TNO Built Environment and Geosciences

Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek / Netherlands Organisation for Applied Scientific Research

Environment, Health and Safety
Laan van Westenenk 501
P.O. Box 342
7300 AH Apeldoorn
The Netherlands

www.tno.nl

T +31 55 549 34 93
F +31 55 541 98 37
tinus.pulles@tno.nl

TNO report

2007-A-R0322/B

Estimation of emissions of fine particulate matter ($PM_{2.5}$) in Europe

Final Report

Version	draft | 2.0
Date	26 March 2007
Author(s)	Tinus Pulles (TNO) Jeroen Kuenen (TNO) Hugo Denier van der Gon (TNO) Mike Woodfield (AEA) Karin Kindbom (IVL
Under contract with	DG Environment Contract: 070501/2005/420903/MAR/C1
Project number	034.64100
Number of pages	59 (incl. appendices)
Number of appendices	

Contents

Tables

Graphs

1 Background and Scope

1.1 Introduction

The Commission is preparing for a revision of the National Emission Ceilings Directive in 2006. Since pollution by fine particulates is an important air quality problem, the Commission considers introducing national emission ceilings for $PM_{2.5}$. To enable this, an accurate emission inventory of $PM_{2.5}$ emissions in all 25 EU Member States and the Accession Countries is needed.

During the development of the project, the following objectives have been formulated. The aim of this project is to develop this emission inventory, based on earlier inventories and on national data, provided by the Member States. The inventory should build upon the best data from a number of existing EU inventories and data supplied by Member States under the CLRTAP. Where possible, and by utilising as much National Data as possible, this inventory will be constructed and presented so that it can be used as a starting point for the development of National emissions inventories for $PM_{2.5}$ where none currently exist.

During the course of the project and following discussions in the Working Group on National Emissions Ceilings & Policy Instruments (NECPI) in July 2006, the objective of the project has changed. It appeared that the Member States had already gone through a series of bilateral consultations with IIASA, yielding a $PM_{2.5}$ inventory that was applied in the RAINS model runs supporting the revision of the NEC Directive. This project then changed course and concentrated on providing an assessment of the IIASA inventory by a comparison of the results, the underlying activity data and the emission factors. Furthermore, national experts were offered all details of the emission estimation methods and activity data as a support of the development of the national expertise and abilities to compile national $PM_{2.5}$ inventories for reporting under the NEC Directive and the LRTAP protocols.

1.2 Scope of the EU25 2000 $PM_{2.5}$ inventory

The overall objective of the project is to compile an EU-wide inventory of emissions of fine particulates ($PM_{2.5}$) to air for the year 2000, making use of existing data sets and national emission reports. The countries involved are listed in Table 1-1.

Table 1-1 Geographical scope of this study.

EU25 Member States:		
Austria Belgium Cyprus Czech Republic Denmark Estonia Finland France Germany	Greece Hungary Ireland Italy Latvia Lithuania Luxembourg Malta	The Netherlands Poland Portugal Slovakia Slovenia Spain Sweden United Kingdom

Candidate Countries:
Bulgaria Romania Turkey
Accessing Countries
Albania Bosnia & Herzegovina Croatia FYR of Macedonia Serbia & Montenegro

1.3 Source categorization

Two separate issues are relevant with respect to the source categorization to be used in the EU25 $PM_{2.5}$ emission inventory:

1) The set of source category definitions should be compatible with:
   - the Nomenclature for Reporting (NFR) as defined by the LRTAP Convention and adopted for the EU NEC Directive; these source definitions are derived from the IPCC categories and hence have a relatively strong link to economic sectors
   - the source definitions as used in IIASA's RAINS model, which is related to the NFR
   - the SNAP source coding as used in the EMEP/CORINAIR Guidebook. The SNAP codes have a relatively strong link to the technological processes, causing the emissions.

   The NFR definitions, as provided by the LRTAP Reporting Guidelines, provide a link table between SNAP and NFR.

   We apply a hierarchical structure of the database that allows for both aggregating the highest level of detail of the NFR towards the source categories as needed by RAINS and for disaggregating to SNAP "technologies".

2) Completeness of the set of source categories. Emissions from some source categories are extremely difficult to estimate or might cause interpretation problems:
   - "Natural emissions" of sea salt or wind blown dust from dry areas (deserts). Although these emissions might be quite relevant for air quality modelling, we consider them as not very relevant for setting ceilings to national emissions and therefore exclude those from the EU25 PM2.5 inventory.
   - Emissions of soil dust from human activities in agriculture and off road activities or driving on unpaved roads. It is generally assumed that the major part of the mass in these inorganic mineral particles (clay, silt, sand) is present in larger particles [Ref 1]. A preliminary assessment showed that these emissions can be quite significant. We therefore include these sources in the EU25 PM2.5 inventory
   - The resuspension of particles, mainly due to road traffic. Since this source in fact is a re-emission of particles that have been emitted in another process (brake and tyre wear) earlier, one could argue that including this source in an inventory, prepared for the establishment of national emission

ceilings would lead to double counting. We therefore propose not to include these emissions in the inventory.

1.4 Available data

At least two, more or less independent data sets, collected at an international level are available:

- the CEPMEIP database, containing emission estimates for TSP, PM10 and PM2.5 for all European countries in the year 1995.
- the PM2.5 emission inventory, collected by IIASA for the EU Member States and the Accession Countries; the IIASA inventory is in many respects a further development of TNO's CEPMEIP inventory

A number of the EU25 Member States and Accession Countries (Austria, Belgium, Denmark, Finland, France, Hungary, Latvia, Netherlands, Spain, Sweden, and United Kingdom[1]) have reported national emissions of PM_{10} in varying levels of detail for the year 2000. Many of these countries have discussed $PM_{2.5}$ emission inventories for the year 2000 with IIASA within the framework of the RAINS model applications supporting the revision of the NEC Directive.

1.5 Data quality

Given the objective of the inventory to provide a sound foundation for the establishment of national emission ceilings for $PM_{2.5}$, special attention is needed for the quality of the inventory. Several aspects of data quality are relevant:

1) Transparency

   means that the assumptions and methodologies used for the inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information.

   Since the inventory will be used for the development of national emission ceilings, transparency is instrumental in the process of negotiations and considerations amongst EU Member States and Accession Countries. An important component will be to illustrate clearly through data referencing and documentation where country specific data has been used in the inventory and where this data has been taken from. This approach will enable country experts and the EU to quickly assess the appropriateness of the data and build on the inventory in future years.

2) Comparability:

   means that estimates of emissions should be comparable among Member States and Accession Countries.

   Comparability is achieved by the application of the standardized source categorization in all national inventories. This quality criterion is relatively straight forward,

---

[1] From Table $_{10}$ in appendix 5 of [Ref 2].

but in some cases Member States can apply different interpretations of specific source categories or fuels.

3) Completeness:

means that an inventory covers all sources. In the case of particulate emissions it might well be the case that important sources are not represented in the inventory because of lack of knowledge. This might occur in some or even all national inventories.

4) Accuracy:

is a relative measure of the exactness of an emission or removal estimate. Estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable.

For specific source categories estimates of emissions of fine particulates can be highly uncertain. This occurs for in instance in the case of combustion of solid bio fuels (wood) in small residential stoves. In most countries statistics on the amount of wood combusted in such small equipment is rather poor and emission factors are strongly dependent upon combustion technology and combustion conditions.

Adoption of this type of quality criteria leads to the necessity of a careful consultation process with national experts in all EU Member States and Accession Countries. It also implies that for reasons of transparency, comparability, completeness and accuracy the EU25 $PM_{2.5}$ Inventory might contain values that deviate from existing reports by individual countries. Whenever this occurs, it must be ensured that the national experts involved understand why these deviations are occurring and that they accept them.

2 Methods

2.1 Procedural

2.1.1 Over all

A key concern when developing a $PM_{2.5}$ inventory that must play its role in establishing national emission ceilings will be that Member States support the estimates. Stakeholder consultation therefore must be a key component of the inventory compilation process. For a number of countries this has actually taken place during the RAINS model applications underpinning the revision of the NEC Directive.

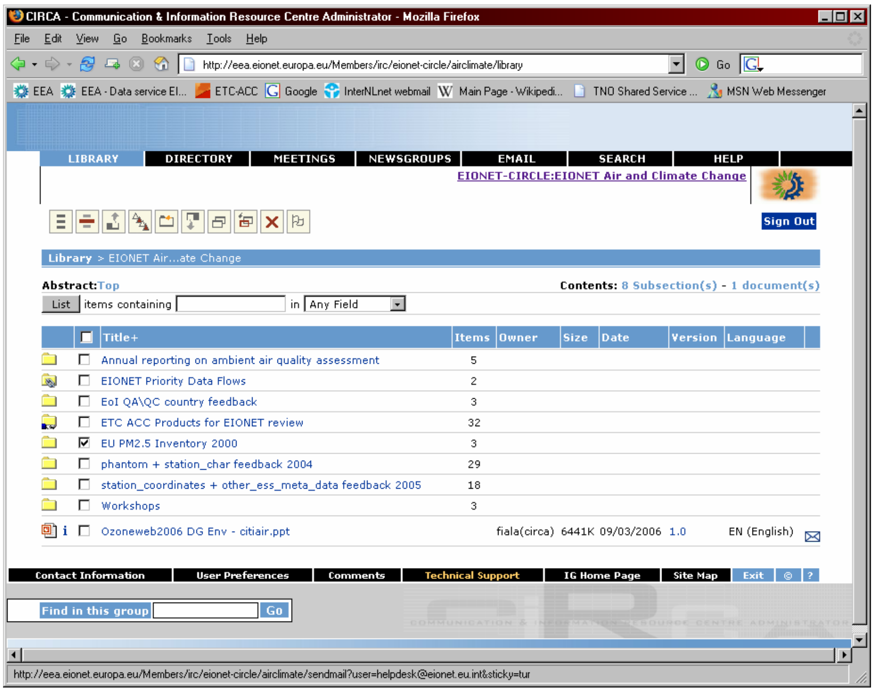
Our approach is aimed at optimizing the above quality criteria as far as practical within the available time and budget. To that end we propose to apply a stepwise approach, gradually improving the quality of the inventory by including more and more transparent country specific information while reducing the uncertainties and keeping the transparency, comparability, completeness and accuracy at the highest achievable level:

1) At the start of the project, we compile a first draft EU25 $PM_{2.5}$ emission inventory for the base year 2000. In compiling this inventory special attention will be paid to aspects of transparency and comparability. Accuracy of the inventory is of less importance at this stage.

   We will distribute the First Order Inventory report to national experts for review and asking for additional data where such is desirable given the results of the uncertainty analysis.

   We use EEA's Circa extranet environment to allow for easy electronic communication between the project team and national experts. All estimates, documents and data for this project can be found at:

   http://eea.eionet.europa.eu/Members/irc/eionet-circle/airclimate/library



All NRC's, NFP's have access to this environment.

2) After receiving the comments and additional information from the national experts we will produce a Second Order Draft EU25 $PM_{2.5}$ inventory for the year 2000. We will clearly indicate how the additional information from the countries and all comments has been used to increase transparency and comparability.

   In our view this Second Order Draft would best be discussed with national experts at a one day workshop. The desirability and the possibilities to arrange such a workshop will be discussed with the Commission.

3) The results of the review of the Second Order Draft and of the workshop will be incorporated in the final EU25 $PM_{2.5}$ inventory and in the Final Inventory Report. The inventory will be made available for use in IIASA's RAINS model, using the NFR to RAINS sectors link tables, available at IIASA.

To improve transparency and to directly link to the further development of the Guidebook, we build the EU25 $PM_{2.5}$ Emission Inventory in a relational database structure as shown in Figure 2-1. This model is implemented in the TNO Emission Assessment Model TEAM. Activity rates are stored in a table, linking to a sector hierarchical definition structure that allows identification of SNAP technologies and NFR sector codes. This link assures easy transformation of the data sets to the formats, needed for application in IIASA's RAINS model.

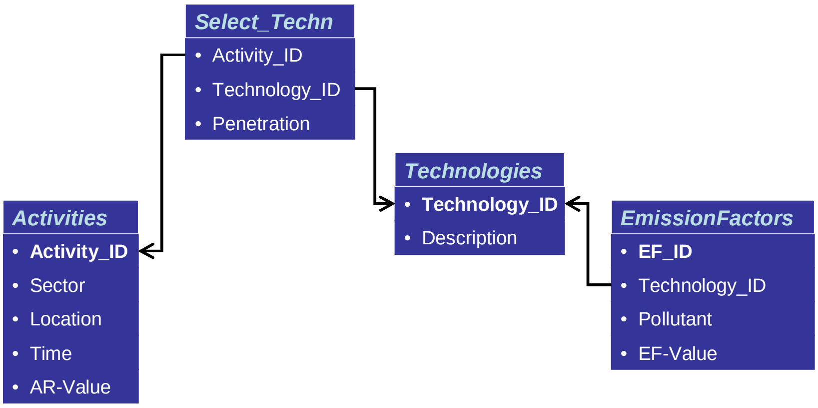


Figure 2-1 Generalized Inventory relational database structure in the TNO Emission Assessment Model (TEAM).

The combined “Technologies” and “Emission Factors” tables will be directly related to existing or new chapters or subchapters in the Guidebook. The “Select_Techn” table links each activity to one or more technologies. In this approach, so-called country-specific emission factors can be modelled, either by a country-specific mix of technologies applied in a certain source category or to country specific technologies directly.

2.1.2 *Consultation with National Experts*

As indicated above, a careful consultation with national experts is essential for achieving an inventory that meets the quality criteria necessary to use the inventory as a tool in establishing national emission ceilings. The consultation will also work to gain acceptance of the inventory by national focal points and experts so that it can form a strong foundation for future $PM_{2.5}$ inventory and policy work. Figure 2-2 indicates on what aspects this consultation could concentrate to ensure transparency, comparability, completeness and accuracy.

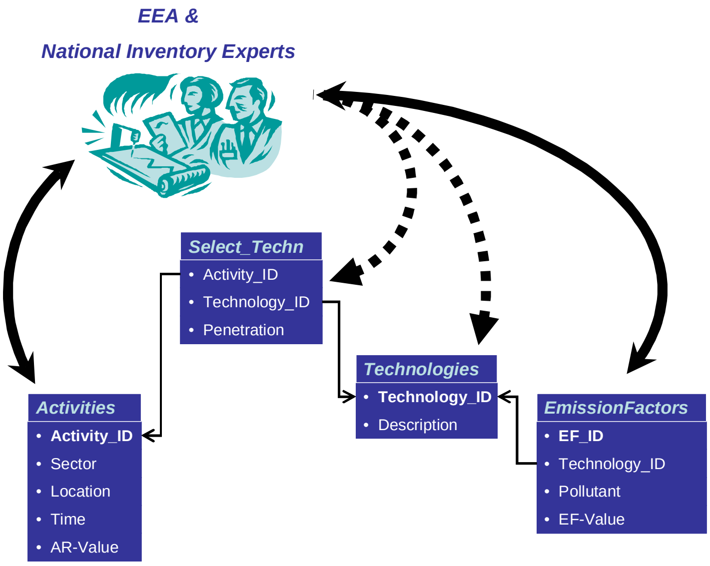


Figure 2-2 Consultation with national inventory experts.

Understanding the source of the activity data and the emission factors selected in each Member State is crucial in assessing transparency and comparability of the inventories. At the same time national experts might have aggregated some sources that others might have estimated separately. A clear understanding of such national approaches is needed to assess completeness of the inventories.

Since we propose to apply an inventory model that explicitly stores information on technologies applied, emission factors used in national inventories must be interpreted in terms of technologies and penetration of technologies.

2.1.3 *Liaison with PM $_{2.5}$ Guidebook development and TFEIP co-chairs*

Simultaneous with this project, DG Environment issued a contract on updating relevant chapters in the Guidebook to include guidance for estimating emissions of $PM_{2.5}$. The relation between both projects is obvious: whatever new guidance is developed in the Guidebook project could be applied in the inventory project and whatever new emission factors are used in the inventory project could feed into the Guidebook project (Figure 2-3).

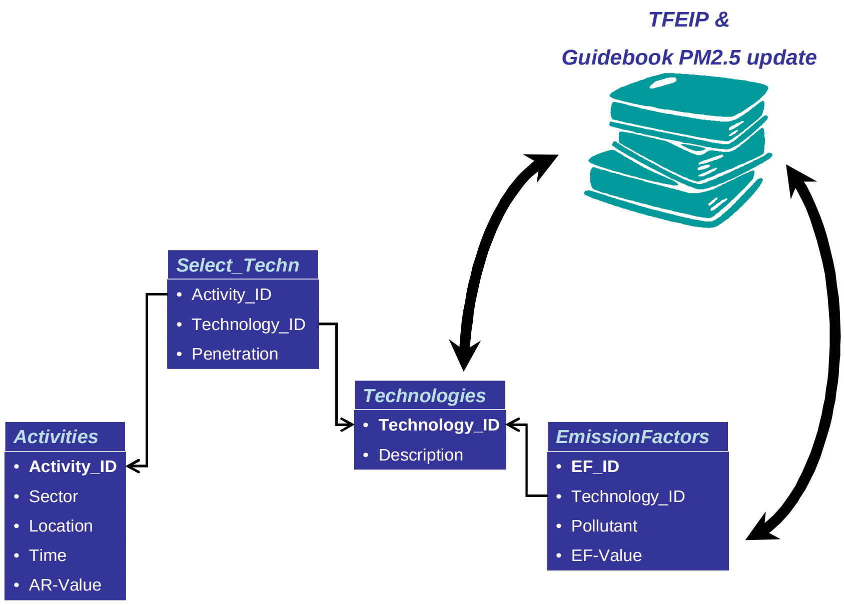


Figure 2-3 Liaison with the DG Environment project developing $PM_{2.5}$ guidance in the Guidebook.

As indicated above, we use an inventory structure that allows for explicit use of the concept of “technologies” which could directly translate to chapters or sub-chapters of the Guidebook.

2.2 Methods

2.2.1 *Activity data*

The inventory, presented in this document, is mainly based upon international activity data derived from the following sources:

IEA	IEA Energy Statistics 2005 Edition. (via 'IEA data v2005.mdb')
RAINS	Download from RAINS online, Feb 2006, CP_CLE_Aug04 (Nov04). IIASA website: http://www.iiasa.ac.at/rains/Rains-online.html?sb=8
UN Statistics	United Nations Industrial Commodity Production Statistics Dataset (CD) 1950-2001
IISI	Steel Statistical Yearbook 2003, International Iron and Steel Institute (IISI)
IISI & BREF	Estimate based on Pig Iron data from IISI and a factor of 1.1kg Sinter / kg Pig Iron from BREF Document Iron and Steel
Eurostat	Eurostat website (http://epp.eurostat.cec.eu.int/portal/page?_pageid=1090,30070682,1090_30298591&_dad=portal&_schema=PORTAL)
FAO	Download from http://faostat.fao.org/

As is shown in the graphs below, the bulk of the $PM_{2.5}$ emissions in the inventory are based on activity data derived from IEA fuel combustion statistics. This data source is used for all stationary combustion and part of the mobile combustion. For mobile sources (road transport) data on vehicle kilometres are derived from IIASA's RAINS model. These data have been checked against the fuel sales statistics for road transport. Data on vehicle kilometres have been used for both the tail pipe and non-tail pipe emissions from road transport.

Other mobile sources (trains, inland shipping) have been derived from the IEA data. Industrial processes and product use data are taken from various international statistics and agriculture data from FAO.

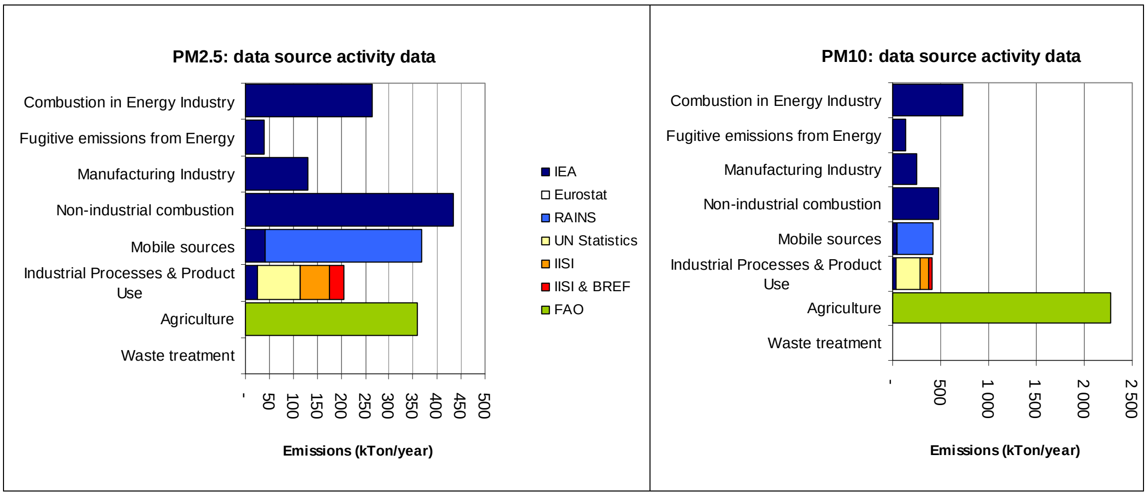


Figure 2-4 Source of activity data used in the inventory.

2.2.2 Emission factors

Emission factors applied in inventory are a further development of the emission factors provided in the CEPMEIP project. For most source categories several alternative technologies are defined and for each of these emission factors, based on the CEPMEIP study were attributed. We also used CEPMEIP data on the "sophistication" of each countries industrial and other economic sectors to select a specific technology for each of the source categories in each of the countries. We assumed in this first order draft, that within each source category the country only uses one specific technology. The details of these assumptions are available for each country's experts to comment and correct.

In brief, the Coordinated European Particulate Matter Emission Inventory (CEPMEIP) is based on a wide range of information sources. Below, a short outline of the procedure applied and the main types of information sources used is given.

The project started in 2000 with an official request for information to European national experts that was sent out by project partner EMEP. The requested information comprised all available national PM emission inventories and underlying information.
Also the results of series of and single source-oriented measurements of emission/concentration/particle size distribution data were taken into account. In total about 3/4 of all UNECE Member States responded by sending results of various types of efforts to determine PM emissions. A special role was played by Poland from which an extensive range of PM emission/concentration/particle size distribution data was submitted as a result of a specific EMEP-led query for information.

The second source of information comprised data that had become available from previously performed projects by TNO related to PM emission. An important contribution was made by underlying information of the Dutch Emission Registration. Further contributions came from many international environmental bench marking projects, source-related stack concentration measurement surveys and PM related information available from heavy metal emission studies.

The third type of information that was considered comprised public reports and handbooks that deal with or somehow include source related emission (factor) data. In this category are reports by:

- IPPC Bureau (BREF/BAT documents)
- UN-ECE Expert Groups (e.g. on HM)
- UN-ECE MSC-East (e.g. work by S. Kakareka et al.)
- US-EPA (e.g. AP42, AIRCHIEF and the United States National Inventory of PM10/PM2.5)
- German Umweltbundesamt UBA (e.g. report 297 44 853 by Dreiseidler et al.)
- Swiss BUWAL
- Austrian JOANEUM
- Dutch RIVM and KEMA
- British APEG
- The COPERT and HBEFA emission models for mobile sources
- CONCAWE

Fourthly, a study to information available from the open scientific literature was made. This yielded a collection of relevant articles and papers on source-related PM emission data from scientific journals and congresses from the period 1970 to 2000.

The last type of information considered were nationally applying emission limit values for stationary sources of primary PM. Actual measurements of PM emissions (as mentioned above) were nevertheless preferred over emission standards in order to estimate real world emission factors.

Annex A provides an overview of all emission factors used.

2.2.3 Uncertainties

Uncertainties are estimated, using a Monte Carlo approach (@Risk add-in for MS Excel). For this approach a probability distribution needs to be defined for all input data, both activity data and emission factors.

For emission factors lognormal distribution functions were selected and the point estimates and the upper and lower limit values of the 95 % confidence intervals as provided in Annex A were used to define the parameters of this distribution. Emission factor uncertainties are quite large in many cases. Where we did not found any information on the uncertainty in the emission factors, we assumed a factor of two.

We used a Gaussian distribution with a standard deviation of 10% for all activity data. For a number of countries the uncertainty range for wood and wood waste fuels was set a factor of 5 higher. This did not result in significantly different resulting uncertainties for the full inventory. The analyses therefore are assumed to be relatively insensitive to the uncertainties in the activity data.

3 Results

3.1 National total emissions

This chapter describes the resulting $PM_{2.5}$ inventory for Europe, as was sent to the countries for comments. Table 3-1 presents the national total $PM_{2.5}$ and PM_{10} emissions as estimated in this study.

Table 3-1 National total emissions of $PM_{2.5}$ and PM_{10} in 2000.

Emission(kTon)		Pollutant	
CountryGroup	CountryName	PM2.5	PM10
EU25	Austria	23.92	46.66
	Belgium	34.67	65.59
	Cyprus	1.95	4.46
	Czech Republic	35.99	121.55
	Denmark	16.71	50.79
	Estonia	9.48	27.25
	Finland	21.35	51.16
	France	228.72	525.60
	Germany	161.77	359.90
	Greece	37.28	88.20
	Hungary	26.73	98.41
	Ireland	12.60	34.16
	Italy	140.07	318.11
	Latvia	15.53	39.38
	Lithuania	15.69	53.18
	Luxembourg	3.77	7.96
	Malta	0.68	1.35
	Netherlands	23.45	48.13
	Poland	141.06	454.58
	Portugal	36.30	78.58
	Slovak Republic	12.98	42.09
	Slovenia	7.78	15.25
	Spain	140.13	354.64
	Sweden	23.44	61.75
	United Kingdom	109.53	234.94
EU25 Total		**1 281.57**	**3 183.69**
CC	Bulgaria	37.02	123.38
	Romania	86.75	262.85
	Turkey	281.37	804.87
CC Total		**405.14**	**1 191.10**
AC	Albania	3.97	12.40
	Bosnia-Herzegovina	13.24	45.17
	Croatia	15.83	41.80
	Federal Republic of Yugoslavia (Serbia&Montenegro)	49.27	174.82
	Former Yugoslav Republic of Macedonia	8.28	25.74
AC Total		**90.59**	**299.93**
EFTA	Iceland	0.41	0.88
	Norway	13.58	28.41
	Switzerland	8.02	16.49
EFTA Total		**22.01**	**45.78**
Grand Total		**1 799.32**	**4 720.50**

The following is observed:

- Total $PM_{2.5}$ emissions in the EU25 amount to about 1300 kTon.
- The other countries in this study add about 500 kTon
- Total $PM_{2.5}$ emissions are about 40% of the PM_{10} emissions
- Larger countries contribute more to the total emissions than smaller countries.

Figure 3-1 and Table 3-2 provide the estimated national total emissions and the uncertainty ranges surrounding these. As indicated above, IIASA has developed an independent estimate as part of the RAINS model runs for the revision of the NEC Directive. Table 3-2 provides the RAINS estimate for comparison.

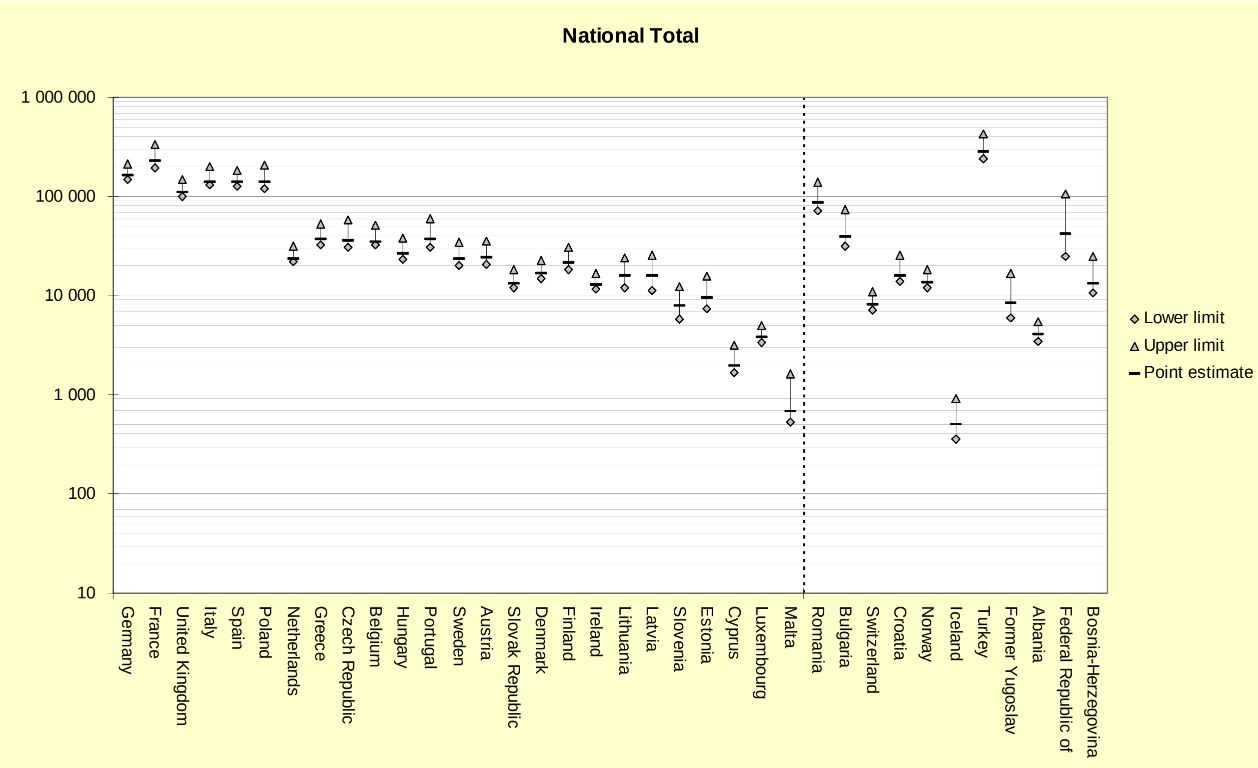


Figure 3-1 Estimated emissions of $PM_{2.5}$ in Europe (tons/year); vertical bars indicate the 95 % confidence intervals. EU25 Member States are sorted on decreasing population sizes.

We observe the following:

1) Generally large countries show higher emissions.
2) The uncertainties are considerable; the 95 % confidence intervals are in the order of a factor of two around the point estimate. This means that a value that is a factor of two higher or lower than the point estimate is within this 95 % confidence interval.
3) Comparison with the estimates as used by IIASA shows that for seven out of thirty six countries the IIASA estimate lies outside the 95 % confidence limit in this inventory; in chapter 0 we will analyse these differences in more detail.

Table 3-2 National total emissions of $PM_{2.5}$ in 2000 (tonnes/year), estimated in this project; the estimate used by IIASA in RAINS is given for comparison.

Group	Country	Population (millions)	National Total			IIASA estimate
			Point estimate	Upper limit	Lower limit	
EU25	Austria	8.0	24 000	35 500	20 400	28 300
	Belgium	10.3	34 700	51 700	33 000	35 400
	Cyprus	0.7	1 970	3 210	1 700	2 330
	Czech Republic	10.3	36 000	57 600	30 700	47 300
	Denmark	5.3	16 800	23 000	14 800	18 000
	Estonia	1.4	9 480	15 500	7 340	**21 800**
	Finland	5.2	21 500	30 800	18 600	21 900
	France	60.9	229 000	332 000	192 000	321 000
	Germany	82.3	162 000	213 000	150 000	178 000
	Greece	10.9	37 300	53 400	32 400	49 500
	Hungary	10.2	26 700	37 800	23 000	**57 000**
	Ireland	3.8	12 600	16 700	11 800	13 400
	Italy	57.0	140 000	201 000	132 000	159 000
	Latvia	2.4	15 600	25 400	11 200	13 600
	Lithuania	3.5	15 800	23 800	12 200	17 100
	Luxembourg	0.4	3 770	4 990	3 410	**2 880**
	Malta	0.4	684	1 650	533	585
	Netherlands	16.0	23 400	31 300	22 100	**32 700**
	Poland	38.3	141 000	207 000	119 000	196 000
	Portugal	10.3	36 300	59 800	30 300	56 200
	Slovak Republic	5.4	13 000	18 400	11 900	17 000
	Slovenia	2.0	7 780	12 500	5 790	11 700
	Spain	40.5	140 000	183 000	127 000	171 000
	Sweden	8.9	23 600	34 300	20 300	28 100
	United Kingdom	59.0	110 000	150 000	101 000	127 000
Other	Albania		3 970	5 480	3 450	
	Bosnia-Herzegovina		13 200	24 800	10 600	
	Bulgaria	7.9	39 400	73 800	31 400	64 300
	Croatia	4.4	15 900	25 300	13 800	
	Serbia & Montenegro		41 400	107 000	24 600	
	FYR of Macedonia		8 290	16 700	5 980	
	Iceland	0.3	492	902	358	
	Norway	4.5	13 600	18 100	11 800	**32 600**
	Romania	22.4	86 800	138 000	70 800	**145 000**
	Switzerland	7.2	8 020	10 900	7 160	**12 300**
	Turkey		281 000	426 000	242 000	344 000
Population data from Eurostat.						

Figure 3-2 presents the per capita emissions for the EU25 Member States and those countries where EUROSTAT population data are available. Apart from Luxembourg, Estonia and Latvia, all countries appear to have comparable $PM_{2.5}$ emissions per inhabitant. This emission is in the order of 2 to 5 kg/inhabitant per year.

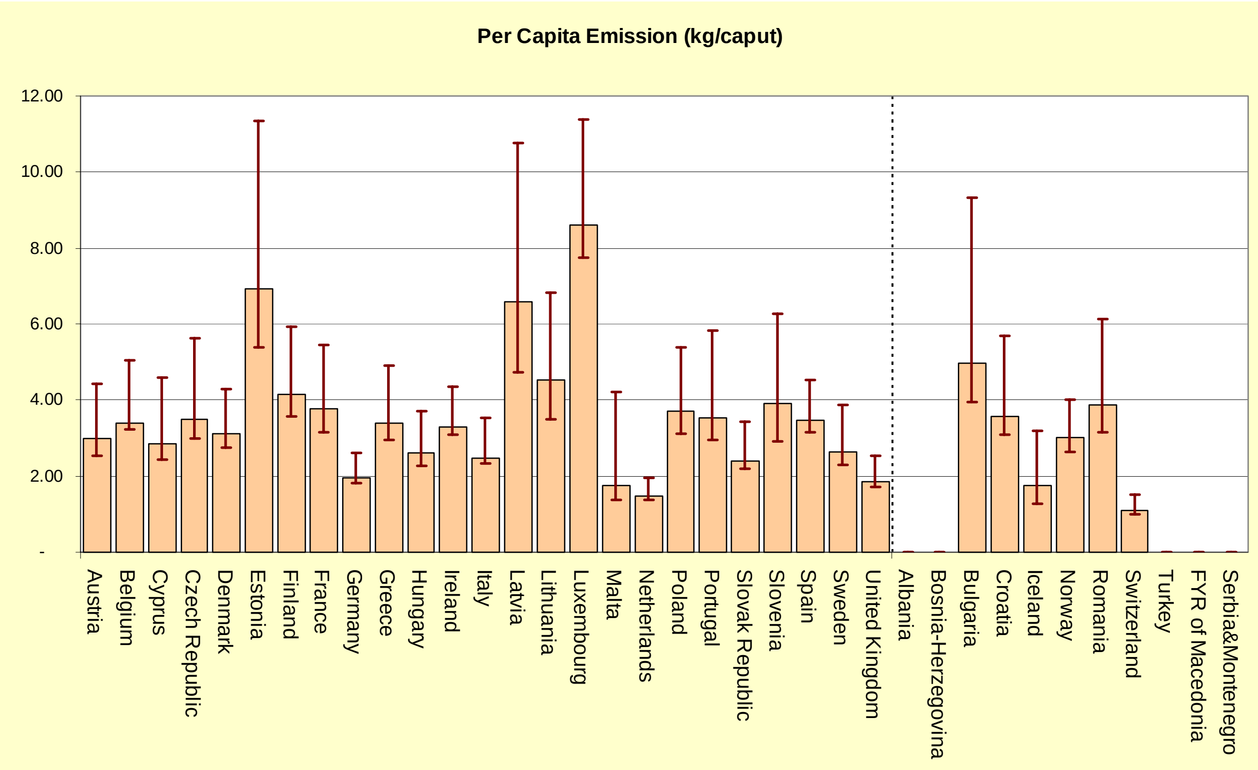


Figure 3-2 Per capita $PM_{2.5}$ emissions in Europe (kg/caput); error bars indicate the 95 % confidence intervals.

3.2 Sector contributions

3.2.1 Main sectors

Table 3-3 presents the main sector contributions of $PM_{2.5}$ and PM_{10} emissions in Europe in the year 2000. We observe the following:

- Mobile sources and non-industrial combustion, combustion in energy transformation and in industrial processes are major contributors to the emissions of both $PM_{2.5}$ and PM_{10}.
- Agriculture is also a major contributor, but in this case the importance of agriculture for the $PM_{2.5}$ emissions is much lower than for PM_{10}.

Table 3-3 Main sector contributions to $PM_{2.5}$ and PM_{10} emissions in Europe in 2000.

Emission(kTon)		Pollutant	
CountryGroup	SectorGroupName	PM2.5	PM10
EU25	Combustion in Energy Industry	178.20	393.07
	Manufacturing Industry	48.92	74.83
	Non-industrial combustion	292.25	325.34
	Mobile sources	323.23	375.16
	Fugitive emissions from Energy	29.72	102.74
	Industrial Processes & Product Use	151.40	296.15
	Agriculture	255.29	1 613.84
	Waste treatment	2.56	2.56
EU25 Total		**1 281.57**	**3 183.69**
CC	Combustion in Energy Industry	55.56	211.57
	Manufacturing Industry	72.90	158.98
	Non-industrial combustion	113.49	126.41
	Mobile sources	29.02	32.19
	Fugitive emissions from Energy	6.47	23.58
	Industrial Processes & Product Use	44.89	99.81
	Agriculture	82.81	538.56
	Waste treatment	0.01	0.01
CC Total		**405.14**	**1 191.10**
AC	Combustion in Energy Industry	31.59	129.43
	Manufacturing Industry	6.80	14.55
	Non-industrial combustion	20.70	24.43
	Mobile sources	7.63	8.43
	Fugitive emissions from Energy	1.71	6.97
	Industrial Processes & Product Use	5.61	11.52
	Agriculture	16.12	104.17
	Waste treatment	0.43	0.43
AC Total		**90.59**	**299.93**
EFTA	Combustion in Energy Industry	0.32	0.33
	Manufacturing Industry	0.54	0.77
	Non-industrial combustion	6.42	6.44
	Mobile sources	7.68	9.34
	Fugitive emissions from Energy	0.72	2.17
	Industrial Processes & Product Use	3.02	6.27
	Agriculture	3.22	20.36
	Waste treatment	0.09	0.09
EFTA Total		**22.01**	**45.78**
Grand Total		**1 799.32**	**4 720.50**

Figure 3-3 shows the same contributions of the main sources to the annual emissions of $PM_{2.5}$ in European countries. The emissions in most countries are indeed mainly due to combustion processes. In some countries (Iceland, Slovak Republic, Belgium) industrial process emissions are important. Emissions from agriculture are significant in all countries in this study.

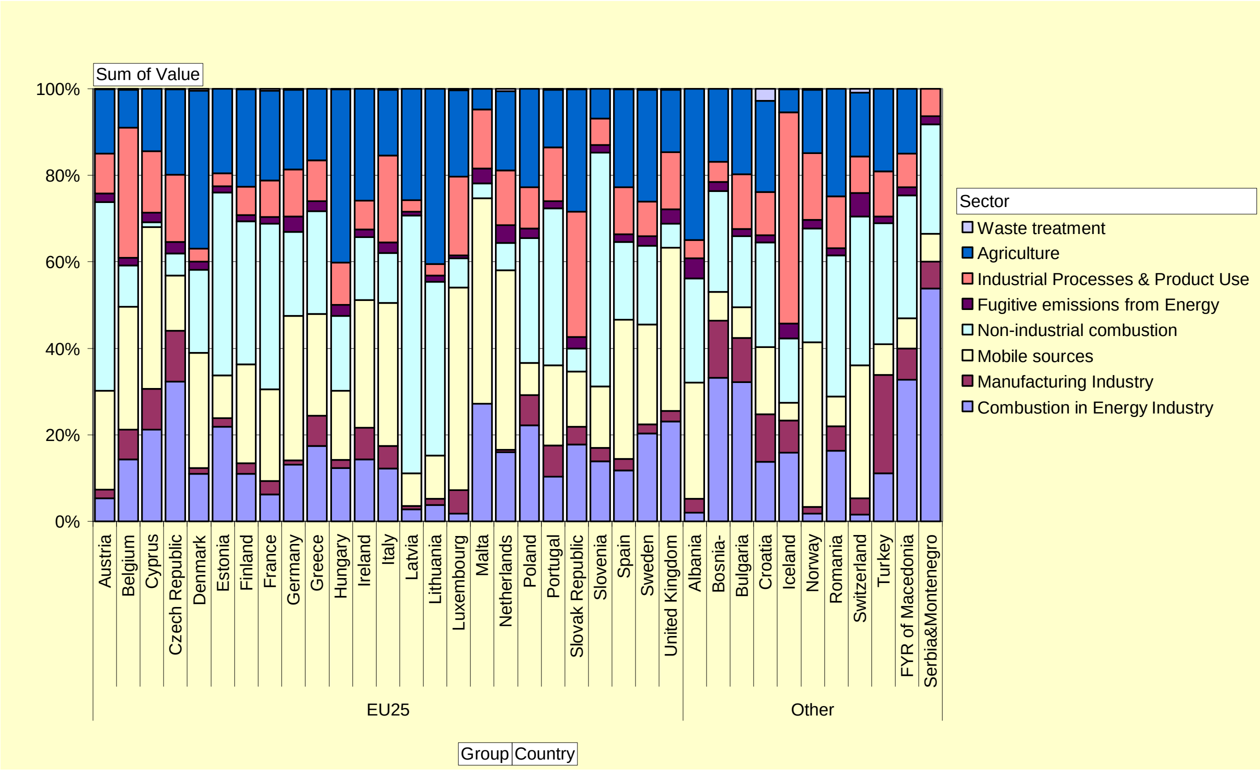


Figure 3-3 Source contributions to $PM_{2.5}$ emissions in 2000.

3.2.2 Fuels

Combustion is a major contributor to $PM_{2.5}$ and PM_{10} emissions. Table 3-4 presents an overview of fuel related emissions in the countries in this study.

Table 3-4 Contribution by fuel type to $PM_{2.5}$ and PM_{10} emissions in 2000.

Emission(kTon)		FuelGroup						
Pollutant	**CountryGroup**	**Solids**	**Liquids**	**Gaseous**	**Waste**	**Biomass**	**.**	**Grand Total**
PM2.5	EU25	143.04	373.58	9.88	10.97	269.28	474.82	1 281.57
	CC	94.88	65.70	1.02	0.67	106.92	135.96	405.14
	AC	36.14	12.27	0.11		17.75	24.32	90.59
	EFTA	0.12	8.33	0.23	0.14	5.26	7.93	22.01
PM2.5 Total		**274.18**	**459.88**	**11.24**	**11.78**	**399.21**	**643.03**	**1 799.32**
PM10	EU25	373.84	393.34	9.88	14.12	287.89	2 104.62	3 183.69
	CC	320.77	86.78	1.02	1.12	114.84	666.57	1 191.10
	AC	141.02	15.46	0.11		19.07	124.27	299.93
	EFTA	0.28	8.55	0.23	0.19	5.27	31.27	45.78
PM10 Total		**835.91**	**504.13**	**11.24**	**15.42**	**427.06**	**2 926.73**	**4 720.50**

It is shown that gaseous fuels contribute relatively little to the emissions. Contributions of solid fuels (coal, lignite), liquids (diesel in road transport) and biomass (wood in residential combustion) are important.

3.2.3 *Agriculture*

This study is the first to include an estimate of wind blown dust in the $PM_{2.5}$ inventory. Table 3-5 provides an overview of the contributions of the detailed sub-sources in agriculture to these emissions. Wind erosion on arable lands is by far the largest contribution, while soil tilling also contributes significantly.

Although the $PM_{2.5}$ emissions are relatively small when compared to the PM10 emissions from these sources, they still are important in the national totals (Table 3-3).

Table 3-5 Detailed contribution of agriculture sub-sectors to $PM_{2.5}$ and PM_{10} emissions in 2000.

Emission(kTon)		CountryGroup				
Pollutant	**Subsector**	**EU25**	**CC**	**AC**	**EFTA**	**Grand Total**
PM2.5	Arable land - wind erosion	154.52	55.07	10.50	1.95	222.05
	Arable land - soil tilling	39.15	13.95	2.66	0.50	56.25
	Arable land - pesticide application	8.55	3.05	0.58	0.11	12.29
	Arable land - harvesting	7.73	2.75	0.53	0.10	11.10
	Arable land - fertilizer	7.01	2.50	0.48	0.09	10.07
	Cattle	8.36	1.32	0.30	0.24	10.21
	Pigs	12.07	0.58	0.47	0.15	13.28
	Chickens	9.72	2.68	0.34	0.08	12.83
	Turkeys	5.85	0.28	0.11	0.00	6.25
	Ducks	2.11	0.31	0.06	0.00	2.49
	Geese	0.23	0.32	0.08		0.64
PM2.5 Total		**255.29**	**82.81**	**16.12**	**3.22**	**357.44**
PM10	Arable land - wind erosion	1 030.16	367.10	70.03	13.03	1 480.32
	Arable land - soil tilling	257.54	91.78	17.51	3.26	370.08
	Arable land - pesticide application	56.66	20.19	3.85	0.72	81.42
	Arable land - harvesting	51.51	18.36	3.50	0.65	74.02
	Arable land - fertilizer	46.36	16.52	3.15	0.59	66.61
	Cattle	37.56	5.93	1.33	1.06	45.88
	Pigs	53.46	2.58	2.10	0.68	58.82
	Chickens	43.34	11.95	1.53	0.38	57.20
	Turkeys	26.61	1.27	0.52	0.00	28.40
	Ducks	9.61	1.41	0.28	0.00	11.30
	Geese	1.04	1.48	0.37		2.89
PM10 Total		**1 613.84**	**538.56**	**104.17**	**20.36**	**2 276.93**

3.2.4 *Road transport*

Both fuel combustion and other processes (brake and tyre wear, road abrasion) contribute to the particulate emissions from transport (Table 3-6). In this estimate, road abrasion does not contribute to the $PM_{2.5}$ emissions, whereas it is important in the PM_{10} emissions. The contribution of brake and tyre wear amounts to about 10 % of the total $PM_{2.5}$ emissions from transport. Brake and tyre wear and road abrasion together contribute about 20 % to the PM_{10} emissions from road transport.

Table 3-6 Detailed contribution of transport sub-sectors to $PM_{2.5}$ and PM_{10} emissions in 2000.

Emission(kTon)			CountryGroup				
Pollutant	CRF/NFRCode	CRF/NFRName	EU25	CC	AC	EFTA	Grand Total
PM2.5	1.A.3.b.ii	road transport, light duty vehicles	98.22	7.03	1.87	1.00	108.12
	1.A.3.b.iii	road transport, heavy duty vehicles	152.60	16.24	3.88	2.85	175.57
	1.A.3.b.iv	road transport, mopeds & motorcycles	8.64	0.06	0.61	0.17	9.48
	1.A.3.b.vi	road transport, automobile tyre and brake wear	29.70	1.78	0.45	0.88	32.81
	1.A.3.b.vii	road transport, automobile road abrasion	0.00	0.00	0.00	0.00	0.00
	1.A.3.c	railways	14.10	2.51	0.32	0.13	17.07
	1.A.3.d.ii	national navigation	19.69	1.39	0.22	2.65	23.94
	1.A.3.e	other (please specify in a covering note)	0.28		0.28		0.56
PM2.5 Total			323.23	29.02	7.63	7.68	367.56
PM10	1.A.3.b.ii	road transport, light duty vehicles	98.22	7.03	1.87	1.00	108.12
	1.A.3.b.iii	road transport, heavy duty vehicles	152.60	16.24	3.88	2.85	175.57
	1.A.3.b.iv	road transport, mopeds & motorcycles	8.64	0.06	0.61	0.17	9.48
	1.A.3.b.vi	road transport, automobile tyre and brake wear	47.14	2.83	0.72	1.39	52.08
	1.A.3.b.vii	road transport, automobile road abrasion	31.91	1.79	0.47	0.98	35.15
	1.A.3.c	railways	15.47	2.75	0.35	0.15	18.72
	1.A.3.d.ii	national navigation	20.88	1.49	0.23	2.80	25.39
	1.A.3.e	other (please specify in a covering note)	0.30		0.30		0.61
PM10 Total			375.16	32.19	8.43	9.34	425.12

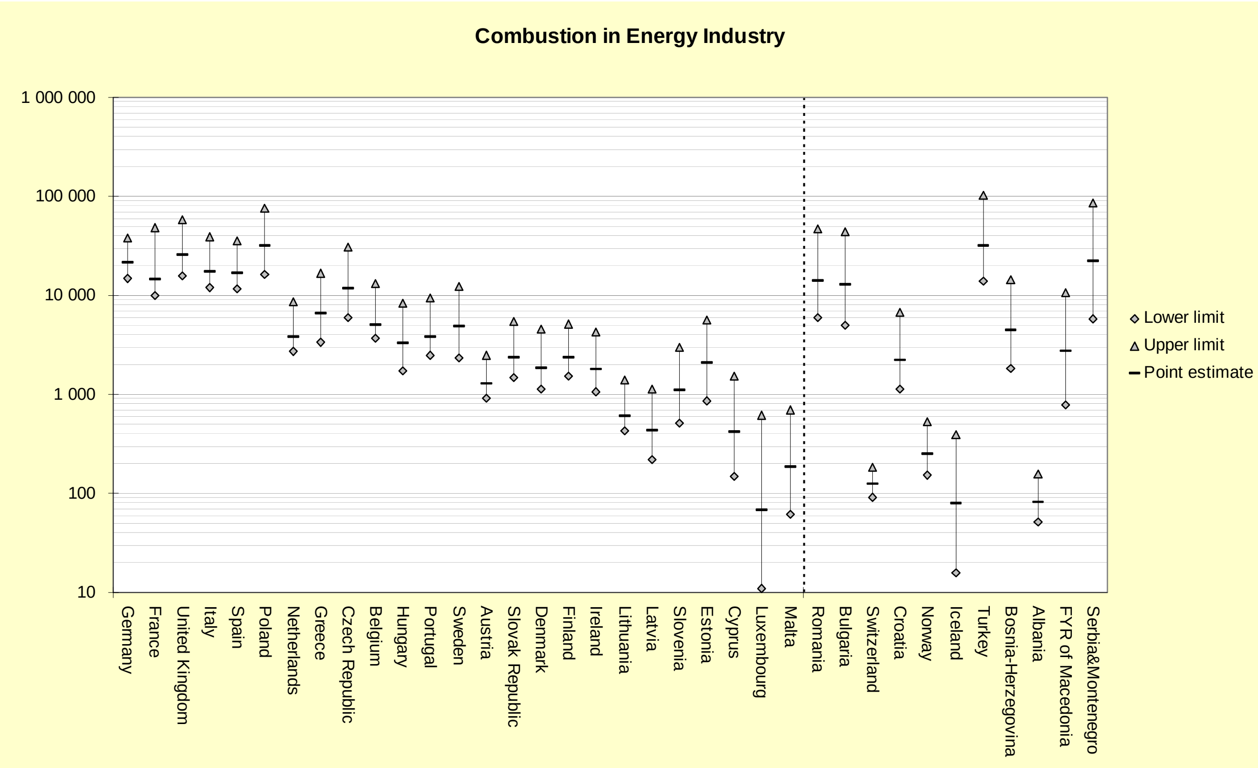
3.2.5 *Uncertainties*

Figure 3-4 and Figure 3-5 present the contributions of stationary and mobile combustion sources to the $PM_{2.5}$ emissions in 2000. The uncertainties in non-industrial combustion (Figure 3-5, upper graph) are mainly due to combustion in residential applications. Figure 3-6 presents the national total emissions due to industrial processes and agriculture.

Taking into account the contribution of the different source sectors to the total emissions, the uncertainties in non-industrial combustion, combustion in energy industries seem to be the most important ones. The uncertainties in agriculture and in industrial processes are important too.

We observe a relatively low uncertainty in the emissions due to (road) transport. This is for a large part due to the fact that uncertainty ranges for this sector are not available and therefore have been assumed to amount to a factor of 2. This range however is comparable to the uncertainty ranges as used for other source sectors.

An interesting issue here is whether or not the uncertainties as estimated in this report could be decreased. Part of the uncertainties will be due to incomplete knowledge of the processes leading to the emissions. Another part however will be due to the intrinsic stochastic processes related to turbulence in both combustion processes, the condition of roads (road abrasion, brake and tyre wear) and in the atmosphere (wind blown dust). The first type of uncertainties could, at least in principle, be decreased. The latter type of uncertainties is much more difficult to avoid and decrease.



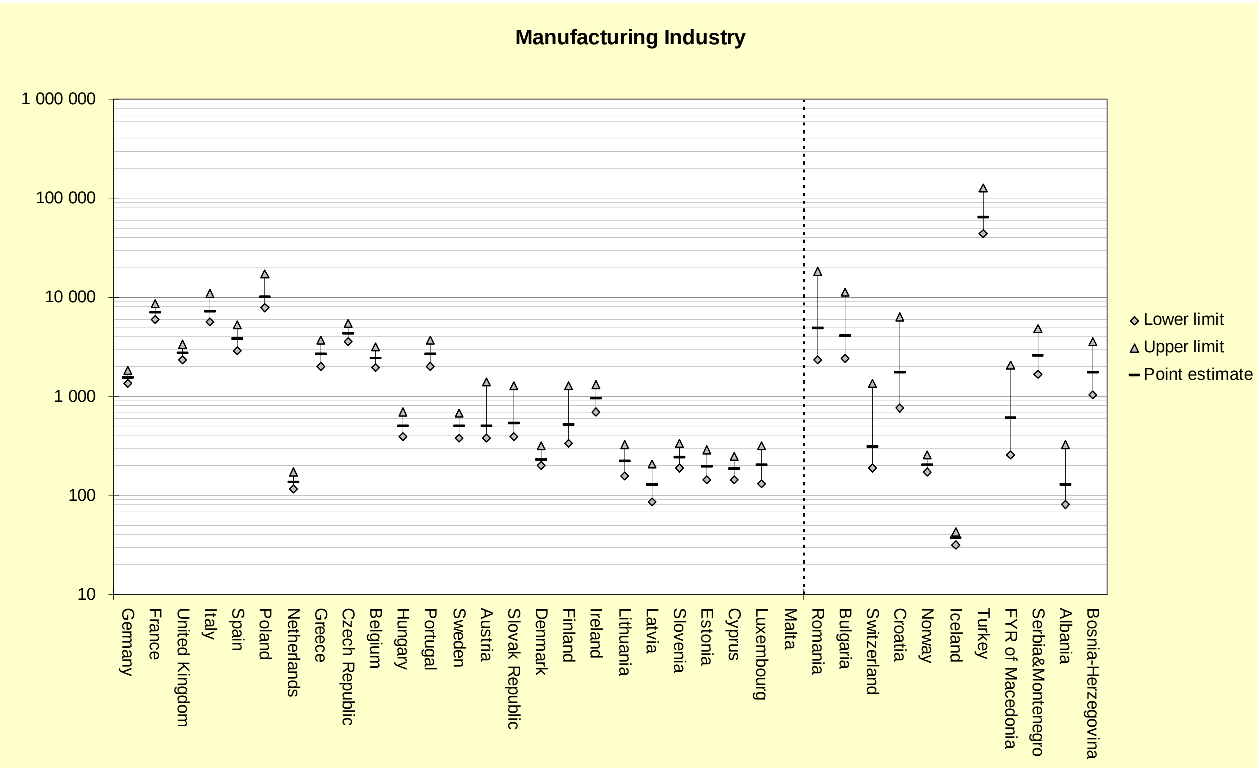


Figure 3-4 Estimated emissions of $PM_{2.5}$ in Europe (tons/year) from Combustion in Energy transformation (above) and in industrial combustion (below); vertical bars indicate the 95 % confidence intervals.

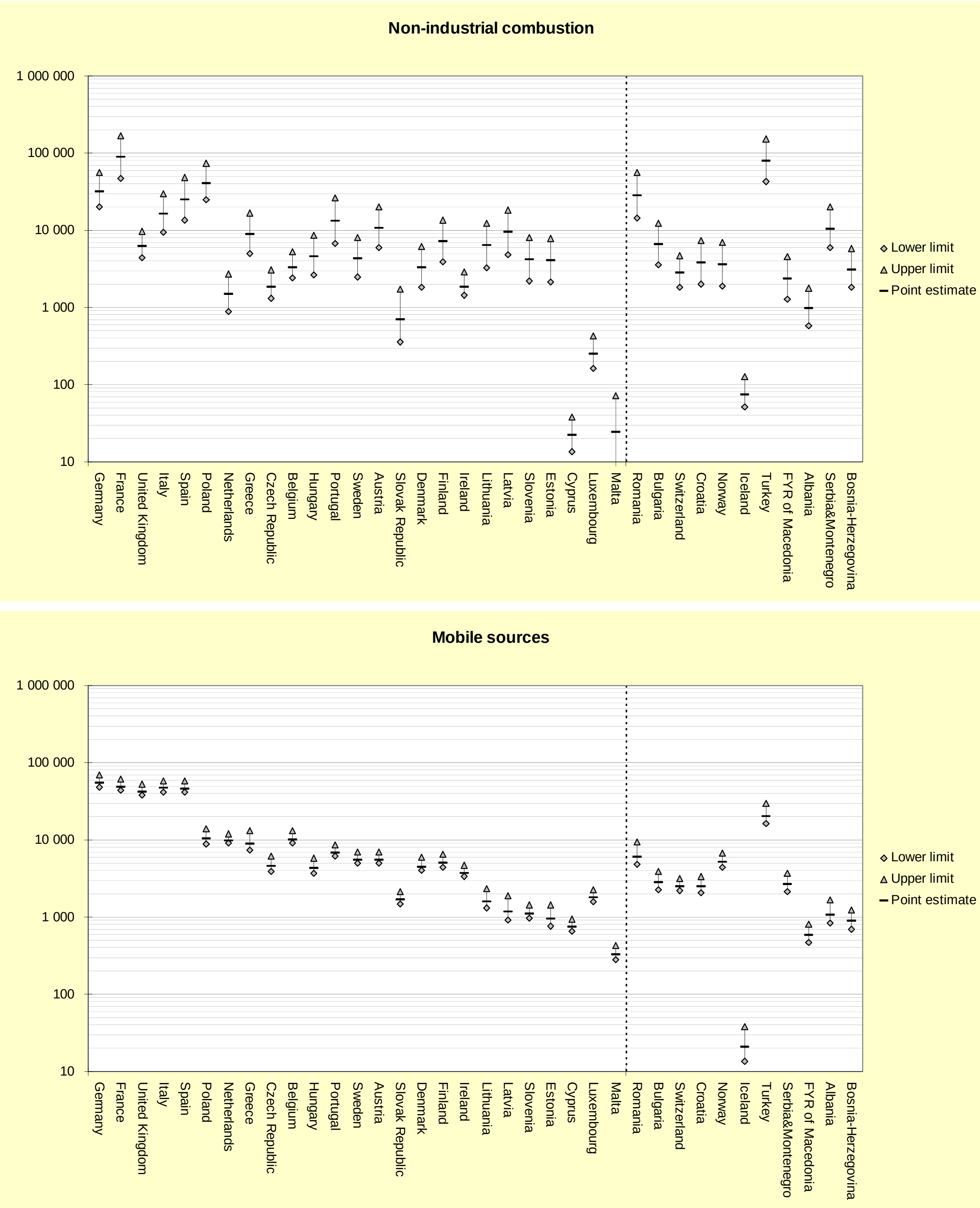
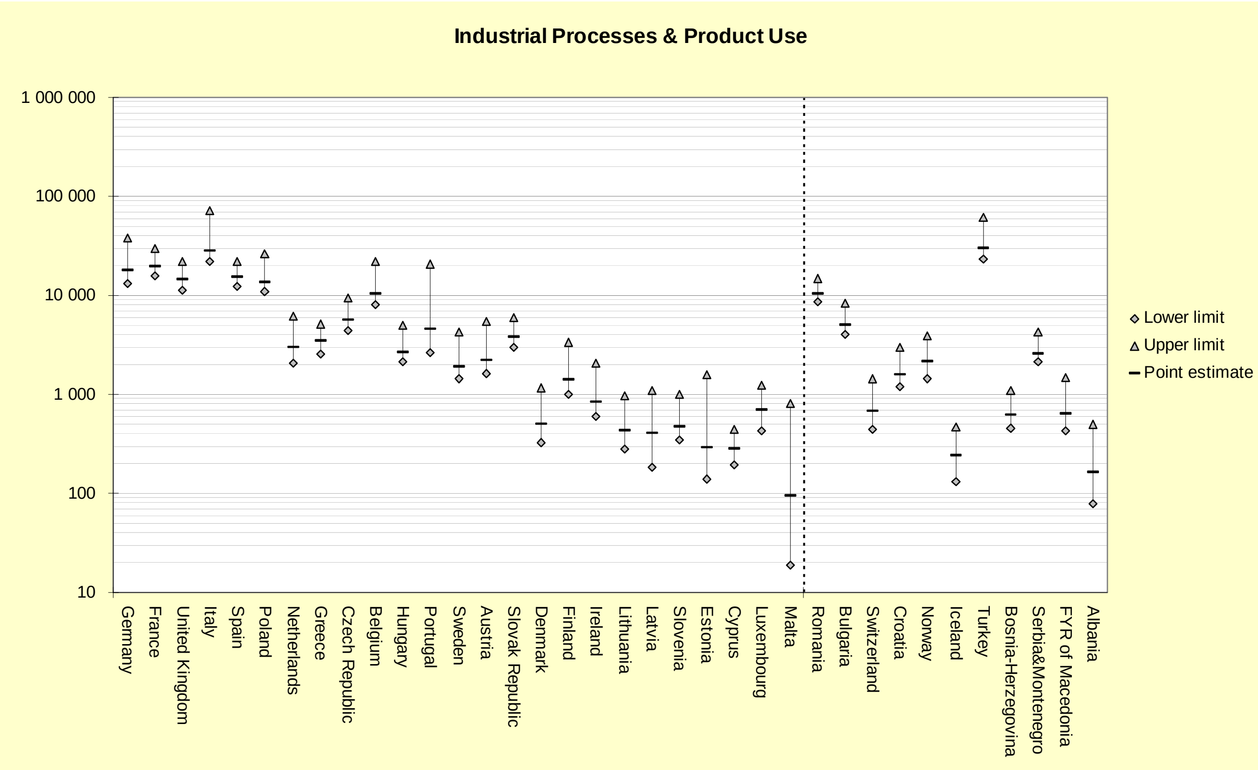


Figure 3-5 Estimated emissions of $PM_{2.5}$ in Europe (tons/year) from non-industrial stationary combustion (above) and mobile sources (below); vertical bars indicate 95 % confidence intervals.



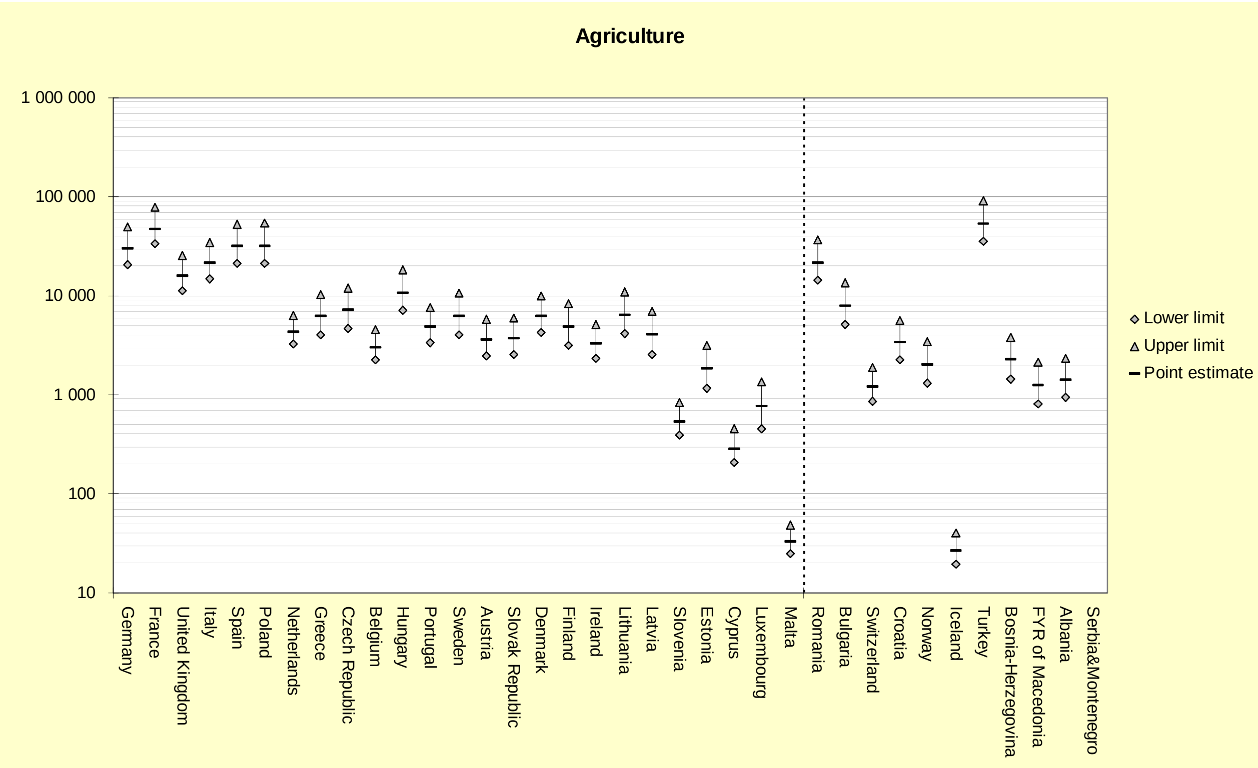


Figure 3-6 Estimated emissions of $PM_{2.5}$ in Europe (tons/year) from industrial processes (above) and agriculture (below); vertical bars indicate 95 % confidence intervals.

3.3 Country comments

The first order draft inventory was published on Circa's website in June 2006. A number of countries (Albania, Austria, Czech Republic, Estonia, Germany, Hungary, Latvia and Norway) have responded to this first order draft. Norway, Portugal and Spain have indicated to be satisfied with the IIASA estimates, used in the RAINS models.

The quantitative comments received were all within the uncertainty ranges of both the activity data and the emission factors and recognized the fact that in this study some sources (wind blown dust) were estimated for the first time. The presentation of the results and the conclusions drawn from these therefore are not changed since they were presented t the TFEIP/EIONET meeting in Thessaloniki (October/November 2006).

Some countries have asked the project team for support in developing their own national emission inventories. Specific questions have been answered and detailed activity data and emission factors as used in this study have been made available to all who have asked for those. These data are also available on the Circa web site.

4 Comparison with the IIASA emission data for $PM_{2.5}$

4.1 Introduction

This chapter describes a comparison study between the EU25 $PM_{2.5}$ inventory prepared in this study (using the TEAM model, TNO Emission Assessment Model) and the $PM_{2.5}$ emission inventory from the IIASA-RAINS model (Regional Air Pollution Information and Simulation), which combines information on economic and energy development, emission control potentials and costs, atmospheric dispersion characteristics and environmental sensitivities towards air pollution [[Ref 1], [Ref 2]]. The comparison is a kind of validation for both datasets and is relevant since the IIASA-RAINS model is used to assess the establishments of new National Emission Ceilings for $PM_{2.5}$.

In this analysis we include 30 countries. Besides the EU25 countries we include the 3 Candidate Countries (Bulgaria, Romania and Turkey) and 2 countries from the European Free Trade Association (Norway and Switzerland). For the other countries that are included in the EU25 $PM_{2.5}$ inventory, $PM_{2.5}$ emission data from IIASA are not available.

To look in more detail to differences between the two inventories, we compare the total of $PM_{2.5}$ emissions from all individual countries included in this analysis. The result is shown in Table 4-1 and Figure 4-1.

4.2 Overall comparison

Table 4-1 provides a comparison between our estimate, using the TEAM model and the national totals, calculated from the data on the GAINS online model. These national totals differ for the Czech Republic and Spain from the values as reported in [Ref 3] in table 7.4. It appears that for these countries the table in [Ref 3] contains an error.

Table 4-1 shows that the Grand Total of $PM_{2.5}$ emissions are 25 % higher for the IIASA inventory compared to the TEAM emission inventory. The TEAM emission estimate is only higher for five countries compared to the IIASA estimate (Germany, Lithuania, Luxembourg, Malta and Sweden). The figure also shows that IIASA emissions are significantly higher for all major countries in Europe.

Table 4-1 $PM_{2.5}$ emissions per country, for IIASA and TEAM emission inventory.

CountryGroup	CountryName	TEAM	IIASA	Difference
EU25	Austria	23 944	30 857	78%
	Belgium	34 760	35 546	**98%**
	Cyprus	1 876	2 206	85%
	Czech Republic	36 254	57 345	63%
	Denmark	16 672	24 759	67%
	Estonia	9 493	23 473	40%
	Finland	21 356	27 733	77%
	France	228 953	293 291	78%
	Germany	**161 976**	157 330	**103%**
	Greece	37 310	47 391	79%
	Hungary	26 819	52 316	51%
	Ireland	12 612	15 701	80%
	Italy	140 151	157 767	89%
	Latvia	15 551	18 284	85%
	Lithuania	**15 679**	12 495	125%
	Luxembourg	**3 681**	2 734	135%
	Malta	**637**	543	117%
	Netherlands	23 460	27 484	85%
	Poland	142 577	197 026	72%
	Portugal	35 870	80 713	44%
	Slovak Republic	13 009	24 556	53%
	Slovenia	7 780	11 961	65%
	Spain	140 352	142 848	**98%**
	Sweden	**23 457**	23 303	**101%**
	United Kingdom	109 917	120 626	**91%**
EU25 Total		**1 284 147**	**1 588 289**	
CC	Bulgaria	37 105	61 201	61%
	Romania	87 735	127 177	69%
	Turkey	282 078	312 955	**90%**
CC Total		**406 918**	**501 332**	
EFTA	Norway	13 646	55 527	25%
	Switzerland	8 027	9 236	87%
EFTA Total		**21 673**	**64 763**	
Grand Total		**1 712 738**	**2 154 384**	

The column

- "IIASA" shows the national totals as calculated from the "sector totals" download from the IIASA GAINS-online website on March 1st, 2007.
- "Difference" shows the ratio TEAM/IIASA in percentages

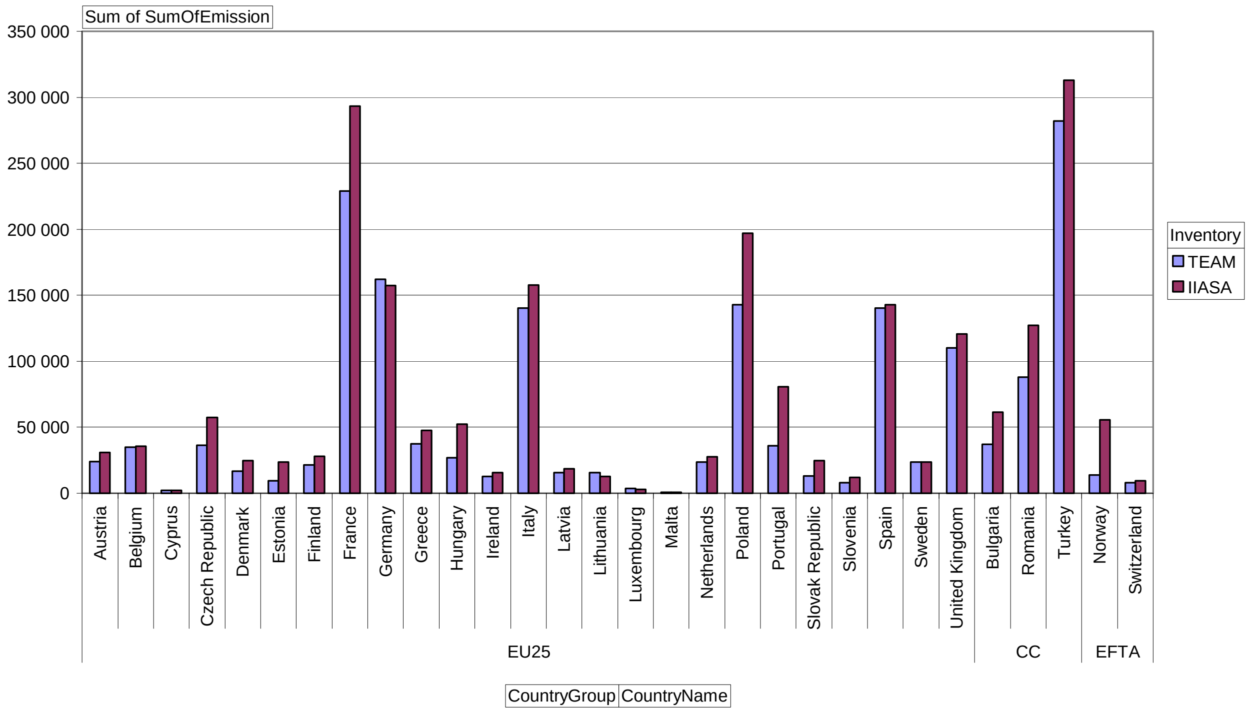


Figure 4-1 *Annual $PM_{2.5}$ emissions from every individual country.*

4.3 Activity data

To compare both emission datasets from a different perspective, we now turn our attention to the source of the emission, the activity causing the emission. The emissions are from 4 main categories: energy, industrial processes, agriculture and others. For the first main activity (energy), we distinct between fuel combustion and fugitive emissions. Fuel combustion emissions are again subcategorized. This leads to the following classification:

- Total Energy (Fuels)
  - Fuel Combustion
    - ✓ Energy Industry
    - ✓ Manufacturing Industry and Construction
    - ✓ Transport
    - ✓ Other sectors
  - Fugitive Emissions from Fuels
- Industrial Processes
- Agriculture
- Other sources

Figure 4-2 shows the annual emission of $PM_{2.5}$ for each of these sectors.

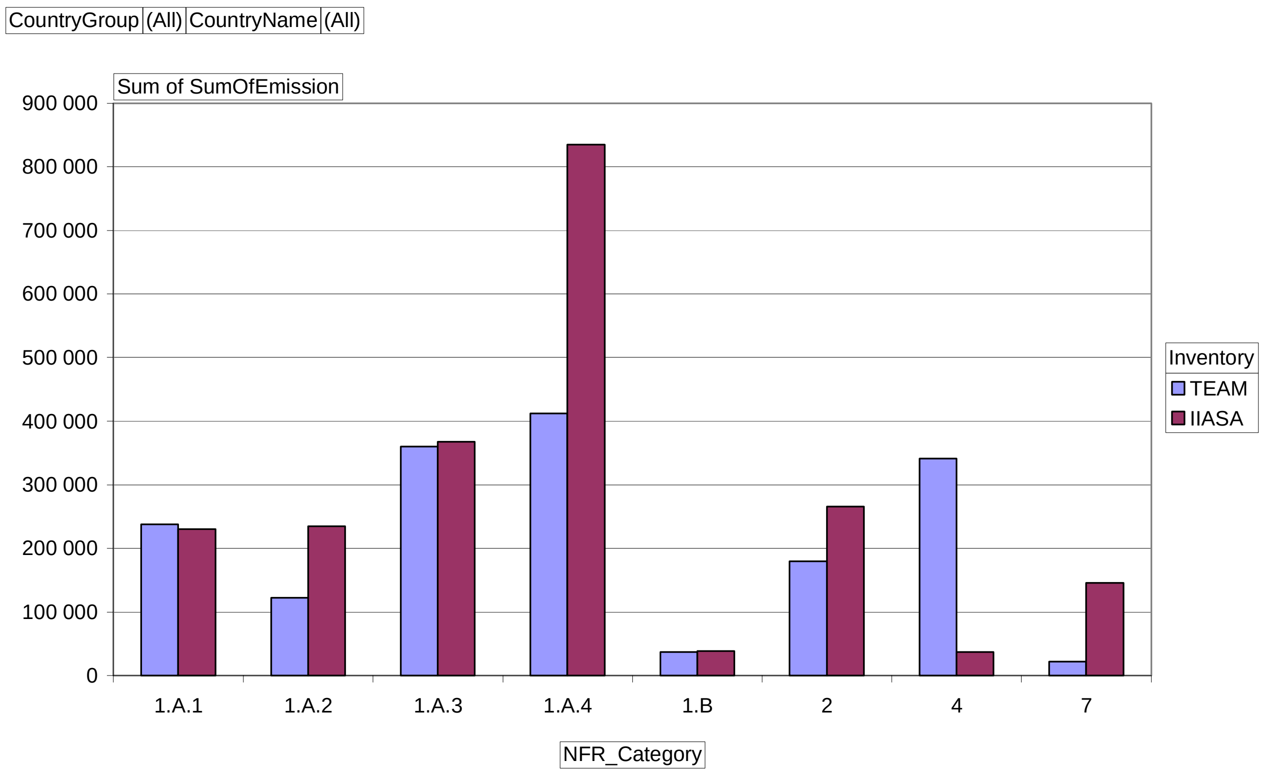


Figure 4-2 $PM_{2.5}$ emissions per sector for both the TEAM and IIASA emission inventory.
1.A.1: Combustion in Energy Sector
1.A.2 Combustion in Manufacturing Industry
1.A.3 Combustion in Transport
1.A.4 Combustion in Residential
1.B Fugitive from Energy
2 Industrial Processes
4 Agriculture
7 Other emissions

The most significant differences between the two inventories are found:

- in the residential sector, the IIASA emission exceeds the TEAM emission by more than a factor 2;
- in the Manufacturing Industry sector, where the IIASA emission exceeds the TEAM emission by almost a factor of 2;
- in the Agriculture sector, where the $PM_{2.5}$ emissions from this inventory are significantly higher than the emissions from IIASA. The reason for this difference is the fact that emissions from soil dust from human activities in agriculture and off-road activities are included in the TEAM inventory, while these are not in the IIASA inventory.

4.4 Fuel use

To look in more detail to the differences in the Combustion sectors, we now turn our attention to the fuels that are used. Since both emission inventories use different fuel classifications and it is difficult to relate these, we here categorize the fuels in 5 major categories:

- Solid fuels
- Liquid fuels
- Gaseous fuels
- Fuels from biomass or waste
- No fuel

Table 4-2 shows the activities (expressed in TJ) for every fuel combustion category and for every fuel used. This is only done for the fuel combustion category, since for the other categories no fuels are used.

Table 4-2 Activities per category and per fuel, for both the TEAM and IIASA inventory.

Fuel_ID	NFR_Category	TEAM	IIASA
Solids	Energy Industry	10 180 572	10 157 485
	Manufacturing Industry	1 029 414	1 584 654
	Transport	379	
	Residential	593 656	653 276
Solids Total		11 804 020	12 395 415
Liquids	Energy Industry	2 425 405	2 679 273
	Manufacturing Industry	1 822 633	2 139 353
	Transport	13 435 708	15 042 326
	Residential	3 830 823	4 693 604
Liquids Total		21 514 569	24 554 556
Gaseous	Energy Industry	7 451 210	6 393 674
	Manufacturing Industry	5 427 211	5 176 374
	Transport	15 663	16 424
	Residential	7 312 516	6 668 850
Gaseous Total		20 206 601	18 255 322
Biomass/Waste	Energy Industry	566 885	209 628
	Manufacturing Industry	62 479	342 165
	Residential	1 537 635	1 594 672
Biomass/Waste Total		2 166 999	2 146 465
Grand Total		55 692 189	57 351 758

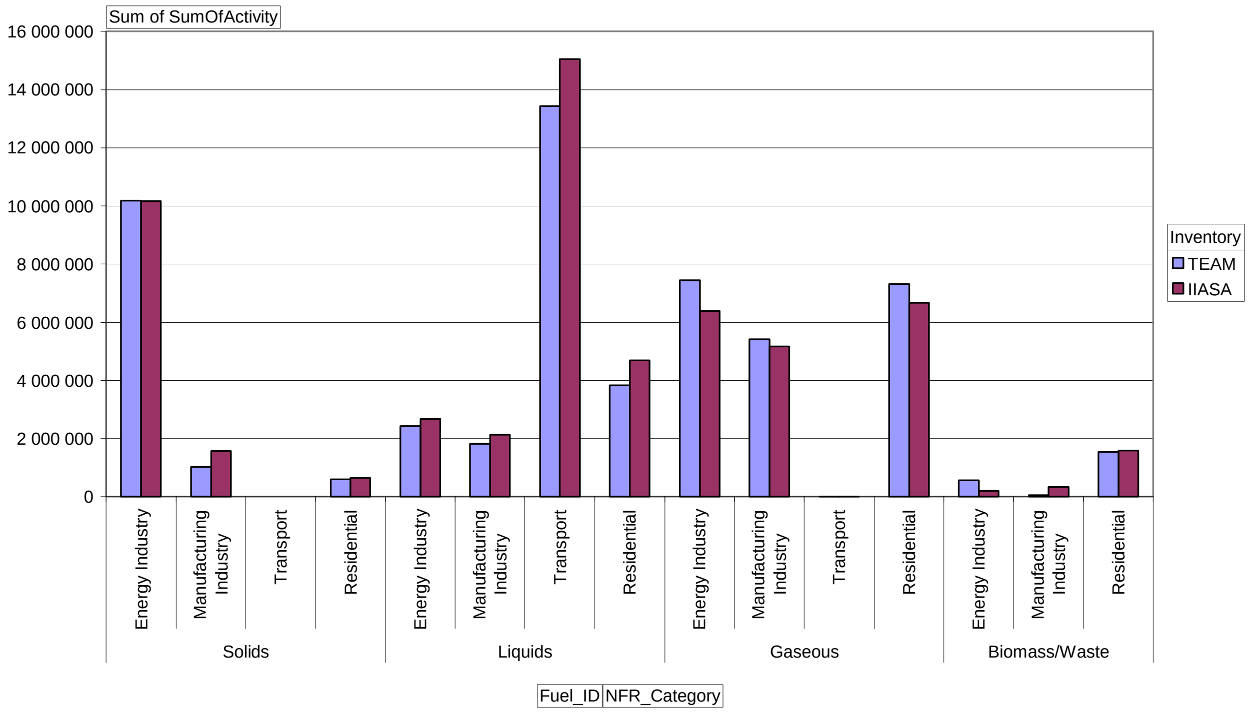


Figure 4-3 *Activity (in TJ) per sector per fuel.*

Table 4-2 and Figure 4-3 show that the amount of fuel used in fuel combustion sectors is higher in the IIASA inventory for most sector-fuel combinations. The total activity is 3 % higher in the IIASA inventory compared to the TEAM inventory. Table 4-3 shows how much $PM_{2.5}$ is emitted from every activity-fuel combination, for the TEAM as well as for the IIASA emission database.

Table 4-3 Emissions per activity category and per fuel.

	EU25		CC		EFTA		All Countries	
NFR_Category	TEAM	IIASA	TEAM	IIASA	TEAM	IIASA	TEAM	IIASA
Energy Industry	109 382	122 925	46 734	87 223	3	4	156 119	210 151
Manufacturing Industry	19 135	13 307	43 867	5 521	97	51	63 098	18 879
Transport	52		4				57	0
Residential	16 070	146 698	4 732	32 024	14	52	20 816	178 774
	144 639	**282 930**	**95 336**	**124 767**	**114**	**106**	**240 090**	**407 804**
Energy Industry	32 993	17 471	8 996	1 508	104	22	42 092	19 001
Manufacturing Industry	25 538	39 549	28 233	2 495	260	1 142	54 030	43 186
Transport	293 297	296 621	27 866	26 723	6 809	5 435	327 973	328 779
Residential	21 990	89 197	1 819	6 573	1 084	2 115	24 892	97 884
	373 817	**442 838**	**66 914**	**37 298**	**8 256**	**8 714**	**448 987**	**488 850**
Energy Industry	7 022	1 003	679	67	236	21	7 937	1 091
Manufacturing Industry	2 188	473	369	39	6	6	2 563	518
Transport	0	9	24	4			24	13
Residential	1 401	1 543	48	22	14	19	1 463	1 583
	10 611	**3 027**	**1 120**	**132**	**256**	**46**	**11 987**	**3 204**
Energy Industry	25 419	62	267	21	25	2	25 710	85
Manufacturing Industry	2 058	7 354	436	164	142	184	2 635	7 703
Residential	252 788	364 733	106 887	150 219	5 235	41 909	364 911	556 861
ɔtal	**280 265**	**372 149**	**107 589**	**150 404**	**5 402**	**42 096**	**393 256**	**564 649**
	809 331	**1 100 944**	**270 960**	**312 601**	**14 029**	**50 962**	**1 094 321**	**1 464 507**

4.5 Emission factors

From the table it can be seen that IIASA $PM_{2.5}$ emissions are higher for all fuel categories. The most significant difference is found in the biomass/waste fuel category, where the IIASA emission exceeds the TEAM emission by 67%.

Figure 4-4 shows the results from table 3 in a graph. From this figure we see large differences between the fuels used for various activities in both inventories. The largest differences are found in the residential sector, where the IIASA emission is much higher than the TEAM value, except for the gaseous sector where all emissions are rather small.

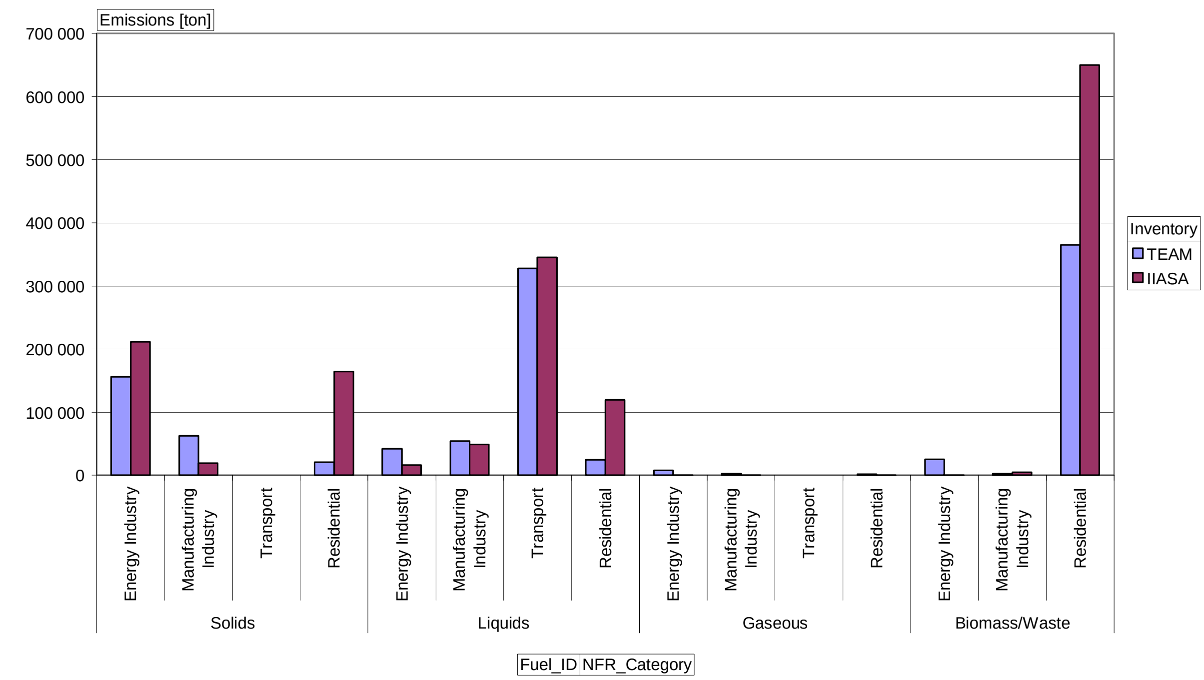


Figure 4-4 Emissions per fuel and per fuel combustion sector, for both the TEAM and IIASA inventory.

These large differences between both inventories are not present in the activities (see Table 4-2and Figure 4-3), therefore these differences must be caused by a difference in emission factors between the two inventories.

In Table 4-4 and Figure 4-5 the implied emission factor is shown for both inventories, again per fuel and per fuel combustion category. The implied emission factor is determined by dividing the emission by the activity, both of which are also shown in Table 4-4.

Table 4-4 Activity, Emission and Implied emission factor for both inventories, per fuel and per fuel combustion category.

	Activity [TJ]		Emission [ton]		Implied emission factor [ton/PJ]	
NFR Category	**TEAM**	**IIASA**	**TEAM**	**IIASA**	**TEAM**	**IIASA**
Energy Industry	10 180 572	10 514 498	156 119	210 151	15.3	20.0
Manufacturing Industry	1 029 414	2 147 801	63 098	18 879	61.3	8.8
Transport	379		57		150.0	not available
Residential	593 656	660 251	20 816	178 774	35.1	270.8
	11 804 020	**13 322 550**	**240 090**	**407 804**	**20.3**	**30.6**
Energy Industry	2 425 405	2 694 709	42 092	19 001	17.4	7.1
Manufacturing Industry	1 822 633	2 211 212	54 030	43 186	29.6	19.5
Transport	13 435 708	15 047 729	327 973	328 779	24.4	21.8
Residential	3 830 823	4 693 604	24 892	97 884	6.5	20.9
	21 514 569	**24 647 254**	**448 987**	**488 850**	**20.9**	**19.8**
Energy Industry	7 451 210	6 393 674	7 937	1 091	1.1	0.2
Manufacturing Industry	5 427 211	5 176 374	2 563	518	0.5	0.1
Transport	15 663	18 867	24	13	1.5	0.7
Residential	7 312 516	6 704 873	1 463	1 583	0.2	0.2
	20 206 601	**18 293 788**	**11 987**	**3 204**	**0.6**	**0.2**
Energy Industry	566 885	209 628	25 710	85	45.4	0.4
Manufacturing Industry	62 479	342 165	2 635	7 703	42.2	22.5
Residential	1 537 635	1 594 672	364 911	556 861	237.3	349.2
	2 166 999	**2 146 465**	**393 256**	**564 649**	**181.5**	**263.1**
	55 692 189	**58 410 057**	**1 094 321**	**1 464 507**	**19.6**	**25.1**

In the Emission Factor column, the "Total" row contains the average emission factor for this fuel (total emission divided by total activity).

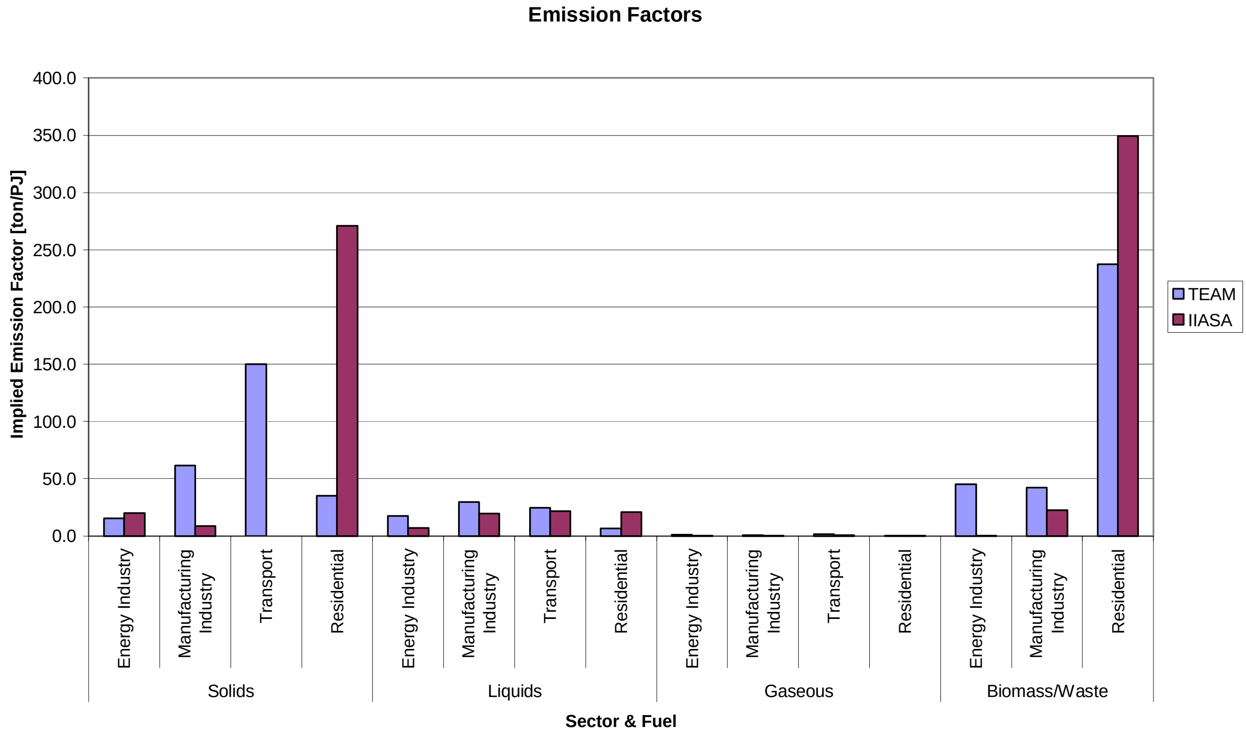


Figure 4-5 Implied Emission Factors for $PM_{2.5}$, for all fuels and fuel combustion categories, for the IIASA as well as the TEAM emission inventory.

Figure 4-5 displays the significant differences in the implied emission factors between the two inventories. The most significant differences are found in the residential sector, where the implied emission factors from the IIASA inventory are higher for all fuels except gaseous fuel.

As can be seen from Table 4-4, residential combustion is the most important contributor to $PM_{2.5}$ emissions. Since residential combustion usually occurs on a small scale, it is very difficult to estimate the emission factor for this sector. This might partly explain the wide variety of emission factors in this sector.

For biomass (wood) burning in the residential sector, this problem is even more complex, because of:

- the variety of wood burning devices that are used;
- several tree species with its own characteristic PM2.5 emission factor;
- variation in operating these devices.

We believe that the IIASA estimate for $PM_{2.5}$ emission factors concerning small-scale residential burning of fuel wood is too high. The IIASA emission factors are based on various literature values, including emission factors from EPA [Ref 4]]. The EPA emission factors for $PM_{2.5}$ are more than a factor 3 higher than the estimate from CEPMEIP [Ref 5], used in our inventory. The Coordinated European Particulate Matter Emission Inventory (CEPMEIP) is based on a wide range of information sources. A brief outline of the procedure followed and the main types of information sources is as follows:

- The project started in 2000 with an official request for information to European national experts that was sent out by the project partner EMEP. The requested information comprised all available national PM emission inventories and underlying information. Also the results of series of and single source-oriented measurements of emission, concentration and/or particle size distribution data were taken into account. In total about 3/4 of all UNECE Member States responded.
- The second source of information comprised data that had become available from previous projects by TNO related to PM emission. An important contribution was made by underlying information of the Dutch Emission Registration. Further contributions came from many international environmental bench marking projects, source-related stack concentration measurement surveys and PM related information available from heavy metal emission studies.
- The third type of information that was considered comprised public reports and handbooks that dealt with or somehow included source related emission (factor) data. In this category are reports by:
    - IPPC Bureau (BREF/BAT documents)
    - UN-ECE Expert Groups (e.g. on HM)
    - UN-ECE MSC-East (e.g. work by S. Kakareka et al.)
    - US-EPA (e.g. AP42, AIRCHIEF and the United States National Inventory of PM10/PM2.5)
    - German Umweltbundesamt UBA (e.g. report 297 44 853 by Dreiseidler et al.)
    - Swiss BUWAL
    - Austrian JOANEUM
    - Dutch RIVM and KEMA
    - British APEG
    - The COPERT and HBEFA emission models for mobile sources

- CONCAWE

Many of the information sources used in the CEPMEIP database are not readily available or easily to find. Since IIASA's estimate is heavily relying on direct consultations with national experts, many of these experts might in fact use the EPA emission factors for solid fuels in residential combustion. If this is indeed the case, use of EPA derived emission factors might explain the higher estimates in the IIASA inventory.

A 1998 study [Ref 6] has also shown that the EPA emission factor is too high.

Another significant difference is found in the use of biomass fuel in Energy Industry. For the use of fuel wood in the energy sector, there is no separate emission factor available from CEPMEIP. The emission factor estimate that we have used is therefore based on a different category, which might partly explain the difference found.

In the use of solid as well as biomass fuels in the Manufacturing Industry sector, our estimate for the emission factor is significantly higher than the IIASA estimate. This is also the case for the use of liquid fuels in Energy Industry.

4.6 Discussion

The comparison in this chapter, between the inventory derived in this study and the one provided by IIASA, using the RAINS/GAINS model, shows the following:

- The IIASA estimate for total PM2.5 emissions in EU25 is about 300 000 ton higher than the estimate derived in this study (Table 4-1):
  - IIASA reports about 290 000 tons higher emissions from the combustion processes (Table 4-3), mainly due to
    - ✓ Residential solid fuels (coal; 130 000 tons)
    - ✓ Residential Biomass/Waste fuels (112 000 tons)
    - ✓ Residential Liquid fuels (67 000 tons)
    - ✓ Several smaller differences in both directions

    Apart from differences in the activity data, where RAINS is believed to have better values, (Table 4-2), these differences are also to be explained by differences in the emission factors. We believe that the emission factors used in the RAINS estimate for these sources are too high.
- The TEAM inventory includes for the first time an estimate of the emissions of wind blown dust from human activities in agriculture. The total amount of PM2.5 emissions from this source in the EU25 is about 250 000 tons per year.
- Further differences between the two inventories are obtained in the Industrial Processes sector. However a direct comparison is difficult. We used international production statistics and the emission factors from CEPMEIP, whereas IIASA has used in many cases an "Index (in 2000=100)" as the unit for activity data. Overall the RAINS inventory has about 300 000 tons more PM2.5 emissions from Industrial Processes, compared with our estimate.

5 Conclusions

Within this study an independent $PM_{2.5}$ and PM_{10} emissions inventory for the base year 2000 in Europe has been developed. This inventory has been compiled in close cooperation and consultation with the project that was updating the emission estimation guidance in the EMEP/Corinair Guidebook [Ref 7]. The inventory resulting from this study therefore is consistent with this updated guidance in the Guidebook on particulates. The methods used to estimate emissions from wind blown dust have as yet not been officially included in the Guidebook and are still under consideration in the Task Force on Emission Inventories and Projections.

The main assets of this work are:

- highlighting the potentially important role of wind-blown dust from agricultural sources; so far this source had been excluded from most inventories because little is known on how to estimate such emissions;
- the development of a methodology to quantify uncertainties of emission estimates, and
- the linkages to the EMEP/CORINAIR emission inventory guidebook.

Across Europe $PM_{2.5}$ emissions are in the order of 3 to 5 kg/inhabitant per year. Major contributions are due to various combustion processes, transport and agriculture.

This inventory shows for the first time an estimate for particulate emissions from wind blown dust from agricultural soils. Wind erosion from arable lands appears to be a relatively important source of $PM_{2.5}$, although the major fraction consists of larger particles (PM_{10} and larger).

These emissions of soil dust arise from human activities in agriculture and off road activities or driving on unpaved roads. It is generally assumed that the major part of the mass in these inorganic mineral particles (clay, silt, sand) is present in larger particles [Ref 1]. In our view these emissions are clearly due to human activities and for that reason could be included in the national emission ceilings. However, our estimate is the first one available and might still include major uncertainties. Furthermore, we used a uniform emission factor for all countries in Europe, irrespective of meteorological and soil conditions. Given the relative importance of this source, this could be an oversimplification.

The inventory has been reviewed by a number of national inventory experts. Comments and corrections were in all cases within the uncertainty boundaries of the inventory. Other countries have used this inventory as a starting point or as additional information while compiling their own inventories.

The inventory is accompanied by an uncertainty analysis. The uncertainties in the national emission estimates are considerable. The RAINS inventory is not accompanied by an uncertainty analysis. One might expect that in the scientific sense the uncertainties in the RAINS inventory are of the same order of magnitude. However, since the RAINS inventory has been compiled using more direct bilateral consultations with the national experts, the procedural confidence in the RAINS inventory will be higher. In this sense it can be stated that the procedural uncertainties in the RAINS inventory will be considerably lower, at least as far as the confidence of national experts in the inventory for the own country is concerned.

Some differences between the two inventories however are observed and are caused by

- The use of a different, and probably better, set of activity data for the residential combustion of biomass by the RAINS model; this data have been discussed and agreed with national experts during bilateral consultations between IIASA and the Member States
- The estimation of wind blown dust in the present inventory; the RAINS inventory does not include this source
- The RAINS emission factors for residential combustion are higher than the emission factors used in this report (TEAM model). In our opinion the RAINS emission factors for these sources are higher than can be expected on the basis of available literature.

Against this background, it can be concluded that for most countries the resulting inventory is consistent with the inventory as used in the RAINS model runs supporting the revision of the NEC Directive.

The main role of an uncertainty analysis will generally be as a tool to prioritise actions in an inventory improvement programme. Identifying those sources that are contributing the most to the overall uncertainties of the inventory will be the starting point of any inventory improvement programme. On the other hand, when using the uncertainty results of this study in developing emission ceilings for PM2.5 the scientific uncertainties might hamper a quantitative decision on the level of the emission ceilings. Different possibilities are open to solve such difficulties:

- Setting national emission ceilings in absolute levels despite the scientific uncertainties and allowing new science to be included in the inventory development over time. In this case, new or improved science might either make meeting the targets easier, when present estimates appear to be high or more difficult when new sources are discovered or updated methods yield higher values.
- Using absolute targets, but excluding sources that are presently not well know or even fully unknown. This possibility will work best if only those sources are included where Member States are quite confident on their estimation methods. It is our feeling that this is not the case for many emission sources of fine particulates.
- Using relative targets together with an obligation to apply consistent emission estimation methods for both the base year and the target years. This is the approach taken by the Climate Convention. When choosing this approach, uncertainties in the trend will in almost all cases be smaller than uncertainties in the absolute levels. If, in such cases Member States improve their emission inventory methods they should apply such improved methods in the full time series between base year and target years.

It is outside the scope of this project to choose between the three options provided above.

The inventory produced in this project has served its two main objectives:

- It showed that the inventories as used in the RAINS model in the framework of the revision of the NEC Directive are largely consistent with the independent inventory developed in this project
- It has served as a source of expertise and knowledge that can be used by national experts in developing and improving the national $PM_{2.5}$ inventories.

6 References

[Ref 1] **Tegen, I., and I. Fung** (1994), *Modelling of mineral dust transport in the atmosphere: Sources, transport, and optical thickness*. J. Geophys. Res. 99, 22897-22914.

[Ref 2] **V. Vestreng, K. Breivik, M. Adams, A. Wagner, J. Goodwin, O. Rozovskaya, J.M. Pacyna** (2005), Inventory Review 2005, Technical Report MSC-W 1/2005

[Ref 3] **Markus Amann, Willem Asman, Imrich Bertok, Janusz Cofala, Chris Heyes, Zbigniew Klimont, Max Posch, Wolfgang Schöpp, Fabian Wagner,** Emission control scenarios that meet the environmental objectives of the Thematic Strategy on Air Pollution Part 2: Scenario analysis, IIASA, 2006

[Ref 4] **EPA** (1998), Compilation of Air Pollutant Emission Factors, 5th edition: EPA AP-42. United States Environmental Protection Agency. Research Triangle Park, North Carolina.

[Ref 5] **CEPMEIP** (Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance) (2002), http://www.air.sk/tno/cepmeip.

[Ref 6] **J. Spitzer, P. Enzinger, G. Frankenhauser, W. Fritz, F. Golja, R. Stiglbrunner** (1998), *Emissionsfaktoren für feste Brennstoffe*, Joanneum Research, Nr. IEF-B-07/98

[Ref 7] **Task Force on Emission Inventories and Projections**, EMEP/Corinair Guidebook: http://reports.eea.europa.eu/EMEPCORINAIR4/en/page002.html

7 Signature

Apeldoorn, 26 March 2007

TNO Built Environment and Geosciences

Henk Buijtenhek
Group leader

Tinus Pulles
Author

Annex A Emission Factors Overview

Pollutant ***$PM_{2.5}$***

SectorGroupName *Agriculture*

FuelName

Description	Unit	Value	95% confidence interval Upper	Lower
live stock, pigs: All activities	ton/head	0.000079	0.00016	0.000039
No control - Arable land - fertilizer	ton/1000 Ha	0.068		
No control - Arable land - harvesting	ton/1000 Ha	0.075		
No control - Arable land - pesticide application	ton/1000 Ha	0.083		
No control - Arable land - soil tilling	ton/1000 Ha	0.38		
No control - Arable land - wind erosion	ton/1000 Ha	1.5		
poultry, chickens: All activities	ton/head	0.0000083	0.000017	0.0000042
poultry, other poultry: All activities	ton/head	0.000055	0.00014	0.000022
stock, cattle: All activities	ton/head	0.000089	0.00018	0.000044

SectorGroupName *Combustion in Energy Industry*

FuelName

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	35	58	21
Industrial combustion >50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); large unit	g/GJ	3	3.4	2.6
Industrial combustion >50MWth: Low S-fuel; efficient combustion	g/GJ	10	17	6
Industrial combustion >50MWth: Low-medium S-fuel; conventional large installation	g/GJ	35	53	23

FuelName Blast Furnace Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Burner with optimized combustion; low-dust fuel	g/GJ	0.1	0.5	0.02
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	5	25	1

FuelName Coke Oven Coke and

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in petroleum refineries: Uncontrolled plant	g/GJ	100	200	50

FuelName Coke Oven Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Burner with optimized combustion; low-	g/GJ	0.1	0.5	0.02

Description	Unit	Value	Upper	Lower
dust fuel				
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	5	25	1
Industrial combustion in petroleum refineries: Conventional refinery gas fuelled unit	g/GJ	5	10	2.5

FuelName Coking Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional ESP (removal efficiency equal or better than 98%)	g/GJ	17	51	5.7
Autoproducer electricity, heat and CHP plants, and public heat plants: FGD or fabric filter; <20 mg/Nm3 stack PM concentration; BAT	g/GJ	5	13	2
Autoproducer electricity, heat and CHP plants, and public heat plants: Older ESP or equivalent (removal effciency equal or below 95%)	g/GJ	40	160	10

FuelName Crude Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: High S-fuel or sub-optimal combustion	g/GJ	12	48	3
Autoproducer electricity, heat and CHP plants, and public heat plants: Medium S-fuel, conventional installation	g/GJ	10	40	2.5

FuelName Ethane

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in petroleum refineries: Conventional refinery gas fuelled unit	g/GJ	5	10	2.5

FuelName Gas Works Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	5	25	1

FuelName Gas/Diesel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional burner	g/GJ	5	20	1.3
Autoproducer electricity, heat and CHP plants, and public heat plants: Optimized combustion	g/GJ	2	8	0.5

FuelName Gas/Liquids from Biomass

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	150	450	50
Autoproducer electricity, heat and CHP plants, and public heat plants: Modern optimized large installation; BAT	g/GJ	2.5	10	0.63

FuelName Heavy Fuel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: High S-fuel or sub-optimal combustion	g/GJ	12	48	3
Autoproducer electricity, heat and CHP plants, and public heat plants: Low S-fuel with optimized burner or ESP	g/GJ	2.5	10	0.63
Autoproducer electricity, heat and CHP plants, and public heat plants: Low-medium S-fuel, conventional installation	g/GJ	9	36	2.3
Autoproducer electricity, heat and CHP plants, and public heat plants: Medium S-fuel, conventional installation	g/GJ	10	40	2.5
Industrial combustion in petroleum refineries: Conventional refinery; low-medium S fuel	g/GJ	35	53	23
Industrial combustion in petroleum refineries: Refinery furnace; high S fuel	g/GJ	130	620	27

FuelName Industrial Wastes

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Effective end-of-pipe emission control	g/GJ	10	100	1
Autoproducer electricity, heat and CHP plants, and public heat plants: Uncontrolled; optimized combustion	g/GJ	55	550	5.5
Autoproducer electricity, heat and CHP plants, and public heat plants: Uncontrolled; sub-optimal combustion	g/GJ	210	2100	21

FuelName Lignite/Brown Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional ESP (removal efficiency around 98%)	g/GJ	20	60	6.7
Autoproducer electricity, heat and CHP plants, and public heat plants: Efficient 3 or 4-field ESP only (removal efficiency about 99.5%)	g/GJ	14	42	4.7
Autoproducer electricity, heat and CHP plants, and public heat plants: FGD or fabric filter; <20 mg/Nm3 stack PM concentration; BAT	g/GJ	6	15	2.4
Autoproducer electricity, heat and CHP plants, and public heat plants: Older ESP (removal effciency around or below 95%)	g/GJ	50	200	13

FuelName Liquefied Petroleum Gases

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Burner with optimized combustion; low-dust fuel	g/GJ	0.1	0.5	0.02
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	5	25	1
Industrial combustion in petroleum refineries: Conventional refinery gas fuelled unit	g/GJ	5	10	2.5

FuelName Municipal Wastes

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Effective end-of-pipe emission control	g/GJ	10	100	1
Autoproducer electricity, heat and CHP plants, and public heat plants: Uncontrolled; optimized combustion	g/GJ	55	550	5.5

FuelName Naphtha

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in petroleum refineries: All units	g/GJ	5	20	1.3

FuelName Natural Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Burner with optimized combustion	g/GJ	0.1	0.3	0.033
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	0.2	0.6	0.067
Industrial combustion in petroleum refineries: All units	g/GJ	0.2	0.4	0.1

FuelName Other Bituminous Coal &

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional ESP (removal efficiency equal or better than 98%)	g/GJ	17	51	5.7
Autoproducer electricity, heat and CHP plants, and public heat plants: Efficient 3 or 4-field ESP only (removal efficiency about 99.5%)	g/GJ	12	36	4

Autoproducer electricity, heat and CHP plants, and public heat plants: FGD or fabric filter; <20 mg/Nm3 stack PM concentration; BAT	g/GJ	5	13	2
Autoproducer electricity, heat and CHP plants, and public heat plants: Older ESP or equivalent (removal effciency equal or below 95%)	g/GJ	40	160	10

FuelName Other Petroleum Products

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: High S-fuel or sub-optimal combustion	g/GJ	12	48	3
Autoproducer electricity, heat and CHP plants, and public heat plants: Low S-fuel with optimized burner or ESP	g/GJ	2.5	10	0.63
Autoproducer electricity, heat and CHP plants, and public heat plants: Low-medium S-fuel, conventional installation	g/GJ	9	36	2.3
Autoproducer electricity, heat and CHP plants, and public heat plants: Medium S-fuel, conventional installation	g/GJ	10	40	2.5
Industrial combustion in petroleum refineries: Conventional refinery; low-medium S fuel	g/GJ	35	53	23

FuelName Oxygen Steel Furnace Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	5	25	1

FuelName Peat

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional technology	g/GJ	20	80	5
Autoproducer electricity, heat and CHP plants, and public heat plants: Equipped with modern end-of-pipe emission controll technology	g/GJ	6	24	1.5

FuelName Petroleum Coke

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in petroleum refineries: Conventional refinery; multicyclone only	g/GJ	35	110	12
Industrial combustion in petroleum refineries: Uncontrolled plant	g/GJ	100	200	50

FuelName Refinery Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Burner with optimized combustion; low-dust fuel	g/GJ	0.1	0.5	0.02
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional installation	g/GJ	5	25	1
Industrial combustion in petroleum refineries: Conventional refinery gas fuelled unit	g/GJ	5	10	2.5

FuelName Sub-Bituminous Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Autoproducer electricity, heat and CHP plants, and public heat plants: Conventional ESP (removal efficiency equal or better than 98%)	g/GJ	17	51	5.7
Autoproducer electricity, heat and CHP plants, and public heat plants: Efficient 3 or 4-field ESP only (removal efficiency about 99.5%)	g/GJ	12	36	4
Autoproducer electricity, heat and CHP plants, and public heat plants: Older ESP or equivalent (removal effciency equal or below 95%)	g/GJ	40	160	10

FuelName Wood and wood waste **95% confidence interval**

Description	Unit	Value	Upper	Lower
Public electricity and CHP plants: Uncontrolled conventional	g/GJ	55	170	18

SectorGroupName Fugitive emissions from

FuelName

Description	Unit	Value	95% confidence interval Upper	Lower
Brown coal mining: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Brown coal mining: Uncontrolled	ton/ton	0.000005	0.000025	0.000001
Fugitive emissions from small industrial emitters: All countries	ton/inhab	0.00006	0.00012	0.00003
Hard coal mining: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Hard coal mining: Uncontrolled	ton/ton	0.000005	0.000025	0.000001

SectorGroupName Industrial Processes &

FuelName

Description	Unit	Value	95% confidence interval Upper	Lower
Agglomeration plants: sinter: (multi-) Cyclone control only	ton/ton	0.0005	0.001	0.00025
Agglomeration plants: sinter: Conventional installation with ESP	ton/ton	0.00025	0.0005	0.00013
Agglomeration plants: sinter: Fabric filter, high efficiency wet scrubbing or high efficiency ESP; BAT	ton/ton	0.0001	0.0002	0.00005
Basic oxygen steel making: Conventional installation of average age; primary dedusting by ESP / wet scrubbing; limited capturing of secondary dust emission	ton/ton	0.00032	0.00063	0.00016
Basic oxygen steel making: High efficiency ESP or added fabric filter to control primary sources; extensive secondary dedusting using fabric filters; BAT	ton/ton	0.00012	0.0006	0.000024
Basic oxygen steel making: Older plant; primary dedusting by scrubber with removal efficiency around 97%; limited capturing of secondary dust emission	ton/ton	0.00054	0.0011	0.00027
Bauxite mining: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Bauxite mining: Uncontrolled	ton/ton	0.000005	0.000025	0.000001
Blast furnaces (tapping and top gas): High efficiency ESP or equivalent to control primary sources; fabric filters for fugitive emission; BAT	ton/ton	0.000036	0.00011	0.000012
Blast furnaces (tapping and top gas): Installation with average age; conventional dedusting: ESP, wet scrubber; some capturing of fugitives	ton/ton	0.00012	0.00024	0.00006
Blast furnaces (tapping and top gas): Older technology; (multi-)cyclones only	ton/ton	0.0005	0.001	0.00025
Coke ovens at iron and steel works: Effective oven door sealing; efficient capturing of fugitive emission; use of clean fuel; BAT	ton/ton	0.00002	0.0002	0.000002
Coke ovens at iron and steel works: Moderate collection of fugitive dust; combined usage of cyclones, ESP and scrubbers; conventional installation	ton/ton	0.0001	0.0002	0.00005
Coke ovens at iron and steel works: Older plant with limited control of fugitive emission	ton/ton	0.0003	0.0006	0.00015
Copper ore mining: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Copper ore mining: Uncontrolled	ton/ton	0.000005	0.000025	0.000001
Electric arc furnaces: Conventional installation with moderate abatement of fugitive sources; ESP or wet scrubbing to control primary emission sources	ton/ton	0.00021	0.00042	0.00011
Electric arc furnaces: Modern plant; efficient capturing of fugitive sources (e.g. using a doghouse construction) with fabric filters; fabric filters to control primary emission; BAT	ton/ton	0.00006	0.00012	0.00003

Electric arc furnaces: Older plant; limited abatement of fugitive sources; scrubber with removal efficiency around 95%	ton/ton	0.00022	0.00045	0.00011
Gray iron foundries: All foundries	ton/ton	0.00009	0.00018	0.000045
Iron ore mining: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Iron ore mining: Uncontrolled	ton/ton	0.000005	0.000025	0.000001
Mining of manganese ore: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Mining of manganese ore: Uncontrolled	ton/ton	0.000005	0.000025	0.000001
Open hearth furnaces: Conventional installation with ESP; limited abatement of fugitive sources	ton/ton	0.00065	0.0019	0.00022
Open hearth furnaces: Older plant; removal efficiency control equipment primary emission below 95%; limited abatement of fugitive sources	ton/ton	0.0026	0.0052	0.0013
Production of carbon black: Conventional plant	ton/ton	0.00045	0.0022	0.00009
Production of carbon black: Old plant; uncontrolled	ton/ton	0.0014	0.0072	0.00029
Production of cement: Conventional plant with ESP on main stack and smaller fabric filters for moderate control of fugitive sources	ton/ton	0.00018	0.00027	0.00012
Production of cement: Limited control fugitive sources; removal efficiencies ESP main stack below 97%	ton/ton	0.0003	0.00045	0.0002
Production of cement: Modern facility with addional fabric filters on the oven stack; effective control of fugitive sources	ton/ton	0.00008	0.00012	0.000053
Production of flat glass, blown or drawn glass and container glass: Electrically heated, ESP, scrubber or fabric filter	ton/ton	0.000024	0.00012	0.0000048
Production of flat glass, blown or drawn glass and container glass: Gas or fuel oil-fired, uncontrolled or limited emission control	ton/ton	0.0004	0.0012	0.00013
Production of flat glass, blown or drawn glass and container glass: Uncontrolled; old plant	ton/ton	0.0016	0.0048	0.00053
Production of glass fibres: Electrically heated, ESP	ton/ton	0.00035	0.001	0.00012
Production of glass fibres: Gas or fuel oil-fired, uncontrolled	ton/ton	0.0007	0.0014	0.00035
Production of glass fibres: Uncontrolled; old plant	ton/ton	0.0014	0.0042	0.00047
Production of gypsum: Control of fugitive emission	ton/ton	0.0000075	0.000038	0.0000015
Production of gypsum: Uncontrolled	ton/ton	0.00001	0.00005	0.000002
Production of lime: Effective control fugitive sources	ton/ton	0.00003	0.0003	0.000003
Production of lime: Limited control fugitive sources	ton/ton	0.00006	0.0006	0.000006
Production of lime: Moderate collection of fugitive dust	ton/ton	0.00004	0.0004	0.000004
Production of nitrogen fertilizer: All plants	ton/ton	0.00018	0.00036	0.00009
Production of primary aluminium: Cyclones or scrubbers only; limited abatement of fugitive emission	ton/ton	0.0027	0.004	0.0018
Production of primary aluminium: Effective capturing fugitive sources; extensive application of fabric filters	ton/ton	0.0013	0.0026	0.00064
Production of primary aluminium: Moderate collection of fugitive dust; combined usage of cyclones, ESP and scrubbers; conventional installation	ton/ton	0.0014	0.0022	0.00096
Production of primary copper: Conventional installation using ESP and settling chambers; moderate control of fugitive emission	ton/ton	0.00072	0.0022	0.00024
Production of primary copper: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.0004	0.0012	0.00013
Production of primary copper: Older plant with limited control of fugitive sources	ton/ton	0.001	0.003	0.00033
Production of primary lead: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive	ton/ton	0.0002	0.0008	0.00005
Production of primary lead: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.00006	0.00018	0.00002
Production of primary lead: Older plant with limited control of fugitive sources	ton/ton	0.0006	0.0024	0.00015
Production of primary nickel: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive sources	ton/ton	0.0003	0.0006	0.00015

Production of primary nickel: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.0003	0.0006	0.00015
Production of primary nickel: Older plant with limited control of fugitive sources	ton/ton	0.003	0.012	0.00075
Production of primary zinc: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive sources	ton/ton	0.0003	0.0012	0.000075
Production of primary zinc: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.00016	0.00064	0.00004
Production of primary zinc: Older plant with limited control of fugitive sources	ton/ton	0.004	0.016	0.001
Production of PVC: All plants	ton/ton	0.00001	0.00005	0.000002
Production of secondary aluminium: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive sources	ton/ton	0.00048	0.00072	0.00032
Production of secondary aluminium: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.0004	0.00061	0.00027
Production of secondary aluminium: Older plant with limited control of fugitive sources	ton/ton	0.00055	0.00082	0.00037
Production of secondary copper: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive sources	ton/ton	0.0006	0.006	0.00006
Production of secondary copper: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.0006	0.006	0.00006
Production of secondary copper: Older plant with limited control of fugitive sources	ton/ton	0.0006	0.006	0.00006
Production of secondary lead: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive sources	ton/ton	0.00016	0.00032	0.00008
Production of secondary lead: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.00015	0.0003	0.000075
Production of secondary lead: Older plant with limited control of fugitive sources	ton/ton	0.0004	0.0008	0.0002
Production of secondary zinc: Conventional plant using ESP, settlers, scrubbers; moderate control of fugitive sources	ton/ton	0.0003	0.0015	0.00006
Production of secondary zinc: Modern plant with fabric filters for most emission sources, BAT	ton/ton	0.0003	0.0009	0.0001
Production of secondary zinc: Older plant with limited control of fugitive sources	ton/ton	0.0003	0.003	0.00003
Use of fire works: All activities	ton/inhab	0.000035	0.00014	0.0000088
Zinc ore mining: Control of fugitive emission	ton/ton	0.0000038	0.000019	0.00000075
Zinc ore mining: Uncontrolled	ton/ton	0.000005	0.000025	0.000001

SectorGroupName *Manufacturing Industry*

FuelName Black liquor and other bio — **95% confidence interval**

Description	**Unit**	**Value**	**Upper**	**Lower**
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	150	450	50

FuelName Blast Furnace Gas — **95% confidence interval**

Description	**Unit**	**Value**	**Upper**	**Lower**
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	5	10	2.5
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in the iron and steel sector: Conventional industrial installation	g/GJ	5	10	2.5

FuelName Charcoal — **95% confidence interval**

Description	**Unit**	**Value**	**Upper**	**Lower**
Industrial combustion <50MWth: Conventional small industrial uncontrolled unit or equipped with multicyclone only	g/GJ	35	44	28
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	35	58	21

FuelName Coke Oven Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in other industrial sectors: Clean fuel with efficient combustion	g/GJ	0.2		
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	5	10	2.5
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in the iron and steel sector: Conventional industrial installation	g/GJ	5	10	2.5

FuelName Coking Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Conventional small industrial uncontrolled unit or equipped with multicyclone only	g/GJ	35	44	28
Industrial combustion <50MWth: Older installation; uncontrolled	g/GJ	150	300	75
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	35	58	21
Industrial combustion >50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); large unit	g/GJ	3	3.4	2.6
Industrial combustion >50MWth: Older installation; uncontrolled or cyclone only	g/GJ	100	200	50

FuelName Crude Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: High S-fuel and/or sub-optimal combustion	g/GJ	130	620	27
Industrial combustion >50MWth: High S-fuel and/or sub-optimal combustion	g/GJ	130	620	27
Industrial combustion >50MWth: Low-medium S-fuel; conventional large installation	g/GJ	35	53	23

FuelName Ethane

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	5	10	2.5
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in the iron and steel sector: Conventional industrial installation	g/GJ	5	10	2.5

FuelName Gas Works Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in other industrial sectors: Clean fuel with efficient combustion	g/GJ	0.2		
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	5	10	2.5
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in the iron and steel sector: Conventional industrial installation	g/GJ	5	10	2.5

FuelName Gas/Diesel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Optimized combustion	g/GJ	3	4	2.3
Industrial combustion <50MWth: Small industrial plant; conventional burner	g/GJ	5	6	4.2
Industrial combustion >50MWth: Optimized combustion	g/GJ	2	4	1
Industrial combustion in the iron and steel sector: Conventional burner	g/GJ	5	6	4.2

FuelName Gas/Liquids from Biomass

Description	Unit	Value	95% confidence interval Upper	Lower

Industrial combustion <50MWth: Modern optimized industrial installation; BAT	g/GJ	10	30	3.3
Industrial combustion >50MWth: Modern larger optimized industrial installation; BAT	g/GJ	10	30	3.3
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	150	450	50
Industrial combustion in the iron and steel sector: Conventional installation	g/GJ	150	450	50

FuelName Heavy Fuel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: High S-fuel and/or sub-optimal combustion	g/GJ	130	620	27
Industrial combustion <50MWth: Low S-fuel; conventional installation	g/GJ	40	80	20
Industrial combustion <50MWth: Low S-fuel; efficient combustion	g/GJ	10	13	7.5
Industrial combustion >50MWth: High S-fuel and/or sub-optimal combustion	g/GJ	130	620	27
Industrial combustion >50MWth: Low S-fuel; efficient combustion	g/GJ	10	17	6
Industrial combustion >50MWth: Low-medium S-fuel; conventional large installation	g/GJ	35	53	23

FuelName Industrial Wastes

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Older installation; uncontrolled	g/GJ	210	2100	21
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	55	550	5.5
Industrial combustion >50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); large unit	g/GJ	10	100	1
Industrial combustion >50MWth: Older installation; uncontrolled	g/GJ	210	2100	21
Industrial combustion<50MWth: Conventional smaller industrial unit; uncontrolled	g/GJ	80	800	8

FuelName Lignite/Brown Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Conventional small industrial uncontrolled unit or equipped with multicyclone only	g/GJ	35	70	18
Industrial combustion <50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); small unit	g/GJ	25		
Industrial combustion <50MWth: Older installation; uncontrolled	g/GJ	150	300	75
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	35	56	22
Industrial combustion >50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); large unit	g/GJ	3	6	1.5
Industrial combustion >50MWth: Older installation; uncontrolled or cyclone only	g/GJ	100	200	50

FuelName Liquefied Petroleum Gases

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in other industrial sectors: Clean fuel with efficient combustion	g/GJ	0.2		
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	5	10	2.5
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in the iron and steel sector: Conventional industrial installation	g/GJ	5	10	2.5

FuelName Municipal Wastes

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion >50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); large unit	g/GJ	10	100	1
Industrial combustion<50MWth: Conventional smaller industrial unit; uncontrolled	g/GJ	80	800	8

FuelName Natural Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion >50MWth: Conventional larger installation	g/GJ	0.2	0.4	0.1
Industrial combustion >50MWth: Modern unit; optimized combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in other industrial sectors: All smaller industrial combustion plants	g/GJ	0.2		

FuelName Other Bituminous Coal &

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Conventional small industrial uncontrolled unit or equipped with multicyclone only	g/GJ	35	44	28
Industrial combustion <50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); small unit	g/GJ	20	24	17
Industrial combustion <50MWth: Older installation; uncontrolled	g/GJ	150	300	75
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	35	58	21
Industrial combustion >50MWth: End-of-pipe PM capture (scrubber, ESP, fabric filter etc.); large unit	g/GJ	3	3.4	2.6
Industrial combustion >50MWth: Older installation; uncontrolled or cyclone only	g/GJ	100	200	50

FuelName Other Petroleum Products

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: High S-fuel and/or sub-optimal combustion	g/GJ	130	620	27
Industrial combustion <50MWth: Low S-fuel; conventional installation	g/GJ	40	80	20
Industrial combustion >50MWth: High S-fuel and/or sub-optimal combustion	g/GJ	130	620	27
Industrial combustion >50MWth: Low S-fuel; efficient combustion	g/GJ	10	17	6
Industrial combustion >50MWth: Low-medium S-fuel; conventional large installation	g/GJ	35	53	23

FuelName Oxygen Steel Furnace Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05

FuelName Peat

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Conventional smaller industrial unit, multicyclone only	g/GJ	20	80	5
Industrial combustion in the non-metallic minerals industry: All units	g/GJ	20	80	5

FuelName Refinery Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion in other industrial sectors: Conventional industrial installation	g/GJ	5	10	2.5
Industrial combustion in the iron and steel sector: Clean fuel with efficient combustion	g/GJ	0.1	0.2	0.05
Industrial combustion in the iron and steel sector: Conventional industrial installation	g/GJ	5	10	2.5

FuelName Sub-Bituminous Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Industrial combustion <50MWth: Conventional small industrial uncontrolled unit or equipped with multicyclone only	g/GJ	35	44	28
Industrial combustion <50MWth: Older installation; uncontrolled	g/GJ	150	300	75

Description	Unit	Value	Upper	Lower
Industrial combustion >50MWth: Conventional large unit equipped with multicyclone only	g/GJ	35	58	21

SectorGroupName *Mobile sources*

FuelName

Description	**Unit**	**Value**	**95% confidence interval** Upper	Lower
No control - heavy duty trucks and buses, abrasion_Highway	kg/million km	0		
No control - heavy duty trucks and buses, abrasion_Rural	kg/million km	0		
No control - heavy duty trucks and buses, abrasion_Urban	kg/million km	0		
No control - heavy duty trucks and buses, brake wear_Highway	kg/million km	32		
No control - heavy duty trucks and buses, brake wear_Rural	kg/million km	32		
No control - heavy duty trucks and buses, brake wear_Urban	kg/million km	32		
No control - heavy duty trucks and buses, tyre wear_Highway	kg/million km	0		
No control - heavy duty trucks and buses, tyre wear_Rural	kg/million km	0		
No control - heavy duty trucks and buses, tyre wear_Urban	kg/million km	0		
No control - Light duty vehicles: 4-stroke (excl. GDI), abrasion_Highway	kg/million km	0		
No control - Light duty vehicles: 4-stroke (excl. GDI), abrasion_Rural	kg/million km	0		
No control - Light duty vehicles: 4-stroke (excl. GDI), abrasion_Urban	kg/million km	0		
No control - Light duty vehicles: 4-stroke (excl. GDI), brake wear_Highway	kg/million km	6		
No control - Light duty vehicles: 4-stroke (excl. GDI), brake wear_Rural	kg/million km	6		
No control - Light duty vehicles: 4-stroke (excl. GDI), brake wear_Urban	kg/million km	6		
No control - Light duty vehicles: 4-stroke (excl. GDI), tyre wear_Highway	kg/million km	0		
No control - Light duty vehicles: 4-stroke (excl. GDI), tyre wear_Rural	kg/million km	0		
No control - Light duty vehicles: 4-stroke (excl. GDI), tyre wear_Urban	kg/million km	0		
No control - motorcycles 2-stroke, mopeds, abrasion_Highway	kg/million km	0		
No control - motorcycles 2-stroke, mopeds, abrasion_Rural	kg/million km	0		
No control - motorcycles 2-stroke, mopeds, abrasion_Urban	kg/million km	0		
No control - motorcycles 2-stroke, mopeds, brake wear_Highway	kg/million km	3		
No control - motorcycles 2-stroke, mopeds, brake wear_Rural	kg/million km	3		
No control - motorcycles 2-stroke, mopeds, brake wear_Urban	kg/million km	3		
No control - motorcycles 2-stroke, mopeds, tyre wear_Highway	kg/million km	0		
No control - motorcycles 2-stroke, mopeds, tyre wear_Rural	kg/million km	0		
No control - motorcycles 2-stroke, mopeds, tyre wear_Urban	kg/million km	0		
No control - Motorcycles: 4-stroke, abrasion_Highway	kg/million km	0		
No control - Motorcycles: 4-stroke, abrasion_Rural	kg/million km	0		
No control - Motorcycles: 4-stroke, abrasion_Urban	kg/million km	0		
No control - Motorcycles: 4-stroke, brake wear_Highway	kg/million km	3		
No control - Motorcycles: 4-stroke, brake wear_Rural	kg/million km	3		
No control - Motorcycles: 4-stroke, brake wear_Urban	kg/million km	3		
No control - Motorcycles: 4-stroke, tyre wear_Highway	kg/million km	0		
No control - Motorcycles: 4-stroke, tyre wear_Rural	kg/million km	0		
No control - Motorcycles: 4-stroke, tyre wear_Urban	kg/million km	0		

FuelName Coking Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Rail transport: All activities	g/GJ	150	750	30

FuelName Gas/Diesel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
EURO I - 1992 heavy duty vehicles_Highway	kg/million km	300		
EURO I - 1992 heavy duty vehicles_Rural	kg/million km	300		
EURO I - 1992 heavy duty vehicles_Urban	kg/million km	500		
EURO I - 1992/94, diesel light duty and passenger cars_Highway	kg/million km	100		
EURO I - 1992/94, diesel light duty and passenger cars_Rural	kg/million km	50		
EURO I - 1992/94, diesel light duty and passenger cars_Urban	kg/million km	80		
EURO II - 1996 heavy duty vehicles_Highway	kg/million km	300		
EURO II - 1996 heavy duty vehicles_Rural	kg/million km	300		
EURO II - 1996 heavy duty vehicles_Urban	kg/million km	500		
EURO II - 1996, diesel light duty and passenger cars_Highway	kg/million km	100		
EURO II - 1996, diesel light duty and passenger cars_Rural	kg/million km	50		
EURO II - 1996, diesel light duty and passenger cars_Urban	kg/million km	80		
EURO III - 2000 heavy duty vehicles_Highway	kg/million km	300		
EURO III - 2000 heavy duty vehicles_Rural	kg/million km	300		
EURO III - 2000 heavy duty vehicles_Urban	kg/million km	500		
EURO III - 2000, diesel light duty and passenger cars_Highway	kg/million km	100		
EURO III - 2000, diesel light duty and passenger cars_Rural	kg/million km	50		
EURO III - 2000, diesel light duty and passenger cars_Urban	kg/million km	80		
Internal navigation (inland water ways): All activities	g/GJ	88	130	59
No control - heavy duty vehicles_Highway	kg/million km	500		
No control - heavy duty vehicles_Rural	kg/million km	400		
No control - heavy duty vehicles_Urban	kg/million km	750		
No control - light duty and passenger cars_Highway	kg/million km	150		
No control - light duty and passenger cars_Rural	kg/million km	70		
No control - light duty and passenger cars_Urban	kg/million km	100		
Other mobile sources and machinery: Newer machinery	g/GJ	130	260	66
Other mobile sources and machinery: Newer tractors and machinery	g/GJ	130	260	66
Other mobile sources and machinery: Older machinery	g/GJ	130	260	66
Other mobile sources and machinery: Older tractors and machinery	g/GJ	130	260	66
Rail transport: All activities	g/GJ	110	330	37

FuelName Heavy Fuel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Internal navigation (inland water ways): All activities	g/GJ	130	530	33
Rail transport: All activities	g/GJ	130	650	26

FuelName Lignite/Brown Coal

95% confidence interval

Description	Unit	Value	Upper	Lower
Rail transport: All activities	g/GJ	150	750	30

FuelName Liquefied Petroleum Gases

Description	Unit	Value	95% confidence interval Upper	Lower
EURO I, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	kg/million km	0		
EURO I, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	kg/million km	0		
EURO I, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	kg/million km	0		
EURO II, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	kg/million km	0		
EURO II, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	kg/million km	0		
EURO II, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	kg/million km	0		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	kg/million km	0		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	kg/million km	0		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	kg/million km	0		
No control - heavy duty vehicles_Highway	kg/million km	25		
No control - heavy duty vehicles_Rural	kg/million km	30		
No control - heavy duty vehicles_Urban	kg/million km	40		
No control - light duty and passenger cars_Highway	kg/million km	25		
No control - light duty and passenger cars_Rural	kg/million km	30		
No control - light duty and passenger cars_Urban	kg/million km	40		

FuelName Motor Gasoline

Description	Unit	Value	95% confidence interval Upper	Lower
EURO I, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	g/million km	700		
EURO I, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	g/million km	700		
EURO I, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	g/million km	900		
EURO II, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	g/million km	700		
EURO II, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	g/million km	700		
EURO II, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	g/million km	900		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	g/million km	700		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	g/million km	700		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	g/million km	900		
EURO IV, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	g/million km	700		
EURO IV, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	g/million km	700		
EURO IV, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	g/million km	900		
Internal navigation (inland water ways): All activities	g/GJ	23	93	5.8
Mobile sources and machinery in agriculture: Older machinery	g/GJ	93	280	31
Mobile sources and machinery in agriculture: Older tractors and machinery	g/GJ	93	280	31
Motorcycles 4-stroke, stage 1_Highway	kg/million km	0		
Motorcycles 4-stroke, stage 1_Rural	kg/million km	40		
Motorcycles 4-stroke, stage 1_Urban	kg/million km	40		
Motorcycles and mopeds 2-stroke, no control_Highway	kg/million km	120		

Description	Unit	Value	Upper	Lower
Motorcycles and mopeds 2-stroke, no control_Rural	kg/million km	120		
Motorcycles and mopeds 2-stroke, no control_Urban	kg/million km	120		
Motorcycles and mopeds 2-stroke, stage 1_Highway	kg/million km	120		
Motorcycles and mopeds 2-stroke, stage 1_Rural	kg/million km	120		
Motorcycles and mopeds 2-stroke, stage 1_Urban	kg/million km	120		
No control - heavy duty vehicles_Highway	kg/million km	400		
No control - heavy duty vehicles_Rural	kg/million km	400		
No control - heavy duty vehicles_Urban	kg/million km	400		
No control - light duty and passenger cars_Highway	kg/million km	41		
No control - light duty and passenger cars_Rural	kg/million km	44		
No control - light duty and passenger cars_Urban	kg/million km	63		
No control - motorcycles 4-stroke_Highway	kg/million km	0		
No control - motorcycles 4-stroke_Rural	kg/million km	40		
No control - motorcycles 4-stroke_Urban	kg/million km	40		

FuelName Natural Gas

Description	Unit	Value	95% confidence interval Upper	Lower
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Highway	kg/million km	0		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Rural	kg/million km	0		
EURO III, L. Duty, spark ignition engines: 4-stroke, not DI_Urban	kg/million km	0		
No control - light duty and passenger cars_Highway	kg/million km	25		
No control - light duty and passenger cars_Rural	kg/million km	30		
No control - light duty and passenger cars_Urban	kg/million km	40		

FuelName Other Bituminous Coal &

Description	Unit	Value	95% confidence interval Upper	Lower
Rail transport: All activities	g/GJ	150	750	30

FuelName Other Petroleum Products

Description	Unit	Value	95% confidence interval Upper	Lower
Internal navigation (inland water ways): All activities	g/GJ	130	530	33

SectorGroupName Non-industrial combustion

FuelName BKB

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Smokeless fuel, patent fuel and briquettes; conventional units	g/GJ	30	90	10

FuelName Charcoal

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Conventional stove	g/GJ	30	60	15

FuelName Coke Oven Coke and

Description	Unit	Value	95% confidence interval Upper	Lower

Residential, commercial, institutional and other combustion: Smokeless fuel, patent fuel and briquettes; conventional units	g/GJ	30	90	10

FuelName Coking Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Conventional stove	g/GJ	30	60	15
Residential, commercial, institutional and other combustion: Old stove	g/GJ	60	120	30

FuelName Crude Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Medium fuel oil-fired units	g/GJ	40	120	13

FuelName Gas/Diesel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Light fuel oils; all units	g/GJ	5	6.3	4

FuelName Heavy Fuel Oil

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Medium fuel oil-fired units	g/GJ	40	120	13

FuelName Lignite/Brown Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: All brown coal-fired units	g/GJ	70	210	23

FuelName Natural Gas

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: All gas-fired equipment	g/GJ	0.2	0.8	0.05

FuelName Other Bituminous Coal &

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Conventional stove	g/GJ	30	60	15
Residential, commercial, institutional and other combustion: Modern emission optimized stove	g/GJ	25	50	13
Residential, commercial, institutional and other combustion: Old stove	g/GJ	60	120	30

FuelName Other Petroleum Products

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Medium fuel oil-fired units	g/GJ	40	120	13

FuelName Patent Fuel

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Smokeless fuel, patent fuel and briquettes; conventional units	g/GJ	30	90	10

FuelName Peat

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Peat firing	g/GJ	60	180	20

FuelName Petroleum Coke

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Smokeless fuel, patent fuel and briquettes; conventional units	g/GJ	30	90	10

FuelName Sub-Bituminous Coal

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Conventional stove	g/GJ	30	60	15
Residential, commercial, institutional and other combustion: Old stove	g/GJ	60	120	30

FuelName Wood and wood waste

Description	Unit	Value	95% confidence interval Upper	Lower
Residential, commercial, institutional and other combustion: Conventional stove or fireplace	g/GJ	270	540	140
Residential, commercial, institutional and other combustion: Modern emission optimized stove	g/GJ	140	270	68

SectorGroupName Waste treatment

FuelName

Description	Unit	Value	95% confidence interval Upper	Lower
Incineration of municipal solid waste: ESP only	ton/ton	0.0001	0.0006	0.000017
Incineration of municipal solid waste: Modern facility with combined ESP, scrubber and fabric filter	ton/ton	0.00003	0.00018	0.000005
Incineration of municipal solid waste: Small unit with multicyclone or scrubber only	ton/ton	0.0005	0.003	0.000083