06 | 14. 07 | 15.26 | 7.75 | 14.51 | 20.52 | 17.53 | 10.07 |
| Other NK & NPK | 49.54 | 49.54 | 49.54 | 49.54 | 49.54 | 40.76 | 42.54 | 43.45 | 36.29 | 46.45 | 57.74 | 59.10 | 69.99 |
| Other N | 18.49 | 18.49 | 18.49 | 18.49 | 18.49 | 15.18 | 16 26 | 20.30 | 19.60 | 18.43 | 19.72 | 20.67 | 17.73 |
| Total | **158.50** | **158.50** | **158.50** | **158.50** | **158.50** | **145.82** | **168.23** | **164.29** | **149.30** | **148.94** | **170.01** | **157.51** | **163.90** |

| Sources | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonium nitrate (AN) | - | - | - | - | - | - | - | 4.01 | 4.18 | 3.70 | 7.70 | 4.63 | 4.67 |
| Ammonium phosphate (MAP&DAP) | 9.10 | 8.55 | - | - | - | - | 1.01 | 0.54 | 0.21 | 1.37 | 2.04 | 1.11 | 0.56 |
| Ammonium sulphate (AS) | 10.31 | 10.27 | 10.30 | 4.22 | 5.86 | 2.54 | 1.95 | 3.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Calcium ammonia nitrate (CAN) | 35.89 | 43.31 | 29.68 | 19.21 | 34.63 | 26.75 | 27.18 | 34.99 | 23.49 | 17.62 | 25.38 | 18.55 | 19.12 |
| Urea | 9.23 | 8.20 | 11.85 | 20.45 | 21.98 | 26.01 | 24.06 | 13.85 | 22.19 | 20.88 | 15.57 | 24.01 | 32.19 |
| Other NK & NPK | 30.64 | 37.00 | 39.94 | 33.76 | 41.10 | 28.97 | 16.09 | 24.90 | 23.13 | 17.19 | 24.57 | 30.27 | 27.21 |
| Other N | 14.96 | 18.51 | 10.90 | 9.76 | 9.43 | 20.86 | 22.71 | 18.90 | 21.89 | 46.10 | 35.39 | 44.26 | 37.27 |
| Total | **110.13** | **125.84** | **102.66** | **87.39** | **113.01** | **105.13** | **97.29** | **100.25** | **95.09** | **106.86** | **110.64** | **122.84** | **121.03** |

# ANNEX E: WASTE (NFR 5)

Annex Table 20 – National population, waste generation per capita, and municipal waste generation (Mainland)

| Year | Population | Annual per capita generation rate | Pop. served by waste collection syst. | Urban waste production | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Total | Open dump sites | Managed landfills | Composted/ Anaerobic digestion | Incinerated |
| | inhabitants | kg/inh/year | % pop. | kton | | | | |
| **1960** | 8,292,784 | 55.2 | 40 | 425.5 | 425.5 | 0.0 | 0.0 | 0.0 |
| **1961** | 8,271,002 | 58.3 | 41 | 448.5 | 448.5 | 0.0 | 0.0 | 0.0 |
| **1962** | 8,249,219 | 61.6 | 42 | 472.4 | 472.4 | 0.0 | 0.0 | 0.0 |
| **1963** | 8,227,437 | 64.9 | 44 | 497.1 | 497.1 | 0.0 | 0.0 | 0.0 |
| **1964** | 8,205,654 | 68.4 | 45 | 522.8 | 522.8 | 0.0 | 0.0 | 0.0 |
| **1965** | 8,183,872 | 72.0 | 46 | 549.4 | 549.4 | 0.0 | 0.0 | 0.0 |
| **1966** | 8,162,090 | 75.8 | 47 | 576.9 | 576.9 | 0.0 | 0.0 | 0.0 |
| **1967** | 8,140,307 | 79.7 | 48 | 605.4 | 605.4 | 0.0 | 0.0 | 0.0 |
| **1968** | 8,118,525 | 83.8 | 50 | 635.0 | 635.0 | 0.0 | 0.0 | 0.0 |
| **1969** | 8,096,742 | 88.0 | 51 | 665.6 | 665.6 | 0.0 | 0.0 | 0.0 |
| **1970** | 8,074,960 | 92.4 | 52 | 697.2 | 697.2 | 0.0 | 0.0 | 0.0 |
| **1971** | 8,189,669 | 97.0 | 53 | 743.3 | 743.3 | 0.0 | 0.0 | 0.0 |
| **1972** | 8,304,378 | 101.8 | 54 | 791.9 | 791.9 | 0.0 | 0.0 | 0.0 |
| **1973** | 8,419,087 | 106.7 | 56 | 842.9 | 842.9 | 0.0 | 0.0 | 0.0 |
| **1974** | 8,533,796 | 111.9 | 57 | 896.6 | 896.6 | 0.0 | 0.0 | 0.0 |
| **1975** | 8,648,505 | 117.2 | 58 | 953.1 | 953.1 | 0.0 | 0.0 | 0.0 |
| **1976** | 8,763,215 | 122.7 | 59 | 1,012.5 | 1,012.5 | 0.0 | 0.0 | 0.0 |
| **1977** | 8,877,924 | 128.4 | 60 | 1,074.9 | 1,074.9 | 0.0 | 0.0 | 0.0 |
| **1978** | 8,992,633 | 134.3 | 62 | 1,140.4 | 1,140.4 | 0.0 | 0.0 | 0.0 |
| **1979** | 9,107,342 | 140.5 | 63 | 1,209.2 | 1,209.2 | 0.0 | 0.0 | 0.0 |
| **1980** | 9,222,051 | 146.9 | 64 | 1,281.4 | 876.2 | 360.5 | 44.7 | 0.0 |
| **1981** | 9,336,760 | 156.6 | 66 | 1,384.7 | 943.8 | 396.2 | 44.7 | 0.0 |
| **1982** | 9,340,677 | 166.8 | 68 | 1,475.9 | 1,005.8 | 425.4 | 44.7 | 0.0 |
| **1983** | 9,344,593 | 177.5 | 71 | 1,571.5 | 1,070.8 | 456.0 | 44.7 | 0.0 |
| **1984** | 9,348,510 | 188.7 | 73 | 1,671.7 | 1,138.9 | 488.1 | 44.7 | 0.0 |
| **1985** | 9,352,426 | 200.5 | 75 | 1,776.6 | 1,210.2 | 521.7 | 44.7 | 0.0 |
| **1986** | 9,356,343 | 213.9 | 78 | 1,896.3 | 1,291.5 | 560.1 | 44.7 | 0.0 |
| **1987** | 9,360,260 | 227.9 | 80 | 2,021.7 | 1,376.7 | 600.3 | 44.7 | 0.0 |
| **1988** | 9,364,176 | 242.6 | 83 | 2,153.2 | 1,466.0 | 642.5 | 44.7 | 0.0 |
| **1989** | 9,368,093 | 258.0 | 85 | 2,290.9 | 1,559.5 | 686.7 | 44.7 | 0.0 |
| **1990** | 9,372,009 | 274.1 | 88 | 2,435.2 | 1,645.7 | 739.2 | 50.3 | 0.0 |
| **1991** | 9,375,926 | 287.0 | 89 | 2,551.3 | 1,594.9 | 906.1 | 50.3 | 0.0 |
| **1992** | 9,425,268 | 300.4 | 91 | 2,685.5 | 1,678.6 | 956.7 | 50.3 | 0.0 |
| **1993** | 9,474,609 | 314.4 | 92 | 2,826.1 | 1,766.3 | 1,009.6 | 50.3 | 0.0 |
| **1994** | 9,523,951 | 328.9 | 93 | 2,973.3 | 1,726.1 | 1,159.3 | 87.8 | 0.0 |
| **1995** | 9,573,293 | 349.0 | 95 | 3,175.2 | 1,837.7 | 1,227.2 | 110.4 | 0.0 |
| **1996** | 9,622,635 | 368.2 | 96 | 3,370.2 | 1,908.3 | 1,351.1 | 110.8 | 0.0 |
| **1997** | 9,671,976 | 387.6 | 97 | 3,569.1 | 1,883.1 | 1,572.2 | 113.8 | 0.0 |
| **1998** | 9,721,318 | 407.2 | 98 | 3,772.1 | 1,380.2 | 2,275.2 | 116.8 | 0.0 |
| **1999** | 9,770,660 | 446.6 | 99 | 3,979.3 | 905.8 | 2,626.7 | 100.4 | 346.4 |
| **2000** | 9,820,001 | 461.3 | 100 | 4,039.6 | 520.5 | 2,484.7 | 123.3 | 911.1 |
| **2001** | 9,869,343 | 468.0 | 100 | 4,164.3 | 445.0 | 2,700.9 | 126.7 | 891.6 |
| **2002** | 9,950,051 | 479.7 | 100 | 4,314.0 | 0.0 | 3,337.0 | 62.2 | 914.7 |
| **2003** | 9,975,209 | 487.8 | 100 | 4,374.3 | 0.0 | 3,248.4 | 232.5 | 893.3 |
| **2004** | 9,993,865 | 457.8 | 100 | 4,091.4 | 0.0 | 3,087.1 | 127.5 | 876.8 |
| **2005** | 10,008,242 | 458.3 | 100 | 4,065.3 | 0.0 | 2,998.7 | 129.5 | 937.1 |
| **2006** | 10,025,838 | 469.7 | 100 | 4,136.1 | 0.0 | 3,142.7 | 131.9 | 861.4 |
| **2007** | 10,043,520 | 478.6 | 100 | 4,088.1 | 0.0 | 3,113.7 | 142.3 | 832.1 |
| **2008** | 10,051,206 | 521.6 | 100 | 4,456.8 | 0.0 | 3,403.6 | 183.9 | 869.3 |
| **2009** | 10,059,864 | 522.6 | 100 | 4,374.3 | 0.0 | 3,200.7 | 214.8 | 958.9 |
| **2010** | 10,057,999 | 550.8 | 100 | 4,738.7 | 0.0 | 3,542.2 | 232.1 | 964.3 |
| **2011** | 10,030,968 | 522.3 | 100 | 4,511.2 | 0.0 | 3,255.0 | 244.1 | 1,012.2 |
| **2012** | 9,976,649 | 475.3 | 100 | 4,041.6 | 0.0 | 2,789.6 | 332.7 | 919.3 |
| **2013** | 10,057,999 | 449.6 | 100 | 3,854.6 | 0.0 | 2,491.3 | 343.9 | 1,019.5 |
| **2014** | 10,030,968 | 459.8 | 100 | 3,857.5 | 0.0 | 2,425.6 | 483.1 | 948.8 |
| **2015** | 9,976,649 | 468.2 | 100 | 3,734.0 | 0.0 | 2,335.9 | 377.4 | 1,020.7 |

Notes:
Selectively collected wastes (deviated to recycling) excluded.
Sources: INE; APA; Quercus Study

Annex Table 21 – Fermentable industrial waste disposal (Mainland)

| Year | Open dump sites | Managed landfills | Year | Open dump sites | Managed landfills | Year | Open dump sites | Managed landfills |
|---|---|---|---|---|---|---|---|---|
| | kton | | | kton | | | kton | |
| **1960** | 761 | 0 | **1980** | 738 | 304 | **2000** | 208 | 994 |
| **1961** | 773 | 0 | **1981** | 746 | 313 | **2001** | 136 | 824 |
| **1962** | 785 | 0 | **1982** | 756 | 320 | **2002** | 0 | 737 |
| **1963** | 798 | 0 | **1983** | 766 | 326 | **2003** | 0 | 696 |
| **1964** | 810 | 0 | **1984** | 776 | 332 | **2004** | 0 | 722 |
| **1965** | 822 | 0 | **1985** | 786 | 339 | **2005** | 0 | 750 |
| **1966** | 835 | 0 | **1986** | 797 | 345 | **2006** | 0 | 780 |
| **1967** | 848 | 0 | **1987** | 807 | 352 | **2007** | 0 | 807 |
| **1968** | 861 | 0 | **1988** | 818 | 359 | **2008** | 0 | 834 |
| **1969** | 875 | 0 | **1989** | 830 | 365 | **2009** | 0 | 542 |
| **1970** | 888 | 0 | **1990** | 837 | 376 | **2010** | 0 | 473 |
| **1971** | 903 | 0 | **1991** | 789 | 448 | **2011** | 0 | 572 |
| **1972** | 918 | 0 | **1992** | 804 | 458 | **2012** | 0 | 263 |
| **1973** | 933 | 0 | **1993** | 820 | 469 | **2013** | 0 | 269 |
| **1974** | 948 | 0 | **1994** | 786 | 528 | **2014** | 0 | 297 |
| **1975** | 964 | 0 | **1995** | 804 | 537 | **2015** | 0 | 290 |
| **1976** | 979 | 0 | **1996** | 802 | 568 | **2016** | - | - |
| **1977** | 995 | 0 | **1997** | 762 | 636 | **2017** | - | - |
| **1978** | 995 | 0 | **1998** | 539 | 889 | **2018** | - | - |
| **1979** | 1,028 | 0 | **1999** | 374 | 1,083 | **2019** | - | - |

Notes:
Share between open dump and managed landfills based on disposal of municipal solid wastes.
2002 to 2004: disposal on open dump sites refer to disposal on controlled dump sites.
Source: APA (include estimates)

Annex Table 22 – Quantities of waste incinerated (Mainland)

| Year | Clinical waste quantities incinerated | Industrial solid waste incinerated | MSW quantities incinerated |
|---|---|---|---|
| | kton | | |
| **1990** | *12* | *23* | - |
| **1991** | *12* | *23* | - |
| **1992** | *12* | *24* | - |
| **1993** | *12* | *24* | - |
| **1994** | *12* | *25* | - |
| **1995** | 12 | *25* | - |
| **1996** | 13 | *26* | - |
| **1997** | 16 | *26* | - |
| **1998** | 12 | *27* | - |
| **1999** | 10 | 27 | 346 |
| **2000** | 7 | *30* | 911 |
| **2001** | 3 | *32* | 892 |
| **2002** | 3 | 36 | 915 |
| **2003** | 2 | 45 | 893 |
| **2004** | *2* | 52 | 877 |
| **2005** | *1* | 59 | 937 |
| **2006** | 1 | 66 | 861 |
| **2007** | 3 | 72 | 832 |
| **2008** | 3 | 79 | 869 |
| **2009** | 3 | 66 | 959 |
| **2010** | 3 | 19 | 964 |
| **2011** | 2 | 27 | 1012 |
| **2012** | 1 | 38 | 919 |
| **2013** | 1 | 22 | 1020 |
| **2014** | 1 | 22 | 949 |
| **2015** | *1* | *23* | 1021 |

Note: Estimates in italics
Sources: APA; DGS