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Danish emission inventory for particulate matter (PM)

Research Notes from NERI No. 189

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2003

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Data sheet

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Abstract: The first Danish emission inventory that was reported in 2002 was a provisional estimate based on data presently available. This report documents methodology, emission factors and references used for an improved Danish emission inventory for particulate matter. Further results of the improved emission inventory for the year 2000 are shown. The particulate matter emission inventory includes TSP, PM_{10} and $PM_{2,5}$. The report covers emission inventories for transport and stationary combustion. An appendix covering emissions from agriculture is also included. For the transport sector, both exhaust and non-exhaust emission such as tyre and break wear and road abrasion are included.

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Contents

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Preface

This report contains a description of methodology, references and results of the Danish emission inventory of particulate matter.

The work is carried out by the Department of Policy Analysis of the National Environmental Research Institute (NERI). The project has been financed partly by the Danish Environment Protection Agency (EPA) and NERI.

The steering committee of the project consisted of the following members:

Christian Lange Fogh (chairman, EPA), Ulrik Torp (EPA), Jytte Boll Illerup, (NERI), Malene Nielsen (NERI).

Summary

Introduction
At the beginning of 2002 the first Danish emission inventory of particulate matter (PM) was prepared and reported. The emission inventory was part of the Danish emission inventories reported under the UN-ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). This provisional version of the inventory was based on activity data and emission factors presently available. The inventory included total suspended particles (TSP), PM_{10} and $PM_{2.5}$. This report documents methodology, emission factors and references used for an improved Danish emission inventory for particulate matter. Further results of the improved emission inventory for the year 2000 are shown. The particulate matter emission inventory includes TSP, PM_{10} and $PM_{2.5}$. The report covers emission inventories for transport and stationary combustion. An appendix covering emissions from agriculture is also included. For the transport sector both exhaust and non-exhaust emission such as tyre and break wear and road abrasion are included.

Emissions
The improved Danish emission inventory of TSP, PM_{10} and $PM_{2.5}$ from stationary combustion and transport for the year 2000 is shown in Table s1 According to the CLRTAP reporting guideline emissions from international air traffic and international bunkers are not included.

Table s1. Emission inventory year 2000 (stationary combustion and transport), main SNAP categories [1)]

SNAP1	SNAP1 name	TSP Ton	PM10 Ton	PM2.5 Ton
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	1131	948	810
02	NON-INDUSTRIAL COMBUSTION PLANTS	3058	2899	2734
03	COMBUSTION IN MANUFACTURING INDUSTRY	741	575	448
Stationary combustion plants		4930	4423	3992
07	ROAD TRANSPORT, exhaust emissions	3969	3969	3969
07	ROAD TRANSPORT, brake and tyre wear and road abrasion	14783	1116	323
08	OTHER MOBILE SOURCES AND MACHINERY	4355	4152	3957
Transport		23106	9235	8249
Total [1)]		28037	13659	12241

1) Only the emission sources stationary combustion plants and transport are included. In the official Danish inventory 2003 PM emissions from some industrial processes, agriculture and from waste treatment and disposal are also included

From figure s1 it is seen that road transport, other mobile sources and non-industrial combustion plants are the largest sources. Non-exhaust emissions from road transport (brake, tyre wear and road abrasion) are only important for TSP and PM_{10}. In general the uncertainty for the PM emission inventory is high especially for domestic combustion of wood, road abrasion and other mobile sources.

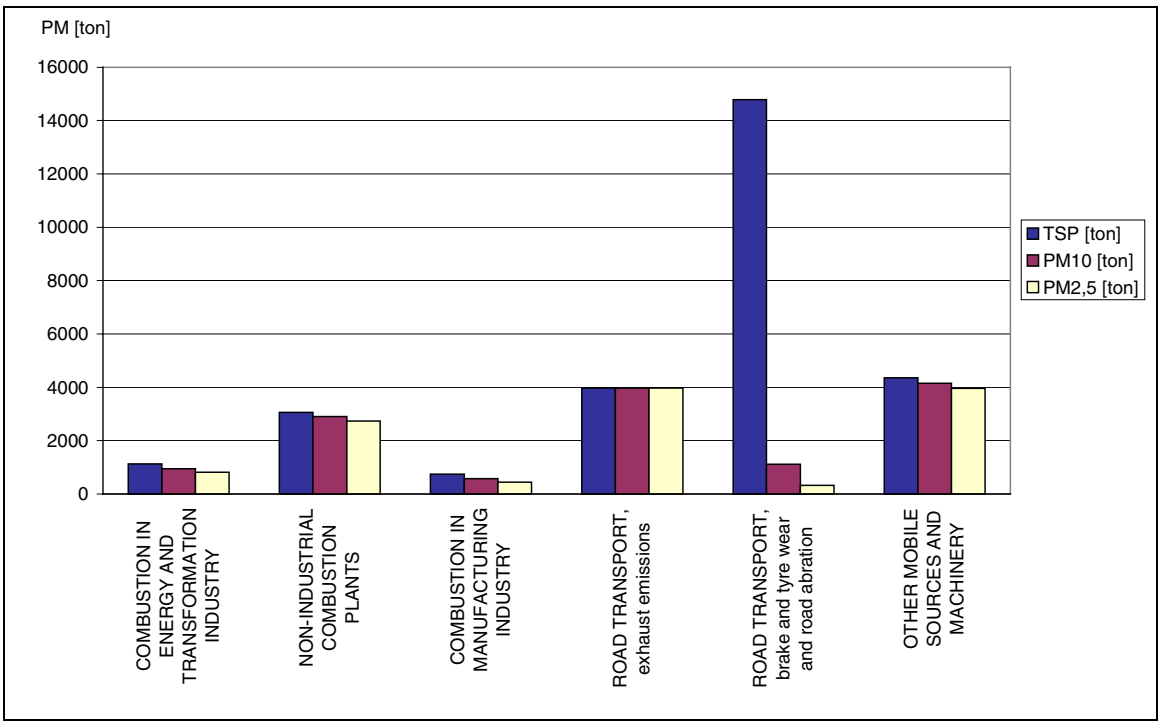


Figure s1 Emission of PM, 2000

Transport

The emission inventory for road transport and other mobile sources is shown in Table s2. Road transport and other mobile sources accounts for 67% of the overall Danish $PM_{2.5}$ emission. Emissions from international sea and air traffic are not included in the UN-ECE inventory. The latter contributions are reported to the UN-ECE as memo items only.

Table s2 Particulate emissions for transport 2000

Category	SNAP codes	TSP [tons]	PM10 [tons]	PM2.5 [tons]
Road traffic	07	3969	3969	3969
Brake wear	0707	400	392	160
Tyre wear	0707	4632	234	163
Road abrasion	0708	9751	490	0
Military	0801	19	19	19
Railways	0802	162	162	162
Inland waterways	0803	72	69	66
National sea traffic	080402	352	335	318
National fishing	080403	398	378	359
Domestic LTO	080501	2	2	2
Domestic cruise	080503	2	2	2
Agriculture	0806	2174	2066	1963
Forestry	0807	2	2	2
Industry	0808	1145	1090	1037
Household and gardening	0809	27	27	27
UN-ECE total		23106	9235	8249
International sea traffic	080404	7618	7237	6875
International LTO	080502	4	4	4
International cruise	080504	34	34	34

The PM results show that around 80%, 20% and 10% of total road traffic TSP, PM_{10} and $PM_{2.5}$ come from non-exhaust sources. The emission shares of agriculture and industry are approximately one half and one fourth, respectively, of the total for other mobile sources.

Stationary combustion plants
The PM emission inventory year 2000 of stationary combustion plants is shown in Table s3. Stationary combustion plants accounts for 33% of the overall Danish emission of $PM_{2.5}$.

According to the improved emission inventory the primary sources of PM emission are:

- Residential boilers, stoves and fireplaces combusting wood
- Farmhouse boilers combusting straw
- Power plants primarily combusting coal
- Coal and residual oil combusted in industrial boilers and processes

Furthermore there are considerable emissions from:
- Residential boilers using gas oil
- Refineries

The PM emission from wood combusted in residential plants is the predominant source. Thus 40% of the $PM_{2.5}$ emission from stationary combustion is emitted from residential wood combustion. This corresponds to 13% of the overall Danish emission. Wood combustion accounts for almost 90% of the $PM_{2.5}$ emission from residential plants in spite of the limited wood consumption share.

Table s3. Improved emission inventory year 2000, stationary combustion plants

snap1	snap1 name	snap2	snap2 name	TSP Ton	PM10 Ton	PM2.5 Ton
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	826	702	594
		0102	District heating plants	161	115	91
		0103	Petroleum refining plants	142	129	122
		0104	Solid fuel transformation plants	0	0	0
		0105	Coal mining, oil / gas extraction, pipeline compressors	3	3	3
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	136	132	123
		0202	Residential plants	2793	2665	2529
		0203	Plants in agriculture, forestry and aquaculture	129	102	81
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	447	339	254
		0303	Processes with contact	294	235	194
Stationary combustion plants				4930	4423	3992

Further improvements
The estimate of the total exhaust emissions from road transport could be improved if a more precise classification of gross vehicle weights for heavy duty vehicles and annual mileage given per first registration year for light and heavy duty vehicles were available. Detailed Danish fleet and mileage data is gathered by the Danish Motor Vehicle Inspection Office in the Danish inspection and maintenance programme and will be made available as input data for future emission modelling. The outcome of other research at NERI and other non-exhaust emission research activities will be the basis for future emission factor improvements.

The literature survey showed that the uncertainty of the emission factors for residential combustion of wood in stoves and boilers are immense. The emission factors used in other Nordic countries are from 3 to 14 times higher than the emission factor used in Denmark. Still, other references supported the current emission factor and at present the emission factor has not been changed. Further studies of this emission factor are of great importance for improvement of the inventory. Improved PM emission factors for decentralised combined heat and power plants have been developed recently and these emission factors will be used in future inventories.

Sammenfatning

Den første danske emissionsopgørelse for partikler (PM) blev udarbejdet i 2002. Emissionsopgørelsen var en del af de danske opgørelser der rapporteres til UN-ECE konventionen om langtransporteret luftforurening (CLRTAP). Den foreløbige opgørelse var udarbejdet på basis af de aktivitetsdata og emissionsfaktorer, der umiddelbart var tilgængelige. Opgørelsen inkluderede totale partikler (TSP), PM_{10} og $PM_{2.5}$. Nærværende rapport dokumenterer de metoder, emissionsfaktorer og referencer, der er anvendt ved udarbejdelsen af en forbedret opgørelse af TSP, PM_{10} og $PM_{2.5}$ for år 2000. Rapporten dækker emissionsopgørelser for transport og stationær forbrænding. Emissioner fra landbruget er beskrevet i et appendiks til rapporten. For transportsektoren omfatter resultaterne emissioner fra såvel udstødning som ikke-udstødning – såsom dæk, bremser og vejslid.

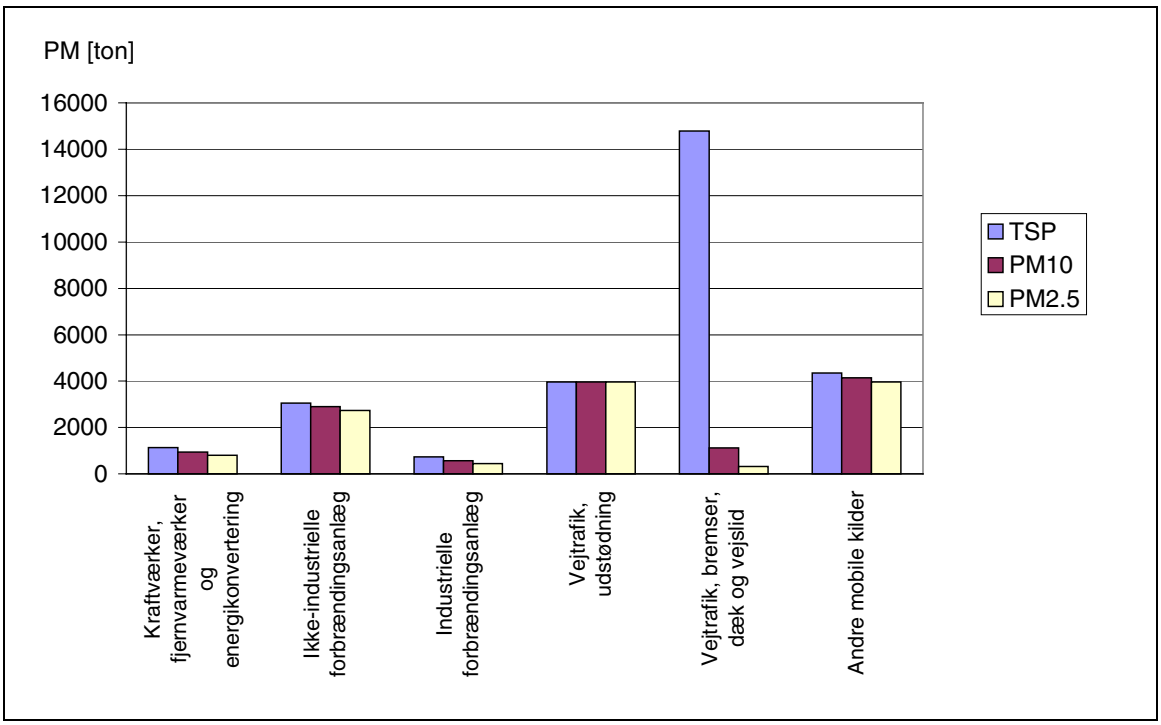
Emissioner
Hovedresultaterne for de forbedrede opgørelser for TSP, PM_{10} og $PM_{2.5}$ fra stationær forbrænding og transport for år 2000 er vist i tabel s1. I henhold til UNECE's retningslinier for rapportering er emissioner fra international flytrafik og skibsfart ikke medregnet i de danske total emissioner.

Table s1. Emissionsopgørelse for stationær forbrænding og transport for år 2000 [1)]

		TSP Ton	PM_{10} Ton	$PM_{2.5}$ Ton
01	Kraft- og fjernvarmeværker og energikonvertering	1131	948	810
02	Ikke-industrielle forbrændingsanlæg	3058	2899	2734
03	Industrielle forbrændingsanlæg	741	575	448
Stationære forbrændingsanlæg		4930	4423	3992
07	Vejtrafik, udstødning	3969	3969	3969
07	Vejtrafik, bremser, dæk og vejslid	14783	1116	323
08	Andre mobile kilder	4355	4152	3957
Transport		23106	9235	8249
Total [1)]		28037	13659	12241

1) Kun emissioner fra stationær forbrænding og transport er inkluderet. I de officielle danske opgørelser for 2001 er også inkluderet emissioner fra visse industrielle processer, landbrug og lossepladser.

Figur s1 viser at vejtrafik, andre mobile kilder og ikke-industrielle forbrændingsanlæg er de største kilder. Kilderne til ikke-udstødnings emissioner fra vejtrafik er kun vigtige for TSP og PM_{10}. Generelt er er der en stor usikkerhed på opgørelserne for forbrænding af træ i husholdninger, vejslid og andre mobile kilder.



Figur s1.Partikelemissioner for 2000

Transport

Emissionsopgørelserne for vejtrafik og andre mobile kilder er vist i tabel s2. Disse to kilder udgør 67% af de samlede danske $PM_{2.5}$ emissioner. Emissioner fra international sø- og lufttrafik er ikke inkluderet i de totale danske emissioner, og er i stedet rapporteret særskilt.

Tabel s2. Partikelemissioner for transport for år 2000

Kategori	SNAP koder	TSP [ton]	PM_{10} [ton]	$PM_{2.5}$ [ton]
Vejtrafik	07	3969	3969	3969
Bremseslid	0707	400	392	160
Dækslid	0707	4632	234	163
Vejslid	0708	9751	490	0
Militær	0801	19	19	19
Jernbane	0802	162	162	162
Småbåde og fritidsfartøjer	0803	72	69	66
National søtransport	080402	352	335	318
Fiskeri	080403	398	378	359
Indenrigs LTO	080501	2	2	2
Indenrigs cruise	080503	2	2	2
Landbrug	0806	2174	2066	1963
Skovbrug	0807	2	2	2
Industri	0808	1145	1090	1037
Hus- og havehold	0809	27	27	27
UN-ECE total		23106	9235	8249
International søtransport	080404	7618	7237	6875
International LTO	080502	4	4	4
International cruise	080504	34	34	34

Emissionerne af TSP, PM_{10} og $PM_{2.5}$ fra ikke-udstødningskilder udgør 80, 20 og 10% af de totale emissioner fra vejtrafik. Emissionsandelen fra landbrug og industri udgør ca. halvdelen og en fjerdedel af de totale emissioner fra andre mobile kilder.

Stationære forbrændingsanlæg
Partikelemissionsopgørelsen for stationære forbrændingsanlæg er vist i tabel s3. Emissionerne fra disse anlæg udgør 33% af de samlede danske emissioner af $PM_{2.5}$.

Den forbedrede opgørelse viser at de vigtigste kilder til partikelemissioner er:

- Træ der forbrændes i husholdningers fyr, brændeovne og pejse.
- Halmfyr i landbrugserhverv
- Kulforbrænding på kraftværker
- Kul- og olieforbrænding i industrielle kedler og processer

Desuden er der betragtelige emissioner fra

- Oliefyr i husholdninger
- Raffinaderier

Forbrænding af træ i husholdninger er den dominerende emissionskilde, og emissionsandelen er 40% af den samlede $PM_{2.5}$ emission fra stationær forbrænding. Det svarer til 13% af den samlede danske emission. Forbrænding af træ udgør næsten 90% af emissionen fra husholdningers forbrændingsanlæg på trods af et begrænset forbrug af træ i denne sektor.

Table s3. Forbedret emissionsopgørelse for stationære forbrændingsanlæg for 2000.

SNAP1	SNAP1 navn	SNAP2	SNAP2 navn	TSP Ton	PM_{10} Ton	$PM_{2.5}$ Ton
01	Kraft- og fjernvarmeværker og energikonvertering	0101	Kraftværker	826	702	594
		0102	Fjernvarmeværker	161	115	91
		0103	Raffinaderier	142	129	122
		0104	Omdannelse af fastbrændsel	0	0	0
		0105	Olie- og gasudvinding	3	3	3
02	Ikke-industrielle forbrændingsanlæg	0201	Erhverv og institutioner	136	132	123
		0202	Husholdninger	2793	2665	2529
		0203	Forbrændingsanlæg i landbrug, skovbrug og dampbrug	129	102	81
03	Industrielle forbrændingsanlæg		Kedler, gasturbiner og stationære motorer	447	339	254
			Processer med kontakt	294	235	194
Stationære forbrændingsanlæg				4930	4423	3992

Fremtidige forbedringer
Emissionsberegningerne for vejtrafikkens udstødning kan forbedres hvis en mere præcis fordeling af totalvægt for lastbiler bliver tilgængelig sammen med differentierede årskørsler per førsteregistreringsår for varebiler og tunge køretøjer. Detaljerede danske data for køretøjsbestand og årskørsler indsamles af Statens Bilinspektion som en del af det generelle synsprogram. Disse data vil blive gjort tilgængelige for emissionsberegningerne i fremtiden. Øvrig forskning på DMU og andre forskningsaktiviter relateret til ikke-udstødning vil blive brugt til at forbedre emissionsfaktorerne for de sidstnævnte kilder

Litteraturundersøgelsen viste at usikkerheden for forbrænding af træ i husholdningers fyr og brændeovne er meget stor. Emissionsfaktorerne brugt i andre nordiske lande er fra 3 til 14 gange større end den emissionsfaktor, der er anvendt i den danske opgørelse. Andre referencer understøtter dog emissionsfaktoren anvendt i den danske opgørelse. Yderligere undersøgelser af emissionsfaktoren er af stor betydning for at kunne forbedre opgørelsen. Forbedrede partikel emissionsfaktorer for decentrale kraftvarmeanlæg er nylig blevet udviklet og disse ville blive anvendt i fremtidige opgørelser.

1 Introduction

At the beginning of 2002 the first Danish emission inventory of particulate matter (PM) was prepared and reported. The emission inventory was part of the Danish emission inventories reported under the UN-ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). This provisional version of the inventory was based on activity data and emission factors presently available. The inventory included total suspended particles (TSP), PM_{10} and $PM_{2.5}$.

Traditionally the emissions of particulate matter have been referred to by their total mass. However, more recently an increased attention has been given to the adverse health effects that particulates can cause depending on their numbers, sizes and chemical compositions. Particulate matter is subject to major research activities in many countries. The Danish Environmental Protection Agency has started a 4-year research project concerning PM. As part of this work The Danish Environmental Protection Agency wanted to get a more detailed emission inventory of PM emission from Danish sources. The input data of the emission inventory had to be improved and the methodology and references documented. The present report includes improved emission inventories for:

- Transport: Exhaust and the non-exhaust emission of the transport sector such as tyre and brake wear, road abrasion.
- Stationary combustion

Further a note about the temporary methodology for the PM emission inventory from agriculture is enclosed.

Methodology, references and results of the improved emission inventory for stationary combustion and transport are presented in this report. The report also identifies the emission sources for which further improvements were required to increase accuracy of the Danish inventory. The selection of sources for further studies was based on the provisional version of the inventory. Detailed reflections, documentation and discussions concerning emissions and sources, activity rates and emission factors of each sector are enclosed in appendix 1 – 3. Revised emission factors are determined and an improved emission inventory for the year 2000 is presented.

Appendix 1: Road transport and other mobile sources.
Appendix 2: Stationary combustion plants.
Appendix 3: Agriculture.

The project has contributed to improve the quality of the Danish emission inventories of particulate matter reported under the UN-ECE CLRTAP. All the emission data shown in the main report are based on the improved inventory.

2 Emission inventory

The improved Danish emission inventory of TSP, PM_{10} and $PM_{2.5}$ from stationary combustion and transport for the year 2000 is shown in Table 1. According to the CLRTAP reporting guidelines emissions from international air traffic and international bunkers are not included. PM emissions from storage of coal, waste treatment and agriculture have been included in the Danish inventory 2003 reported to UNECE/EMEP but these emission sources are not further discussed in this report and the emissions from these sources are not included in totals in tables and figures below. Coal storage and waste treatment account for less than 3% of the total PM emission. Agriculture is an important emission source for TSP but accounts for only about 10% of the $PM_{2.5}$ emission.

The emission source contributions are illustrated in Figure 1 - Figure 4.

Table 1 Emission inventory year 2000 (stationary combustion and transport), main snap categories [1)]

snap1	snap1 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION IN-DUSTRY	1131	948	810
02	NON-INDUSTRIAL COMBUSTION PLANTS	3058	2899	2734
03	COMBUSTION IN MANUFACTURING INDUSTRY	741	575	448
Stationary combustion plants		**4930**	**4423**	**3992**
07	ROAD TRANSPORT, exhaust emissions	3969	3969	3969
07	ROAD TRANSPORT, brake and tyre wear and road abrasion	14783	1116	323
08	OTHER MOBILE SOURCES AND MACHINERY	4355	4152	3957
Transport		**23106**	**9235**	**8249**
Total [1)]		**28037**	**13659**	**12241**

1. Only the emission sources stationary combustion plants and transport are included. In the official Danish inventory reported in 2003 PM emissions from coal storage, agriculture and from waste treatment and disposal are also included

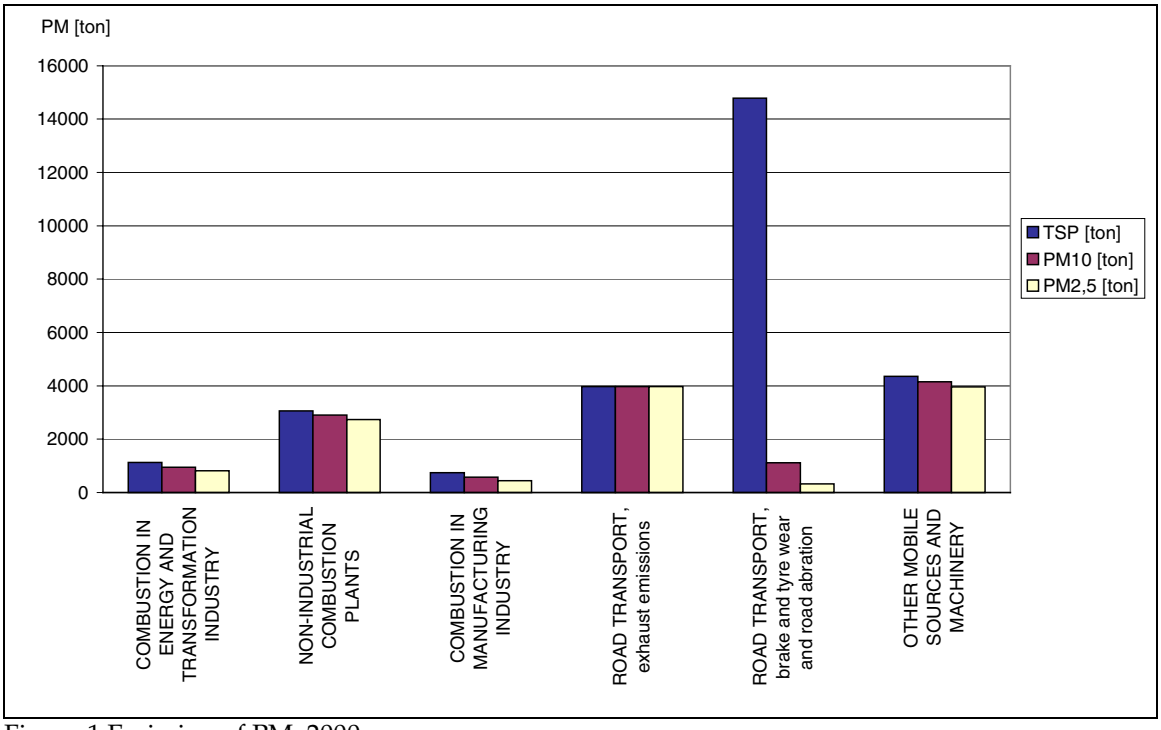


Figure 1 Emission of PM, 2000

From Figure 1 it is seen that road transport, other mobile sources and non-industrial combustion plants are the largest sources. Non-exhaust emissions from road transport (brake, tyre wear and road abrasion) are only important for TSP and PM_{10}. For detailed level emission inventories please refer to appendix 1-3.

In general the uncertainty for the PM emission inventory is high especially for domestic combustion of wood, road abrasion and other mobile sources.

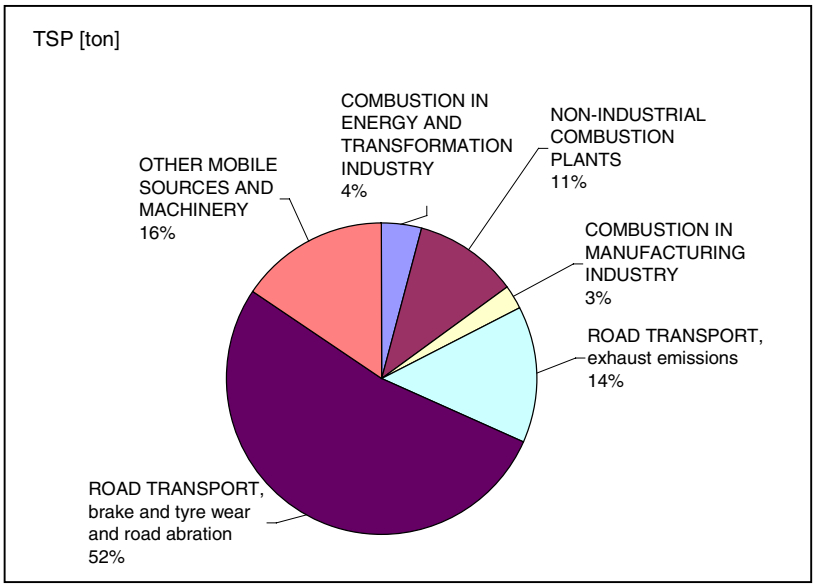


Figure 2 Emission of TSP, 2000

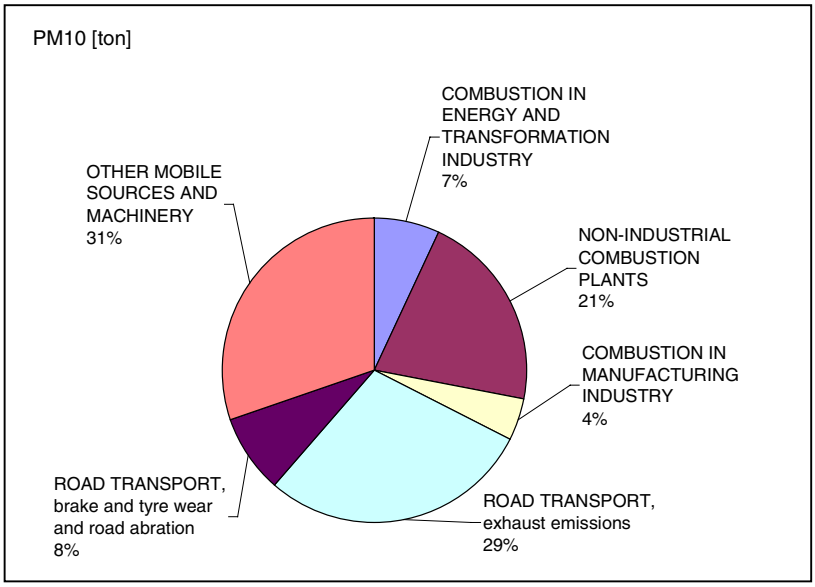


Figure 3 Emission of PM_{10}, 2000

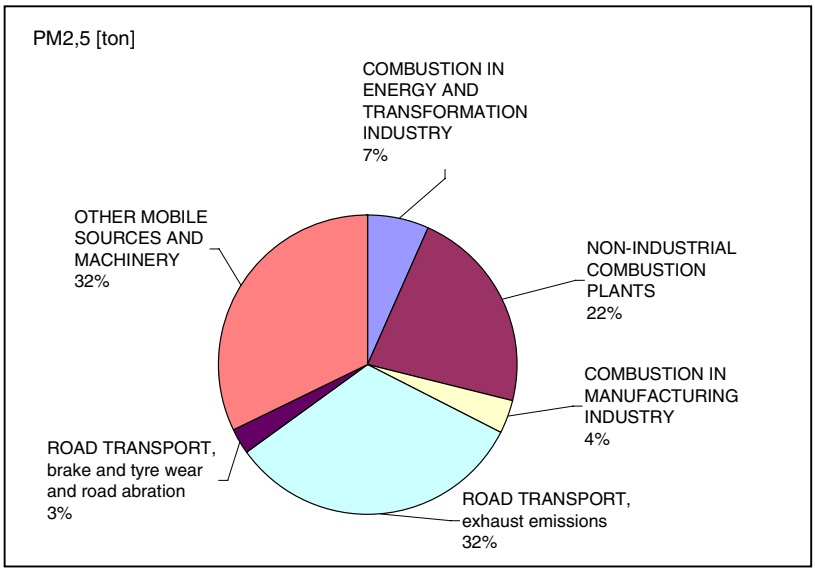


Figure 4 Emission of $PM_{2.5}$, 2000

2.1 Road transport and other mobile sources

The emission inventory for road transport and other mobile sources is shown in Table 2. Road transport and other mobile sources accounts for 67% of the overall Danish $PM_{2.5}$ emission. Emissions from international sea and air traffic are not included in the UN-ECE inventory. The fuel consumption in the international sea and air traffic category comprises the fuel bunkered in Denmark by sea vessels or aircraft with foreign destinations. The associated emissions for the latter categories are not included in the Danish UNECE total. Instead the emissions are reported as memo items.

Table 2 Particulate emissions for transport 2000

Category	snap codes	TSP [tonnes]	PM_{10} [tonnes]	$PM_{2.5}$ [tonnes]
Road traffic	07	3969	3969	3969
Brake wear	0707	400	392	160
Tyre wear	0707	4632	234	163
Road abrasion	0708	9751	490	0
Military	0801	19	19	19
Railways	0802	162	162	162
Inland waterways	0803	72	69	66
National sea traffic	080402	352	335	318
National fishing	080403	398	378	359
Domestic LTO	080501	2	2	2
Domestic cruise	080503	2	2	2
Agriculture	0806	2174	2066	1963
Forestry	0807	2	2	2
Industry	0808	1145	1090	1037
Household and gardening	0809	27	27	27
UN-ECE total		23106	9235	8249
International sea traffic	080404	7618	7237	6875
International LTO	080502	4	4	4
International cruise	080504	34	34	34

Exhaust PM emissions from road transport are shown on a more detailed level in Table 3 and in Figure 5. Non-exhaust emissions from road transport are shown at a detailed level in Table 4.

The PM results show that around 80%, 20% and 10% of total road traffic TSP, PM_{10} and $PM_{2.5}$ come from non-exhaust sources. Since the smallest fractions of particulate matter are known to have the biggest influence on health, and given the absolute figures emitted, road traffic is still the most important source in relation to air quality.

Table 3 Total exhaust $PM_{2.5}$ emissions for road transport year 2000

Category	Urban	Rural	Highway	Total	% of Grand total
	[tonnes]	[tonnes]	[tonnes]	[tonnes]	
Passenger Cars	381	228	124	733	18
Light Duty Vehicles	837	697	232	1766	44
Heavy-duty Vehicles	326	478	289	1092	28
Buses	171	122	32	324	8
Mopeds	25	6	0	31	1
Motorcycles	11	9	3	23	1
Grand total	1750	1539	680	3969	100

For road transport some uncertainties still prevail as regards the split of total road transport fuel use into fuel used by different vehicle categories, and the total mileage driven. The latter point of uncertainty in some cases refers to total mileage numbers and the distribution of mileage into vehicle age. In 2000 the urban, rural and highway shares of total road traffic exhaust PM emissions

(all emissions are $PM_{2.5}$) was 44, 39 and 17%, respectively. The total exhaust emissions have decreased substantially since the mid-1990s due to the stepwise strengthening of emission standards for all vehicle types. This decrease will continue in the future as new low emitting vehicles complying with future emission standards substitute older and more polluting vehicles. In absolute amounts the conventional types of diesel light duty and heavy-duty vehicles have the highest emissions and for these vehicles the future emission reductions will become most effective. Conventional passenger cars still contribute significantly to this vehicle type's PM total. However the conventional emission share will be negligible in the future following the penetration of catalyst vehicles into the Danish traffic.

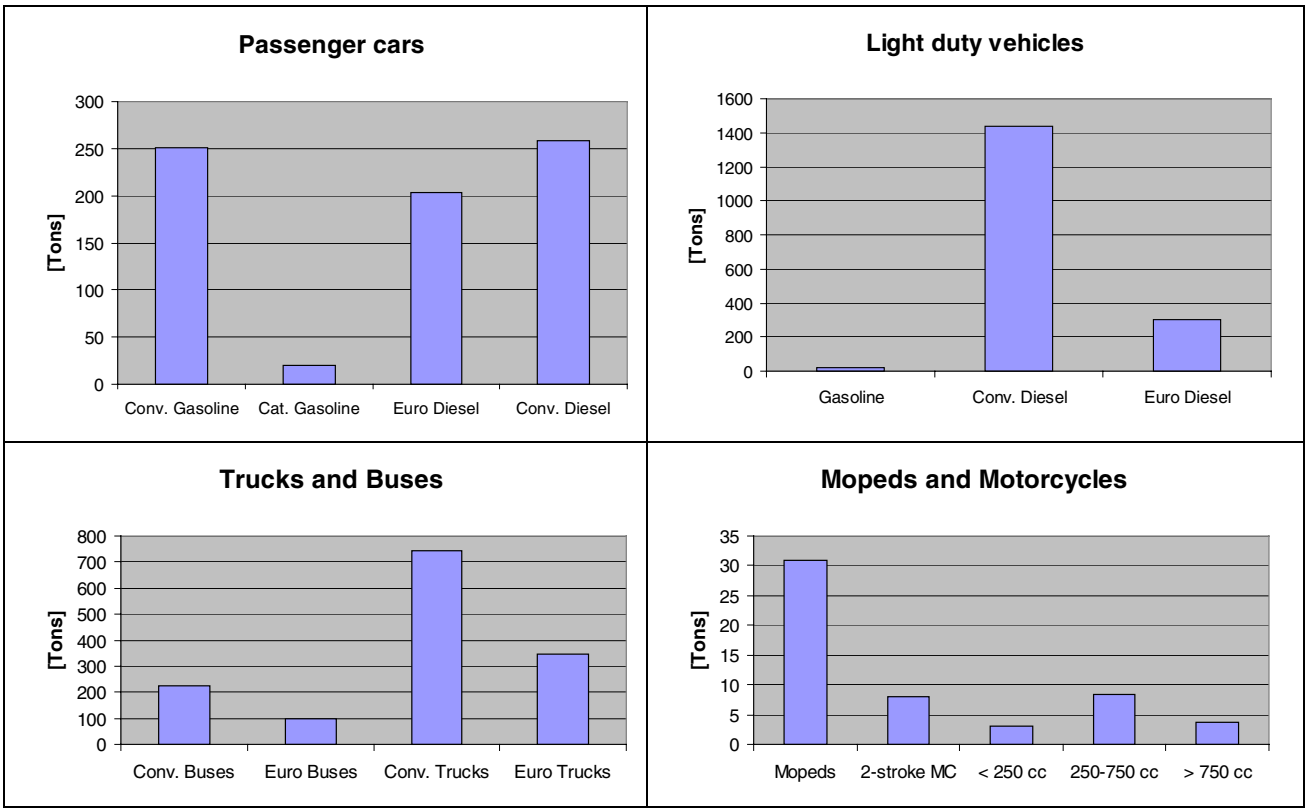


Figure 5 Each vehicle category's exhaust $PM_{2.5}$ emissions divided into layers

Table 4 Non-exhaust emissions per vehicle category in the Danish inventory

	Brake wear (tonnes)			Tyre wear (tonnes)			Road abrasion (tonnes)			Total (tonnes)		
Vehicle category	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Passenger cars	223	219	89	2565	130	91	5390	271	0	8178	620	180
Light duty veh.	61	60	24	732	37	26	1545	77	0	2338	174	50
Heavy-duty veh.	87	85	35	1001	50	35	2112	106	0	3201	241	70
Buses	27	27	11	314	16	11	662	33	0	1003	76	22
Mopeds	0	0	0	4	0	0	9	0	0	14	1	0
Motorcycles	1	1	1	15	1	1	32	2	0	49	4	1
Grand total	400	392	160	4632	234	163	9751	490	0	14783	1115	323

Emission results for other mobile sources are shown in Table 5. The working machinery categories comprise the working equipment and machines in agriculture, forestry, industry, household and gardening.

Table 5 Total Danish PM emissions (exhaust) from other mobile sources in 2000

	TSP [tonnes]	PM_{10} [tonnes]	$PM_{2.5}$ [tonnes]
Military	21	21	21
Railways	162	162	162
Inland waterways[1)]	72	69	66
National fishing	398	378	359
National sea traffic	352	335	318
Domestic aviation	3	3	3
Agriculture	2174	2066	1963
Forestry	2	2	2
Industry	1145	1090	1037
Household and gardening	27	27	27
Grand Total	4357	4153	3959

1. Small boats and pleasure crafts

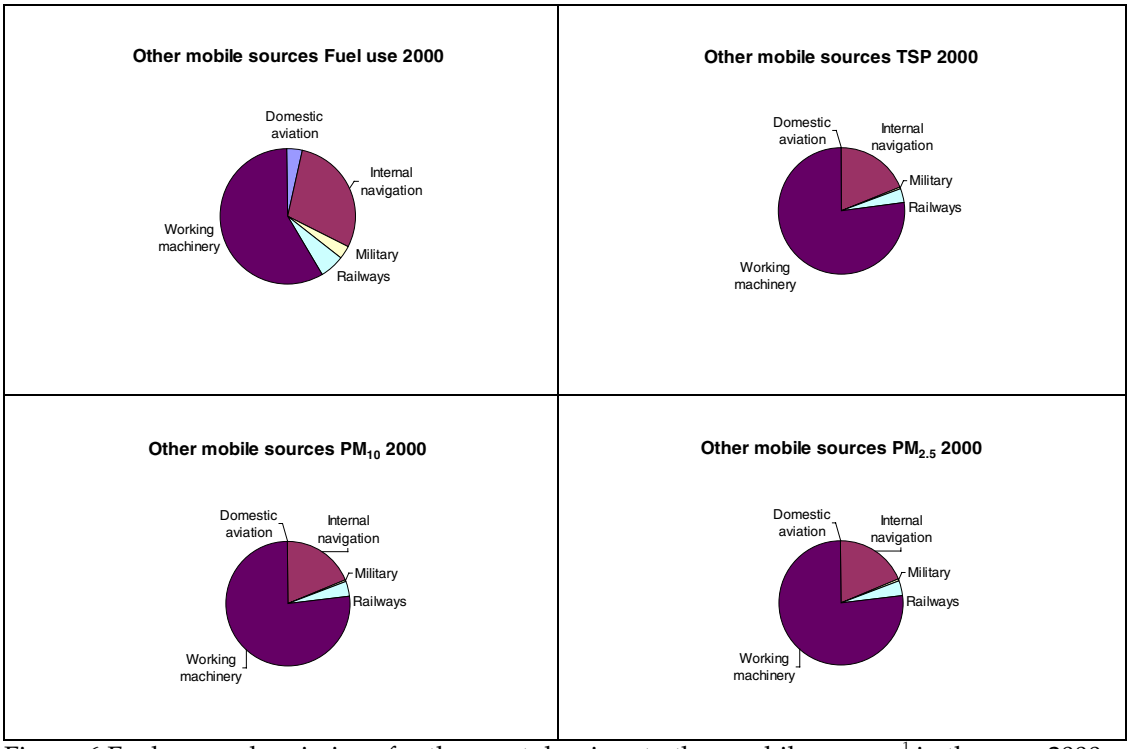


Figure 6 Fuel use and emissions for the most dominant other mobile sources[1] in the year 2000.

The emission shares of agriculture and industry are approximately one half and one fourth, respectively, of the total for other mobile sources. The two sector's fuel use shares are somewhat lower. Due to the implementation of the two stage EU emission directive, a possible strengthening of this, and a future directive for gasoline fuelled working machinery (2000/0336), the emissions from agricultural and industrial machinery (and working machinery in general) will decline in both absolute and relative terms.

[1] Internal navigation comprises the contributions from small boats, pleasure crafts, fishing vessels and the emissions associated with the use of fuel bunkered by ships leaving Danish ports with domestic destinations.

2.2 Stationary combustion plants

The PM emission inventory year 2000 of stationary combustion plants is shown in Table 6. Stationary combustion plants account for 33% of the overall Danish emission of $PM_{2.5}$. According to the improved emission inventory the primary sources of PM emission ranked after importance are:

- Residential boilers, stoves and fireplaces combusting wood
- Farmhouse boilers combusting straw
- Power plants primarily combusting coal
- Coal and residual oil combusted in industrial boilers and processes

Furthermore there are considerable emissions from:

- Residential boilers using gas oil
- Refineries

The PM emission from wood combusted in residential plants is the predominant source. Thus 40% of the $PM_{2.5}$ emission from stationary combustion is emitted from residential wood combustion. This corresponds to 13% of the overall Danish emission. The literature survey showed that the uncertainty of the emission factors for residential combustion of wood in stoves and boilers are immense. In Figure 7 fuel consumption and $PM_{2.5}$ emission of residential plants is shown. Wood combustion accounts for almost 90% of the $PM_{2.5}$ emission from residential plants in spite of the limited wood consumption share.

Table 6 Improved emission inventory year 2000, stationary combustion plants

snap1	snap1 name	snap2	snap2 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power[1)]	826	702	594
		0102	District heating plants	161	115	91
		0103	Petroleum refining plants	142	129	122
		0104	Solid fuel transformation plants	0	0	0
		0105	Coal mining, oil / gas extraction, pipeline compressors	3	3	3
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	136	132	123
		0202	Residential plants	2793	2665	2529
		0203	Plants in agriculture, forestry and aquaculture	129	102	81
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	447	339	254
		0303	Processes with contact	294	235	194
Stationary combustion plants				4930	4423	3992

1. Including both large power plants and decentralised heat and power plants (CHP-plants)

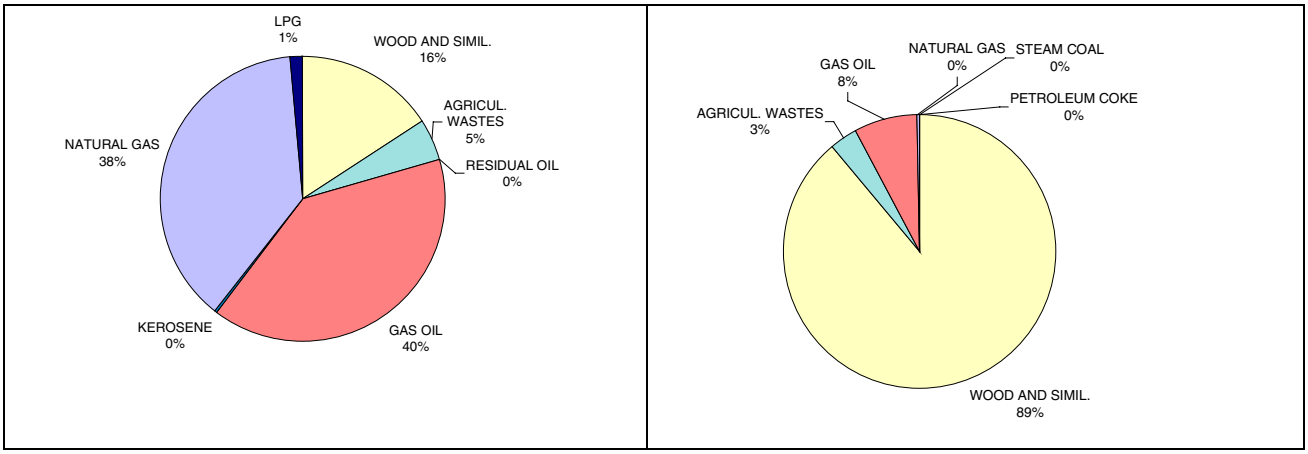


Figure 7 Fuel consumption and $PM_{2.5}$ emission from residential plants

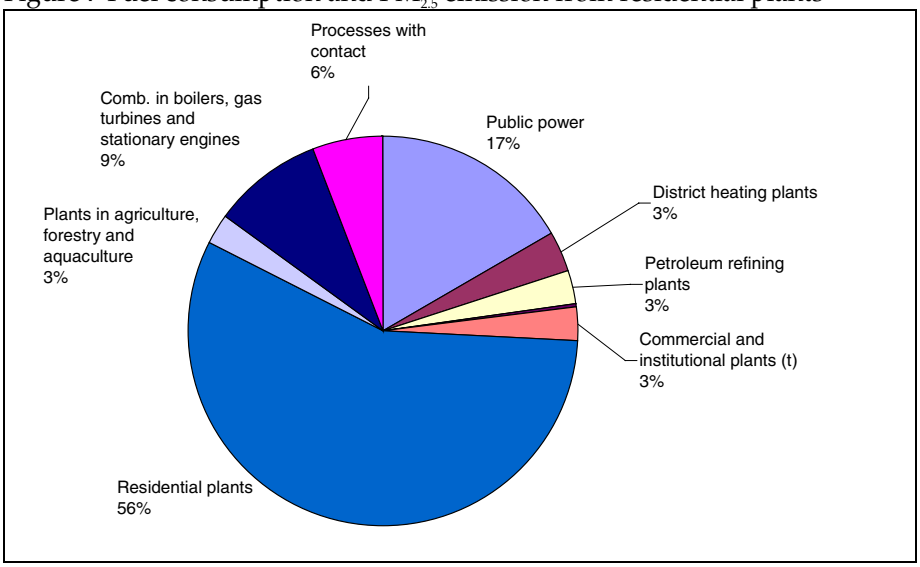


Figure 8 Emission of TSP from stationary combustion

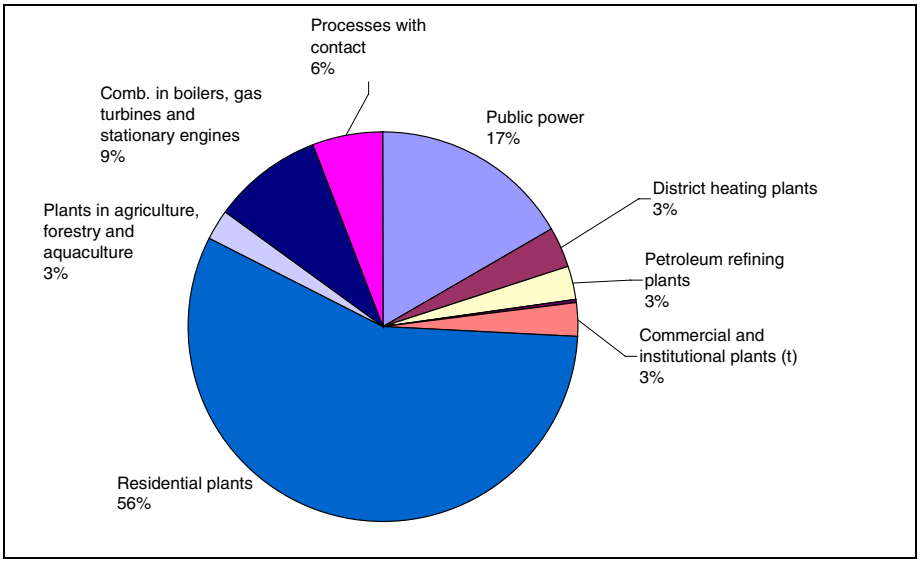


Figure 9 Emission of PM_{10} from stationary combustion

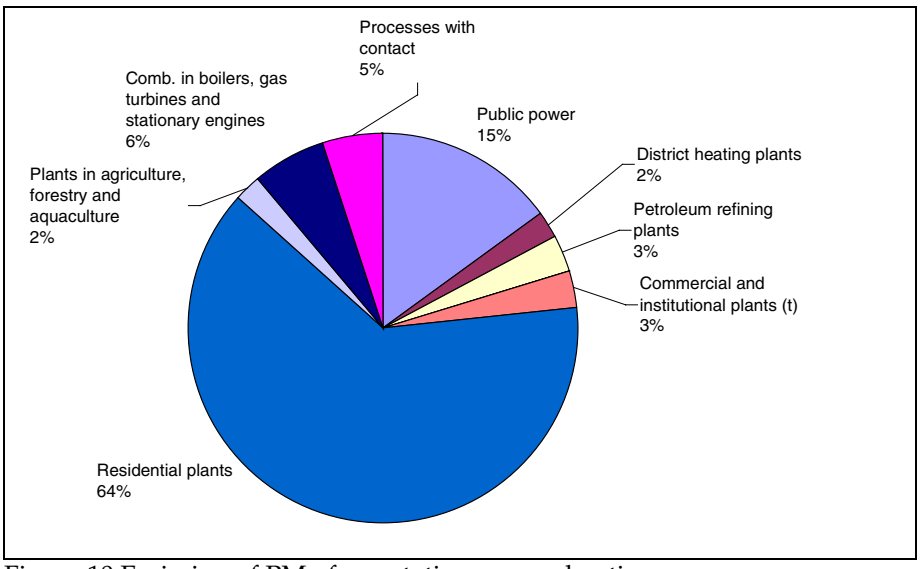


Figure 10 Emission of $PM_{2.5}$ from stationary combustion

3 Methodology and references

The Danish emission inventory is based on the CORINAIR (CORe INventory on AIR emissions) system, which is a European program for air emission inventories. CORINAIR includes a methodology structure and software for inventories. The methodology is described in the Emission Inventory Guidebook 3rd edition, prepared by the UN-ECE/EMEP Task Force on Emissions Inventories and Projections. Emission data are stored in an Access database. The detailed methodology specifications and references of the Danish emission inventory are included in appendix 1-3.

The inventory of emissions from diesel road transport is based on the COPERT model. For gasoline vehicles the COPERT model principle is used in a new database developed at NERI. The total exhaust PM emissions are calculated separately for operationally hot engines and for engines driving under cold start conditions. The non-exhaust emissions are simulated using the hot engine emission calculation methodology. Emissions and fuel use results for operationally hot engines are calculated for each layer, and urban, rural and highway driving. The procedure is to combine fuel use and emission factors, number of vehicles, annual mileage numbers and their urban, rural and highway shares. The cold start emissions are estimated using information on cold:hot emission ratios, average trip length and ambient temperatures.

The inventory of emissions from stationary combustion is based on activity rates from the Danish energy statistics and on emission factors for different fuels, plants and sectors. Large plants like e.g. power plants are registered individually as large point sources and plant specific emission data are used.

3.1 Activity rates

Road transport
Information of the vehicle stock and annual mileage is obtained from the Danish Road Directorate. This covers data for the number of vehicles, annual mileage, mileage split between urban, rural and highway driving and the respective average speeds. The figures are modified as a result of the COPERT model fuel balance. Fuel consumption rates refer to the official Danish energy statistics. Some uncertainties still exist as regards the split of total road transport fuel use into fuel used by different vehicle categories, and the total mileage driven.

Other mobile sources
The activity data for other mobile sources consist of fuel use information provided by the Danish Energy Authority. The sectors: Inland waterways, agriculture, forestry, industry and household and gardening consist of off road working machines and equipment.

Stationary combustion
Activity rates of stationary combustion refer to the official Danish energy statistics prepared by the Danish Energy Authority.

3.2 Emission factors

Road transport
Road transport exhaust emission factors for diesel vehicles are taken from the COPERT model. The COPERT model specifies trip speed dependent fuel use and emission factors. For gasoline vehicles relevant emission factors are derived from Dutch measurements and shown in the TNO/CEPMEIP database.

Table 7 Emission factors (hot and cold aggregated) used in the Danish inventory

Vehicle class	Fuel type	Engine/weight	Urban (g/km)	Rural (g/km)	Highway (g/km)
PC	Gasoline	< 1.4 l.	0.01	0.01	0.01
PC	Gasoline	1.4 – 2 l.	0.01	0.01	0.01
PC	Gasoline	> 2 l.	0.01	0.01	0.01
PC	Diesel	< 2 l.	0.17	0.06	0.10
PC	Diesel	> 2 l.	0.17	0.06	0.10
LDV	Gasoline		0.02	0.02	0.02
LDV	Diesel		0.33	0.19	0.21
Trucks	Diesel	3.5 – 7.5 tonnes	0.27	0.18	0.15
Trucks	Diesel	7.5 – 16 tonnes	0.53	0.36	0.29
Trucks	Diesel	16 – 32 tonnes	0.59	0.40	0.33
Trucks	Diesel	> 32 tonnes	0.63	0.43	0.36
Urban buses	Diesel		0.49	0.33	0.26
Coaches	Diesel		0.48	0.32	0.26
Mopeds	Gasoline		0.12	0.12	
Motorcycles	Gasoline	2 stroke	0.12	0.12	0.12
Motorcycles	Gasoline	< 250 cc 4 stroke	0.04	0.04	0.04
Motorcycles	Gasoline	250 – 750 cc 4 stroke	0.04	0.04	0.04
Motorcycles	Gasoline	> 750 cc 4 stroke	0.04	0.04	0.04

The non-exhaust emission factor of road transport used in the Danish inventory comes from the TNO/CEPMEIP database. The emission factors originate from Dutch roadside measurements, as the only source of information.

Table 8 Emission factors (mg/km) per vehicle category in the Danish inventory

	Brake wear			Tyre wear			Road abrasion		
Vehicle category	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Passenger cars	6	5.9	2.4	69	3.5	2.5	145	7.3	0
Light duty veh.	7.5	7.4	3.0	90	4.5	3.2	190	9.5	0
Heavy-duty veh.	32.25	31.6	12.9	371.25	18.6	13.0	783	39.2	0
Buses	32.25	31.6	12.9	371.25	18.6	13.0	783	39.2	0
Mopeds	1.5	1.5	0.6	17.25	0.9	0.6	36.5	1.85	0
Motorcycles	3	2.9	1.2	34.5	1.7	1.2	73	3.7	0

Other mobile sources

For military ground material and railways aggregated emission factors for diesel are derived from the road traffic emission simulations made by NERI. The diesel emission factors for the remaining sectors come from the EMEP/CORINAIR Guidebook, however size fractions are taken from the TNO/CEPMEIP database. The emission factors for all other fuel types come from the TNO/CEPMEIP database.

Table 9 Danish PM exhaust emission factors for other mobile sources in 2000

	TSP [g/GJ]	PM_{10} [g/GJ]	$PM_{2.5}$ [g/GJ]
Military	13.63	13.63	13.63
Railways	52.40	52.40	52.40
Inland waterways	80.62	77.28	74.10
National fishing	42.12	40.02	38.03
National sea traffic	72.24	68.63	65.20
Domestic aviation	1.63	1.63	1.63
Agriculture	124.67	118.47	112.58
Forestry	32.36	31.82	31.30
Industry	94.14	89.57	85.22
Household and gardening	23.25	23.25	23.25

Stationary combustion
For each fuel and snap (sector and e.g. type of plant) a set of general emission factors has been determined. The emission factors are either national referenced or based on the TNO/CEPMEIP database. Most country specific emission factors refers to:

- Danish legislation
- Danish research reports
- Calculations based on plant specific emissions from a considerable number of power plants
- Calculations based on plant specific emissions from a considerable number of municipal waste incineration plants

TSP emissions from large point sources are often based on emission measurements and thus they are plant specific.

Table 10 shows some of the emission factors used for stationary combustion plants. Please refer to appendix 1.1 for more detailed emission factor tables. Some of the highest emissions factors are seen for wood and straw combustion in the residential sector.

Table 10 Some of the emission factors used for stationary combustion plants

Fuel	snap	Source category	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
Coal	0101	Public power	3	2.6	2.1
Coal	0102	District heating	6	6	5
Petroleum coke	02	Non-industrial combustion	100	60	30
Wood	0101	Public power	8	6	4
Wood	0102	District heating	19	13	10
Wood	0202	Residential plants	150	143	135
Municipal Waste	0101	Public power	6	5	4
Municipal Waste	0102	District heating	6	5	4
Agricultural waste (straw)	0101	Public power	8	6	4
Agricultural waste (straw)	0102	District heating	21	15	12
Agricultural waste (straw)	0202	Residential plants	234	222	211
Residual oil	0101	Public power	3	3	2.5
Residual oil	0102	District heating	3	3	2.5
Residual oil	02 (engines)	Non-industrial combustion in engines	60	50	40
Residual oil	0301	Industrial combustion	14	10.5	7
Gas oil	All	All	5	5	5
Natural gas	All	All	0.1	0.1	0.1
LPG	All	All	0.2	0.2	0.2
Biogas	All	All	1.5	1.5	1.5

4 Further improvements

Transport
Even though the available fleet and mileage data is adequate for emissions calculations with the COPERT II model, a more precise classification of:

- gross vehicle weights for heavy-duty vehicles
- annual mileage given per first registration year for light and heavy-duty vehicles

would improve the estimate of total exhaust emissions.

Detailed Danish fleet and mileage data is gathered by the Danish Motor Vehicle Inspection Office in the Danish inspection and maintenance programme and could be made available as input data for emission modelling in 2003 depending on external resources.

In this study no change in particulate exhaust emission factors is proposed. Instead areas with poor or missing data should await the availability of new and COPERT consistent emission factors in mid-2003. However the use of Swedish factors will be considered depending of the outcome of parallel dispersion studies at NERI. In the first place the factors for road abrasion are kept. However, the outcome of other research at NERI and other non-exhaust emission research activities will be the basis for future emission factor improvements.

Stationary combustion plants
The literature survey showed that the uncertainty of the emission factors for residential combustion of wood in stoves and boilers is high. The emission factors used in other Nordic countries are from 3 to 14 times higher. Still, other references supported the current emission factor and at present the emission factor has not been changed. Further studies of this emission factor are of great importance for improvements of the inventory. Improved PM emission factors for decentralised CHP plants have been developed recently and these emission factors will be used in future inventories.

5 Projections

Transport
Emission projections are made using the Danish official energy use forecast (provided by the DEA) together with the emission projection models for road transport and other mobile sources developed by NERI. For road transport the projections are based on the COPERT III methodology and use the vehicle fleet and mileage projections provided by the Danish Road Traffic Directorate. For other mobile sources fuel related emission factors are used. In this category future emission reductions for diesel engines are taken into account for working machinery and equipment in the sectors agriculture, forestry, industry and household and gardening. For the remaining other mobile sources no real emission improvements are expected.

Table 11 Projections of exhaust emissions ($PM_{2.5}$) for road transport in 2010 and relative changes to 2000

Category	Urban	Rural	Highway	Total	%-change 2000-2010
Passenger Cars	150	82	59	291	-60
Light Duty Vehicles	384	289	109	782	-56
Heavy-duty Vehicles	145	208	123	477	-56
Buses	82	58	15	155	-52
Mopeds	28	7	0	34	10
Motorcycles	12	10	4	27	17
Grand total	801	654	310	1766	-56

From 2000 to 2010 the total exhaust emissions has decreased substantially due to the stepwise strengthening of emission standards for all vehicle types (except 2-wheelers).

Table 12 Projections of non-exhaust emissions for road transport in 2010 and relative changes to 2000

Vehicle category	Brake wear (tonnes)			Tyre wear (tonnes)			Road abrasion (tonnes)			Total (tonnes)			%-change
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	2000-2010
Passenger cars	248	243	99	2850	145	101	5989	302	0	9088	689	200	11
Light duty veh.	77	76	31	926	46	32	1954	98	0	2956	220	63	26
Heavy-duty veh.	106	104	42	1222	61	43	2577	129	0	3904	294	85	22
Buses	32	31	13	364	18	13	768	38	0	1163	88	25	16
Mopeds	0	0	0	5	0	0	10	1	0	16	1	0	11
Motorcycles	2	2	1	19	1	1	40	2	0	61	5	1	24
Grand total	465	456	186	5385	271	190	11338	569	0	17189	1296	376	16

The 16% increase in non-exhaust emissions from 2000 to 2010 is determined by the development in total mileage for road transportation vehicles, which in turn rely on the vehicle fleet numbers, and corresponding annual mileages.

Table 13 Projections of PM emissions for other mobile sources in 2010 and relative changes to 2000

Category	TSP 2010	TSP %-change 2000-2010	PM_{10} 2010	PM_{10} %-change 2000-2010	$PM_{2.5}$ 2010	$PM_{2.5}$ %-change 2000-2010
Military	18	-14	18	-14	18	-14
Railways	83	-49	83	-49	83	-49
Inland waterways	83	15	79	14	76	15
National sea	221	-44	209	-45	199	-45
National fishing	393	12	373	11	355	12
Civil aviation	3	0	3	0	3	0
Agriculture	1901	-13	1807	-13	1718	-12
Forestry	2	0	2	0	2	0
Industry	656	-43	625	-43	596	-43
Household	31	15	31	15	31	15
Total	3390	-22	3231	-22	3081	-22

The development towards lower railway emissions in 2010 is caused by the increased use of electrical locomotives in this sector. For sea vessels, civil aviation and household the emissions in 2010 solely rely on this years fuel consumption, since no improvements in emission factors are taken into account in the calculations. For agricultural and industrial machinery the emissions decline with 12 and 43% from 2000 to 2010 due to the stepwise introduction of stricter emission standards for the vehicles in question.

Stationary combustion plants

No projection models have been developed for projection of particulate matter emissions for stationary combustion plants but a rough estimate of the emission level in 2010 compared to the level in 2000 is made. The estimate is based on the energy forecast from the Danish Energy Authority and the biggest change is seen for power plants where the fuel consumption increases with 33%. The increasing fuel consumption at the power plants is mainly due to increasing use of coal and to a less extent use of wood, straw and natural gas. Since the large combustion plants already have very efficient PM abatement technology no major changes are expected from 2000 to 2010. The PM emissions from the energy sector are estimated assuming that the emissions increase with 33% as the fuel consumption. Given the latest energy projection from the Danish Energy Authority the estimated PM emissions in 2010 for stationary combustion plants will only increase with 7 % for PM_{10} (Table 14).

Table 14. Estimated PM emissions in 2010 for stationary combustion plants.

snap1	snap1 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	1500	1260	1080
02	NON-INDUSTRIAL COMBUSTION PLANTS	3058	2899	2734
03	COMBUSTION IN MANUFACTURING INDUSTRY	741	575	448
Stationary combustion plants		5299	4734	4262

6 Conclusion

An improved Danish PM emission inventory for the year 2000 has been prepared. The inventory includes TSP, PM_{10} and $PM_{2.5}$. The methodology and references for the sources transport, stationary combustion and agriculture are documented in appendix 1-3. Main sources of PM emissions have been analysed and future improvements and uncertainties discussed.

The improved Danish inventory shows that the main source of TSP emission is non-exhaust emissions from road transport. There is a considerable difference if only the fine PM fraction is considered. Thus the main sources of $PM_{2.5}$ emission are other mobile sources, exhaust emissions from road transport and non-industrial combustion plants.

$PM_{2.5}$ emission from transport accounts for 67% of the total Danish emission. The primary sources of $PM_{2.5}$ emission from transport are:

- Exhaust emissions from road transport
- Off road exhaust emissions from agriculture and industry

The primary sources of TSP emission from transport are:

- Road abrasion
- Tyre wear
- Exhaust emissions from road transport

$PM_{2.5}$ emission from stationary combustion accounts for 33% of the total Danish emission. The primary sources of particulate emission from stationary combustion are:

- Residential boilers, stoves and fireplaces combusting wood
- Farmhouse boilers combusting straw
- Power plants primarily combusting coal
- Coal and residual oil combusted in industrial boilers and processes

The PM emission from wood combusted in residential plants is the predominant source. Thus the $PM_{2.5}$ emission corresponds to 13% of the overall Danish emission.

Appendix 1

Inventory of particulate matter (PM) emission from stationary combustion plants

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NERI
January 2003

Contents

1 Introduction

At the beginning of 2002 the first Danish emission inventory of particulate matter (PM) was prepared. The emission inventory was part of the Danish emission inventories reported under the UN-ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). The inventory includes total suspended particles (TSP), PM_{10} and $PM_{2.5}$. In 2002 emission of PM was reported for the first time and the inventory of the year 2000 is considered to be a provisional version based on activity data and emission factors presently available.

The Danish Environmental Protection Agency has started a 4-year research project. The project will increase knowledge of particulate air pollution in Denmark. The primary objective of the work is to characterise the air pollution of particulate matter, including estimation of emission sources based on analyses of particulate size distribution and composition. To supplement and support the conclusions of this work The Danish Environmental Protection Agency wanted to get a more detailed emission inventory of PM emission from Danish sources. The basis of input data of the emission inventory will be improved and the method of calculation documented. This appendix includes improvements of emission inventories of stationary combustion plants.

The project will contribute to improve the quality of the Danish emission inventories of particulate matter reported under the UN-ECE CLRTAP.

This appendix deals only with emissions from stationary combustion plants and waste incineration. Method, results and primary sources of the provisional emission inventory of the year 2000 are discussed. Revised emission factors are determined and an improved emission inventory of the year 2000 is presented.

2 Method of emission inventory

The Danish emission inventory is based on the CORINAIR (CORe INventory on AIR emissions) system, which is a European program for air emission inventories. CORINAIR includes methodology structure and software for inventories.

The inventory is based on activity rates from the Danish energy statistics and on emission factors for different fuels, plants and sectors. Large plants like e.g. power plants are registered individually as large source plant sources and emission data from the actual plant are used. Emission data from large point sources are often based on emission measurements.

Only primary particulate matter emissions are included in the emission inventories. Secondary emissions formed in the atmosphere from oxidation and subsequent reactions of sulphur dioxide, nitrogen oxides, ammonia and volatile organic compounds are not considered.

2.1 Snap categories

All emissions are defined in snap categories (Selected Nomenclature for Air Pollution). 11 main categories are defined; categories that are further divided into a second and third level of snap. The 11 main sectors are:

Table A1-1 Main snap categories

01	Combustion in energy and transformation industry
02	Non-industrial combustion plants
03	Combustion in manufacturing industry
04	Production processes
05	Extraction and distribution of fossil fuels and geothermal energy
06	Solvent and other product use
07	Road transport
08	Other mobile sources and machinery
09	Waste treatment and disposal
10	Agriculture and forestry, land use and wood stock change
11	Nature

Stationary combustion plants are included in the main snap categories 01, 02 and 03: Energy and transformation industry, non-industrial combustion and combustion in the manufacturing industry.

A detailed list of snap codes of combustion plants is shown in Table A1-2. Snap 01 includes power plants, district-heating plants, petroleum refining plants and oil/gas extraction. In Denmark all municipal waste incineration is utilised for heat and power production. Thus incineration of waste is included in snap 0101 or 0102. Snap 02 includes commercial and institutional plants, residential plants and plants in agriculture, forestry and aquaculture. Snap 03 includes industrial combustion in boilers, gas turbines and stationary engines and industrial combustion in processes.

Table A1-2 snap categories of stationary combustion plants (snap 01-03)

snap1	snap1 name	snap2	snap2 name	snap3	snap3_name
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown
				010101	Combustion plants >= 300 MW (boilers)
				010102	Combustion plants >= 50 and < 300 MW (boilers)
				010103	Combustion plants < 50 MW (boilers)
				010104	Gas turbines
				010105	Stationary engines
		0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)
				010203	Combustion plants < 50 MW (boilers)
				010205	Stationary engines
		0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)
				010304	Gas turbines
		0104	Solid fuel transformation plants	010405	Stationary engines
		0105	Coal mining, oil / gas extraction, pipeline compressors	010502	Combustion plants >= 50 and < 300 MW (boilers)
				010504	Gas turbines
				010505	Stationary engines
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown
				020103	Combustion plants < 50 MW (boilers)
				020104	Stationary gas turbines
				020105	Stationary engines
		0202	Residential plants	0202	Plant size unknown
				020202	Combustion plants < 50 MW (boilers)
				020204	Stationary engines
		0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown
				020302	Combustion plants < 50 MW (boilers)
				020303	Stationary gas turbines
				020304	Stationary engines
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown
				030102	Combustion plants >= 50 and < 300 MW (boilers)
				030103	Combustion plants < 50 MW (boilers)
				030104	Gas turbines
				030105	Stationary engines
				030106	Other stationary equipment (n)
		0303	Processes with contact	030303	Gray iron foundries
				030307	Secondary lead production
				030311	Cement (f)
				030315	Container glass (f)

2.2 Activity rates, fuel consumption

Fuel consumption rates also called activity rates are based on the official Danish energy statistics prepared by the Danish Energy Authority. The Danish Energy Authority aggregates fuel consumption rates to snap categories using the official energy statistics. Furthermore some fuels are aggregated to the fuel categories used in the inventories. Emissions from petroleum coke bought abroad and combusted in Danish residential plants (border trade of 251 TJ) are not included in the inventory.

Fuel consumption of large point sources are also reported by the Danish Energy Authority based on a database including fuel consumption of all district heating and power producing plants. This database is updated each year. Fuel consumption of area sources is calculated as total fuel consumption minus fuel consumption of large point sources.

2.3 Emission factors

For each fuel and snap (sector and e.g. type of plant) a set of emission factors has been determined. The temporary emission factors of the year 2000 are shown in Appendix 1.1. Further references of the emission factors are given in this appendix. Note that some references are used for plants or fuels beyond their immediate application. For instance, due to lack of emission factors for agricul-

tural waste (straw) combusted in residential plants the emission factors used in the provisional inventory refer to district heating plants.

2.4 Large point sources

Large point sources like power plants, industrial plants and refineries are included as point sources in the Danish emission inventory. By registering the plants as point sources it is possible to use plant specific emission factors. It is often the case that only some of the emissions included in the inventory have been measured, but the rest can still be based on general emission factor for the fuel/snap. Each point source consists of one or more parts of e.g. a power plant with several units.

In the year 2000 68 large point sources were included in the Danish emission inventory. The point sources were:

- Power plants and CHP plants (combined heat and power plants)
- Municipal waste incineration plants
- A few large industrial plants
- Petroleum refining plants
- One international airport

Fuel consumption of large point sources included in snap categories 01-03 is 306 PJ corresponding to 57% of the overall fuel consumption rate of stationary combustion plants.

Plant name of large point sources and corresponding PM emissions are shown in appendix 1.4 (only snap 01-03) together with the references of particulate emission data. Annual environmental reports of the plants often contain information of TSP emissions. Further some plant owners have informed about TSP emission on inquiry. In general emission data from annual environmental reports are based on emission measurements, but they can be calculated from general emission factors as well.

TSP emission of the largest ten point sources is stated in annual environmental reports of the plants or stated by plant owners. The PM_{10} and $PM_{2.5}$ emissions from the most important sources are not based on measurements but are calculated based on the TNO particulate size distribution (TNO CEPMEIP database, 2001).

2.5 Area sources

Fuel consumption not used on large point sources are included as sector specific area sources in the inventory. Plants like residential boilers, small district heating plants, small CHP plants and industrial plants are defined as area sources. Emission inventories of area sources are based on fuel consumption and emission factors given in appendix 1.1.

In general fuel consumption of the snap categories is stated with good accuracy whereas the emission factors can be very uncertain.

3 Provisional emission inventory of particulate emissions

3.1 Total

The provisional Danish emission inventory of TSP, PM_{10} and $PM_{2.5}$ is shown in Table A1-3. These emission data were reported to UN-ECE in the beginning of 2002. According to the reporting guidelines emissions from international air traffic and international bunkers should not be included. snap categories 01-03 include stationary combustion plants.

The emission source contributions are illustrated in Figure 1 – Figure 3. Only emission from stationary combustion plants, combustion in transport and automobile tyre and brake wear were included in the provisional inventory. As seen from the figures the particulate emission from transport is larger than from stationary combustion plants. The TSP and $PM_{2.5}$ emission from stationary combustion plants contribute with 18% and 31% of the total Danish emissions.

The emission inventory is shown on detailed snap level in appendix 1.2. In appendix 1.3 the emissions from combustion plants is further disaggregated to fuel level.

Table A1-3 Emission inventory year 2000, main snap categories

snap1	snap1 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	1588	1223	1009
02	NON-INDUSTRIAL COMBUSTION PLANTS	2330	2245	2130
03	COMBUSTION IN MANUFACTURING INDUSTRY	1217	801	660
Stationary combustion plants		5135	4269	3798
07	ROAD TRANSPORT	18647	18647	4346
08	OTHER MOBILE SOURCES AND MACHINERY	4357	4153	3959
Transport		23004	22800	8305
09	WASTE TREATMENT AND DISPOSAL	1	1	1
Total		28140	27070	12104

An improved emission inventory has been prepared in this project. Changes of emission factors are discussed in chapter 4.2-4.3 and the improved emission inventory is presented in chapter 5. The data presented in chapter 3 are based on the provisional emission inventory reported to UN-ECE in 2002.

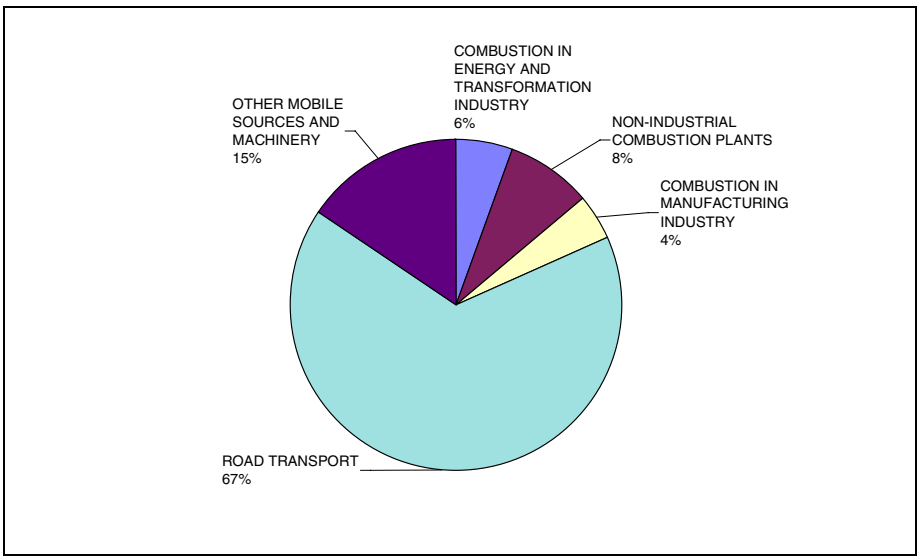

Figure A1-1 Emission of TSP, 2000

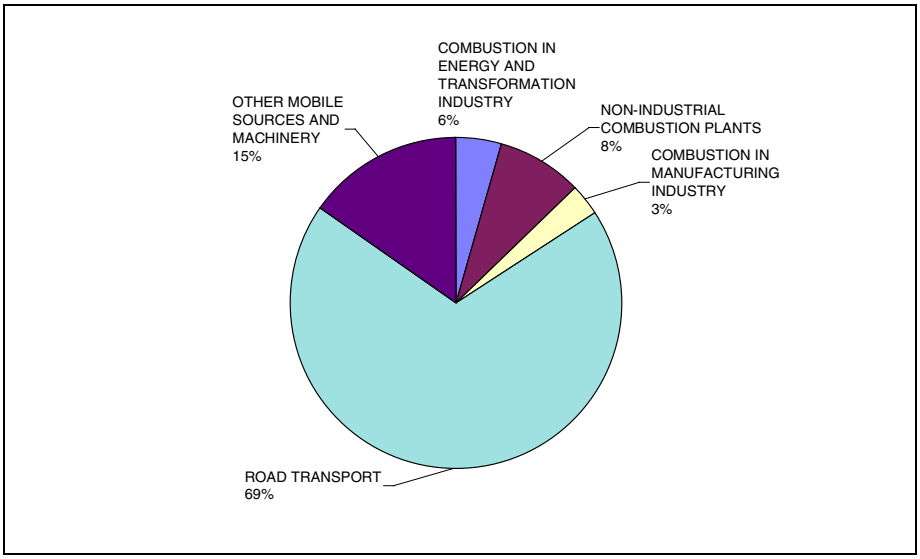

Figure A1-2 Emission of PM_{10}, 2000

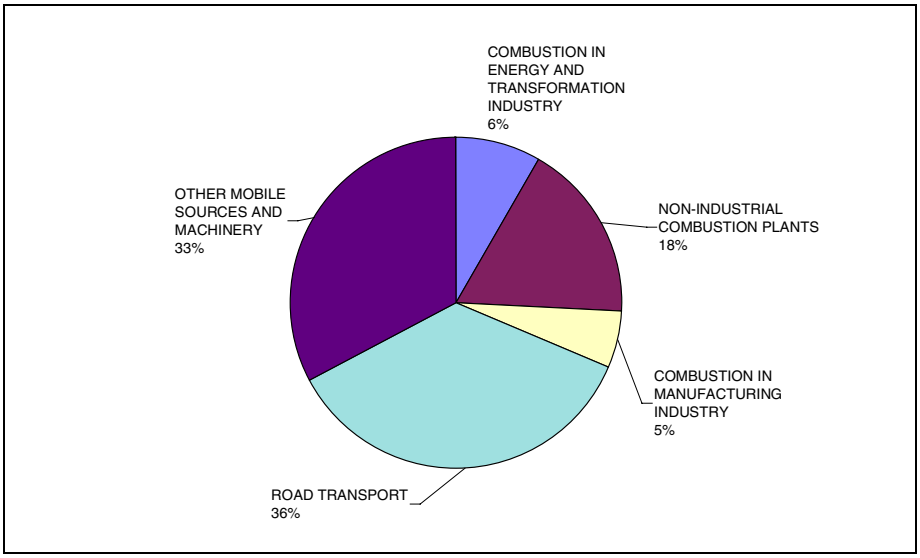

Figure A1-3 Emission of $PM_{2.5}$, 2000

3.2 Stationary combustion plants

Emission inventory of PM from combustion plants is shown on a more detailed snap level in Table A1-4 and in Figure A1-4 – Figure A1-6. The primary sources of emission are discussed in the following chapters. The most important sources are:

- Residential boilers and stoves (snap 0202)
- Public power plants (snap 0101)
- District heating plants (snap 0102)
- Manufacturing industry, combustion in boilers, gas turbines and stationary engines (snap 0301)

Table A1-4 Emission inventory of combustion plants year 2000, snap -2 level

snap1	snap1 name	snap2	snap2 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	910	859	705
		0102	District heating plants	676	361	301
		0103	Petroleum refining plants	0	0	0
		0104	Solid fuel transformation plants	0	0	0
		0105	Coal mining, oil / gas extraction, pipeline compressors	3	3	3
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	178	178	163
		0202	Residential plants	2017	1933	1837
		0203	Plants in agriculture, forestry and aquaculture	135	134	130
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	923	507	416
		0303	Processes with contact	294	294	244
Total			Stationary combustion plants	5135	4269	3798

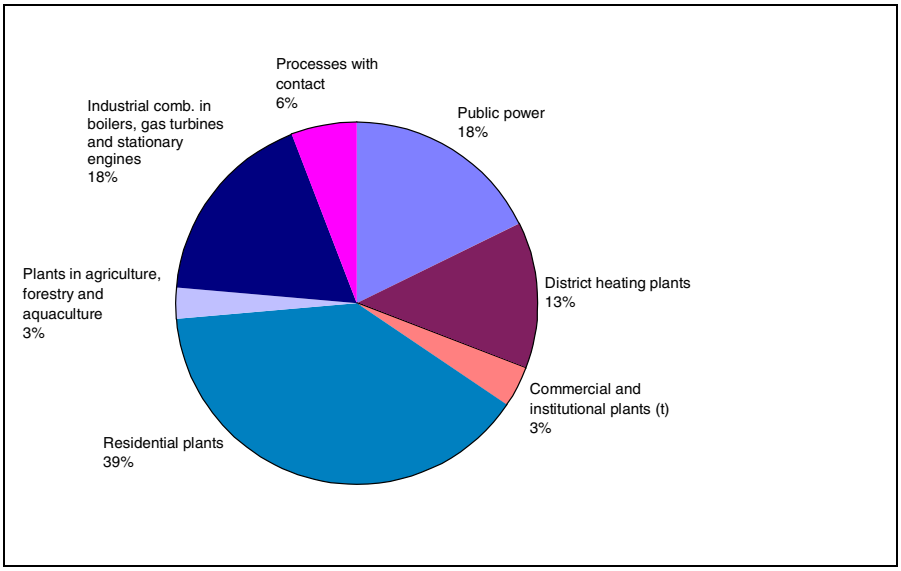

Figure A1-4 TSP emission of stationary combustion plants

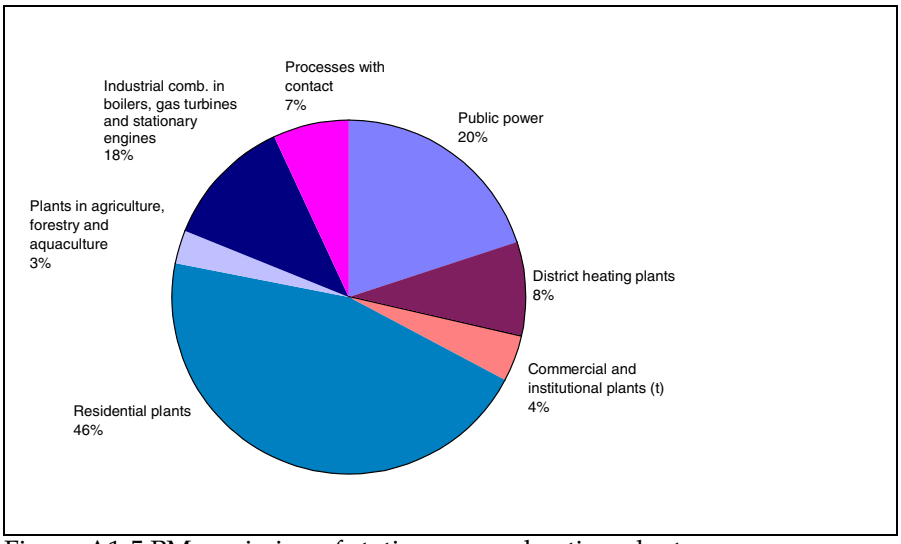

Figure A1-5 PM_{10} emission of stationary combustion plants

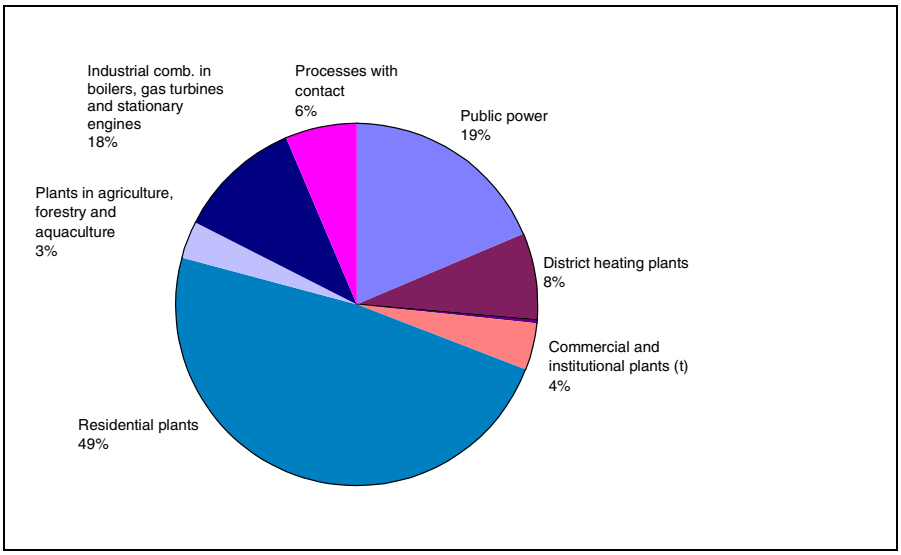

Figure A1-6 $PM_{2.5}$ emission of stationary combustion plants

3.2.1 Residential plants, snap 0202

Residential plants, snap 0202, include stoves and boilers using various fuels. These plants are the predominant source of particulate emission from stationary combustion plants. Figure A1-7 shows fuel consumption of residential plants and Figure A1-8 shows the emission share of each fuel. It appears that combustion of wood is the primary emission source in spite of the limited consumption of this fuel. Emission of $PM_{2.5}$ from wood burning residential plants makes up a total of 42% of emission from all stationary combustion plants in Denmark, however the accuracy of emission factors for residential wood combustion is low.

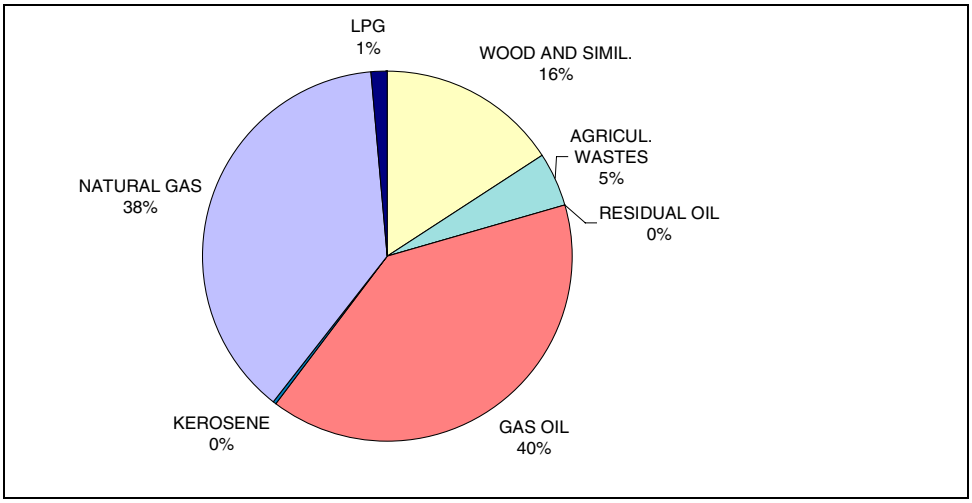

Figure A1-7 Fuel consumption of residential plants

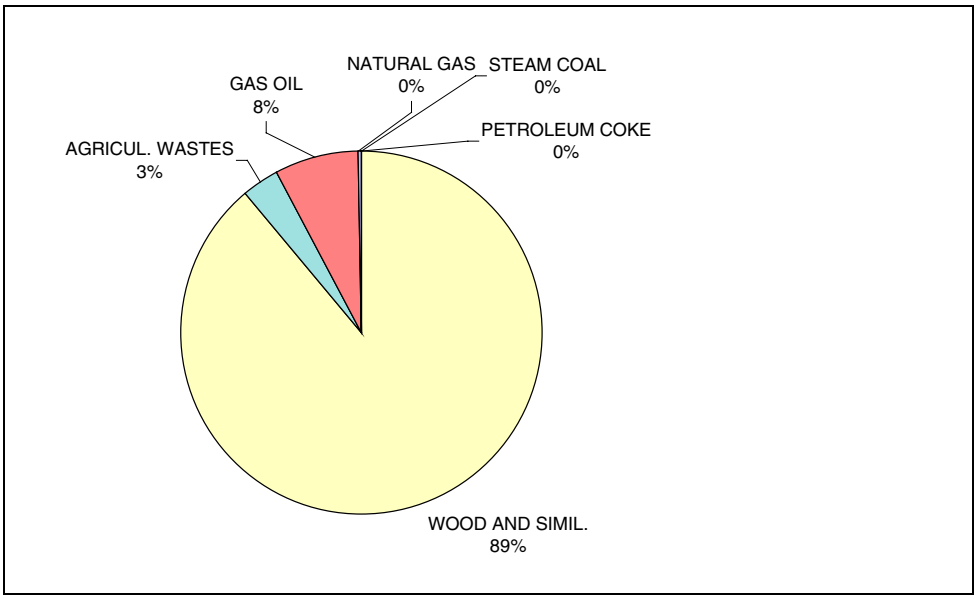

Figure A1-8 $PM_{2.5}$ emission from residential plants

3.2.2 Power plants and CHP plants, snap 0101

Emission of $PM_{2.5}$ from large power plants (>50MW) account for approximately 90% of the total emission from power plants and CHP plants (Figure A1-9). Measurements of TSP emission are usually available from power plants. In the inventories PM_{10} and $PM_{2.5}$ emissions are generally based on particulate size distribution of the fuel/snap stated by TNO.

Data from annual environmental reports of the power plants account for 86% of the TSP emissions from power plants/CHP plants. Thus emission of TSP is relatively well documented. The emission of PM_{10} and $PM_{2.5}$ is less accurate and improvements should focus on particulate size distribution.

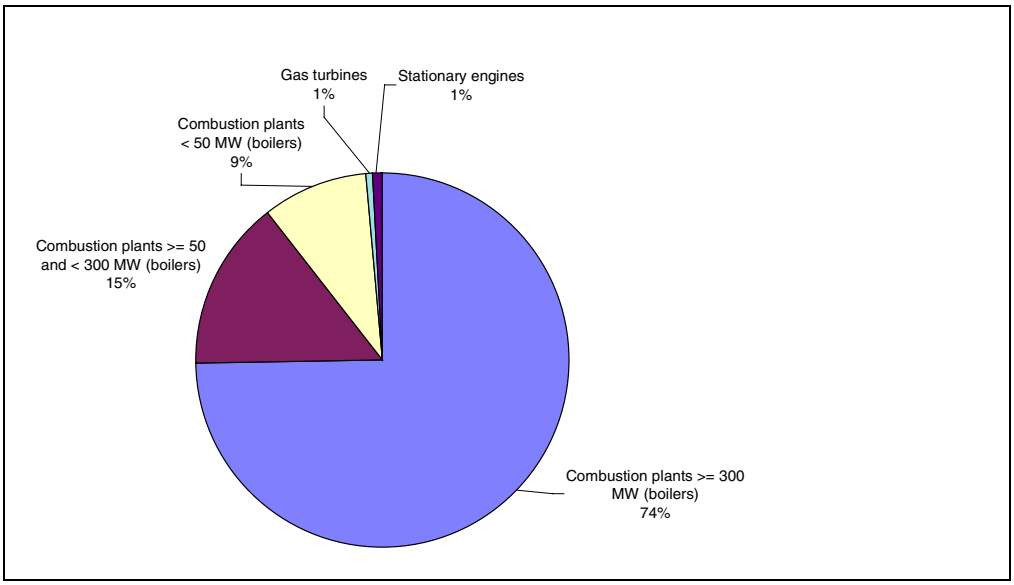

Figure A1-9 $PM_{2.5}$ emission from power plants and CHP plants snap 0101

In the annual environmental reports TSP emission is given as total for several fuels. Thus disaggregation of emission to fuel level have not been possible. The fuel consumption of power plants >50MW is shown in Figure A1-10. It appears that the coal share is 65%. The work was therefore focused on combustion of coal and orimulsion (other liquid fuel in Figure A1-10). PM emissions from natural gas combustion are low.

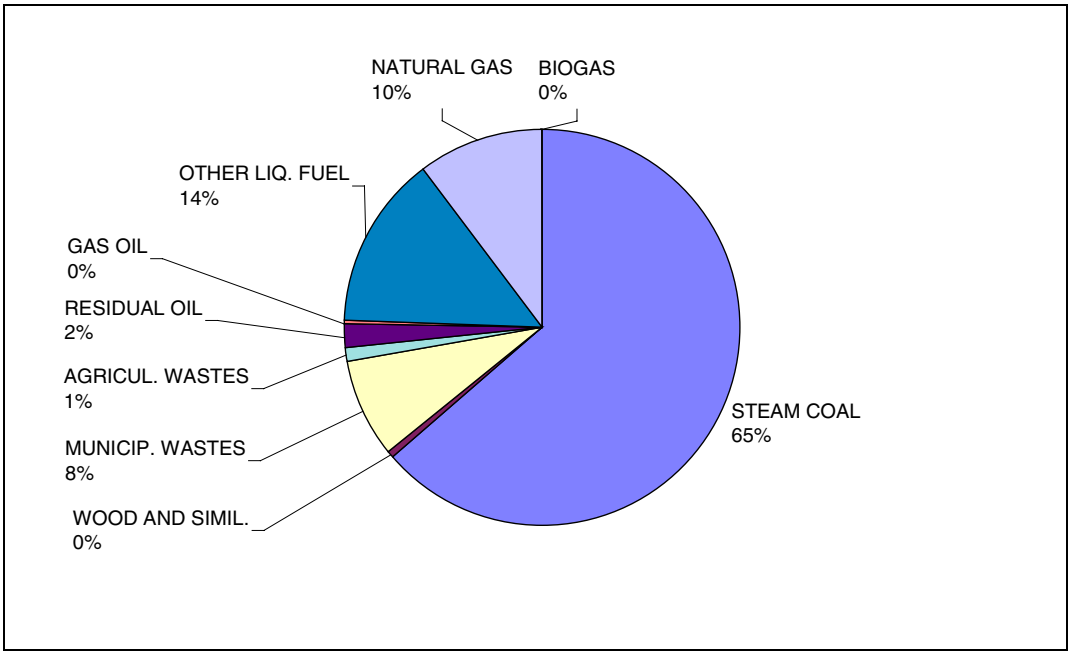

Figure A1-10 Fuel consumption of power plants > 50MW (snap 010101 and 010102)

3.2.3 Combustion in the manufacturing industry, snap 0301

Fuel consumptions of industrial boilers, gas turbines and stationary engines are shown in Figure A1-11 and in Figure A1-12 the emission share of each fuel is shown. As seen from Figure A1-12 wood and residual oil are the primary emission sources.

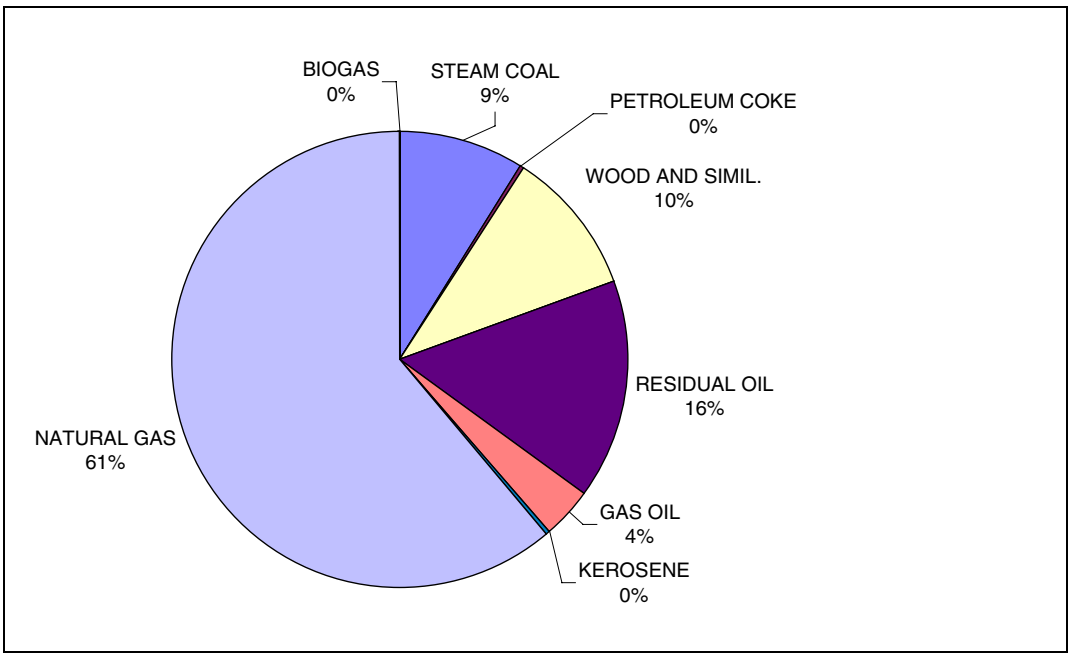

Figure A1-11 Fuel consumption in industrial boilers, gas turbines and stationary engines

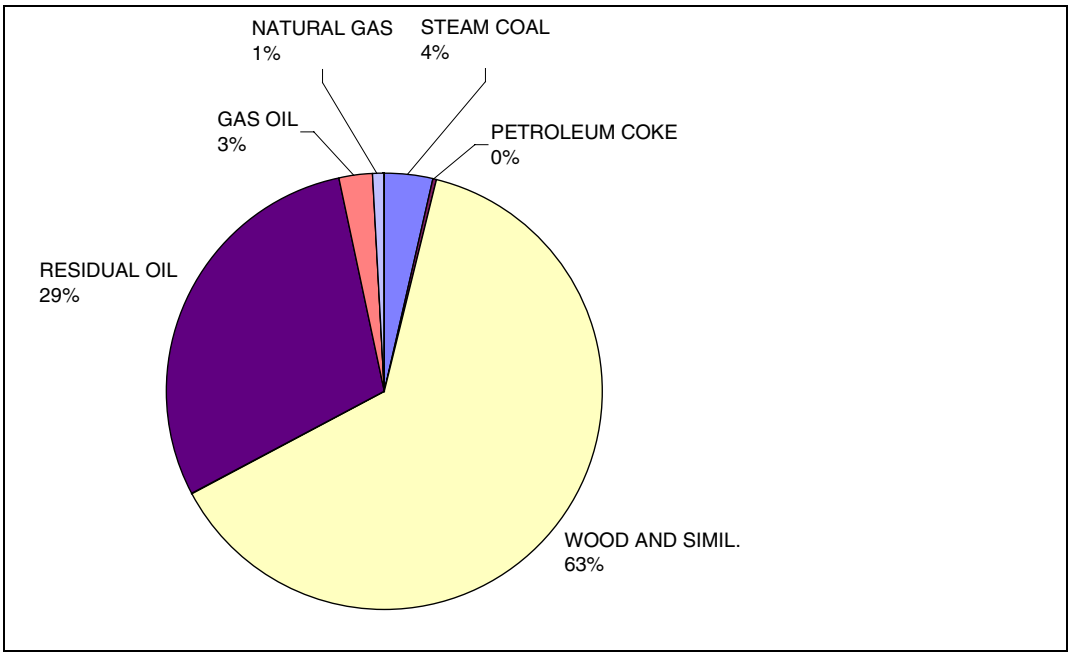

Figure A1-12 $PM_{2.5}$ emission from industrial boilers, gas turbines and stationary engines

3.2.4 District heating plants, snap 0102

More than 95% of the $PM_{2.5}$ emission from district heating plants was registered as area sources and was disaggregated to fuel level as shown in Figure A1-14. The primary emission sources were combustion of wood and straw (agricultural wastes in Figure A1-14).

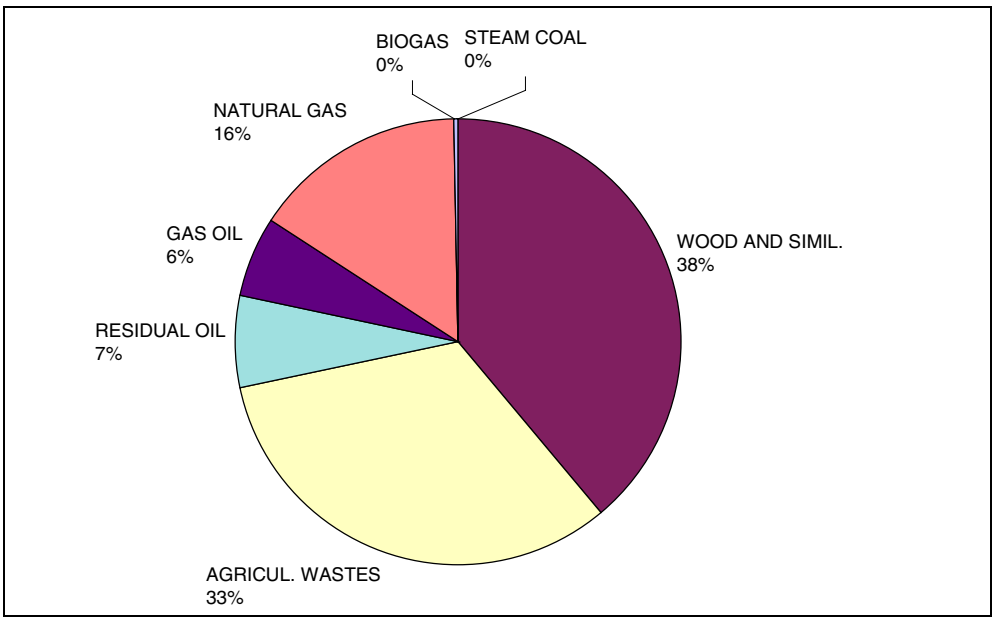

Figure A1-13 Fuel consumption in district heating plants (only area sources included)

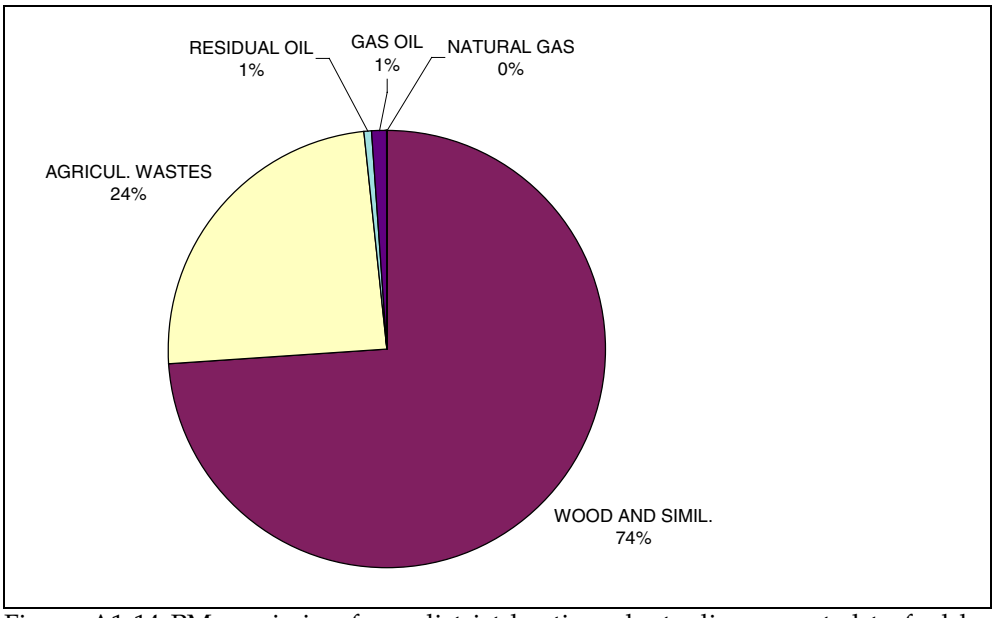

Figure A1-14 $PM_{2.5}$ emission from district heating plants disaggregated to fuel level (only area sources included)

3.2.5 Large point sources

The particulate emission from large point sources of stationary combustion is shown in appendix 1.4. The main sources are Aalborg Portland and Lynetten (sewage works). The emission from municipal waste incineration plants is remarkably low. PM emissions from the Danish Steel Works (Stålvalseværket) and the oil refineries were not included in the provisional inventory.

4 Data, references and improvements of inventory

Below data and references are evaluated for primary sources of PM emission. The data consists of energy statistics and emission factors. Emission measurements carried out on Danish plants are presented and compared to general emission factors. Furthermore a literature survey of the primary emission sources has been carried out focusing on TNO references and data from Scandinavian countries.

4.1 Energy statistics

The emission inventories are based on the official Danish energy statistics prepared by the Danish Energy Authority.

4.1.1 Firewood

The provisional inventory showed that combustion of firewood in stoves, fireplaces and residential boilers is a predominant emission source. Thus the accuracy of activity rate from the energy statistics has been considered. Firewood that has not been traded (private woodcutting) is considered to account for a considerable part of the total consumption of firewood. It is important that this part of the consumption is included in the energy statistics.

The Danish Energy Authority has stated that the consumption of firewood is calculated as described in the note *Firewood Statistics* written by dk-Teknik and Danish Energy Authority (Nielsen, & Evald, 2000). The method includes a qualified estimate of the share of the total consumption that is not traded. Each year Statistics Denmark publishes data concerning traded firewood. The total consumption is estimated to be three times this consumption. The factor 3 is determined from three independent questionnaires where the origin of firewood used in residential plants was examined. The data on consumption of firewood in residential plants from the energy statistics is thus uncertain but still it is the best estimate at present.

From the note Firewood Statistics:

- Firewood *production* in forestry is determined based on annual national agricultural statistics covering all forests above 50 hectares and a representative number of smaller forests
- Firewood *consumption* is calculated to be 3.0 times higher, based on an estimate that 1/3 of all consumers get their firewood from forestry and 2/3 from other sources The factor 3.0 is best estimate based on three telephone surveys covering consumer habits in the use of firewood.
- Using average figures for heating value per m^3 of wood for deciduous and conifer respectively and assuming, that firewood is used after natural drying to an average of 20% moisture, consumption in m^3 is calculated in TJ.
- All firewood is assumed used in private homes for heating purposes. Any minor use in other consumption categories is neglected.

4.1.2 Wood

The Danish energy statistics distinguish between firewood, wood waste, wood pellets and wood chips. In the inventories these fuels are aggregated and marked wood. If the emission factors differ considerably depending on wood category it might be desirable to disaggregate wood consumption in future inventories.

Figure A1-15 and Figure A1-16 show wood consumption and the consumption of each plant category, respectively. Breakdown of fuel consumption will only be relevant for district heating plants and CHP plants where consumption of several types of wood fuels are substantial.

Figure A1-15 Fuel consumption [TJ] of wood chips, firewood, wood pellets and wood waste

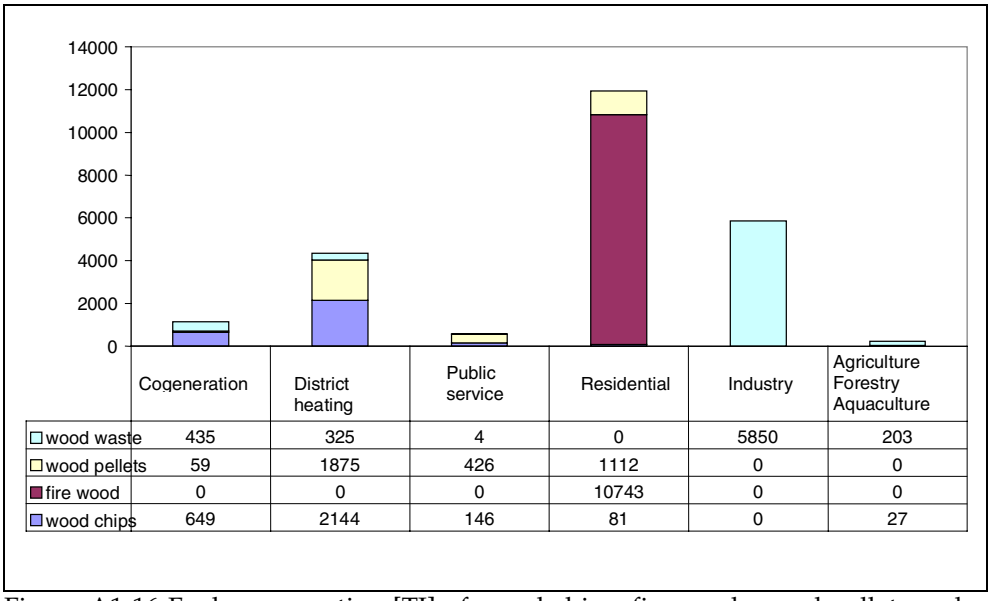

Figure A1-16 Fuel consumption [TJ] of wood chips, firewood, wood pellets and wood waste, different sectors and plants

4.2 Emission factors

The following two Danish research programmes can contribute to increase the quality of PM emission factors:

- Danish study of combustion aerosols from power plants (Livbjerg et al, 2001).
- Eltra PSO project (ongoing project, not yet reported) (Nielsen & Illerup, 2003)

In addition to the Danish research programmes further literature studies have been carried out. The literature studies focused on the sources that turned out to be the main emission sources in the provisional emission inventory. The sectors and fuels to be further discussed are:

- Wood, residential stoves and boilers
- Wood and straw, district heating plants and industrial plants
- Wood and straw, power plants and CHP plants
- Coal, power plants
- Orimulsion, power plants
- Municipal waste, CHP plants
- Residual oil, industry

The temporary emission factors refer partly to Danish emission legislation and emission measurements from Danish plants. Where data from Danish plants were not directly available emission factors from TNO were used instead.

4.2.1 Combustion aerosols from power plants, Danish study

The Danish study *Feltstudier af Forbrændingsaerosoler* by Livbjerg et al. (2001) included extensive measurements of particulate emissions from four Danish power plants:

- Enstedværket, fuelled with straw and wood chips, 40 MW_e , electrofilter (overdimensioned)
- Avedøreværket, fuelled with coal dust, 250 MW_e , electrofilter and desulphurization
- Asnæsværket, fuelled with orimulsion, 640 MW_e , electrofilter (overdimensioned) and desulphurization
- Nordjyllandsværket, fuelled with coal dust, 380 MW_e , electrofilter and desulphurization

The project report Livbjerg et al. (2001) states emission of TSP, PM_{13} and $PM_{2.5}$ (besides PM1). Below PM_{13} emission data are compared to emission factors of PM_{10}. Table A1-5 shows the results of the emission measurements. Revised emission factors for power plants are partly based on these measurements (see chapter 4.2.5-4.2.7) and all four emission factors are changed in the improved inventory. The modifications of orimulsion and coal emission factors are rather small, whereas the estimate of the emission factors for straw and wood are reduced considerably.

Table A1-5 Particulate emission from four Danish power plants

Plant name	TSP [g/GJ]	PM_{10} [1)] [g/GJ]	$PM_{2.5}$ [g/GJ]	PM_{10} [1)] fraction	$PM_{2.5}$ fraction
Enstedværket (straw and wood chips)	1,93	-	0,32	-	17%
Asnæsværket (orimulsion)	1,3-2,5	1,4-2,4	1,3-2,1	77-109%	71-94%
Avedøreværket (coal dust)	2,5-3,0	2,2-2,8	1,9-2,3	81-92%	66-78%
Nordjyllandsværket (coal dust)	2,6-5,0	2,5-3,1	1,8-2,7	64-90%	48-66%
Emission factors of provisional inventory:					
Straw[2)]	19	19	1	100%	5%
Wood[2)]	18	18	18	100%	100%
Orimulsion[2)]	3	3	2,5	100%	83%
Coal dust[2)]	6	6	5	100%	83%

1. Project data are PM_{13}
2. In the emission inventory TSP is taken from annual environmental reports of the plants. PM_{10} and $PM_{2.5}$ are calculates from the PM_{10} and $PM_{2.5}$ fraction of TSP. The general emission factors are included to compare the values.

4.2.2 Eltra PSO

A project funded by the electricity transmission system operator of western Denmark, Eltra, aims at improving emission factors for CHP plants <25 MW_e (Nielsen & Illerup, 2003). Emission factors are calculated from existing emission measurements and additional measurements performed

within the project. The work includes municipal waste CHP plants, biomass fuelled CHP plants, gas turbines and reciprocating gas engines. The results of the project have not been reported yet but some temporary results are shown in Table A1-6. Emission factors of the four plant types will be recalculated when the project has been finally reported. Until then the data from Table A1-6 are used as basis for the revised emission factors.

Table A1-6 Eltra PSO emission factors

Plant	TSP [g/GJ]	PM_{10} [g/GJ]	$PM_{2.5}$ [g/GJ]	PM_{10} fraction	$PM_{2.5}$ fraction
Municipal waste CHP plant	Electrofilter: 7-14 Filter bag: <7 1): 8-33	-	-	-	-
Biomass CHP plant, straw	Electrofilter: 5-10 Filter bag: <5 1): 39	-	-	-	-
Biomass CHP plant, wood chips	Electrofilter: 5-10 Filter bag: <5 1): 39	-	-	-	-
DMU emission factors provisional inventory:					
Municipal waste	6	5	4	83%	67%
Straw	19-21	19-21	1-21	100%	5-100%
Wood chips	18-143	18-70	18-55	49-100%	38-100%

1. Measurements that are not within general emission level

4.2.3 Emission factors for residential wood fired boilers, stoves and fireplaces

Combustion of wood in the domestic sector is an important source of PM emission. It is well known that the emission inventories are quite uncertain because it is difficult to estimate standard emission factors from measurements as the emissions from stoves and domestic boilers very much depend on the combustion conditions and technologies. There are about 300.000 stoves in Denmark and 70.000 small-scale boilers using wood (Serup et al., 1999). Furthermore there are some open fireplaces. Other types like baking ovens can be neglected in Denmark. No statistical survey on the types of stoves used in Denmark is available but almost all stoves are either conventional or non-catalytic stoves (Bjerrum, M., 2002). As seen from Figure A1-16 the dominant wood type used in the domestic sector is firewood. About 10% of the wood are pellets mostly used in small boilers with automatic fuel feeding systems. As mentioned the emission factors of PM from domestic wood fired stoves and boilers are inaccurate. Emission factors of various references and the basis of the factors are presented below.

Scandinavia

Table A1-7 shows the emission factors for wood stoves and boilers used in the official emission inventory reports of Denmark, Finland and Norway (Sternhufvud et al., to be published in 2003).

Denmark

As seen from Table A1-7 the TNO emission factors are used for both stoves and boilers in the Danish PM emission inventory 2000 (TNO CEPMEIP database, 2001). TNO recommends emissions factors in the interval 150 to 300 g/GJ. In the calculation of the PM emission from Denmark TNO use the emission factor 150 g/GJ for combustion of wood whether it is combusted in e.g. an institutional boiler or a residential stove. The emission factor 300 g/GJ is only used for countries where the general emission level is expected to be high. TNO has determined the emission factors from a literature survey discussed later.

The only measurements carried out in Denmark are measurements in laboratory when stoves are approved. These laboratory emission measurements have been carried out since 1995. The measurements were carried out with a wood consumption rate of 1,6 kg/hour and the emission factor was estimated to be 30 g/GJ. At present no emission measurements are being planned in

Denmark but emission measurements in residential areas with many stoves are to be carried out by the end of 2002.

Finland
There are about 1.000.000 small-scale wood burning devices in Finland. The fuel used is predominantly firewood (logs). The amount of pellets used in the domestic sector is increasing.

In the official emission report for 2000 an emission factor for TSP of 400 g/GJ is used based on a literature survey. Some types of small boilers and stoves were measured in the early 1980s by Hahkala et al. (1986). The emissions were highly variable and there were lots of technical measuring problems, especially with condensable PM. The emission factors were estimated to be in the range of 100 g/GJ to 1300 g/GJ. The most important types of stoves in Finland are: Masonry heaters (stoves, made of stones/bricks, that accumulates the produced heat, batch fed, used often as a supplementary heating device), pellet heating stoves, stoves for saunas, masonry ovens (used for baking, mainly in the countryside), kitchen and iron stoves (used for cooking and heating purpose in small recreational buildings), open fireplaces (used primarily for aesthetic effects).

A new 3-year project *Fine particle emissions from wood combustion* started early 2002. Several types of small combustion devices will be investigated in the project. The results will be available during 2003 or 2004.

Norway
About 57% of Norwegian households have stoves installed. The 89% of the stoves are conventional stoves, 7% are either catalytic stoves or stoves with other emission reduction technology and 4% are open fireplaces. The dominant wood type used in the domestic sector is firewood. However, a survey based on a questionnaire have shown that also other types of fuels than wood is used, for instance newspapers, cardboard, and milk cartons (Haakonsen and Kvingedal, 2001). These fuel types are not included in the Norwegian inventory (Haakonsen and Kvingedal, 2001).

Norwegian measurements have shown that emissions of particles strongly depend on the wood load (kg wood/hour). Figure A1-17 shows the emission of PM for various combustion technologies as a function of average wood consumption. It is seen that the PM emission increases dramatically when the consumption rate of wood decreases. It is also seen that the emissions are significantly lower for laboratory and catalytic stoves. Investigations show that a typical load in Norway is 1,0 to 1,25 kg wood/hour resulting in a PM emission of about 40 g/kg wood for conventional stoves (from before 1998) or 2105 g/GJ (assuming a lower heating value of 19 GJ/tonnes of dry wood). The recommended emission factors for open fireplaces and new stoves are 911 g/GJ and 326 g/GJ, respectively. The average PM_{10} emission factor is 1932 g/GJ. Since the emission factor strongly depends on the wood consumption Haakonsen and Kvingedal (2001) recommend that further investigation should be carried out in order to determine the typical wood consumption rate for residential stoves. It is stressed that the emissions factor is quite uncertain.

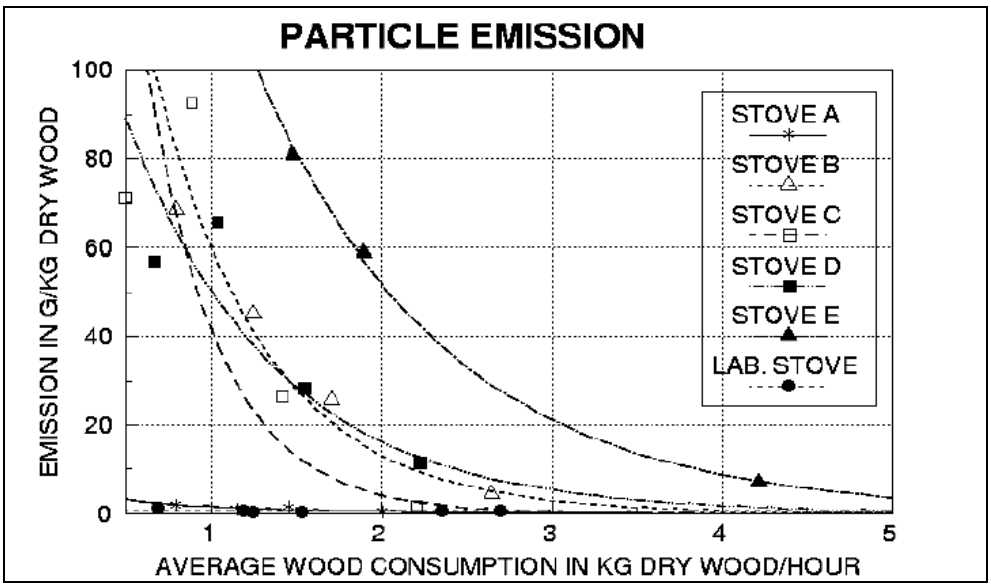

Figure A1-17 PM emission of 6 wood fired stoves. Dependency of wood consumption rate. A: Catalytic stove, B-D: old stoves, E: Open fireplace (Haakonsen and Kvingedal, 2001).

TNO

In 2001 TNO prepared the emission inventories of 1995 for the whole UN-ECE/EMEP region. As part of this work an extensive literature survey was carried out to determine emission factors for different sectors and plants. Emission factors were stated for each fuel and snap and for four levels of technologies. Which emission factors should be used depend on the level of plant regulation and flue gas cleaning. In the TNO inventory for Denmark the lowest emission factor is always used and the provisional Danish inventory is therefore based on the lowest emission factor of TNO as well.

The TNO emission factors for non-industrial wood combustion are 150-300 g/GJ and the emission factor of 150 g/GJ is used for institutional boilers as well as for residential stoves.

References of TNO emission factors for wood are shown in Table A1-8. As it appears from the table emission factors of the TNO references differ very much. Most TNO references are literature surveys themselves.

Other emission factors

Other references of residential wood combustion are shown in Table A1-9.

Spitzer et al. (1998) describes an extensive emission measurement work carried out in 1997-98 in Austria. Measurements were carried out on a total of 180 coal and wood fired plants. The random sampling of residential wood combustion (stoves, boilers, fireplaces and tiled stoves) counted 28 plants. Measurements were carried out during a full cycle starting with firing and ending when the fire burning out resulting in tests of 2-4 hours. Emission measurements of particles were carried out as ongoing ½ hour tests. The plant owners themselves lit the fire and they were asked to do this in the same way they always did. The plant owners informed about the yearly firewood consumption of their residential plants. Emission factors for residential wood burning stoves, fireplaces, boilers etc was estimated to be 148 g/GJ (80-217 g/GJ). The number of measurements was insufficient to calculate separate emission factors for stoves, fireplaces etc.

Emission factor outline

Table A1-7 Emission factor for residential wood combustion, Scandinavian inventories

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
Denmark	[1]	150	143	135
Finland	[2], [3]	400	400	384
Norway	Average [4]	1932	1932	-
	Traditional stoves	2105	2105	-
	New stoves (catalytic or other emission reduction)	326	326	-
	Fireplaces	911	911	-

1. TNO, http://www.air.sk/tno/cepmeip/
2. Statistics Finland (roughly estimated the emission factor based on literature)
3. The PM_{10} /TSP and $PM_{2.5}$/TSP fractions are taken from Karvosenoja (2000). Primary particulate emissions from stationary combustion processes in Finland.
4. Haakonsen and Kvingedal, 2001.

Table A1-8 Emission factor for residential wood combustion, TNO references

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
TNO CEPMEIP database [2]	Non-industrial plants (snap 02)	150-300	143-285	135-270
Karvosenoja [1]	Literature survey.			
	TNO states	1250	-	1200
	Kitchen stoves, open hearths, iron stoves	1000	1000	960
	Baking ovens, accumulation stoves, stoves for sauna	300	300	288
	Modern accumulating stoves, heating boilers	100	100	96
	Modern heating boilers	30	30	29
CITEPA [4]		500	175	105
Dreiseidler [5]	Literature survey.			
	Residential, UBA 1998	-	90%	-
	Firewood, UBA 1989	200	-	-
	Firewood/wood waste, UBA 1998	200	-	-
	Firewood/wood waste, STALA 1996	200	-	-
	Open fireplace, EPA 1998	1330	100%	-
	Stove, EPA 1998	1176	100%	100%
	Stove, Rau 1989		-	90%
WESP [6]	-	333	~250	-
	-	208	~156	-
	-	750	~563	-
Spitzer [3]	-	90	-	-
	-	148	148	148
REMUS [7]	-	-	100%	96%

1. Emission factors based on literature survey by Karvosenoja (2000).
2. TNO CEPMEIP database, 2001.
3. Spitzer et al., 1998.
4. CITEPA, 2000.
5. Dreiseidler et al., 1999.
6. WESP, Dutch Emission Registration, 1999.
7. Remus, 2000.

Table A1-9 Emission factor for residential wood combustion, Other references

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
Certified boilers	Boilers [1]	143	-	-
Danish Technological Institute, Laboratory tests	Stoves [2]	30	-	-
Danish Technological Institute, Laboratory tests	Boilers [3]	15	-	-
Spitzer [4]	Measurements of 28 units Residential	148 (80-217)	-	-
Johansson [6]	Stoves	-	-	95 (7-190)
Gaegauf [5]	Stove, firewood	70	-	-
	Accumulating oven, wood	167	-	-
	Boiler, firewood	28	-	-
	Boiler, wood pellets	20	-	-
	Stove, wood pellets	54	-	-
	Boiler, dry wood chips	94	-	-
	Boiler, wet wood chips	48	-	-
	Boiler, wood chips	64	-	-

1. TSP 300 mg/m_n^3
2. Danish Technological Institute has data of TSP emission from laboratory test of stoves. Stoves are tested for certification. Emissions from stoves are 19,2-48,9 g/GJ, average of approximately 30 g/GJ (Lars German, 2002).
3. Danish Technological Institute has data of TSP emission from laboratory test of boilers. Emission of TSP from boilers of 10-30 kW (most residential wood fired boilers) is approximately 35 mg/m_n^3 at 10% O_2 (Lars German, 2002)
4. Spitzer et al, 1998
5. Gaegauf et al., 2002.
6. Johansson et al., 2001

Emission factors for residential wood combustion have not been changed so far. The emission factors are: TSP 150 g/GJ, PM_{10} 143 g/GJ and $PM_{2.5}$ 135 g/GJ. The emission factors from TNO are confirmed among others by Spitzer et al. (1998) that includes a considerable number of field tests. However several other references indicate that the Danish emission factor is in the lower end of the interval. For instance the Norwegian emission factor is more than 10 times the Danish factor.

In the revised emission inventory emission of wood fuelled residential stoves and boilers counts for 40% of the emission from stationary combustion plants. This corresponds to 13% of the total Danish emission of $PM_{2.5}$. Further study of the emission factor for wood fired residential plants is important to improve the quality of the total PM emission inventory for Denmark. Further work including field test emission measurements and surveys of fuelling habits and plant types will contribute to increase quality. Increased knowledge of particle size distribution is also desirable.

4.2.4 Emission factors for wood and straw, district heating plants and industrial boilers

Combustion of wood and straw has turned out to be the primary sources of emission from district heating plants (with no power production). Several types of wood are combusted in district heating plants: wood chips, wood pellets and a negligible part of wood waste.

The same PM emission factors were used for wood combusted in district heating plants and industrial boilers. Likewise the same emission factors were used for straw combusted in district heating plants and industrial boilers. This practice will be used in future inventories as well. Emission factors refer to PM emission measurements on district heating plants.

Wood chips

Wood chips are combusted in boilers of 1-10 MW with an average of 3,5 MW (Serup et al., 1999). On most plants flue gas cleaning consists of multicyclon that reduces TSP emission to approximately 200 mg/m_n^3 (app. 100 g/GJ). Most plants are further equipped with a flue gas-condensing

unit, which further reduce the TSP emission to 10-50 g/GJ. Emission data from wood chip fired CHP plants are not comparable with district heating plants (with no power production) because unlike district heating plants CHP plants are usually equipped with filter bags.

Various references on emission factors from district heating plants are shown in Table A1-10. All district heating plants using wood chips are >1 MW. The legislation emission value of plants larger than 1 MW is thus a reasonable emission factor of TSP. This emission factor is in accordance with two Danish reports Serup et al. (1999) and Miljøstyrelsen (1997). Emission factors of PM_{10} and $PM_{2.5}$ are determined from particulate size distribution stated by TNO.

Table A1-10 Emission factors for wood chips, district heating plants

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory	District heating plant <50MW	143	70	55
DMU provisional inventory	District heating plant >50MW	18	18	18
DMU new factor	All plant sizes	19	13	10
Legislation: Luftvejledningen [5]	120kW-1MW	143	-	-
Legislation: Luftvejledningen [5]	1MW-50MW	19	-	-
Legislation: Luftvejledningen [5]	1MW-50MW Flue gas condensing	48	-	-
Legislation: Bekendtgørelse om store fyringsanlæg [6]	> 50MW	18	-	-
Træ til energiformål [4]	Wood chips, multicyclon [1]	143 (95-191)	-	-
	Wood chips, flue gas condensing [2]	24 (9-43)	-	-
Fyring med biomasserest-produkter [7]	Wood chips, multicyclon and flue gas condensing [3]	10-30	-	-
	Wood chips, multicyclon without flue gas condensing	80-160	-	-
Eltra PSO	CHP, electrofilter	5-10	-	-
	CHP, filter bag	<5		
TNO	Public power	100	70	55

1. Converted from 300 mg/ m_n^3. at 10% O_2
2. Converted from 50 mg/ m_n^3. at 10% O_2
3. District heating plants with multicyclon and flue gas condensing. Interval of 8 plants. Videncenter for Halm og Flisfyring 1994.
4. Serup et al., 1999
5. Miljøstyrelsen, 2001.
6. Miljøministeriet, 1990.
7. Miljøstyrelsen, 1997.

Wood pellets

Emission factors for district heating plants using wood pellets are shown in Table A1-11. There are approximately 40 district heating plants using wood pellets in Denmark. The average plant size is 6 MW and only 6 plants are less than 1 MW. No emission measurements seem to be reported from wood pellet fired district heating plants and it is therefore reasonable to use the legislation emission factor of TSP for plants >1MW.

Table A1-11 Emission factors for wood pellets, district heating plants

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory	District heating plant <50MW	143	70	55
DMU provisional inventory	District heating plant >50MW	18	18	18
DMU new factor	All plant sizes	19	13	10
Legislation: Luftvejledningen [1)]	120kW-1MW	143	-	-
Legislation: Luftvejledningen [1)]	1MW-50MW	19	-	-
Legislation: Luftvejledningen [1)]	1MW-50MW Flue gas condensing	48	-	-
Legislation: Bekendtgørelse om store fyringsanlæg [2)]	> 50MW	18	-	-
TNO	Public power	100	70	55

1. Miljøstyrelsen, 2001.
2. Miljøministeriet, 1990.

Straw

In Denmark 58 district heating plants combust straw. The plant size is 0,6-9 MW (Nikolaisen et al., 1998). Different flue gas cleaning systems are used on the plants, but most common is a multicyclon followed by a filter bag (Nikolaisen et al., 1998). Flue gas cleaning is necessary to meet legislation in Luftvejledningen for plants >1 MW. Only 3 plants have a heat capacity of less than 1MW. Emission factors for straw fired district- heating plants are shown in Table A1-12 and a TSP emission factor of 21-40 g/GJ seems reasonable. The TSP emission factor 21 g/GJ is chosen because the reported emission measurements from Danish plants are rather old and the plants are assumed to meet current legislation. Emission factors of PM_{10} and $PM_{2.5}$ are calculated from particulate size distribution of wood combustion on power plants stated by TNO. This particle size distribution is not documented for straw combustion.

Table A1-12 Emission factors for straw, district heating plants

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory		19-21	19-21	19-21
DMU new factor		21	15	12
Legislation: Luftvejledningen [3)]	Plants >1MW	21	-	-
Legislation: Bekendtgørelse om store fyringsanlæg [4)]	Plants > 50MW	19	-	-
Halm til energiformål [2)]	Plants with filter bag [1)]	40 (3-100)	-	-

1. Emission measurements on several Danish district heating plants 1987-1993
2. Nikolaisen et al., 1998
3: Miljøstyrelsen, 2001.
4. Miljøministeriet, 1990.

4.2.5 Emission factors for wood and straw, power plants and CHP

Power plants combusting straw and wood (chips) are all equipped with electrofilters or filter bags (Serup et al., 1999 and Nikolaisen et al., 1998). Different emission factors for straw and wood combustion on power plants are shown in Table A1-13. It appears that the temporary emission factors are too high.

Based on annual environmental reports of four Danish plants a TSP emission factor of 4-13 g/GJ is calculated. The electrofilter of the plant Enstedværket is over-dimensioned, thus the particle size distribution of this plant could differ from other biomass power plants.

So far a TSP emission factor of 8 g/GJ will be used for all power plants and CHP plants without regard to plant size. The Eltra PSO project will increase the knowledge of emissions from CHP plants and of particle size fractions. Until the results of this work are available particle size distribution is assumed to follow the TNO distribution of wood used in power plants: PM_{10} 70% of TSP and $PM_{2.5}$ 55% of TSP.

Table A1-13 Emission factors for wood and straw, power plants and CHP

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory	Power plants 50-300MW, wood	18	18	18
	Power plants <50MW, wood	143	70	55
	Power plants 50-300MW, straw	19	19	1
	Power plants <50MW, straw	21	21	21
DMU new factor	All power plants, wood and straw	8	6	4
Legislation: Luftvejledningen [3]	Wood, 120kW-1MW	143	-	-
Legislation: Luftvejledningen [3]	Wood, 1MW-50MW	19	-	-
Legislation: Luftvejledningen [3]	Straw, 1MW-50MW	21	-	-
Legislation: Luftvejledningen [3]	Wood, 1MW-50MW Flue gas condensing	48	-	-
Legislation: Bekendtgørelse om store fyringsanlæg [4]	Wood	18	-	-
Legislation: Bekendtgørelse om store fyringsanlæg [4]	Straw	19	-	-
Feltstudier af forbrændings-aerosoler [2]	Enstedværket Straw and wood, power plant	1,93	-	0,32 17%
Eltra PSO [6]	Straw, CHP	Electrofilter: 5-10 Filter bag: <5	-	-
Eltra PSO [6]	Wood chips, CHP	Electrofilter: 5-10 Filter bag: <5 [1]: 39	-	-
Karvosenoja [5]	Wood, power plants	9,7	8,2	4,0
TNO [7]	Wood, public power	100	70	55

1. Measurements that are not within general emission level
2. Livbjerg et al., 2001
3. Miljøstyrelsen, 2001.
4. Miljøministeriet, 1990.
5. Karvosenoja, 2000.
6. Jacobsen, 2002.
7. TNO CEPMEIP database, 2001

4.2.6 Emission factors for coal, power plants

The emission factors for power plants combusting coal are shown in Table A1-14. The emission measurements on Danish plants are somewhat lower than the TNO emission factors of efficient flue gas cleaning.

Based on TSP emissions from eight Danish power plants an emission factor of 2,8 g/GJ was calculated. This supports the emission factors measured on two Danish plants.

TNO refers to numerous sources but for *power plant*s, *high abatement* and *hard coal* the 55 data set all refer to Dreiseidler et al. (1999).

A new TSP emission factor of 3 g/GJ was determined based primarily on measurements on Danish plants and annual environmental reports of Danish plants. Emission factors of PM_{10} and $PM_{2.5}$ were

determined from particle size distribution from the emission measurements on Danish plants (Table A1-14). Thus emission factors of PM_{10} and $PM_{2.5}$ are 2,6 g/GJ and 2,1 g/GJ respectively.

Table A1-14 Emission factors for coal, power plants

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory		6	6	5
DMU new factor		3,0	2,6	2,1
Feltstudier af forbrænding-saerosoler [3]	Avedøreværket	2,5-3,0	2,2-2,8	1,9-2,3
	Nordjyllandsværket	2,6-5,0	2,5-3,1	1,8-2,7
TNO CEPMEIP database [4]	low	6	6	5
	medium	35	25	12
	medium high	140	70	17
	high	510	180	40
Dreiseidler [6] referred by TNO [2] [4]	high abatement	1,3-15 average: 6	0,9-10 average: 4,4	0,4-5,3 average: 2,3
Karvosenoja [1] [5]	Power plant with electrofilter	33,7	31,5	10,8
	Power plant with electrofilter and desulphurization/filter bag	10	8,9	2,7

1. Calculation based on emission level without flue gas cleaning and assumed flue gas cleaning efficiency of TSP, PM_{10} and $PM_{2.5}$
2. 56 data set from Dreiseidler[6] as referred by TNO
3. Livbjerg et al., 2001
4. TNO CEPMEIP database, 2001
5. Karvosenoja, 2000.
6. Dreiseidler et al., 1999.

4.2.7 Emission factors for orimulsion, power plants

Combustion of orimulsion only takes place at Asnæsværket, unit 5. The emission factor used in the provisional inventory is the residual oil emission factor. Emission measurements from Asnæsværket unit 5 are shown in Table A1-15 and the emission factors will be changed using the emission measurement results instead. PM_{10} and $PM_{2.5}$ fractions are 93% and 83% respectively.

Table A1-15 Emission factors for orimulsion, power plants

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory		3	3	2,5
DMU new factor		1,9	1,8	1,6
Feltstudier af forbrændingsaerosoler [1]	Asnæsværket	1,3-2,5	1,4-2,4	1,3-2,1
TNO	Data of residual oil	3	3	2,5

1. Livbjerg et al., 2001

4.2.8 Emission factors for municipal waste, CHP plants

Municipal waste incineration plants are equipped with efficient flue gas cleaning and are thus a limited emission source of PM. The temporary emission factors are similar to the emission factors from the Eltra PSO project reported so far. In the year 2000 65% of municipal waste was incinerated on plants with filter bag flue gas cleaning. Based on the Eltra PSO temporary results a TSP emission factor of 6 g/GJ seems reasonable.

The temporary emission factor of TSP from municipal waste incineration was based on a calculation of average emission from a large number of Danish plants. The particle size distribution was unknown but the PM_{10} and $PM_{2.5}$ fractions were assumed to be 85% and 70% of TSP. The Eltra PSO project will give a better knowledge of particle size distribution.

Table A1-16 Emission factors for municipal waste incineration, CHP plants

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory		6	5	4
DMU new factor		6	5	4
Eltra PSO	Electrofilter: 5-10 Filter bag: <5 [1]: 6-41		-	-

1. Emission measurements that differ from the general level

4.2.9 Emission factors for residual oil, industry

The emission factors for the industrial combustion of residual oil are shown in Table A1-17. TNO refers to a large number of sources concerning emissions from residual oil combustion. In the Danish inventory the plant size of industrial combustion of residual oil is often unknown. The temporary emission factor for plants <50MW refer to the legislation, however, compared to the TNO data this emission factor is high and the emission factor will therefore be changed to 14 g/GJ independent of plant size. PM_{10} and $PM_{2.5}$ emission factors are also changed and the particle size distribution will be based on TNO data. The same particle size distribution will also be used for non-industrial plants.

Table A1-17 Emission factors for residual oil, industry

Reference	Comment	Emission factor		
		TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
DMU provisional inventory	Plant size unknown	14	14	14
	Boilers >50MW	14	12	10
	Boilers <50MW	47	40	10
DMU new factor	All boilers	14	10,5	7
TNO CEPMEIP database [2]	low	20	15	10
	medium	60	50	40
	medium high	60	50	40
	high	240	190	130
Legislation: Luftvejledningen [3]	Boilers 2-50MW	47	-	-
Legislation: Bekendtgørelse om store fyringsanlæg [4]	Boilers > 50MW	14	-	-
Dreiseidler [7]	Boilers, Lützke 1987	3,3	92%	76%
	Boilers, UBA 1989	30		
	Boilers <1MW, Stala 1996	34,1		
	Boilers, EPA 1998	238	86%	56%
	Boilers multicyclon, EPA 1998	48	95%	22%
		1,5		
	Boilers, UBA 1989	4,7	50%	12%
	Boilers, EPA 1998		90%	
	Boilers, UBA 1998			
BUWAL [9]	[1]	24	-	-
REMUS [8]	[1]	16,5	15,8	12,3
CITEPA [6]	Boilers >300MW [1]	2,9	2,2	1,7
Karvosenoja [5]	Industrial plants, cyclone	12,3	11,8	9

1. Data referred by TNO
2. TNO CEPMEIP database, 2001
3. Miljøstyrelsen, 2001
4. Miljøministeriet, 1990
5. Karvosenoja, 2000.
6. CITEPA, 2000.
7. Dreiseidler et al., 1999.
8. Remus, 2000.
9. BUWAL, 1995.

4.2.10 Other emission factors

Though the Eltra PSO project results are not reported yet it is evident that the emission factor for natural gas fuelled engines is to low, due to lube oil emission. The emission from this source will be included in the emission factor for natural gas used on gas engines when the results from the Eltra PSO project is available but until then the emission factor is not changed.

The TSP emission factor for combustion of coal in the industry refers to legislation whereas the emission factors of PM_{10} and $PM_{2.5}$ refer to TNO. The particle size distribution indicated by the temporary emission factors is however misleading and instead emission factors of PM_{10} and $PM_{2.5}$ are calculated from particle size distribution stated by TNO. The revised emission factors are: TSP 17 g/GJ, PM_{10} 12 g/GJ and $PM_{2.5}$ 7 g/GJ. The same emission factors will be used for non-industrial plants (snap 02).

The TSP emission factor for residual oil combusted in power plants and district heating plants also refers to legislation. The emission factors are considerably higher than the TNO emission factors and are also high compared with emission factors for coal combusted on the same plants using the same flue gas cleaning. Thus the TSP emission factor is changed to follow the TNO emission factor of 3 g/GJ (snap 0101 and 0102).

The temporary TSP emissions factor (19 g/GJ) for farmhouse boilers combusting straw refers to legislation of larger boilers. Farmhouse boilers can obtain certification if TSP emission is less than 600 g/m_n^3 (dry) at 10% O_2 corresponding to 312 g/GJ. The Danish Technological Institute has estimated the emission to be 300-600 g/m_n^3 (dry) at 10% O_2 during laboratory tests. This corresponds to approximately 234 g/GJ. Measurements on Danish plants before 1990 show emission factors of approximately 400 g/GJ (Jensen, 1990). The TSP emission factor is changed to 234 g/GJ. The PM_{10} and $PM_{2.5}$ emission factors are calculated based on TNO particle size distribution of residential wood burning.

The emissions from the refineries and the Danish Steel Works (Stålvalseværket) were not included in the provisional emission inventory. The TSP emission from the Danish Steel Works is reported in the annual environmental report and in 2000 the TSP emission was 36 tonnes. The TNO emission factors for refineries are shown in A1-Table 18. The emission factors in Table A1-18 will be used in the improved inventory.

Table A1-18 Emission factors for refineries and oil/gas production. TNO data [1)]

Fuel	Emission factor		
	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ
Refinery gas	5	5	5
Residual oil	50	40	35

1. TNO CEPMEIP database, 2001

4.3 Revised emission factors

Table A1-19 shows the revised emission factors. A complete list of emission factors for stationary combustion plants is included in appendix 1.1.

Table A1-19 Revised emission factors

Fuel	Sector	snap	Temporary emission factor			Improved emission factor			Fraction (improved)	
			TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	PM_{10} %	$PM_{2.5}$ %
Municipal waste	Public power	0101	6	5	4	6	5	4	85	70
Residual oil	Industry	0301	14-47	12-40	10-14	14	10,5	7	75	50
Residual oil	Public power District heating	0101, 0102	14-47	3	2,5	3	3	2,5	100	83
Residual oil	Refinery	0103	47	40	35	50	40	35	80	70
Straw	District heating Industry	0102, 0301	19-21	19-21	19-21	21	15	12	70	55
Straw	Residential	0202	19	19	19	234	222	211	95	90
Coal	Public power	0101	6	6	5	3	2,6	2,1	80	66
Coal	Non-industrial combustion Industrial combustion	02, 03	27	7-27	5-25	17	12	7	70	40
Orimulsion	Public power	0101	3	3	2,5	1,9	1,8	1,6	93	83
Refinery gas	Refinery	0103	0,1	0,1	0,1	5	5	5	100	100
Wood	District heating Industry	0102, 0301	18-143	18-70	18-55	19	13	10	70	55
Wood and straw	Public power	0101	18-143	18-70	1-55	8	6	4	70	55

Comparing Table A1-21 and Table A1-4 it appears that the primary changes of the inventory are:

- Residential plants (0202). The increase of emission factor for farmhouse boilers using straw results in an increase of TSP emission of 777 tonnes.
- District heating plants (0102). Due mainly to the lower emission factor for wood the resulting PM emission is much lower in the improved inventory. TSP emission of wood combusted in district heating plants is 483 tonnes lower than in the provisional inventory.
- Industrial combustion (0301). The improved (lower) emission factor for wood has turned out to be important for the industrial combustion emission. Thus TSP emission from wood combusted in industrial plants is 529 tonnes lower in the improved inventory than in the provisional inventory.

Emission factors for some CHP plants will be changed when results of the Eltra PSO project are reported. Change of emission factors is expected for the following plants:

- Natural gas fuelled reciprocating engines (snap 010105, 010405, 010505, 020105, 020204, 020304, 030105)
- Natural gas fuelled gas turbines (snap 010104, 010304, 010504, 020104, 020303, 030104).
- Municipal waste incineration power producing plants (snap 0101). Emission factors for district heating plants might be changed as well.
- Biomass CHP plants (snap 0101)

5 Improved Danish emission inventory

The improved particulate emission inventory of stationary combustion plants is shown in Table A1-20 and Table A1-21. The detailed emission inventory is enclosed in appendix 1.2 and in appendix 1.3 the inventory is further disaggregated to fuel level.

According to the improved emission inventory the primary sources of particulate emission are:

- Residential boilers, stoves and fireplaces combusting wood
- Farmhouse boilers combusting straw
- Power plants primarily combusting coal
- Coal and residual oil combusted in industrial boilers and processes

Furthermore there are considerable emissions from:

- Residential boilers using gas oil
- Refineries

Table A1-20 Improved emission inventory year 2000, main snap categories

snap1	snap1 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	1131	948	810
02	NON-INDUSTRIAL COMBUSTION PLANTS	3058	2899	2734
03	COMBUSTION IN MANUFACTURING INDUSTRY	741	575	448
Stationary combustion plants		4930	4423	3992

Table A1-21 Improved emission inventory year 2000, snap -2 level

snap1	snap1 name	snap2	snap2 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	826	702	594
		0102	District heating plants	161	115	91
		0103	Petroleum refining plants	142	129	122
		0104	Solid fuel transformation plants	0	0	0
		0105	Coal mining, oil / gas extraction, pipeline compressors	3	3	3
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	136	132	123
		0202	Residential plants	2793	2665	2529
		0203	Plants in agriculture, forestry and aquaculture	129	102	81
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	447	339	254
		0303	Processes with contact	294	235	194
Stationary combustion plants				4930	4423	3992

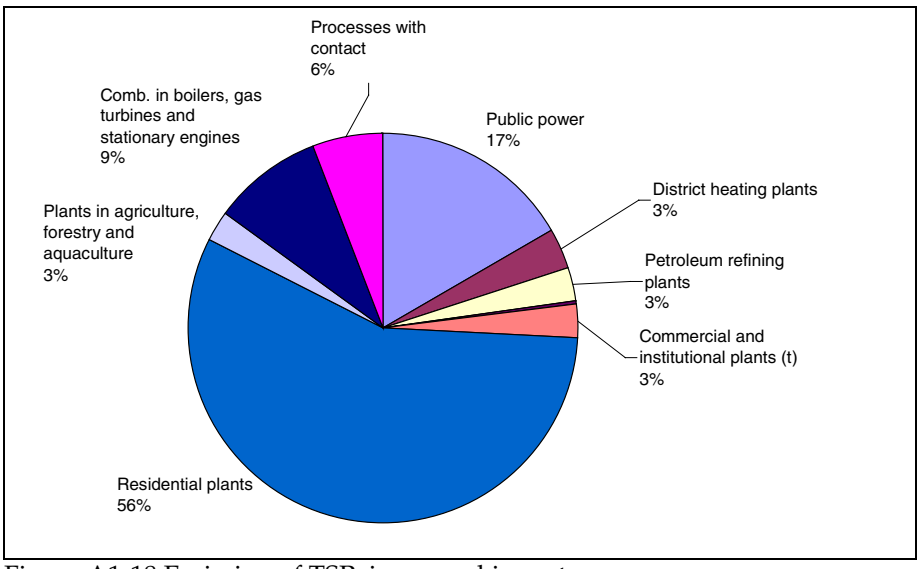

Figure A1-18 Emission of TSP, improved inventory

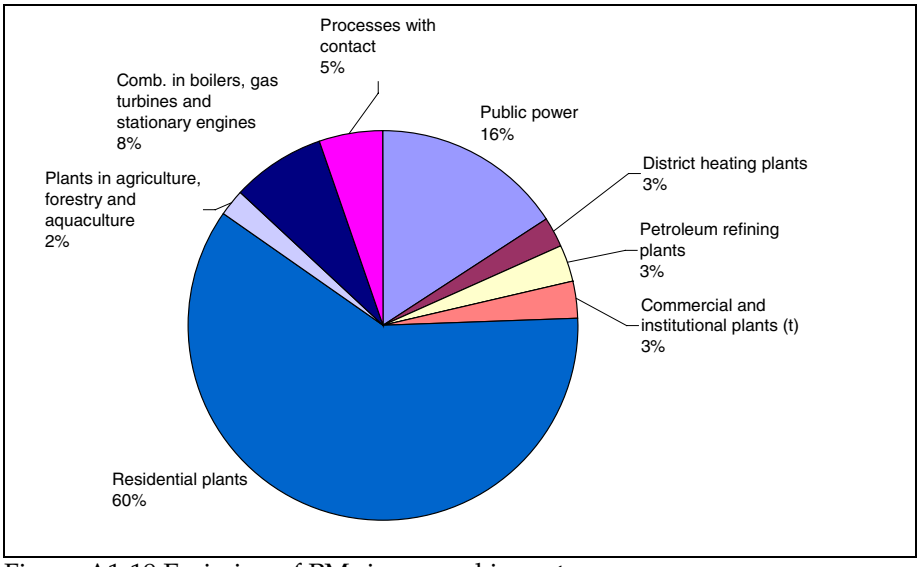

Figure A1-19 Emission of PM_{10} improved inventory

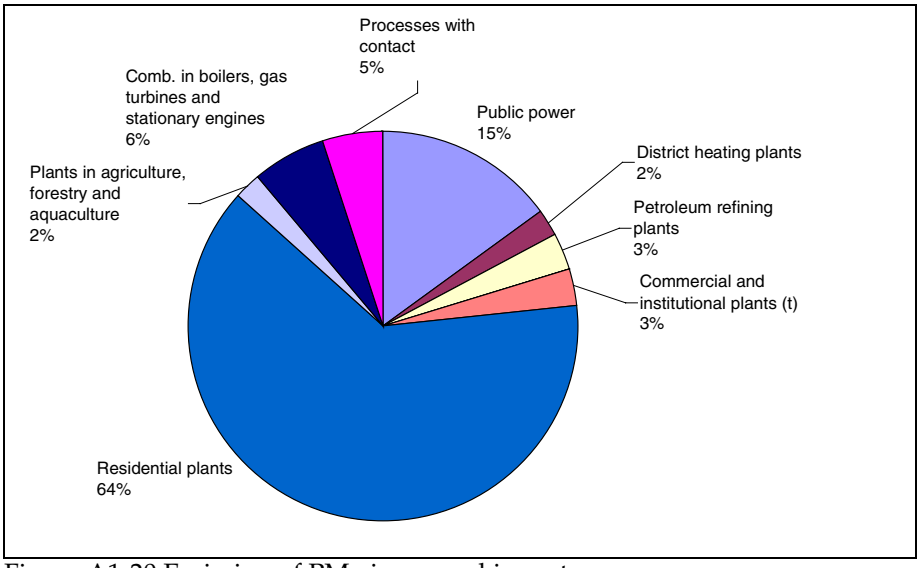

Figure A1-20 Emission of $PM_{2.5}$ improved inventory

6 Emission Projections

No projection models have been developed for projection of particulate matter emissions for stationary combustion plants but an estimate of the emission level in 2010 compared with the level in 2000 is given in this chapter.

Table A1-22 shows the latest energy forecast (excluding transport) from the Danish Energy Authority (Danish Energy Authority, 2003 http://www.ens.dk/sw998.asp). The fuel consumption is distributed between sectors and the biggest change is seen for power plants where the fuel consumption increases by 33%. Changes in fuel consumption are also seen in the offshore industry and the households. However, the increasing use of natural gas in the offshore industry will not change the emissions of PM significantly since the emission factor for natural gas is low. The decreasing use of gas oil in the households is not going to effect the emissions substantially because the largest contribution to PM emissions come from combustion of wood which is assumed almost constant from 2000 to 2010.

Table A1-22. Energy forecast from the Danish Energy Authority

		2000 (PJ)	2010 (PJ)	Difference (PJ)
North Sea	Own consumption	25	33	8
	Flaring	10	9	0
Refineries own consumption		17	17	0
Gas works		1	1	0
District heating plants		26	23	-3
Electric power plants, condensing production		91	187	95
Combined heat and power production		199	210	11
Production	Agriculture etc.	34	34	0
	Manufacturing	87	87	0
	Construction	7	7	0
Trade and Service	Public service	6	6	0
	Private trade and service	12	13	1
Households		85	77	-8
Total		599	704	105

The increasing fuel consumption at the power plants is mainly due to increasing use of coal and to less extent use of wood, straw and natural gas. Since the large combustion plants all ready have very efficient PM abatement technology no major changes are expected from 2000 to 2010. A rough estimate of the PM emissions from the energy sector is calculated assuming that the emissions increase by 33% as the fuel consumption. Given the latest energy projection from the Danish Energy Authority the estimated PM emissions in 2010 for stationary combustion plants will only increase with 7 % for PM_{10} (Table A1-23).

Table A1-23. Estimated PM emissions in 2010 for stationary combustion plants.

snap1	snap1 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	1500	1260	1080
02	NON-INDUSTRIAL COMBUSTION PLANTS	3058	2899	2734
03	COMBUSTION IN MANUFACTURING INDUSTRY	741	575	448
Stationary combustion plants		5299	4734	4262

7 Conclusion

The first Danish inventory of particulate matter emission was reported to UN-ECE in the beginning of 2002. The provisional inventory indicated that TSP emissions from stationary combustion plants add up to 18% of the overall emission. The percentage from stationary combustion plants is higher if only the fine particulate fractions are considered. Thus $PM_{2.5}$ emission from stationary combustion plants adds up to 31% of the overall emission.

An improved particulate matter emission inventory of stationary combustion plants for the year 2000 has been prepared. The revision is based on a survey of primary emission sources. Several emission factors have been changed as a result of improved knowledge of emission measurements performed on Danish plants and during literature surveys.

The changes of emission factors that cause considerable changes of the emission inventory are:

- An increase of emission factors for farmhouse boilers combusting straw. The TSP emission factor is changed from 19 g/GJ to 234 g/GJ.
- A decrease of emission factors for district heating boilers combusting wood.
- A decrease of emission factors for industrial boilers combusting wood.

According to the improved emission inventory the primary sources of particulate emission are:

- Residential boilers, stoves and fireplaces combusting wood
- Farmhouse boilers combusting straw
- Power plants primarily combusting coal
- Coal and residual oil combusted in industrial boilers and processes

Further there is considerable emissions from:

- Residential boilers using gas oil
- Refineries

The PM emission from wood combusted in residential plants is the predominant source. Thus 40% of the $PM_{2.5}$ emission from stationary combustion is emitted from residential wood combustion. This corresponds to 13% of the overall Danish emission. $PM_{2.5}$ emission from straw combustion in farmhouse boilers accounts for 19% of the total emission of stationary combustion plants.

The literature survey showed that the uncertainty of the emission factors for residential combustion of wood in stoves and boilers is high. The emission factors used in other Nordic countries are from 3 to 14 times higher. Still, other references supported the current emission factor and at present the emission factor has not been changed. Further studies of this emission factor are of great importance for further improvements of the inventory.

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Appendix 1.1 Emission Factors

Table A1-24 Emission factors for area sources, provisional inventory

Fuel id	Fuel	Snap1	Snap 1 name	Snap2	Snap 2 name	Snap3	Snap 3 name	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	Reference TSP[1)]	Reference PM_{10} & $PM_{2.5}$[1)]
102	STEAM COAL	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010103	Combustion plants < 50 MW (boilers)	6	6	5	TNO	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	6	6	5	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	6	6	5	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0202	Residential plants	0202	Plant size unknown	27	27	25	Legislation	PM_{10}: all $PM_{2.5}$: TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	27	27	25	Legislation	PM_{10}: all $PM_{2.5}$: TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	27	7	3	Legislation	TNO 2)
110	PETROLEUM COKE	02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	100	60	30	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	100	60	30	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	100	60	30	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	10	7	3	TNO	TNO 2)
111	WOOD AND SIMIL.	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	18	18	18	Legislation	all
						010103	Combustion plants < 50 MW (boilers)	143	70	55	Legislation	TNO
						010105	Stationary engines	143	70	55	Legislation	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	18	18	18	Legislation	all
						010203	Combustion plants < 50 MW (boilers)	143	70	55	Legislation	TNO
						010205	Stationary engines	143	70	55	Legislation	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	143	143	135	Legislation	TNO
				0202	Residential plants	0202	Plant size unknown	150	143	135	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	143	143	135	Legislation	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	143	70	55	Legislation	TNO
						030102	Combustion plants >= 50 and < 300 MW (boilers)	18	18	18	Legislation	all
						030103	Combustion plants < 50 MW (boilers)	143	70	55	Legislation	TNO
114	MUNICIP. WASTES	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	6	5	4	LPS2000	TNO distr.
						010103	Combustion plants < 50 MW (boilers)	6	5	4	LPS2000	TNO distr.
						010104	Gas turbines	6	5	4	LPS2000	TNO distr.
						010105	Stationary engines	6	5	4	LPS2000	TNO distr.
				0102	District heating plants	010203	Combustion plants < 50 MW (boilers)	6	5	4	LPS2000	TNO distr.
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	100	95	90	TNO	TNO
						020103	Combustion plants < 50 MW (boilers)	100	95	90	TNO	TNO
117	AGRICUL. WASTES	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	19	19	1	Legislation	PM_{10}:all $PM_{2.5}$: Elsam
						010103	Combustion plants < 50 MW (boilers)	21	21	21	Legislation	all
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	19	19	19	Legislation	all
						010203	Combustion plants < 50 MW (boilers)	21	21	21	Legislation	all
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	19	19	19	Legislation	all
				0202	Residential plants	0202	Plant size unknown	19	19	19	Legislation	all
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	19	19	19	Legislation	all
						020302	Combustion plants < 50 MW (boilers)	19	19	19	Legislation	all
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	030102	Combustion plants >= 50 and < 300 MW (boilers)	19	19	19	Legislation	all
						030105	Stationary engines	19	19	19	Legislation	all

Fuel id	Fuel	Snap1	Snap 1 name	Snap2	Snap 2 name	Snap3	Snap 3 name	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	Reference TSP[1)]	Reference PM_{10} & $PM_{2.5}$[1)]
203	RESIDUAL OIL	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	14	3	2,5	Legislation	TNO
						010101	Combustion plants >= 300 MW (boilers)	14	3	2,5	Legislation	TNO
						010102	Combustion plants >= 50 and < 300 MW (boilers)	14	3	2,5	Legislation	TNO
						010103	Combustion plants < 50 MW (boilers)	47	3	2,5	Legislation	TNO
						010104	Gas turbines	47	3	2,5	Legislation	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	14	3	2,5	Legislation	TNO
						010203	Combustion plants < 50 MW (boilers)	47	3	2,5	Legislation	TNO
				0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)	47	40	35	Legislation	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	14	14	14	Legislation	all
						020105	Stationary engines	60	50	40	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	14	14	14	Legislation	all
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	14	14	14	Legislation	all
						020304	Stationary engines	60	50	40	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	14	14	14	Legislation	all
						030102	Combustion plants >= 50 and < 300 MW (boilers)	14	12	10	Legislation	TNO
						030103	Combustion plants < 50 MW (boilers)	47	40	10	Legislation	PM_{10}: TNO distr. $PM_{2.5}$: TNO
						030104	Gas turbines	47	40	10	Legislation	
204	GAS OIL	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	5	5	5	TNO	TNO
						010101	Combustion plants >= 300 MW (boilers)	5	5	5	TNO	TNO
						010102	Combustion plants >= 50 and < 300 MW (boilers)	5	5	5	TNO	TNO
						010103	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						010104	Gas turbines	5	5	5	TNO	TNO
						010105	Stationary engines	5	5	5	TNO	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	5	5	5	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						010205	Stationary engines	5	5	5	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	5	5	5	TNO	TNO
						020103	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						020105	Stationary engines	5	5	5	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	5	5	5	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	020304	Stationary engines	5	5	5	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	5	5	5	TNO	TNO
						030102	Combustion plants >= 50 and < 300 MW (boilers)	5	5	5	TNO	TNO
						030103	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						030104	Gas turbines	5	5	5	TNO	TNO
						030105	Stationary engines	5	5	5	TNO	TNO
						030106	Other stationary equipments (n)	5	5	5	TNO	TNO
206	KEROSENE	02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	5	5	5	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	5	5	5	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	5	5	5	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	5	5	5	TNO	TNO

Fuel id	Fuel	Snap1	Snap 1 name	Snap2	Snap 2 name	Snap3	Snap 3 name	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	Reference TSP[1)]	Reference PM_{10} & $PM_{2.5}$[1)]
301	NATURAL GAS	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						010102	Combustion plants >= 50 and < 300 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010103	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010104	Gas turbines	0,1	0,1	0,1	TNO	TNO
						010105	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
				0103	Petroleum refining plants	010304	Gas turbines	0,1	0,1	0,1	TNO	TNO
				0104	Solid fuel transformation plants	010405	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0105	Coal mining, oil / gas extraction, pipeline compressors	010502	Combustion plants >= 50 and < 300 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010504	Gas turbines	0,1	0,1	0,1	TNO	TNO
						010505	Stationary engines	0,1	0,1	0,1	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						020103	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						020104	Stationary gas turbines	0,1	0,1	0,1	TNO	TNO
						020105	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						020202	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						020204	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						020303	Stationary gas turbines	0,1	0,1	0,1	TNO	TNO
						020304	Stationary engines	0,1	0,1	0,1	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						030103	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						030104	Gas turbines	0,1	0,1	0,1	TNO	TNO
						030105	Stationary engines	0,1	0,1	0,1	TNO	TNO
						030106	Other stationary equipments (n)	0,1	0,1	0,1	TNO	TNO
303	LPG	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0102	District heating plants	010203	Combustion plants < 50 MW (boilers)	0,2	0,2	0,2	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	0,2	0,2	0,2	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	0,2	0,2	0,2	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	0,2	0,2	0,2	TNO	TNO
308	REFINERY GAS	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010304	Gas turbines	0,1	0,1	0,1	TNO	TNO
309	BIOGAS	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	1,5	1,5	1,5	Legislation	all
						010103	Combustion plants < 50 MW (boilers)	1,5	1,5	1,5	Legislation	all
						010105	Stationary engines	1,5	1,5	1,5	Legislation	all
				0102	District heating plants	010203	Combustion plants < 50 MW (boilers)	1,5	1,5	1,5	Legislation	all
				0104	Solid fuel transformation plants	010405	Stationary engines	1,5	1,5	1,5	Legislation	all
				0105	Coal mining, oil / gas extraction, pipeline compressors	010505	Stationary engines	1,5	1,5	1,5	Legislation	all
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	1,5	1,5	1,5	Legislation	all
						020103	Combustion plants < 50 MW (boilers)	1,5	1,5	1,5	Legislation	all
						020105	Stationary engines	1,5	1,5	1,5	Legislation	all
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	1,5	1,5	1,5	Legislation	all
						020304	Stationary engines	1,5	1,5	1,5	Legislation	all
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	1,5	1,5	1,5	Legislation	all
						030102	Combustion plants >= 50 and < 300 MW (boilers)	1,5	1,5	1,5	Legislation	all
						030105	Stationary engines	1,5	1,5	1,5	Legislation	all

1. Legislation: Luftvejledningen (Miljøstyrelsen, 2001) and Bekendtgørelse 698 1990, (Miljøministeriet, 1990) - TNO: NO (TNO CEPMEIP database, 2001) - LPS2000: Emission factor calculated as average of municipal waste combustion plants 2000 (point sources) - TNO dist.: Calculation based on particle size distribution stated by TNO - all.: TSP is assumed <2,5µm
2. Emission factors for iron and steel sector have been used. TNO also states emission factors for "Other industrial sectors".

Table A1-25 Emission factors for area sources, improved emission inventory

Fuel id	Fuel	Snap1	Snap 1 name	Snap2	Snap 2 name	Snap3	Snap 3 name	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	Reference TSP[1)]	Reference PM_{10} & $PM_{2.5}$[1)]
102	STEAM COAL	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010103	Combustion plants < 50 MW (boilers)	3	2,6	2,1	NR	NR
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	6	6	5	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	6	6	5	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0202	Residential plants	0202	Plant size unknown	17	12	7	Legislation	TNO distr.
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	17	12	7	Legislation	TNO distr.
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	17	12	7	Legislation	TNO distr.
110	PETROLEUM COKE	02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	100	60	30	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	100	60	30	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	100	60	30	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	10	7	3	TNO	TNO 2)
111	WOOD AND SIMIL.	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	8	6	4	NR	TNO distr.
						010103	Combustion plants < 50 MW (boilers)	8	6	4	NR	TNO distr.
						010105	Stationary engines	8	6	4	NR	TNO distr.
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	19	13	10	Legislation	TNO distr.
						010203	Combustion plants < 50 MW (boilers)	19	13	10	Legislation	TNO distr.
						010205	Stationary engines	19	13	10	Legislation	TNO distr.
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	143	143	135	Legislation	TNO
				0202	Residential plants	0202	Plant size unknown	150	143	135	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	143	143	135	Legislation	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	19	13	10	Legislation	TNO distr.
						030102	Combustion plants >= 50 and < 300 MW (boilers)	19	13	10	Legislation	TNO distr.
						030103	Combustion plants < 50 MW (boilers)	19	13	10	Legislation	TNO distr.
114	MUNICIP. WASTES	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	6	5	4	LPS2000	TNO distr.
						010103	Combustion plants < 50 MW (boilers)	6	5	4	LPS2000	TNO distr.
						010104	Gas turbines	6	5	4	LPS2000	TNO distr.
						010105	Stationary engines	6	5	4	LPS2000	TNO distr.
				0102	District heating plants	010203	Combustion plants < 50 MW (boilers)	6	5	4	LPS2000	TNO distr.
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	100	95	90	TNO	TNO
						020103	Combustion plants < 50 MW (boilers)	100	95	90	TNO	TNO
117	AGRICUL. WASTES	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	8	6	4	NR	TNO distr.
						010103	Combustion plants < 50 MW (boilers)	8	6	4	NR	TNO distr.
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	21	15	12	Legislation	TNO distr.
						010203	Combustion plants < 50 MW (boilers)	21	15	12	Legislation	TNO distr.
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	21	15	12	Legislation	TNO distr.
				0202	Residential plants	0202	Plant size unknown	234	222	211	NR	NR
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	21	15	12	Legislation	TNO distr.
						020302	Combustion plants < 50 MW (boilers)	21	15	12	Legislation	TNO distr.
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	030102	Combustion plants >= 50 and < 300 MW (boilers)	21	15	12	Legislation	TNO distr.
						030105	Stationary engines	21	15	12	Legislation	TNO distr.

Fuel id	Fuel	Snap1	Snap 1 name	Snap2	Snap 2 name	Snap3	Snap 3 name	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	Reference TSP[1)]	Reference PM_{10} & $PM_{2.5}$[1)]
203	RESIDUAL OIL	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	3	3	2,5	TNO	TNO
						010101	Combustion plants >= 300 MW (boilers)	3	3	2,5	TNO	TNO
						010102	Combustion plants >= 50 and < 300 MW (boilers)	3	3	2,5	TNO	TNO
						010103	Combustion plants < 50 MW (boilers)	3	3	2,5	TNO	TNO
						010104	Gas turbines	3	3	2,5	TNO	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	3	3	2,5	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	3	3	2,5	TNO	TNO
				0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)	50	40	35	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	14	10,5	7	Legislation	TNO distr.
						020105	Stationary engines	60	50	40	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	14	10,5	7	Legislation	TNO distr.
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	14	10,5	7	Legislation	TNO distr.
						020304	Stationary engines	60	50	40	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	14	10,5	7	Legislation	TNO distr.
						030102	Combustion plants >= 50 and < 300 MW (boilers)	14	10,5	7	Legislation	TNO distr.
						030103	Combustion plants < 50 MW (boilers)	14	10,5	7	Legislation	TNO distr.
						030104	Gas turbines	14	10,5	7	Legislation	TNO distr.
204	GAS OIL	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	5	5	5	TNO	TNO
						010101	Combustion plants >= 300 MW (boilers)	5	5	5	TNO	TNO
						010102	Combustion plants >= 50 and < 300 MW (boilers)	5	5	5	TNO	TNO
						010103	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						010104	Gas turbines	5	5	5	TNO	TNO
						010105	Stationary engines	5	5	5	TNO	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	5	5	5	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						010205	Stationary engines	5	5	5	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	5	5	5	TNO	TNO
						020103	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						020105	Stationary engines	5	5	5	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	5	5	5	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	020304	Stationary engines	5	5	5	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	5	5	5	TNO	TNO
						030102	Combustion plants >= 50 and < 300 MW (boilers)	5	5	5	TNO	TNO
						030103	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						030104	Gas turbines	5	5	5	TNO	TNO
						030105	Stationary engines	5	5	5	TNO	TNO
						030106	Other stationary equipments (n)	5	5	5	TNO	TNO
206	KEROSENE	02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	5	5	5	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	5	5	5	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	5	5	5	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	5	5	5	TNO	TNO

Fuel id	Fuel	Snap1	Snap 1 name	Snap2	Snap 2 name	Snap3	Snap 3 name	TSP g/GJ	PM_{10} g/GJ	$PM_{2.5}$ g/GJ	Reference TSP[1)]	Reference PM_{10} & $PM_{2.5}$[1)]
301	NATURAL GAS	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						010102	Combustion plants >= 50 and < 300 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010103	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010104	Gas turbines	0,1	0,1	0,1	TNO	TNO
						010105	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010203	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
				0103	Petroleum refining plants	010304	Gas turbines	0,1	0,1	0,1	TNO	TNO
				0104	Solid fuel transformation plants	010405	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0105	Coal mining, oil / gas extraction, pipeline compressors	010502	Combustion plants >= 50 and < 300 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						010504	Gas turbines	0,1	0,1	0,1	TNO	TNO
						010505	Stationary engines	0,1	0,1	0,1	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						020103	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						020104	Stationary gas turbines	0,1	0,1	0,1	TNO	TNO
						020105	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						020202	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						020204	Stationary engines	0,1	0,1	0,1	TNO	TNO
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						020303	Stationary gas turbines	0,1	0,1	0,1	TNO	TNO
						020304	Stationary engines	0,1	0,1	0,1	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	0,1	0,1	0,1	TNO	TNO
						030103	Combustion plants < 50 MW (boilers)	0,1	0,1	0,1	TNO	TNO
						030104	Gas turbines	0,1	0,1	0,1	TNO	TNO
						030105	Stationary engines	0,1	0,1	0,1	TNO	TNO
						030106	Other stationary equipments (n)	0,1	0,1	0,1	TNO	TNO
303	LPG	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0102	District heating plants	010203	Combustion plants < 50 MW (boilers)	0,2	0,2	0,2	TNO	TNO
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	0,2	0,2	0,2	TNO	TNO
				0202	Residential plants	0202	Plant size unknown	0,2	0,2	0,2	TNO	TNO
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	0,2	0,2	0,2	TNO	TNO
308	REFINERY GAS	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)	5	5	5	TNO	TNO
						010304	Gas turbines	5	5	5	TNO	TNO
309	BIOGAS	01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	010102	Combustion plants >= 50 and < 300 MW (boilers)	1,5	1,5	1,5	Legislation	all
						010103	Combustion plants < 50 MW (boilers)	1,5	1,5	1,5	Legislation	all
						010105	Stationary engines	1,5	1,5	1,5	Legislation	all
				0102	District heating plants	010203	Combustion plants < 50 MW (boilers)	1,5	1,5	1,5	Legislation	all
				0104	Solid fuel transformation plants	010405	Stationary engines	1,5	1,5	1,5	Legislation	all
				0105	Coal mining, oil / gas extraction, pipeline compressors	010505	Stationary engines	1,5	1,5	1,5	Legislation	all
		02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	1,5	1,5	1,5	Legislation	all
						020103	Combustion plants < 50 MW (boilers)	1,5	1,5	1,5	Legislation	all
						020105	Stationary engines	1,5	1,5	1,5	Legislation	all
				0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	1,5	1,5	1,5	Legislation	all
						020304	Stationary engines	1,5	1,5	1,5	Legislation	all
		03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	1,5	1,5	1,5	Legislation	all
						030102	Combustion plants >= 50 and < 300 MW (boilers)	1,5	1,5	1,5	Legislation	all
						030105	Stationary engines	1,5	1,5	1,5	Legislation	all

1. Legislation: Luftvejledningen (Miljøstyrelsen, 2001) and Bekendtgørelse 698 1990, (Miljøministeriet, 1990) - TNO : TNO (TNO CEPMEIP database, 2001), TNO distr. : Calculation based on particle size distribution stated by TNO - LPS2000: Emission factor calculated as average of municipal waste combustion plants 2000 (point sources) - all.: TSP is assumed <2, 5 ∝m NR: National reference, measurements on Danish plants
2. Emission factors for iron and steel sector have been used. TNO also states emission factors for "Other industrial sectors"

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Appendix 1.2 Detailed emission inventory

Table A1-26 Detailed emission inventory, provisional inventory

snap1	snap1 name	snap2	snap2 name	snap3	snap3 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	0	0	0
				010101	Combustion plants >= 300 MW (boilers)	640	634	526
				010102	Combustion plants >= 50 and < 300 MW (boilers)	142	136	105
				010103	Combustion plants < 50 MW (boilers)	111	79	64
				010104	Gas turbines	11	5	5
				010105	Stationary engines	5	5	5
		0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	9	8	8
				010203	Combustion plants < 50 MW (boilers)	659	349	289
				010205	Stationary engines	8	4	3
		0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)	0	0	0
				010304	Gas turbines	0	0	0
		0104	Solid fuel transformation plants	010405	Stationary engines	0	0	0
		0105	Coal mining, oil / gas extraction, pipeline compressors	010502	Combustion plants >= 50 and < 300 MW (boilers)	3	3	3
				010504	Gas turbines	0	0	0
				010505	Stationary engines	0	0	0
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	118	118	112
				020103	Combustion plants < 50 MW (boilers)	59	59	49
				020104	Stationary gas turbines	0	0	0
				020105	Stationary engines	1	1	1
		0202	Residential plants	0202	Plant size unknown	2017	1933	1837
				020202	Combustion plants < 50 MW (boilers)	0	0	0
				020204	Stationary engines	0	0	0
		0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	134	134	129
				020302	Combustion plants < 50 MW (boilers)	0	0	0
				020303	Stationary gas turbines	0	0	0
				020304	Stationary engines	1	1	1
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	816	434	355
				030102	Combustion plants >= 50 and < 300 MW (boilers)	36	35	34
				030103	Combustion plants < 50 MW (boilers)	70	37	26
				030104	Gas turbines	1	1	1
				030105	Stationary engines	0	0	0
				030106	Other stationary equipments (n)	0	0	0
		0303	Processes with contact	030303	Gray iron foundries	0		
				030307	Secondary lead production	0		
				030311	Cement (f)	294	294	244
				030315	Container glass (f)	0		

snap1	snap1 name	snap2	snap2 name	snap3	snap3_name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
07	ROAD TRANSPORT	0701	Passenger cars (r)	070101	Highway driving	123	123	123
				070102	Rural driving	225	225	225
				070103	Urban driving	374	374	374
		0702	Light duty vehicles < 3.5 t (r)	070201	Highway driving	232	232	232
				070202	Rural driving	695	695	695
				070203	Urban driving	835	835	835
		0703	Heavy-duty vehicles > 3.5 t and buses (r)	070301	Highway driving	319	319	319
				070302	Rural driving	600	600	600
				070303	Urban driving	498	498	498
		0704	Mopeds and Motorcycles < 50 cm3	0704		21	21	21
		0705	Motorcycles > 50 cm3	070501	Highway driving	1	1	1
				070502	Rural driving	9	9	9
				070503	Urban driving	11	11	11
		0707	Automobile tyre and brake wear	0707		14703	14703	402
08	OTHER MOBILE SOURCES AND MACHINERY	0801	Military	0801		21	21	21
		0802	Railways	0802		162	162	162
		0803	Inland waterways	0803		72	69	66
		0804	Maritime activities	080402	National sea traffic within EMEP area	352	335	318
				080403	National fishing	398	378	359
		0805	Air traffic	080501	Domestic airport traffic (LTO cycles - <1000 m)	2	2	2
				080503	Domestic cruise traffic (>1000 m)	1	1	1
		0806	Agriculture	0806		2174	2066	1963
		0807	Forestry	0807		2	2	2
		0808	Industry	0808		1145	1090	1037
		0809	Household and gardening	0809		27	27	27
09	WASTE TREATMENT AND DISPOSAL	0902	Waste incineration	090206	Flaring in gas and oil extraction	1	1	1
Total						28140	27070	12104

Table A1-27 Detailed emission inventory, improves inventory of snap 01- 03

snap1	snap1 name	snap2	snap2 name	snap3	snap3 name	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes
01	COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRY	0101	Public power	0101	Plant size unknown	0	0	0
				010101	Combustion plants >= 300 MW (boilers)	634	541	462
				010102	Combustion plants >= 50 and < 300 MW (boilers)	122	101	83
				010103	Combustion plants < 50 MW (boilers)	59	49	40
				010104	Gas turbines	6	5	5
				010105	Stationary engines	5	5	5
		0102	District heating plants	010202	Combustion plants >= 50 and < 300 MW (boilers)	9	7	6
				010203	Combustion plants < 50 MW (boilers)	151	108	85
				010205	Stationary engines	1	1	1
		0103	Petroleum refining plants	010303	Combustion plants < 50 MW (boilers)	6	6	6
				010304	Gas turbines	12	12	12
				010306	Process furnaces	124	111	105
		0104	Solid fuel transformation plants	010405	Stationary engines	0	0	0
		0105	Coal mining, oil / gas extraction, pipeline compressors	010502	Combustion plants >= 50 and < 300 MW (boilers)	3	3	3
				010504	Gas turbines	0	0	0
				010505	Stationary engines	0	0	0
02	NON-INDUSTRIAL COMBUSTION PLANTS	0201	Commercial and institutional plants (t)	0201	Plant size unknown	118	116	110
				020103	Combustion plants < 50 MW (boilers)	17	15	12
				020104	Stationary gas turbines	0	0	0
				020105	Stationary engines	1	1	1
		0202	Residential plants	0202	Plant size unknown	2793	2665	2529
				020202	Combustion plants < 50 MW (boilers)	0	0	0
				020204	Stationary engines	0	0	0
		0203	Plants in agriculture, forestry and aquaculture	0203	Plant size unknown	128	102	81
				020302	Combustion plants < 50 MW (boilers)	0	0	0
				020303	Stationary gas turbines	0	0	0
				020304	Stationary engines	1	1	1
03	COMBUSTION IN MANUFACTURING INDUSTRY	0301	Comb. in boilers, gas turbines and stationary engines	0301	Plant size unknown	287	210	144
				030102	Combustion plants >= 50 and < 300 MW (boilers)	148	121	103
				030103	Combustion plants < 50 MW (boilers)	11	8	6
				030104	Gas turbines	1	1	1
				030105	Stationary engines	0	0	0
				030106	Other stationary equipments (n)	0	0	0
		0303	Processes with contact	030303	Gray iron foundries	0	0	0
				030307	Secondary lead production	0	0	0
				030311	Cement (f)	294	235	194
				030315	Container glass (f)	0	0	0

Appendix 1.3 Detailed fuel specific emission inventory

Table A1-28 Detailed fuel specific emission inventory, provisional inventory

snap_id	fuel_id	fuel	fuel_rate [GJ]	Emission factor [g/GJ]			EMISSION Tonnes		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
010101	102	STEAM COAL	146911420	(point sources)	(point sources)	(point sources)	640,258	634,086	526,266
	114	MUNICIP. WASTES	1230861						
	117	AGRICUL. WASTES	1119600						
	203	RESIDUAL OIL	4045724						
	204	GAS OIL	135602,22						
	225	OTHER LIQ. FUEL	34148181						
	301	NATURAL GAS	23541558,1						
010102	102	STEAM COAL	6224846	(point sources)	(point sources)	(point sources)	135,774	129,278	97,940
	111	WOOD AND SIMIL.	720713						
	114	MUNICIP. WASTES	18305717,7						
	117	AGRICUL. WASTES	1826796						
	203	RESIDUAL OIL	513002						
	204	GAS OIL	278595						
	301	NATURAL GAS	1456749						
	309	BIOGAS	619						
010103	114	MUNICIP. WASTES	8361289	(point sources)	(point sources)	(point sources)	50,470	43,900	33,810
	301	NATURAL GAS	39989						
010104	114	MUNICIP. WASTES	416975	(point sources)	(point sources)	(point sources)	4,825	4,408	3,991
	204	GAS OIL	74447						
	301	NATURAL GAS	19924570,54						
010105	204	GAS OIL	763	(point sources)	(point sources)	(point sources)	0,000	0,000	0,000
010203	111	WOOD AND SIMIL.	36841	(point sources)	(point sources)	(point sources)	8,750	7,680	5,950
	114	MUNICIP. WASTES	1395589						
	203	RESIDUAL OIL	7803						
010502	301	NATURAL GAS	340513,76	(point sources)	(point sources)	(point sources)	0,034	0,034	0,034
020103	114	MUNICIP. WASTES	13770	(point sources)	(point sources)	(point sources)	59,300	59,300	49,220
	204	GAS OIL	71306						
	309	BIOGAS	86680						
030102	102	STEAM COAL	874519	(point sources)	(point sources)	(point sources)	0,128	0,128	0,128
	203	RESIDUAL OIL	93085						
	301	NATURAL GAS	2690206						
	309	BIOGAS	13802						
030104	301	NATURAL GAS	2162962	(point sources)	(point sources)	(point sources)	0,216	0,216	0,216
030311	102	STEAM COAL	5708047	(point sources)	(point sources)	(point sources)	294,000	294,000	244,020
	110	PETROLEUM COKE	6474742,8						
	114	MUNICIP. WASTES	505233						
	118	SEWAGE SLUDGE	40162						
	203	RESIDUAL OIL	858853,2						
0101	203	RESIDUAL OIL	17206	14	3	2,5	0,241	0,052	0,043
0101	204	GAS OIL	6427	5	5	5	0,032	0,032	0,032
0101	301	NATURAL GAS	14558	0,1	0,1	0,1	0,001	0,001	0,001
010102	111	WOOD AND SIMIL.	369618	18	18	18	6,653	6,653	6,653
010102	309	BIOGAS	25152	1,5	1,5	1,5	0,038	0,038	0,038
010103	102	STEAM COAL	35480	6	6	5	0,213	0,213	0,177
010103	111	WOOD AND SIMIL.	297612	143	70	55	42,559	20,833	16,369
010103	117	AGRICUL. WASTES	640340	21	21	21	13,447	13,447	13,447
010103	203	RESIDUAL OIL	82101	47	3	2,5	3,859	0,246	0,205
010103	301	NATURAL GAS	640635	0,1	0,1	0,1	0,064	0,064	0,064
010103	309	BIOGAS	134968	1,5	1,5	1,5	0,202	0,202	0,202
010104	203	RESIDUAL OIL	117319	47	3	2,5	5,514	0,352	0,293
010104	204	GAS OIL	16935	5	5	5	0,085	0,085	0,085
010104	301	NATURAL GAS	3049107	0,1	0,1	0,1	0,305	0,305	0,305
010105	111	WOOD AND SIMIL.	428	143	70	55	0,061	0,030	0,024
010105	204	GAS OIL	73486	5	5	5	0,367	0,367	0,367
010105	301	NATURAL GAS	25826778	0,1	0,1	0,1	2,583	2,583	2,583
010105	309	BIOGAS	1548734	1,5	1,5	1,5	2,323	2,323	2,323
010202	102	STEAM COAL	371	6	6	5	0,002	0,002	0,002
010202	111	WOOD AND SIMIL.	179937	18	18	18	3,239	3,239	3,239
010202	117	AGRICUL. WASTES	150510	19	19	19	2,860	2,860	2,860
010202	203	RESIDUAL OIL	58729	14	3	2,5	0,822	0,176	0,147
010202	204	GAS OIL	399458	5	5	5	1,997	1,997	1,997
010202	301	NATURAL GAS	217700	0,1	0,1	0,1	0,022	0,022	0,022
010203	102	STEAM COAL	3551	6	6	5	0,021	0,021	0,018
010203	111	WOOD AND SIMIL.	3845382	143	70	55	549,890	269,177	211,496
010203	117	AGRICUL. WASTES	3290636	21	21	21	69,103	69,103	69,103
010203	203	RESIDUAL OIL	642590	47	3	2,5	30,202	1,928	1,606
010203	204	GAS OIL	230214	5	5	5	1,151	1,151	1,151
010203	301	NATURAL GAS	1416762	0,1	0,1	0,1	0,142	0,142	0,142
010203	303	LPG	246	0,2	0,2	0,2	0,000	0,000	0,000
010203	309	BIOGAS	21733	1,5	1,5	1,5	0,033	0,033	0,033

010205	111	WOOD AND SIMIL.	53040	143	70	55	7,585	3,713	2,917
010205	204	GAS OIL	190	5	5	5	0,001	0,001	0,001
010303	308	REFINERY GAS	1170793	0,1	0,1	0,1	0,117	0,117	0,117
010502	301	NATURAL GAS	24685860	0,1	0,1	0,1	2,469	2,469	2,469
010504	301	NATURAL GAS	164410	0,1	0,1	0,1	0,016	0,016	0,016
010505	301	NATURAL GAS	13250	0,1	0,1	0,1	0,001	0,001	0,001
010505	309	BIOGAS	32507	1,5	1,5	1,5	0,049	0,049	0,049
0201	110	PETROLEUM COKE	12070	100	60	30	1,207	0,724	0,362
0201	111	WOOD AND SIMIL.	575926	143	143	135	82,357	82,357	77,750
0201	114	MUNICIP. WASTES	35615	100	95	90	3,562	3,383	3,205
0201	203	RESIDUAL OIL	342842	14	14	14	4,800	4,800	4,800
0201	204	GAS OIL	4957566	5	5	5	24,788	24,788	24,788
0201	206	KEROSENE	63008	5	5	5	0,315	0,315	0,315
0201	301	NATURAL GAS	5854391	0,1	0,1	0,1	0,585	0,585	0,585
0201	303	LPG	121621	0,2	0,2	0,2	0,024	0,024	0,024
0201	309	BIOGAS	423606	1,5	1,5	1,5	0,635	0,635	0,635
020103	301	NATURAL GAS	43211	0,1	0,1	0,1	0,004	0,004	0,004
020104	301	NATURAL GAS	23335	0,1	0,1	0,1	0,002	0,002	0,002
020105	204	GAS OIL	859	5	5	5	0,004	0,004	0,004
020105	301	NATURAL GAS	967874	0,1	0,1	0,1	0,097	0,097	0,097
020105	309	BIOGAS	504895	1,5	1,5	1,5	0,757	0,757	0,757
0202	102	STEAM COAL	45201	27	27	25	1,220	1,220	1,130
0202	110	PETROLEUM COKE	10790	100	60	30	1,079	0,647	0,324
0202	111	WOOD AND SIMIL.	11936295	150	143	135	1790,444	1706,890	1611,400
0202	117	AGRICUL. WASTES	3611833	19	19	19	68,625	68,625	68,625
0202	203	RESIDUAL OIL	35611	14	14	14	0,499	0,499	0,499
0202	204	GAS OIL	30275667	5	5	5	151,378	151,378	151,378
0202	206	KEROSENE	91190	5	5	5	0,456	0,456	0,456
0202	301	NATURAL GAS	27562772	0,1	0,1	0,1	2,756	2,756	2,756
0202	303	LPG	986141	0,2	0,2	0,2	0,197	0,197	0,197
020202	301	NATURAL GAS	55319	0,1	0,1	0,1	0,006	0,006	0,006
020204	301	NATURAL GAS	1439173	0,1	0,1	0,1	0,144	0,144	0,144
0203	102	STEAM COAL	1079213	27	27	25	29,139	29,139	26,980
0203	110	PETROLEUM COKE	6154	100	60	30	0,615	0,369	0,185
0203	111	WOOD AND SIMIL.	230030	143	143	135	32,894	32,894	31,054
0203	117	AGRICUL. WASTES	2407889	19	19	19	45,750	45,750	45,750
0203	203	RESIDUAL OIL	1782543	14	14	14	24,956	24,956	24,956
0203	206	KEROSENE	8213	5	5	5	0,041	0,041	0,041
0203	301	NATURAL GAS	3467279	0,1	0,1	0,1	0,347	0,347	0,347
0203	309	BIOGAS	64084	1,5	1,5	1,5	0,096	0,096	0,096
020302	117	AGRICUL. WASTES	5800	19	19	19	0,110	0,110	0,110
020303	301	NATURAL GAS	61906	0,1	0,1	0,1	0,006	0,006	0,006
020304	203	RESIDUAL OIL	4017	60	50	40	0,241	0,201	0,161
020304	204	GAS OIL	4774	5	5	5	0,024	0,024	0,024
020304	301	NATURAL GAS	3032714	0,1	0,1	0,1	0,303	0,303	0,303
020304	309	BIOGAS	65452	1,5	1,5	1,5	0,098	0,098	0,098
0301	102	STEAM COAL	5038216	27	7	3	136,032	35,268	15,115
0301	110	PETROLEUM COKE	285426	10	7	3	2,854	1,998	0,856
0301	111	WOOD AND SIMIL.	3836511	143	70	55	548,621	268,556	211,008
0301	203	RESIDUAL OIL	8241264	14	14	14	115,378	115,378	115,378
0301	204	GAS OIL	2026017	5	5	5	10,130	10,130	10,130
0301	206	KEROSENE	7552	5	5	5	0,038	0,038	0,038
0301	301	NATURAL GAS	28746747	0,1	0,1	0,1	2,875	2,875	2,875
0301	309	BIOGAS	55682	1,5	1,5	1,5	0,084	0,084	0,084
030102	111	WOOD AND SIMIL.	1557075	18	18	18	28,027	28,027	28,027
030102	203	RESIDUAL OIL	555468	14	12	10	7,777	6,666	5,555
030102	204	GAS OIL	3138	5	5	5	0,016	0,016	0,016
030102	309	BIOGAS	1029	1,5	1,5	1,5	0,002	0,002	0,002
030103	111	WOOD AND SIMIL.	439542	143	70	55	62,855	30,768	24,175
030103	203	RESIDUAL OIL	139691	47	40	10	6,565	5,588	1,397
030103	204	GAS OIL	82107	5	5	5	0,411	0,411	0,411
030103	301	NATURAL GAS	116411	0,1	0,1	0,1	0,012	0,012	0,012
030104	204	GAS OIL	51	5	5	5	0,000	0,000	0,000
030104	301	NATURAL GAS	4593377	0,1	0,1	0,1	0,459	0,459	0,459
030105	117	AGRICUL. WASTES	386	19	19	19	0,007	0,007	0,007
030105	204	GAS OIL	103	5	5	5	0,001	0,001	0,001
030105	301	NATURAL GAS	1556394	0,1	0,1	0,1	0,156	0,156	0,156
030105	309	BIOGAS	1487	1,5	1,5	1,5	0,002	0,002	0,002
030106	204	GAS OIL	8070,3	5	5	5	0,040	0,040	0,040
030106	301	NATURAL GAS	50809,4	0,1	0,1	0,1	0,005	0,005	0,005
Total							**5135**	**4269**	**3798**

Table A1-29 Detailed fuel specific emission inventory, improved inventory

snap_id	fuel_id	fuel	fuel_rate [GJ]	Emission factor [g/GJ]			EMISSION Tonnes		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
010101	102	STEAM COAL	146911420	(point sources)	(point sources)	(point sources)	634,086	540,876	461,796
010101	114	MUNICIP. WASTES	1230861						
010101	117	AGRICUL. WASTES	1119600						
010101	203	RESIDUAL OIL	4045724						
010101	204	GAS OIL	135602,22						
010101	225	OTHER LIQ. FUEL	34148181						
010101	301	NATURAL GAS	23541558,1						
010102	102	STEAM COAL	6224846	(point sources)	(point sources)	(point sources)	118,995	99,093	81,172
010102	111	WOOD AND SIMIL.	720713						
010102	114	MUNICIP. WASTES	18305717,7						
010102	117	AGRICUL. WASTES	1826796						
010102	203	RESIDUAL OIL	513002						
010102	204	GAS OIL	278595						
010102	301	NATURAL GAS	1456749						
010102	309	BIOGAS	619						
010103	114	MUNICIP. WASTES	8361289	(point sources)	(point sources)	(point sources)	50,470	42,910	35,330
010103	301	NATURAL GAS	39989						
010104	114	MUNICIP. WASTES	416975	(point sources)	(point sources)	(point sources)	4,825	4,408	3,991
010104	204	GAS OIL	74447						
010104	301	NATURAL GAS	19924570,54						
010105	204	GAS OIL	763	(point sources)	(point sources)	(point sources)	0,000	0,000	0,000
010203	111	WOOD AND SIMIL.	36841	(point sources)	(point sources)	(point sources)	5,740	4,890	4,020
010203	114	MUNICIP. WASTES	1395589						
010203	203	RESIDUAL OIL	7803						
010304	308	REFINERY GAS	2400233	(point sources)	(point sources)	(point sources)	12,001	12,001	12,001
010306	203	RESIDUAL OIL	1322995	(point sources)	(point sources)	(point sources)	124,393	111,163	104,548
010306	308	REFINERY GAS	11648701						
010502	301	NATURAL GAS	340513,76	(point sources)	(point sources)	(point sources)	0,034	0,034	0,034
020103	114	MUNICIP. WASTES	13770	(point sources)	(point sources)	(point sources)	17,300	14,710	12,110
020103	204	GAS OIL	71306						
020103	309	BIOGAS	86680						
030102	102	STEAM COAL	1063375	(point sources)	(point sources)	(point sources)	113,667	97,188	84,789
030102	203	RESIDUAL OIL	284834,55						
030102	301	NATURAL GAS	2690206						
030102	309	BIOGAS	15755						
030104	301	NATURAL GAS	2162962	(point sources)	(point sources)	(point sources)	0,216	0,216	0,216
030311	102	STEAM COAL	5708047	(point sources)	(point sources)	(point sources)	294,000	235,200	194,040
030311	110	PETROLEUM COKE	6474742,8						
030311	114	MUNICIP. WASTES	505233						
030311	118	SEWAGE SLUDGE	40162						
030311	203	RESIDUAL OIL	858853,2						
0101	203	RESIDUAL OIL	17206	3	3	2,5	0,052	0,052	0,043
0101	204	GAS OIL	6427	5	5	5	0,032	0,032	0,032
0101	301	NATURAL GAS	14558	0,1	0,1	0,1	0,001	0,001	0,001
010102	111	WOOD AND SIMIL.	369618	8	6	4	2,957	2,218	1,478
010102	309	BIOGAS	25152	1,5	1,5	1,5	0,038	0,038	0,038
010103	102	STEAM COAL	35480	3	2,6	2,1	0,106	0,092	0,075
010103	111	WOOD AND SIMIL.	297612	8	6	4	2,381	1,786	1,190
010103	117	AGRICUL. WASTES	640340	8	6	4	5,123	3,842	2,561
010103	203	RESIDUAL OIL	82101	3	3	2,5	0,246	0,246	0,205
010103	301	NATURAL GAS	640635	0,1	0,1	0,1	0,064	0,064	0,064
010103	309	BIOGAS	134968	1,5	1,5	1,5	0,202	0,202	0,202
010104	203	RESIDUAL OIL	117319	3	3	2,5	0,352	0,352	0,293
010104	204	GAS OIL	16935	5	5	5	0,085	0,085	0,085
010104	301	NATURAL GAS	3049107	0,1	0,1	0,1	0,305	0,305	0,305
010105	111	WOOD AND SIMIL.	428	8	6	4	0,003	0,003	0,002
010105	204	GAS OIL	73486	5	5	5	0,367	0,367	0,367
010105	301	NATURAL GAS	25826778	0,1	0,1	0,1	2,583	2,583	2,583
010105	309	BIOGAS	1548734	1,5	1,5	1,5	2,323	2,323	2,323
010202	102	STEAM COAL	371	6	6	5	0,002	0,002	0,002
010202	111	WOOD AND SIMIL.	179937	19	13	10	3,419	2,339	1,799
010202	117	AGRICUL. WASTES	150510	21	15	12	3,161	2,258	1,806
010202	203	RESIDUAL OIL	58729	3	3	2,5	0,176	0,176	0,147
010202	204	GAS OIL	399458	5	5	5	1,997	1,997	1,997
010202	301	NATURAL GAS	217700	0,1	0,1	0,1	0,022	0,022	0,022
010203	102	STEAM COAL	3551	6	6	5	0,021	0,021	0,018
010203	111	WOOD AND SIMIL.	3845382	19	13	10	73,062	49,990	38,454
010203	117	AGRICUL. WASTES	3290636	21	15	12	69,103	49,360	39,488
010203	203	RESIDUAL OIL	642590	3	3	2,5	1,928	1,928	1,606
010203	204	GAS OIL	230214	5	5	5	1,151	1,151	1,151

010203	301	NATURAL GAS	1416762	0,1	0,1	0,1	0,142	0,142	0,142
010203	303	LPG	246	0,2	0,2	0,2	0,000	0,000	0,000
010203	309	BIOGAS	21733	1,5	1,5	1,5	0,033	0,033	0,033
010205	111	WOOD AND SIMIL.	53040	19	13	10	1,008	0,690	0,530
010205	204	GAS OIL	190	5	5	5	0,001	0,001	0,001
010303	308	REFINERY GAS	1170793	5	5	5	5,854	5,854	5,854
010502	301	NATURAL GAS	24685860	0,1	0,1	0,1	2,469	2,469	2,469
010504	301	NATURAL GAS	164410	0,1	0,1	0,1	0,016	0,016	0,016
010505	301	NATURAL GAS	13250	0,1	0,1	0,1	0,001	0,001	0,001
010505	309	BIOGAS	32507	1,5	1,5	1,5	0,049	0,049	0,049
0201	110	PETROLEUM COKE	12070	100	60	30	1,207	0,724	0,362
0201	111	WOOD AND SIMIL.	575926	143	143	135	82,357	82,357	77,750
0201	114	MUNICIP. WASTES	35615	100	95	90	3,562	3,383	3,205
0201	203	RESIDUAL OIL	342842	14	10,5	7	4,800	3,600	2,400
0201	204	GAS OIL	4957566	5	5	5	24,788	24,788	24,788
0201	206	KEROSENE	63008	5	5	5	0,315	0,315	0,315
0201	301	NATURAL GAS	5854391	0,1	0,1	0,1	0,585	0,585	0,585
0201	303	LPG	121621	0,2	0,2	0,2	0,024	0,024	0,024
0201	309	BIOGAS	423606	1,5	1,5	1,5	0,635	0,635	0,635
020103	301	NATURAL GAS	43211	0,1	0,1	0,1	0,004	0,004	0,004
020104	301	NATURAL GAS	23335	0,1	0,1	0,1	0,002	0,002	0,002
020105	204	GAS OIL	859	5	5	5	0,004	0,004	0,004
020105	301	NATURAL GAS	967874	0,1	0,1	0,1	0,097	0,097	0,097
020105	309	BIOGAS	504895	1,5	1,5	1,5	0,757	0,757	0,757
0202	102	STEAM COAL	45201	17	12	7	0,768	0,542	0,316
0202	110	PETROLEUM COKE	10790	100	60	30	1,079	0,647	0,324
0202	111	WOOD AND SIMIL.	11936295	150	143	135	1790,444	1706,890	1611,400
0202	117	AGRICUL. WASTES	3611833	234	222	211	845,169	801,827	762,097
0202	203	RESIDUAL OIL	35611	14	10,5	7	0,499	0,374	0,249
0202	204	GAS OIL	30275667	5	5	5	151,378	151,378	151,378
0202	206	KEROSENE	91190	5	5	5	0,456	0,456	0,456
0202	301	NATURAL GAS	27562772	0,1	0,1	0,1	2,756	2,756	2,756
0202	303	LPG	986141	0,2	0,2	0,2	0,197	0,197	0,197
020202	301	NATURAL GAS	55319	0,1	0,1	0,1	0,006	0,006	0,006
020204	301	NATURAL GAS	1439173	0,1	0,1	0,1	0,144	0,144	0,144
0203	102	STEAM COAL	1079213	17	12	7	18,347	12,951	7,554
0203	110	PETROLEUM COKE	6154	100	60	30	0,615	0,369	0,185
0203	111	WOOD AND SIMIL.	230030	143	143	135	32,894	32,894	31,054
0203	117	AGRICUL. WASTES	2407889	21	15	12	50,566	36,118	28,895
0203	203	RESIDUAL OIL	1782543	14	10,5	7	24,956	18,717	12,478
0203	206	KEROSENE	8213	5	5	5	0,041	0,041	0,041
0203	301	NATURAL GAS	3467279	0,1	0,1	0,1	0,347	0,347	0,347
0203	309	BIOGAS	64084	1,5	1,5	1,5	0,096	0,096	0,096
020302	117	AGRICUL. WASTES	5800	21	15	12	0,122	0,087	0,070
020303	301	NATURAL GAS	61906	0,1	0,1	0,1	0,006	0,006	0,006
020304	203	RESIDUAL OIL	4017	60	50	40	0,241	0,201	0,161
020304	204	GAS OIL	4774	5	5	5	0,024	0,024	0,024
020304	301	NATURAL GAS	3032714	0,1	0,1	0,1	0,303	0,303	0,303
020304	309	BIOGAS	65452	1,5	1,5	1,5	0,098	0,098	0,098
0301	102	STEAM COAL	4849360	17	12	7	82,439	58,192	33,946
0301	110	PETROLEUM COKE	285426	10	7	3	2,854	1,998	0,856
0301	111	WOOD AND SIMIL.	3836511	19	13	10	72,894	49,875	38,365
0301	203	RESIDUAL OIL	8241264	14	10,5	7	115,378	86,533	57,689
0301	204	GAS OIL	2026017	5	5	5	10,130	10,130	10,130
0301	206	KEROSENE	7552	5	5	5	0,038	0,038	0,038
0301	301	NATURAL GAS	28746747	0,1	0,1	0,1	2,875	2,875	2,875
0301	309	BIOGAS	54758	1,5	1,5	1,5	0,082	0,082	0,082
030102	111	WOOD AND SIMIL.	1557075	19	13	10	29,584	20,242	15,571
030102	203	RESIDUAL OIL	363718	14	10,5	7	5,092	3,819	2,546
030102	204	GAS OIL	3138	5	5	5	0,016	0,016	0,016
030103	111	WOOD AND SIMIL.	439542	19	13	10	8,351	5,714	4,395
030103	203	RESIDUAL OIL	139691	14	10,5	7	1,956	1,467	0,978
030103	204	GAS OIL	82107	5	5	5	0,411	0,411	0,411
030103	301	NATURAL GAS	116411	0,1	0,1	0,1	0,012	0,012	0,012
030104	204	GAS OIL	51	5	5	5	0,000	0,000	0,000
030104	301	NATURAL GAS	4593377	0,1	0,1	0,1	0,459	0,459	0,459
030105	117	AGRICUL. WASTES	386	21	15	12	0,008	0,006	0,005
030105	204	GAS OIL	103	5	5	5	0,001	0,001	0,001
030105	301	NATURAL GAS	1556394	0,1	0,1	0,1	0,156	0,156	0,156
030105	309	BIOGAS	1487	1,5	1,5	1,5	0,002	0,002	0,002
030106	204	GAS OIL	8070,3	5	5	5	0,040	0,040	0,040
030106	301	NATURAL GAS	50809,4	0,1	0,1	0,1	0,005	0,005	0,005
Total							**4930**	**4423**	**3992**

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Appendix 1.4 Large point source emission

Table A1-30 Large point source emission (snap 01-03), provisional inventory

Large point source	part	snap	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes	TSP ref 4)	PM_{10} / $PM_{2.5}$ ref 4)	Comments
Amagerværket	01	010101	0,000	0,000	0,000	E2	TNO frac.	All emissions included in unit 3
	02	010101	0,000	0,000	0,000			
	03	010101	54,000	54,000	44,820			
Svanemølleværket	05	010101	0,202	0,202	0,202	EMF	EMF	
	07	010104	0,733	0,733	0,733	EMF	EMF	
H.C.Ørstedsværket	03	010101	2,206	0,638	0,567	EMF	EMF	
	07	010101	3,715	1,196	1,082	EMF	EMF	
Kyndbyværket	21	010101	8,000	8,000	6,640	E2	TNO frac.	All emissions included in unit 21
	22	010101	0,000	0,000	0,000			
	26	010101	0,000	0,000	0,000			
	28	010101	0,000	0,000	0,000			
	41	010105	0,000	0,000	0,000			
	51	010104	0,000	0,000	0,000			
	52	010104	0,000	0,000	0,000			
Masnedøværket	12	010102	10,564	10,564	1,580	EMF	EMF[1)]	MKV77
	31	010104	0,025	0,025	0,025	EMF	EMF	MAV31
Stigsnæsværket	01	010101	0,000	0,000	0,000	E2	TNO frac.	
	02	010101	46,000	46,000	38,180			
Asnæsværket	01	010101	2,655	0,569	0,474	EMF	EMF	
	03	010101	0,000	0,000	0,000	E2	TNO frac.	All emissions included in unit 5
	04	010101	0,000	0,000	0,000			
	05	010101	240,000	240,000	199,200			
Avedøreværket	01	010101	16,000	16,000	13,280	E2	TNO frac.	
Fynsværket	03	010101	0,000	0,000	0,000	AER	TNO frac.	All emissions included in unit 7
	07	010101	71,000	71,000	58,930			
	08	010101	0,800	0,800	0,660	AER	TNO frac.	Municipal waste
Studstrupværket	03	010101	0,000	0,000	0,000	AER	TNO frac.	All emissions included in unit 4
	04	010101	57,500	57,500	47,730			
Vendsysselværket	03	010101	54,170	54,170	44,960	AER	TNO frac.	
Skærbækværket	01	010101	0,000	0,000	0,000	AER	TNO frac.	All emissions included in unit 3
	03	010101	2,000	2,000	1,660			
Enstedværket	03	010101	50,430	50,430	41,860	AER	TNO frac.	EV3
	04	010101	1,580	1,580	1,120	AER	TNO frac.	Biomass
Esbjergværket	03	010101	30,000	30,000	24,900	AER	TNO frac.	
Østkraft	06	010102	4,973	4,556	3,816	EMF	EMF	ØKR6
Dansk Naturgas Behandlingsanlæg	01	010502	0,034	0,034	0,034	EMF	TNO frac.	(combustion)
Horsens Kraftvarmeværk	01	010102	8,850	7,700	5,930	AER	TNO frac.	Municipal waste
	02	010104	0,080	0,080	0,080	EMF	EMF	Gas turbine
Herningværket	01	010102	20,000	20,000	16,600	AER	TNO frac.	
Vestforbrændingen	01	010102	1,000	1,000	0,830	AER	TNO frac.	Unit 5 (new)
	02	010102	8,000	6,960	5,360	AER	TNO frac.	Unit 1-4
Amagerforbrændingen	01	010102	16,790	14,610	11,250	AER	TNO frac.	
Randersværket	01	010102	16,098	16,098	13,415	EMF	EMF	coal + biogas
	02	010102	1,010	1,010	1,010	EMF	EMF	gas oil
Grenåværket	01	010102	21,900	21,900	18,180	AER	TNO frac.	
Hillerødværket	01	010104	0,332	0,332	0,332	EMF	EMF	
Helsingørværket	01	010104	0,184	0,184	0,184	EMF	EMF	
Stora Dalum	01	030102	0,108	0,108	0,108	EMF	EMF	
Assens Sukkerfabrik [2)]	01	030102	0,021	0,021	0,021	EMF [2)]	EMF [2)]	
Kolding Kraftvarmeværk	01	010103	2,440	2,120	1,630	AER	TNO frac.	Unit 2
	02	010103	3,400	2,960	2,280	AER	TNO frac.	Unit 3-4
Måbjergværket	02	010102	12,000	12,000	9,960	AER	TNO frac.	
Sønderborg Kraftvarmeværk	01	010102	1,680	1,460	1,130	AER	TNO frac.	Municipal waste
	02	010104	0,104	0,104	0,104	EMF	EMF	Gas turbine
Kara Affalds-forbrændingsanlæg	01	010102	1,340	1,170	0,900	AER	TNO frac.	
Viborg Kraftvarmeværk	01	010104	0,226	0,226	0,226	EMF	EMF	

Large point source	part	snap	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes	TSP ref [4]	PM_{10} / $PM_{2.5}$ ref [4]	Comments
Nordforbrændingen	01	010102	3,040	2,640	2,040	AER	TNO frac.	
Aalborg Portland	01	030311	294,000	294,000	244,020	AER	TNO frac. [3]	
Århus Nord	01	010102	6,420	5,590	4,300	AER	TNO frac.	
	02	010102	0,000	0,000	0,000			All emissions included in unit 1
Reno Nord	01	010103	12,080	10,510	8,090	AER	TNO frac.	
Silkeborg Kraftvarmeværk	01	010104	0,338	0,338	0,338	EMF	EMF	
Rensningsanlægget Lynetten	01	020103	59,300	59,300	49,220	AER	TNO frac. [3]	
AVV Forbrændingsanlæg	01	010103	1,890	1,640	1,270	AER	TNO frac.	
I/S REFA Kraftvarmeværk	01	010103	1,570	1,370	1,050	AER	TNO frac.	
Svendborg Kraftvarmeværk	01	010102	0,670	0,580	0,450	AER	TNO frac.	
Kommunekemi	01	010102	1,000	1,000	0,830	AER	TNO frac.	
	02	010102	0,210	0,210	0,170	AER	TNO frac.	
	03	010102	0,230	0,230	0,190	AER	TNO frac.	
	04	010104	0,000	0,000	0,000	EMF	EMF	
I/S Fælles Forbrænding	01	010203	2,300	2,000	1,540	AER	TNO frac.	
Vestfyns Forbrænding	01	010203	1,000	0,870	0,670	AER	TNO frac.	
I/S Reno Syd	01	010103	5,370	4,670	3,600	AER	TNO frac.	
I/S Kraftvarmeværk Thisted	01	010103	2,860	2,490	1,920	AER	TNO frac.	
Knudmoseværket	01	010103	0,960	0,840	0,640	AER	TNO frac.	
Kavo I/S Energien	01	010103	2,810	2,440	1,880	AER	TNO frac.	
VEGA	01	010203	3,560	3,100	2,390	AER	TNO frac.	
Hadsund Bys Fjernvarmeværk	01	010203	1,390	1,210	0,930	AER	TNO frac.	
Års Fjernvarmeforsyning	01	010103	7,690	6,690	5,150	AER	TNO frac.	
Haderslev Kraftvarmeværk	01	010103	1,900	1,650	1,270	AER	TNO frac.	
Frederikshavn Affaldskraftvarmeværk	01	010103	0,670	0,580	0,450	AER	TNO frac.	
Vejen Kraftvarmeværk	01	010103	6,830	5,940	4,580	AER	TNO frac.	
Bofa I/S	01	010203	0,500	0,500	0,420	AER	TNO frac.	
DTU	01	010104	0,119	0,119	0,119	EMF	EMF	
Næstved Kraftvarmeværk	01	010104	2,556	2,139	1,722	EMF	EMF	
Maricogen	01	030104	0,216	0,216	0,216	EMF	EMF	
Hjørring KVV	01	010104	0,128	0,128	0,128	EMF	EMF	
Total stationary combustion (LPS)			**1194**	**1173**	**962**			

1. Emission factor of PM2.5, straw stated by Tech-wise (1 g/GJ)
2. Emission factor for coal and residual oil not included (error). Only emission from bio gas included
3. TNO size distribution of coal or fuel oil.
4. AER: annual environmental report 2000, EMF: emission factor, E2: data stated by plant owner Energi E2, TNO-frac.: TNO particle size distribution (TNO CEPMEIP database, 2001).

Table A1-31 Large point source emission (snap 01-03), improved inventory

Large point source	part	snap	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes	TSP ref 1)	PM_{10} / $PM_{2.5}$ ref 1)	Comments
Amagerværket	01	010101	0,000	0,000	0,000	E2	TNO frac.	All emissions included in unit 3
	02	010101	0,000	0,000	0,000			
	03	010101	54,000	43,200	35,640			
Svanemølleværket	05	010101	0,202	0,202	0,202	EMF	EMF	
	07	010104	0,733	0,733	0,733	EMF	EMF	
H.C.Ørstedsværket	03	010101	0,638	0,638	0,567	EMF	EMF	
	07	010101	1,196	1,196	1,082	EMF	EMF	
Kyndbyværket	21	010101	8,000	8,000	6,640	E2	TNO frac.	All emissions included in unit 21
	22	010101	0,000	0,000	0,000			
	26	010101	0,000	0,000	0,000			
	28	010101	0,000	0,000	0,000			
	41	010105	0,000	0,000	0,000			
	51	010104	0,000	0,000	0,000			
	52	010104	0,000	0,000	0,000			
Masnedøværket	12	010102	4,477	3,360	2,242	EMF	EMF	MKV77
	31	010104	0,025	0,025	0,025	EMF	EMF	MAV31
Stigsnæsværket	01	010101	0,000	0,000	0,000	E2	TNO frac.	
	02	010101	46,000	36,800	30,360			
Asnæsværket	01	010101	0,569	0,569	0,474	EMF	EMF	
	03	010101	0,000	0,000	0,000	E2	TNO frac.	All emission included in unit 5
	04	010101	0,000	0,000	0,000			
	05	010101	240,000	223,200	199,200			
Statoil Raffinaderi	01	010306	66,640	60,151	56,907			
Avedøreværket	01	010101	16,000	12,800	10,560	E2	TNO frac.	
Fynsværket	03	010101	0,000	0,000	0,000	AER	TNO frac.	All emission included in unit 7
	07	010101	71,000	56,800	46,860			
	08	010101	0,800	0,680	0,560	AER	TNO frac.	Affaldsanlæg
Studstrupværket	03	010101	0,000	0,000	0,000	AER	TNO frac.	All emission included in unit 4
	04	010101	57,500	46,000	37,950			
Vendsysselværket	03	010101	54,170	43,340	35,750	AER	TNO frac.	
Shell Raffinaderi	01	010306	57,753	51,012	47,641			
	05	010304	12,001	12,001	12,001			
Skærbækværket	01	010101	0,000	0,000	0,000	AER	TNO frac.	All emission included in unit 3
	03	010101	2,000	2,000	2,000			
Enstedværket	03	010101	50,430	40,340	33,280	AER	TNO frac.	EV3
	04	010101	1,580	1,110	0,870	AER	TNO frac.	Biomass
Esbjergværket	03	010101	30,000	24,000	19,800	AER	TNO frac.	
Østkraft	06	010102	2,329	2,028	1,635	EMF	EMF	ØKR6
Danisco Ingredients	01	030102	9,789	6,910	4,031	EMF	EMF	
Dansk Naturgas Behandlingsanlæg	01	010502	0,034	0,034	0,034	EMF	TNO frac.	combustion
Horsens Kraftvarmeværk	01	010102	8,850	7,520	6,200	AER	TNO frac.	Municipal waste
	02	010104	0,080	0,080	0,080	EMF	EMF	Gas turbine
Herningværket	01	010102	20,000	16,000	13,200	AER	TNO frac.	
Vestforbrændingen	01	010102	1,000	0,850	0,700	AER	TNO frac.	Unit 5 (new)
	02	010102	8,000	6,800	5,600	AER	TNO frac.	Unit 1-4
Amagerforbrændingen	01	010102	16,790	14,270	11,750	AER	TNO frac.	
Randersværket	01	010102	8,049	6,976	5,635	EMF	EMF	coal + biogas
	02	010102	1,010	1,010	1,010	EMF	EMF	gas oil
Grenåværket	01	010102	21,900	17,520	14,450	AER	TNO frac.	
Hillerødværket	01	010104	0,332	0,332	0,332	EMF	EMF	
Helsingørværket	01	010104	0,184	0,184	0,184	EMF	EMF	
Stålvalseværket	01	030102	35,770	35,770	35,770	AER	All	
Stora Dalum	01	030102	0,108	0,108	0,108	EMF	EMF	
Assens Sukkerfabrik	01	030102	68,000	54,400	44,880	AER	TNO frac.	
Kolding Kraftvarmeværk	01	010103	2,440	2,070	1,710	AER	TNO frac.	Unit 2
	02	010103	3,400	2,890	2,380	AER	TNO frac.	Unit 3-4
Måbjergværket	02	010102	12,000	10,200	8,400	AER	TNO frac.	
Sønderborg Kraftvarmeværk	01	010102	1,680	1,430	1,180	AER	TNO frac.	Municipal waste
	02	010104	0,104	0,104	0,104	EMF	EMF	Gas turbine
Kara Affalds-forbrændingsanlæg	01	010102	1,340	1,140	0,940	AER	TNO frac.	
Viborg Kraftvarmeværk	01	010104	0,226	0,226	0,226	EMF	EMF	

Large point source	part	snap	TSP Tonnes	PM_{10} Tonnes	$PM_{2.5}$ Tonnes	TSP ref [1]	PM_{10} / $PM_{2.5}$ ref [1]	Comments
Nordforbrændingen	01	010102	3,040	2,580	2,130	AER	TNO frac.	
Aalborg Portland	01	030311	294,000	235,200	194,040	AER	TNO frac.	
Århus Nord	01	010102	6,420	5,460	4,490	AER	TNO frac.	
	02	010102	0,000	0,000	0,000			All emission included in unit 1
Reno Nord	01	010103	12,080	10,270	8,460	AER	TNO frac.	
Silkeborg Kraftvarmeværk	01	010104	0,338	0,338	0,338	EMF	EMF	
Rensningsanlægget Lynetten	01	020103	17,300	14,710	12,110	AER	TNO frac.	
AVV Forbrændingsanlæg	01	010103	1,890	1,610	1,320	AER	TNO frac.	
I/S REFA Kraftvarmeværk	01	010103	1,570	1,330	1,100	AER	TNO frac.	
Svendborg Kraftvarmeværk	01	010102	0,670	0,570	0,470	AER	TNO frac.	
Kommunekemi	01	010102	1,000	1,000	0,830	AER	TNO frac.	
	02	010102	0,210	0,180	0,150	AER	TNO frac.	
	03	010102	0,230	0,200	0,160	AER	TNO frac.	
	04	010104	0,000	0,000	0,000	EMF	EMF	
I/S Fælles Forbrænding	01	010203	2,300	1,960	1,610	AER	TNO frac.	
Vestfyns Forbrænding	01	010203	1,000	0,850	0,700	AER	TNO frac.	
I/S Reno Syd	01	010103	5,370	4,560	3,760	AER	TNO frac.	
I/S Kraftvarmeværk Thisted	01	010103	2,860	2,430	2,000	AER	TNO frac.	
Knudmoseværket	01	010103	0,960	0,820	0,670	AER	TNO frac.	
Kavo I/S Energien	01	010103	2,810	2,390	1,970	AER	TNO frac.	
VEGA	01	010203	0,550	0,470	0,390	AER	TNO frac.	
Hadsund Bys Fjernvarmeværk	01	010203	1,390	1,180	0,970	AER	TNO frac.	
Års Fjernvarmeforsyning	01	010103	7,690	6,540	5,380	AER	TNO frac.	
Haderslev Kraftvarmeværk	01	010103	1,900	1,620	1,330	AER	TNO frac.	
Frederikshavn Affaldskraftvarmeværk	01	010103	0,670	0,570	0,470	AER	TNO frac.	
Vejen Kraftvarmeværk	01	010103	6,830	5,810	4,780	AER	TNO frac.	
Bofa I/S	01	010203	0,500	0,430	0,350	AER	TNO frac.	
DTU	01	010104	0,119	0,119	0,119	EMF	EMF	
Næstved Kraftvarmeværk	01	010104	2,556	2,139	1,722	EMF	EMF	
Maricogen	01	030104	0,216	0,216	0,216	EMF	EMF	
Hjørring KVV	01	010104	0,128	0,128	0,128	EMF	EMF	
Total of stationary combustion (LPS)			**1376**	**1163**	**994**			

1. AER: annual environmental report 2000, EMF: general emission factor, E2: data stated by plant owner Energi E2, TNO-frac.: TNO particle size distribution (fraction) (TNO CEPMEIP database, 2001).

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Appendix 2 Emission inventory for particulate matter – Road transport and other mobile sources

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Contents

1 Introduction

Traditionally the emissions of particulate matter from transportation vehicles have been referred to by their total mass. However, more recently an increased attention has been given to the adverse health effects on humans that particulates can cause depending on their numbers, sizes and chemical compositions and now particulates are subject to large research activities in many countries. The increased research efforts have lead the attention to the non-exhaust sources such as tyre and brake wear, road abrasion and the re-suspension of road dust recognising them as well to be important contributors to the overall emission total.

This report serves as a documentation of the Danish inventory for the transport emissions of TSP, PM_{10} and $PM_{2.5}$ from exhaust as well as the non-exhaust sources tyre and brake wear and road abrasion according to the new UNECE convention guidelines. Another aim of the present work is to identify the weak parts of the inventory where better data should become available in order to improve the accuracy of the emissions estimates.

2 Road Transport

The particulate emissions from road transport that contribute directly to ambient air concentrations come from various sources. These are the exhaust from vehicles in the street (only $PM_{2.5}$), tyre and brake/clutch wear, road abrasion and the resuspension of particles already emitted. Until recently the annual Danish particulate emissions estimates only comprised the exhaust emissions from diesel vehicles. However this limitation is not expedient since also exhaust emissions from gasoline vehicles and not least the emissions from the non-exhaust emission sources contribute significantly to the particulate emissions load.

The focus on the "new" sources of particulate emissions has also influenced national obligations in terms of emission information: From 2000 and onwards countries which are parties to the UNECE convention are obliged to produce national estimates including both exhaust emission totals and non-exhaust figures for tyre and brake wear. For consistency reasons the UNFCCC emission estimation approach has been adopted by the UNECE guidelines. Now the total statistical fuel sale figures are used in the simulations instead of previously where the statistical fuel sales related to the mileage driven on Danish roads were used.

2.1 Activity data

The Danish particulate exhaust emissions from diesel road transportation vehicles are calculated with the European COPERT model (Ntziachristos et al. 2000) both for operationally hot engines and during cold start. In the model all present vehicle types are grouped into vehicle layers. This is a sub-division of all vehicle classes into groups of vehicles with the same average fuel use and emission behaviour. No PM emission data are available in the model for gasoline vehicles. For the latter vehicles, the COPERT model principle is used instead in a new database developed at NERI. An overview of the different COPERT layers with years of implementation is given in appendix 2.1.

Table A2-1 Vehicle numbers and annual mileage given in vehicle sub-classes, 2000.

Vehicle classe	Fuel type	Engine size/weight	Vehicle No	Annual mileage
PC	Gasoline	< 1.4 l.	861438	17678
PC	Gasoline	1.4 – 2 l.	843902	18979
PC	Gasoline	> 2 l.	89262	18371
PC	Diesel	< 2 l.	116235	34995
PC	Diesel	> 2 l.	6104	35047
LDV	Gasoline		53766	18101
LDV	Diesel		218355	32789
Trucks	Diesel	3.5 – 7.5 tonnes	5166	34246
Trucks	Diesel	7.5 – 16 tonnes	10920	37550
Trucks	Diesel	16 – 32 tonnes	17035	64092
Trucks	Diesel	> 32 tonnes	15806	64092
Urban buses	Diesel		4516	95765
Coaches	Diesel		5304	77850
Mopeds	Gasoline		160000	1614
Motorcycles	Gasoline	2 stroke	11054	6029
Motorcycles	Gasoline	< 250 cc 4 stroke	12529	6029
Motorcycles	Gasoline	250 – 750 cc 4 stroke	34453	6029
Motorcycles	Gasoline	> 750 cc 4 stroke	15660	6029

Table A2-2 Model vehicle classes, trip speeds and mileage split.

Vehicle class	Trip speed			Mileage [%]		
	Urban	Rural	Highway	Urban	Rural	Highway
PC	40	70	100	35	46	19
LDV	40	65	80	35	50	15
Trucks < 16 tonnes	35	60	80	32	47	21
Trucks > 16 tonnes	35	60	80	19	45	36
Urban buses	30	50	70	51	41	8
Coaches	35	60	80	32	47	21
Mopeds	30	30	-	81	19	0
Motorcycles	40	70	100	47	39	14

From the Danish Road Directorate information of the vehicle stock and annual mileage is obtained. This covers data for the number of vehicles, annual mileage, mileage split between urban, rural and highway driving and the respective average speeds. The number of vehicles and annual mileage per layer is shown in appendix 2.1. However the annual mileages are not the original figures from the Danish Road Directorate. The figures shown are modified as a result of the COPERT model fuel balance as explained in the following.

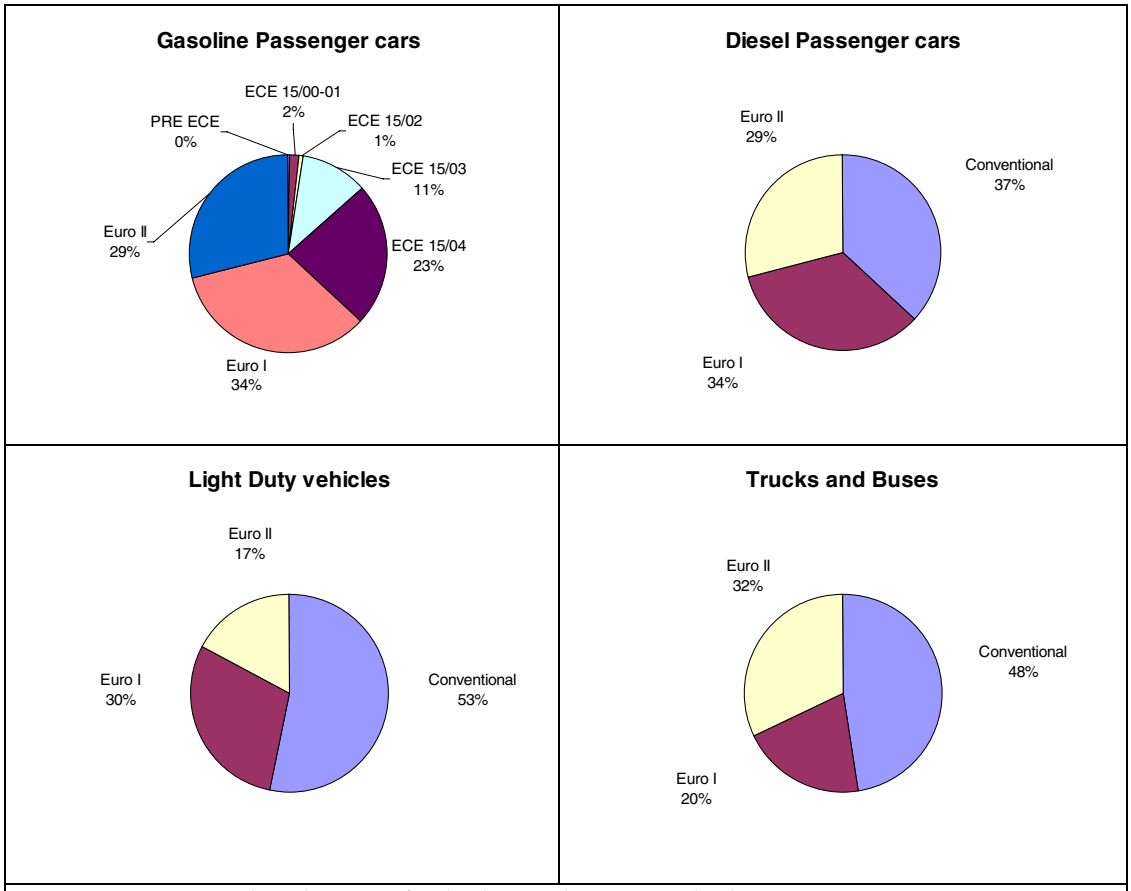

Figure A2-1 Layer distribution of vehicle numbers per vehicle type in 2000

Even though fleet and mileage data are available on an adequate level for COPERT III model simulations the background data can still be improved in certain areas to obtain more accurate road traffic emission estimates. In terms of vehicle numbers a more precise distribution is desired of vehicle categories into subcategories. This relates to the engine size distribution for diesel passenger cars and the gross vehicle weight distribution for heavy-duty vehicles. Better information is also sought for reflecting the vehicle fleet distribution and annual mileage per first registration year for light and heavy-duty vehicles.

The Danish Road Directorate foresees a considerable improvement of their statistical figures from 2003. Relevant vehicle fleet and mileage information comprising designation of vehicle category, fuel type, engine size and gross vehicle weight, and odometer readings for all individual Danish road transportation vehicles will be provided by the Danish Motor Vehicle Inspection Office. Here vehicle specific data has been gathered since 1998 in the Danish inspection and maintenance programme and will be available in a usable format starting from 1999. With proper assumptions the latter data can be used as a tool to improve earlier year's traffic data. By all means the Danish Road Directorate is going to carry out a separate project to determine the total mileage figure driven abroad by Danish vehicles. An important question, which still remains unsolved, is the amount of mileage on Danish roads driven by vehicles from foreign countries.

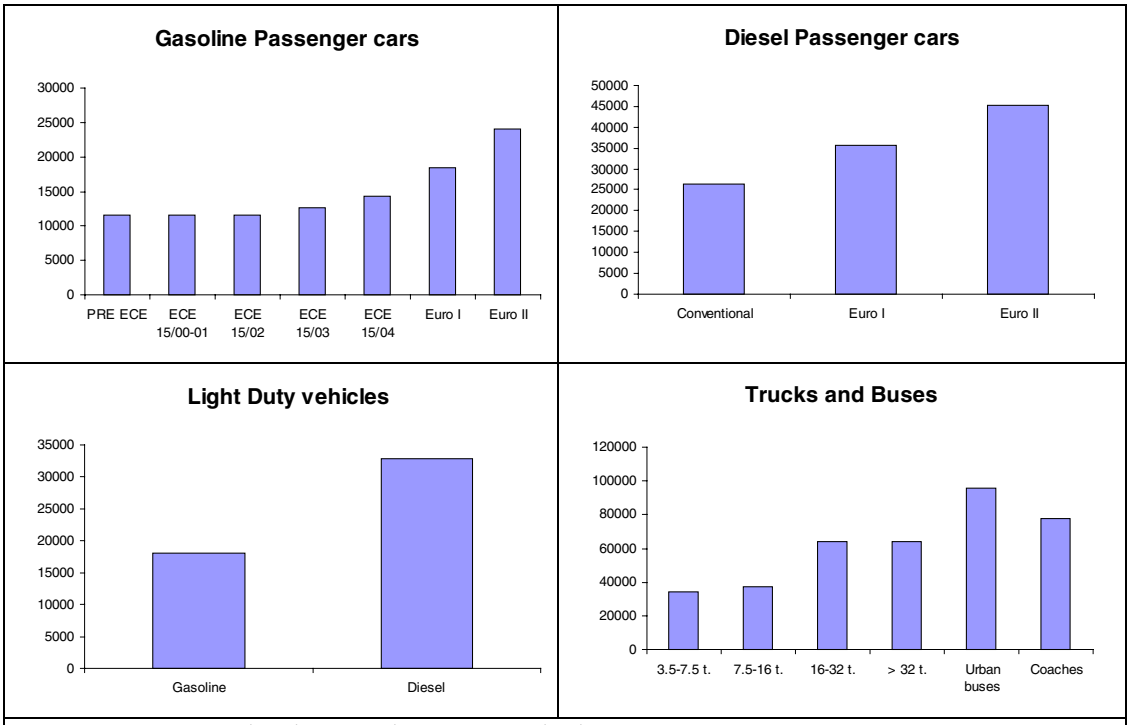

Figure A2-2 Annual mileage in layers per vehicle type in 2000

2.2 Emission factors

2.2.1 Exhaust emission factors

Trip speed dependent fuel use and emission factors (only for diesel vehicles) are taken from the COPERT model using trip speeds as shown in Table A2-2. For gasoline vehicles relevant emission factors, see TNO (2001), are derived from Dutch measurements (Klein et al., 2002). All emission factors are listed in appendix 2.1 and the hot and cold aggregated emission factors per vehicle class and fuel type are shown in Table A2-3.

Table A2-3 Emission factors (hot and cold aggregated) used in the Danish inventory

Vehicle class	Fuel type	Engine/weight	Urban (g/km)	Rural (g/km)	Highway (g/km)
PC	Gasoline	< 1.4 l.	0.01	0.01	0.01
PC	Gasoline	1.4 – 2 l.	0.01	0.01	0.01
PC	Gasoline	> 2 l.	0.01	0.01	0.01
PC	Diesel	< 2 l.	0.17	0.06	0.10
PC	Diesel	> 2 l.	0.17	0.06	0.10
LDV	Gasoline		0.02	0.02	0.02
LDV	Diesel		0.33	0.19	0.21
Trucks	Diesel	3.5 – 7.5 tonnes	0.27	0.18	0.15
Trucks	Diesel	7.5 – 16 tonnes	0.53	0.36	0.29
Trucks	Diesel	16 – 32 tonnes	0.59	0.40	0.33
Trucks	Diesel	> 32 tonnes	0.63	0.43	0.36
Urban buses	Diesel		0.49	0.33	0.26
Coaches	Diesel		0.48	0.32	0.26
Mopeds	Gasoline		0.12	0.12	
Motorcycles	Gasoline	2 stroke	0.12	0.12	0.12
Motorcycles	Gasoline	< 250 cc 4 stroke	0.04	0.04	0.04
Motorcycles	Gasoline	250 – 750 cc 4 stroke	0.04	0.04	0.04
Motorcycles	Gasoline	> 750 cc 4 stroke	0.04	0.04	0.04

In Germany, Austria and Switzerland the DACH model is used to give national estimates of road traffic emissions. The underlying emission factors come from the "Handbook Emission Factors for Road Transport version 1.2". In the present project hot emission factors for standard traffic situations are taken from the latter model and are subsequently fitted to trip speed dependent regression curves. The final emission factors are calculated using the urban, rural and highway speeds for comparison and given in Table A2-2.

The Swedish road traffic emission calculations are made with the EMV model (Hammarström & Karlsson, 1998). A fine agreement between modelled and measured figures for air quality is achieved by SMHI (the Swedish Meteorological and Hydraulic Institute) in Sweden using the EMV data as a basis for dispersion modelling in urban streets. For the present project the EMV emission factors are provided by VTI (Väg- och transportforskningsinstitutet), given as urban factors and factors for driving conditions outside urban areas.

A light duty vehicle type A (Swedish classification) and an urban bus (capacity: 30-59 passengers) is selected to represent vans and buses, respectively. For heavy-duty vehicles the EMV model distinguish between < 16 tonnes and > 16 tonnes vehicle weights, in both cases the emission factors are given with and without trailer (Hammarström & Henriksson, 1997). To reflect Danish fleet conditions the < 16 tonnes truck without trailer and the 16 tonnes truck with trailer should represent the < 16 tonnes and > 16 tonnes truck categories respectively.

The transformation from Swedish emission data to Danish emission formats has been made as follows. For a Danish vehicle with a given first registration year EMV emission data must be selected corresponding to the Danish EURO standard. If EMV give varying emission data for a specific EURO level according to different first registration years, emission factors should be used which correspond to the same first registration year for the Danish vehicle in question. In cases where no EMV data are available for a given first registration year emission data should be used for the latest first registration year present in the EMV database. The comparison between EMV and COPERT data is made only for hot engines.

Table A2-4 Diesel vehicle emission factors from COPERT III (Danish inventory), the Handbook version 1.2and EMV

	COPERT III (g/km)			Handbook (g/km)			EMV (g/km)	
	Urban	Rural	Highway	Urban	Rural	Highway	Urban	Highway
Passenger cars	0.10	0.06	0.10	0.07	0.06	0.08	0.18	0.11
Light duty vehicles	0.18	0.19	0.21	0.12	0.14	0.09	0.29	0.17
Urban buses	0.49	0.33	0.26				0.14	0.19
HDV < 16 tonnes	0.45	0.31	0.25				0.13	0.17
HDV > 16 tonnes	0.61	0.42	0.34				0.39	0.25

In spite of the differences between the COPERT factors used in Denmark and the Swedish EMV factors in particular, no changes will be made at present to the Danish inventory. Several reasons explains this decision. The Swedish emission legislation is not fully consistent with the Danish (EU) rules and the EMV size classification of trucks does not fully correspond to the Danish fleet information. As regards the Handbook data an uncertainty is introduced into the derived emission factors by fitting a curve to the traffic situations available in the Handbook. However, the urban emission factors from the EMV model will be used in a parallel project as an input to a Danish street pollution model (OSPM). If a good relationship is obtained between modelled and measured air quality the further use of EMV data in Denmark will be considered.

Table A2-5 Gasoline vehicle emission factors from CEPMEIP (used in Danish inventory) and EMV

		CEPMEIP (g/km)			EMV (g/km)	
		Urban	Rural	Highway	Urban	Highway
Passenger cars	Conventional	0.035	0.024	0.024	0.021	0.008
	Catalyst	0.001	0.001	0.001	0.005	0.004
Light duty vehicles	Conventional	0.040	0.040	0.040	0.032	0.012
	Catalyst	0.001	0.001	0.001	0.005	0.004

Also for gasoline vehicles the decision is to maintain the emission factors (CEPMEIP) used so far in the Danish inventory. More measurements and a consistent evaluation of emission data are needed in order to produce reliable emission factors for these vehicles.

Generally there is a need for more representative emission measurements for road traffic vehicles since the present exhaust emission factors in many cases are derived directly from measured or simulated factors for old vehicle technologies. For new technologies these factors are simply scaled according to ratios for relevant emission legislation standards. This imposes a problem since the emission behaviour during real-world driving is often very different from the emissions measured in laboratory tests. Moreover during real world driving modern engine emissions in some cases are higher than the emissions from older engine designs. This is a known fact especially for heavy-duty trucks for which modern engines are equipped with electronic engine control systems that can be optimised for low emissions in steady state conditions (type approval tests) and for fuel efficiency in the off cycle points (Hausberger et al., 2002).

The lack of emission measurements for new vehicles will to some extent be overcome in the two clustered EU 5th framework research projects Particulates (2002) and Artemis (Assessment and Reliability of Transport Emissions, 2002). The derived emission factors are likely to improve the Danish inventory in areas where data are scarce and uncertain. An important goal for Artemis and Particulates is to obtain new sets of both exhaust and non-exhaust emission factors (only tyre and brake wear) for all road vehicle types by measurements. The purpose of Artemis is to obtain harmonised emission data and inventory models for all transport modes. In Particulates the focus is on establishing a harmonised protocol of measuring particulate emissions, see Ntziachristos et al. (2002). The relevant emission data are expected to be publically available in 2004. Relevant for the annual Danish road transport estimates is that Artemis is going to replace the COPERT model as a tool for estimating the emissions from road transport.

2.2.2 Non exhaust emission factors

The non-exhaust emission sources treated in this study are tyre, brake and road asphalt wear. Different

factors affect tyre wear such as tyre construction, composition and size, accumulated mileage, driving behaviour, vehicle type, vehicle settings and maintenance, road surface characteristics and weather. Brake wear only occurs during forced decelerations, and therefore most of the emissions should be observed near busy junctions, traffic lights, pedestrian crossings, and corners.

The emission factors used until now in the Danish inventory come from TNO (2001) which has conducted a literature study targeted at proposing particulate emission factors of TSP, PM_{10} and $PM_{2.5}$ relevant for national inventories in the context of the UNECE convention. The non-exhaust particulate data originate from Dutch roadside measurements, as the only source of information (Brink 1996).

The tyre and brake wear factors have been established from mass balance experiments for passenger cars, while for other vehicle types the tyre wear factors have been estimated using information from people employed in the tyre business and industry. Brake wear factors for the same vehicle types have been estimated using the same ratio between brake and tyre wear as for passenger cars.

The road abrasion factors are taken from an emission inventory by RIZA (Institute for Inland Water Management and Waste Water Treatment) in the Netherlands in 1994. Here a total road abrasion mass was found to be 60% higher than the figure for total tyre abrasion mass. This factor (1.6) was then used to derive the road abrasion factors from the tyre wear factors. In the CEPMEIP database the factor is somewhat changed to be around 2.1.

Table A2-6 Old and new emission factors (mg/km) per vehicle category in the Danish inventory

		Brake wear			Tyre wear			Road abrasion		
	Vehicle category	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Old factors	Passenger cars	6	6	6	69	3.5	0	145	7.3	0
	Light duty veh.	7.5	7.5	7.5	90	4.5	0	190	9.5	0
	Heavy-duty veh.	32.25	32.25	32.25	371.3	18.6	0	783	39.2	0
	Buses	32.25	32.25	32.25	371.3	18.6	0	783	39.2	0
	Mopeds	1.5	1.5	1.5	17.25	0.85	0	36.5	1.85	0
	Motorcycles	3	3	3	34.5	1.7	0	73	3.7	0
New factors	Passenger cars	6	5.9	2.4	69	3.5	2.5	145	7.3	0
	Light duty veh.	7.5	7.4	3.0	90	4.5	3.2	190	9.5	0
	Heavy-duty veh.	32.25	31.6	12.9	371.25	18.6	13.0	783	39.2	0
	Buses	32.25	31.6	12.9	371.25	18.6	13.0	783	39.2	0
	Mopeds	1.5	1.5	0.6	17.25	0.9	0.6	36.5	1.85	0
	Motorcycles	3	2.9	1.2	34.5	1.7	1.2	73	3.7	0

Extensive literature surveys are made by Luhana et al (2002) and Gustafsson (2001) in order to summarise the current knowledge about particulate emissions arising from tyre, brake and asphalt road pavement wear. The work by Luhana et al (2002) is made as a part of the 5th framework project Particulates. Both surveys consider aspects of particulate chemical characteristics, emissions and health and environmental effects. The two surveys refer data for particulate size distribution and emission rates, which deviates largely.

Luhana et al. (2002) and Gustafsson (2001) refer to some studies, which suggest that tyre, brake and road wear particles appear in all size ranges, see e.g. Fauser (1999). This conflicts with the particle data from CEPMEIP; here all brake wear particulates are reported as $PM_{2.5}$ whereas for the same size range zero particulates are reported from tyre and road asphalt wear. The disagreement of particulate size fractions justifies some changes in the factors to be used in Denmark.

For tyre wear the Danish TSP emission factor (CEPMEIP) remains unchanged. A variety of emission factors have been reported in the literature so far. The CEPMEIP factor of 69 mg/km is within this interval and is moreover supported by the findings of 97 mg/km in the experimental part of Particulates (Luhana

et al., 2002). On the basis of their literature review the latter source further suggests that between 1 and 10% of all emitted particles from tyres can be classed as PM_{10}. This is in accordance with the PM_{10} fraction of 5% used in CEPMEIP. However, USEPA (1995) and TNO (1997) suggest that 70% of PM_{10} is emitted as $PM_{2.5}$, a size fraction which is adapted to calculate new Danish $PM_{2.5}$ factors for tyre wear.

Also the Danish TSP factor for brake wear is maintained for the same reasons as for tyre wear. New PM_{10} and $PM_{2.5}$ emission factors are calculated using the findings from USEPA (1995) and TNO (1997) where PM_{10} and $PM_{2.5}$ shares of total TSP are reported to be 98 and 40% respectively.

At present being it is not possible to determine road abrasion emission factors with some degree of certainty from the available literature. Road abrasion is typically included in the emission factor for total non-exhaust particulate matter; the sum of tyre and brake wear, road abrasion and resuspended material from the road surface. Due to missing data no changes will be made to the factors used in the Danish inventory (see also section 2.4).

Generally the non-exhaust emission factors must be considered as preliminary and may be subject to revisions when new information becomes available.

2.3 Emissions calculation method

The total exhaust PM emissions are calculated separately for operationally hot engines and for engines driving under cold start conditions. The total fuel use is estimated in parallel and finally a fuel balance is made in order to remove the gap between the simulated fuel use with the national fuel sale statistics provided by the Danish Energy Authority. The non-exhaust emissions are simulated using the hot engine emission calculation method.

Emissions and fuel use for hot engines
Emissions and fuel use results for operationally hot engines are calculated for each layer, and urban, rural and highway driving. The procedure is to combine fuel use and emission factors, number of vehicles, annual mileage numbers and their urban, rural and highway shares given in Table A2-2. This yields:

$$E_{R,j} = \sum_{R,j} EF_{R,j} \cdot R_S \cdot N_j \cdot M_j \quad (1)$$

Where E = Fuel use/emission results, R = road type, j = layer, EF = fuel use/emission factors, N = number of vehicles, M = annual mileage numbers, and R_S = road type share.

Extra emissions and fuel use for cold engines
Extra particulate emissions from cold start are simulated separately in the COPERT model for diesel passenger cars and light duty vehicles only. Due to lack of data no additional estimates are made outside the COPERT model to determine the cold extra emissions from gasoline vehicles. In COPERT each trip is associated with an amount of cold start emission and is assumed to take place under urban driving conditions. The number of trips is distributed evenly in months. At first cold emission factors are calculated as the hot emission factor times the cold:hot emission ratio. Secondly the extra emission factor during cold start is found by subtracting the hot emission factor from the cold emission factor. Lastly this extra factor is applied on the fraction of the total mileage driven with a cold engine (the β-factor) for all vehicles in the specific layer.

The cold:hot ratios from COPERT depend on the average trip length and the monthly ambient temperature distribution, and are equivalent for diesel passenger cars and vans, respectively. The cold extra emissions become:

$$CE_j = \sum_j \beta \cdot N_j \cdot M_j \cdot EF_{U,j} \cdot (CEr - 1) \quad (2)$$

Where CE = Cold extra emissions or fuel use, j = layer, β= cold driven trip fraction, EF_U = urban fuel use/emission factors, N = number of vehicles, M = annual mileage numbers, CE_r = cold:hot fuel use or emission ratio.

Fuel use balance
The calculated fuel use in the model must equal the statistical fuel sale totals from the Danish Energy Authority according to the UNECE emissions reporting format. The standard approach to achieve a fuel balance in annual emission inventories is to multiply the annual mileage with a fuel balance factor derived as the ratio between simulated and statistical fuel figures for gasoline and diesel, respectively. This method is also used in the present model.

For gasoline vehicles all mileage numbers are equally scaled in order to obtain a gasoline fuel equilibrium. For diesel fuel balance purposes the mileage for light and heavy-duty vehicles and buses are adjusted, given that the mileage and fuel consumption factors for these vehicles are regarded as the most uncertain parameters in the diesel model part.

2.4 Results

Table A2-7 Total exhaust $PM_{2.5}$ emissions (tonnes) for Denmark in 2000

Category	Urban [tonnes]	Rural [tonnes]	Highway [tonnes]	Total [tonnes]
Passenger Cars	381	228	124	733
Light Duty Vehicles	837	697	232	1766
Heavy-duty Vehicles	326	478	289	1092
Buses	171	122	32	324
Mopeds	25	6	0	31
Motorcycles	11	9	3	23
Total	1750	1539	680	3969

In 2000 the urban, rural and highway shares of total road traffic exhaust PM emissions (all emissions are $PM_{2.5}$) was 44, 39 and 17%, respectively. The total PM exhaust emissions have decreased substantially since the mid-1990s due to the stepwise strengthening of emission standards for all vehicle types (except 2-wheelers). This decrease will continue in the future as new low emitting vehicles complying with future emission standards substitute older and more polluting vehicles. In absolute amounts the conventional types of diesel light duty and heavy-duty vehicles have the highest emissions and for these vehicles the future emission reductions will become most effective. Conventional passenger cars still contribute significantly to this vehicle type's PM total. However the conventional emission share will be negligible in the future following the penetration of catalyst vehicles into the Danish traffic.

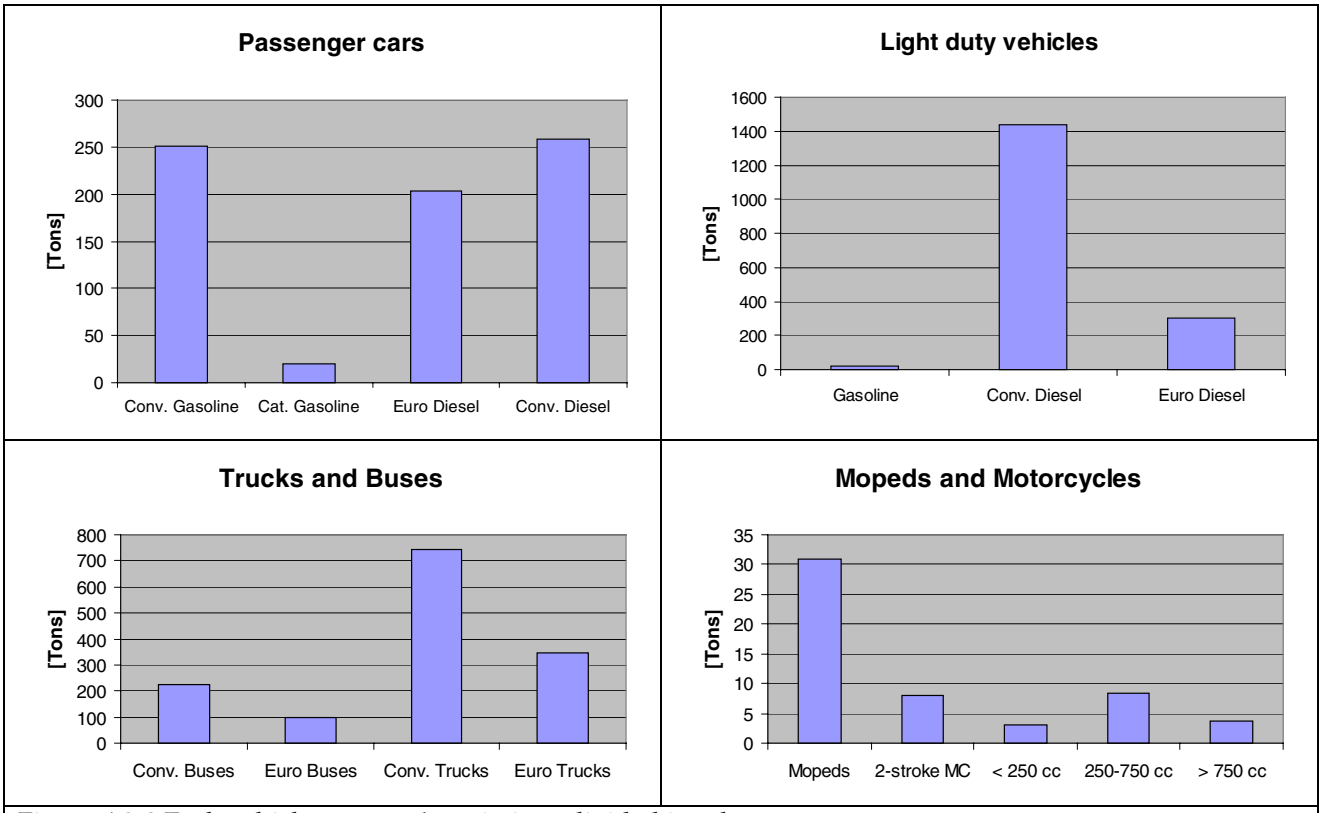

Figure A2-3 Each vehicle category's emissions divided into layers

In the Danish inventory a database has been constructed specificially to estimate the emissions from brake and tyre wear and road abrasion. The basic calculation principle is to multiply the total annual mileage per vehicle category with the correspondent average emission factors for each source type.

Table A2-8 Non exhaust emissions per vehicle category in the Danish inventory

	Brake wear (tonnes)			Tyre wear (tonnes)			Road abrasion (tonnes)			Total (tonnes)		
Vehicle category	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Old estimate												
Passenger cars	223	223	223	2565	130	0	5390	271	0	8178	624	223
Light duty veh.	61	61	61	732	37	0	1545	77	0	2338	175	61
Heavy-duty veh.	87	87	87	1001	50	0	2112	106	0	3201	243	87
Buses	27	27	27	314	16	0	662	33	0	1003	76	27
Mopeds	0	0	0	4	0	0	9	0	0	14	1	0
Motorcycles	1	1	1	15	1	0	32	2	0	49	4	1
Grand total	400	400	400	4632	234	0	9751	490	0	14783	1123	400
New estimate												
Passenger cars	223	219	89	2565	130	91	5390	271	0	8178	620	180
Light duty veh.	61	60	24	732	37	26	1545	77	0	2338	174	50
Heavy-duty veh.	87	85	35	1001	50	35	2112	106	0	3201	241	70
Buses	27	27	11	314	16	11	662	33	0	1003	76	22
Mopeds	0	0	0	4	0	0	9	0	0	14	1	0
Motorcycles	1	1	1	15	1	1	32	2	0	49	4	1
Grand total	400	392	160	4632	234	163	9751	490	0	14783	1115	323

In terms of total emissions Gustafsson (2001) provides estimates for the Swedish TSP for tyre and brake wear. The estimates are around twice as high as the Danish estimates shown in Table A2-8. Taking into account the larger Swedish fleet and route network the Swedish and the present study's results are comparable. For road abrasion Gustafsson (2001) suggests total emissions which are an order of magnitude higher than the Danish result. The large difference is due to the extensive use of studded tyres in Sweden.

For brake emissions Salway et al. (1997) report an estimate of 3,900 tonnes in the UK for PM_{10}, which is comparable to the Danish total assuming that differences in country size give proportional emission changes. No consistence in tyre wear totals can be derived from the results for Germany (Rauterberg-Wulff, 1999). the UK (Salway et al., 1997) and Denmark.

The PM results show that around 80, 20 and 10% of total road traffic TSP, PM_{10} and $PM_{2.5}$ come from non-exhaust sources. In urban areas the emissions in many cases are more harmful due to the relatively higher population density. Here the exhaust emission share is a little larger. In the future the non-exhaust share of total particulate emissions will increase due to the effect of the step-wise strengthening of exhaust emission standards. The Danish PM_{10} emissions for urban areas are markedly lower than 50% as suggested by Düring et al. (2002). In a total emissions perspective two main reasons explain why no changes are made to the CEPMEIP road abrasion factors in the Danish inventory.

Primarily, annual emission calculations must be regarded as average results made to provide environmental information in emission trends. Consequently the national vehicle fleet and mileage data behind the estimations are not able to reflect real world fleet composition and traffic behaviour in single streets. Secondly, local conditions such as weather conditions, road material and road surface maintenance level also have a strong effect on the resulting road abrasion rates. This means that it is essential to have correspondent air quality measurements and traffic counts on a local street scale if more qualified reverse calculations of the road abrasion factors should be made. The feasibility of making such reverse calculation estimates must be investigated in future research.

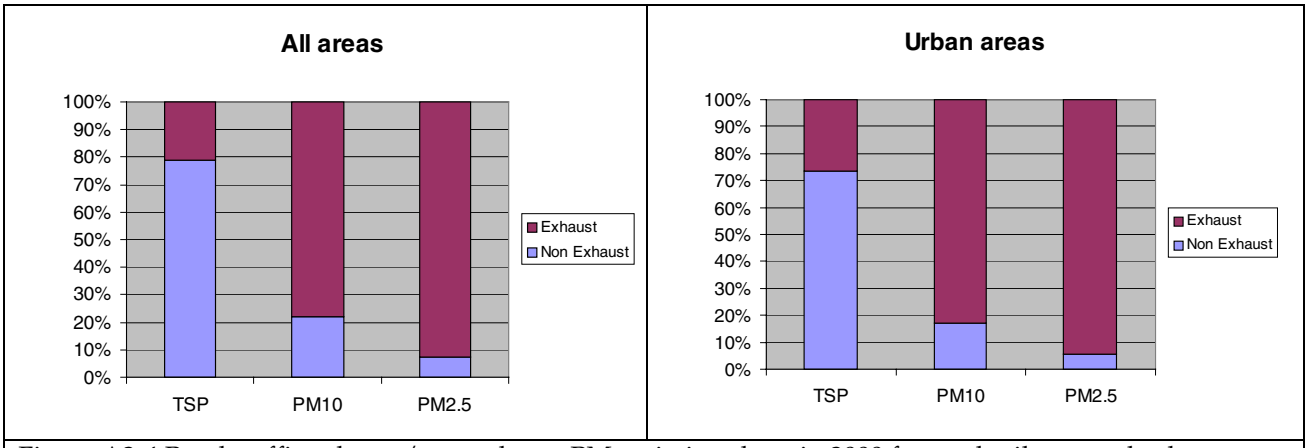

Figure A2-4 Road traffic exhaust/non-exhaust PM emission share in 2000 for total mileage and urban areas

3 Other mobile sources

3.1 Activity data

The activity data for other mobile sources consist of fuel use information provided by the DEA. The sectors: Inland waterways (small boats and pleasure crafts), agriculture, forestry, industry and household and gardening consist of off road working machines and equipment. For all sectors fuel use figures are given in appendix 2.2.

Table A2-10 Danish fuel use for other mobile sources in 2000

Category	GJ
Military	1.52
Railways	3.09
Inland waterways	0.90
National fishing	9.45
National sea traffic	4.88
Domestic aviation	1.91
Agriculture	17.44
Forestry	0.06
Industry	12.17
Household and gardening	1.16
Grand Total	52.58

3.2 Emission factors

For military ground material and railways aggregated emission factors for diesel are derived from the road traffic emission simulations made by NERI. The diesel emission factors for the remaining sectors come from the EMEP/CORINAIR guidebook, see CORINAIR (1999), however size fractions are taken from CEPMEIP. The biggest emission factors are seen for agricultural machinery (in this sector the diesel fuel use is relatively big compared to gasoline), whereas the emission factors for household and gardening are small (here only gasoline is used). The emission factors for all other fuel types come from CEPMEIP. For all sectors emission factors are given in appendix 2.2.

Table A2-11 Danish PM emission factors for other mobile sources in 2000

	TSP [g/GJ]	PM_{10} [g/GJ]	$PM_{2.5}$ [g/GJ]
Military	13.63	13.63	13.63
Railways	52.40	52.40	52.40
Inland waterways	80.62	77.28	74.10
National fishing	42.12	40.02	38.03
National sea traffic	72.24	68.63	65.20
Domestic aviation	1.63	1.63	1.63
Agriculture	124.67	118.47	112.58
Forestry	32.36	31.82	31.30
Industry	94.14	89.57	85.22
Household and gardening	23.25	23.25	23.25

3.3 Results

For military aircraft, railways, national sea traffic, fishing and aviation the emissions are calculated using fuel related emission factors and fuel use from the Danish Energy Authority.

The air traffic estimations are made separately for Landing and Take Offs (LTOs < 3000 ft) and cruise (> 3000 ft). The overall calculation scheme is explained in e.g. Winther (2001). The emissions from off road working machines and equipment in the sectors: Inland waterways, agriculture, forestry, industry and household and gardening are calculated with a new model developed at NERI (Winther et al., 1999). The new model takes into account the implementation of two emission legislation directives; one for non-road machinery (97/68/EC) and one for agricultural tractors (2000/25/EC) depending on engine size. Each directive has two stages, which become effective for new machinery in use in 1999-2001 and 1999-2003 respectively.

Table A2-12 Total Danish PM emissions from other mobile sources in 2000

	TSP [tonnes]	PM_{10} [tonnes]	$PM_{2.5}$ [tonnes]
Military	21	21	21
Railways	162	162	162
Inland waterways	72	69	66
National fishing	398	378	359
National sea traffic	352	335	318
Domestic aviation	3	3	3
Agriculture	2174	2066	1963
Forestry	2	2	2
Industry	1145	1090	1037
Household and gardening	27	27	27
Grand Total	4357	4153	3959

The fuel use and emissions in internal navigation comprise the contributions from small boats, pleasure crafts, fishing vessels and ships leaving Danish ports with domestic destinations. The working machinery category comprises the working equipment and machines in agriculture, forestry, industry, household and gardening.

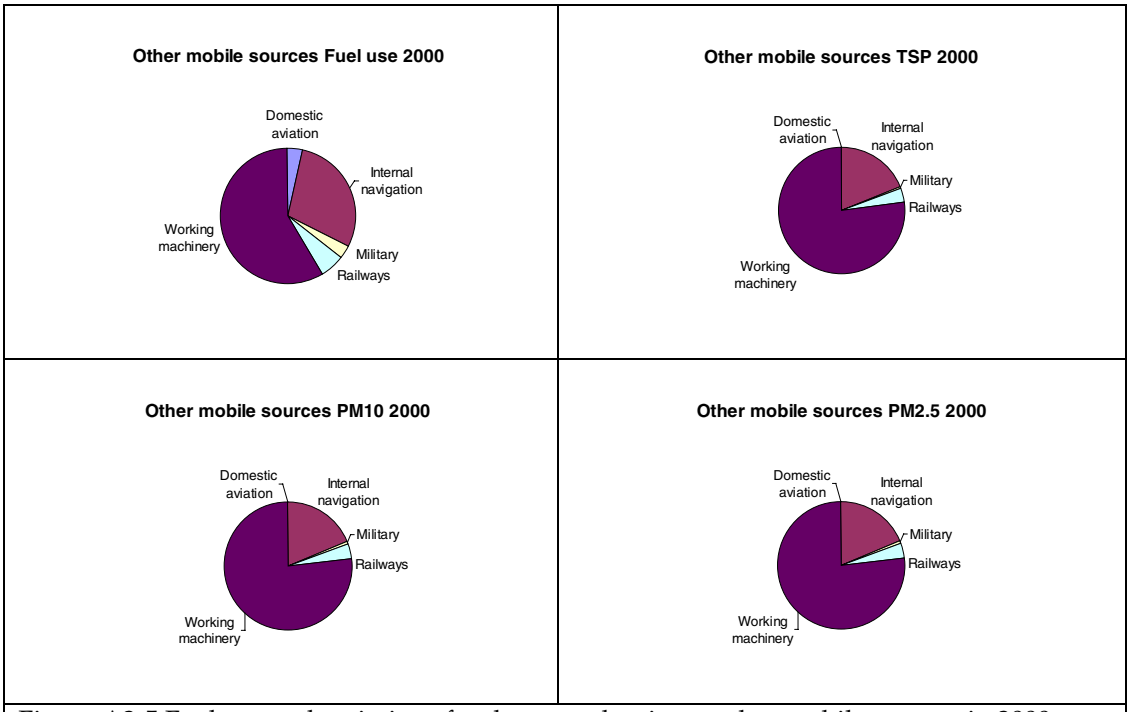

Figure A2-5 Fuel use and emissions for the most dominant other mobile sources in 2000

The emission shares for agriculture and industry are approximately one half and one fourth, respectively, of the total for other mobile sources. The two sector's fuel use shares are somewhat lower. Due to the implementation of the two stage EU emission directive, a possible strengthening of this, and a future directive for gasoline fuelled working machinery (2000/0336), the emissions from agricultural and industrial machinery (and working machinery in general) will decline in both absolute and relative terms.

4 Total emissions

Table A2-13 Particulate emission totals for all transport modes in 2000

Category	TSP [tonnes]	PM_{10} [tonnes]	$PM_{2.5}$ [tonnes]
Road traffic	3969	3969	3969
Brake wear	400	392	160
Tyre wear	4632	234	163
Road abrasion	9751	490	0
Military	19	19	19
Railways	162	162	162
Inland waterways	72	69	66
National sea traffic	352	335	318
National fishing	398	378	359
Domestic LTO	2	2	2
Domestic cruise	2	2	2
Agriculture	2174	2066	1963
Forestry	2	2	2
Industry	1145	1090	1037
Household and gardening	27	27	27
UNECE total	23106	9235	8249
International sea traffic	7618	7237	6875
International LTO	4	4	4
International cruise	34	34	34

The particulate emissions figure from road abrasion is not included in the UNECE total. Excluded are also the emissions from international sea and air traffic, meaning sea vessels and aircraft leaving Danish ports or airports with foreign destinations. The latter contributions are reported to the UNECE as memo items only.

5 Emission projections

Emission projections are made using the Danish official energy use forecast (provided by the Danish Energy Authority) together with the emission projection models for road transport and other mobile sources explained in Illerup et al (2002) and Winther (2002). For road transport the projections are based on the COPERT III metho-dology and use the vehicle fleet and mileage projections provided by the Danish Road Traffic Directorate. For other mobile sources fuel related emission factors are used. In this category future emission reductions for diesel engines are taken into account for working machinery and equipment in the sectors agriculture, forestry, industry and household and gardening. For the remaining other mobile sources no real emission improvements are expected.

The 2002-2010 emission results for road transport (exhaust PM: and non-exhaust PM) and the 2001-2010 emission results for other mobile sources are shown in appendix 2.3-2.5.

Table A2-14 Projections of exhaust emissions ($PM_{2.5}$) for road transport in 2010 and relative changes to 2000

Category	Urban	Rural	Highway	Total	%-change 2000-2010
Passenger Cars	150	82	59	291	-60
Light Duty Vehicles	384	289	109	782	-56
Heavy-duty Vehicles	145	208	123	477	-56
Buses	82	58	15	155	-52
Mopeds	28	7	0	34	10
Motorcycles	12	10	4	27	17
Grand total	801	654	310	1766	-56

From 2000 to 2010 the total exhaust emissions are expected to decrease substantially due to the stepwise strengthening of emission standards for all vehicle types (except 2-wheelers).

Table A2-15 Projections of non-exhaust emissions for road transport in 2010 and relative changes to 2000

Vehicle category	Brake wear (tonnes)			Tyre wear (tonnes)			Road abrasion (tonnes)			Total (tonnes)			%-change
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	2000-2010
Passenger cars	248	243	99	2850	145	101	5989	302	0	9088	689	200	11
Light duty veh.	77	76	31	926	46	32	1954	98	0	2956	220	63	26
Heavy-duty veh.	106	104	42	1222	61	43	2577	129	0	3904	294	85	22
Buses	32	31	13	364	18	13	768	38	0	1163	88	25	16
Mopeds	0	0	0	5	0	0	10	1	0	16	1	0	11
Motorcycles	2	2	1	19	1	1	40	2	0	61	5	1	24
Grand total	465	456	186	5385	271	190	11338	569	0	17189	1296	376	16

The 16% increase in non-exhaust emissions from 2000 to 2010 is determined by the development in total mileage for road transportation vehicles, which in turn rely on the vehicle fleet numbers and corresponding annual mileages.

Table A2-16 Projections of PM emissions for other mobile sources in 2010 and relative changes to 2000

Category	TSP		PM_{10}		$PM_{2.5}$	
	2010	%-change 2000-2010	2010	%-change 2000-2010	2010	%-change 2000-2010
Military	18	-14	18	-14	18	-14
Railways	83	-49	83	-49	83	-49
Inland waterways	83	15	79	14	76	15
National sea	221	-44	209	-45	199	-45
National fishing	393	12	373	11	355	12
Civil aviation	3	0	3	0	3	0
Agriculture	1901	-13	1807	-13	1718	-12
Forestry	2	0	2	0	2	0
Industry	656	-43	625	-43	596	-43
Household	31	15	31	15	31	15
Total	3390	-22	3231	-22	3081	-22

The development towards lower railway emissions in 2010 is caused by the increased use of electrical locomotives in this sector. For sea vessels, civil aviation and household the emissions in 2010 solely rely on this years fuel consumption, since no improvements in emission factors are taken into account in the calculations. For agricultural and industrial machinery the emissions are expected to decline with 12 and 43% from 2000 to 2010 due to the stepwise introduction of stricter emission standards for the vehicles in question.

6 Conclusion

Even though the available fleet and mileage data are adequate for emissions calculations with the COPERT II model, a more precise classification of gross vehicle weights for heavy-duty vehicles and annual mileages given per first registration year for light and heavy-duty vehicles would improve the estimate of total exhaust emissions of particulate matter. Detailed Danish fleet and mileage data are gathered by the Danish Motor Vehicle Inspection Office in the Danish inspection and maintenance programme and could be made avail-able as input data for emission modelling in 2003 depending on external resources.

In this study no change in particulate exhaust emission factors is proposed on the basis of comparisons with Handbook emission factors for diesel passenger cars and light duty vehicles, and Swedish EMV emission factors for all vehicle types. Instead areas with poor or missing data should await the availability of new and COPERT consistent emission factors in 2004. However the use of the Swedish factors will be considered depending of the outcome of parallel dispersion studies at NERI.

Modifications of the CEPMEIP emission factors behind the Danish inventory is made for brake wear using PM_{10} and $PM_{2.5}$ fractions of 98 and 40% of total TSP derived from the findings in other studies. In the same way a new $PM_{2.5}$ emission factor is estimated for tyre wear as 70% of the existing factor for PM_{10}. It is decided to maintain the factors for road abrasion and instead let the outcome of parallel research at NERI and other non-exhaust emission research activities be the basis for future emission factor improvements.

The 2010 exhaust emissions of particulate matter for road transportation vehicles and working machinery in agriculture and industry are expected to be respectively 56, 12 and 43% less, than the emission figures for 2000. The expected emission decline is due to the step-wise strengthening of emission standards. For non-exhaust emissions there are an expected 16% increase in the same time period. In relative terms this means that the non-exhaust emissions will become more important in the years to come.

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Appendix

Appendix 2.1 Fleet and mileage numbers, emission factors (g/km) and total exhaust emissions (tonnes) for road transport in 2000

Sector	Subsector	Tech	FYear	LYear	Popula-tion	Mile-age	PMu_ EF	PMr_EF	PMh_ EF	PMu	PMr	PMh
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	1969	1744	11507	0,063	0,044	0,041	0,442	0,406	0,156
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	1970	1978	17980	11507	0,063	0,044	0,041	4,562	4,187	1,612
Passenger Cars	Gasoline <1,4 l	ECE 15/02	1979	1980	7348	11507	0,063	0,044	0,041	1,864	1,711	0,659
Passenger Cars	Gasoline <1,4 l	ECE 15/03	1981	1985	118929	12591	0,042	0,029	0,029	22,012	19,976	8,251
Passenger Cars	Gasoline <1,4 l	ECE 15/04	1986	1990	235890	14356	0,030	0,020	0,020	35,559	31,156	12,869
Passenger Cars	Gasoline <1,4 l	Euro I - 91/441/EEC	1991	1996	270268	18497	0,001	0,001	0,001	1,925	1,610	0,665
Passenger Cars	Gasoline <1,4 l	Euro II - 94/12/EC	1997	2000	209279	24054	0,001	0,001	0,001	1,938	1,621	0,670
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	0	1969	1356	11507	0,063	0,044	0,041	0,344	0,316	0,122
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	1970	1978	12537	11507	0,063	0,044	0,041	3,181	2,920	1,124
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	1979	1980	4642	11507	0,063	0,044	0,041	1,178	1,081	0,416
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	1981	1985	67222	12591	0,042	0,029	0,029	12,442	11,291	4,664
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	1986	1990	160800	14356	0,030	0,020	0,020	24,239	21,238	8,772
Passenger Cars	Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC	1991	1996	309587	18497	0,001	0,001	0,001	2,205	1,844	0,762
Passenger Cars	Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC	1997	2000	287758	24054	0,001	0,001	0,001	2,665	2,229	0,921
Passenger Cars	Gasoline >2,0 l	PRE ECE	0	1969	129	11507	0,063	0,044	0,041	0,033	0,030	0,012
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	1970	1978	1110	11507	0,063	0,044	0,041	0,282	0,259	0,099
Passenger Cars	Gasoline >2,0 l	ECE 15/02	1979	1980	371	11507	0,063	0,044	0,041	0,094	0,086	0,033
Passenger Cars	Gasoline >2,0 l	ECE 15/03	1981	1985	9722	12591	0,042	0,029	0,029	1,799	1,633	0,674
Passenger Cars	Gasoline >2,0 l	ECE 15/04	1986	1990	21251	14356	0,030	0,020	0,020	3,203	2,807	1,159
Passenger Cars	Gasoline >2,0 l	Euro I - 91/441/EEC	1991	1996	30519	18497	0,001	0,001	0,001	0,217	0,182	0,075
Passenger Cars	Gasoline >2,0 l	Euro II - 94/12/EC	1997	2000	26160	24054	0,001	0,001	0,001	0,242	0,203	0,084
Passenger Cars	Diesel <2,0 l	Euro I - 91/441/EEC	1991	1996	39518	35677	0,103	0,035	0,072	50,746	22,388	19,260
Passenger Cars	Diesel <2,0 l	Euro II - 94/12/EC	1997	2000	33856	45221	0,103	0,035	0,072	55,106	24,311	20,915
Passenger Cars	Diesel <2,0 l	Conventional	0	1990	42861	26288	0,358	0,132	0,170	141,245	68,519	36,393
Passenger Cars	Diesel >2,0 l	Euro I - 91/441/EEC	1991	1996	2087	35677	0,103	0,035	0,072	2,680	1,182	1,017
Passenger Cars	Diesel >2,0 l	Euro II - 94/12/EC	1997	2000	1789	45221	0,103	0,035	0,072	2,912	1,285	1,105
Passenger Cars	Diesel >2,0 l	Conventional	0	1990	2228	26288	0,358	0,132	0,170	7,342	3,562	1,892
Passenger Cars	LPG	Conventional	0	1990	32	12591	0,040	0,030	0,025	0,006	0,006	0,002
Passenger Cars	2-Stroke	Conventional	0	9999	300	12591	0,120	0,120	0,120	0,159	0,209	0,086
Light Duty Vehicles	Gasoline <3,5t	Conventional	0	1994	28488	18101	0,040	0,040	0,040	7,219	10,313	3,094
Light Duty Vehicles	Gasoline <3,5t	Euro I - 93/59/EEC	1995	1998	15979	18101	0,001	0,001	0,001	0,091	0,101	0,030
Light Duty Vehicles	Gasoline <3,5t	Euro II - 96/69/EC	1999	2001	9299	18101	0,001	0,001	0,001	0,053	0,059	0,018
Light Duty Vehicles	Diesel <3,5 t	Conventional	0	1994	115695	32789	0,513	0,303	0,322	681,559	575,302	183,136
Light Duty Vehicles	Diesel <3,5 t	Euro I - 93/59/EEC	1995	1998	64894	32789	0,126	0,066	0,090	93,654	70,005	28,853
Light Duty Vehicles	Diesel <3,5 t	Euro II - 96/69/EC	1999	2001	37766	32789	0,126	0,066	0,090	54,503	40,740	16,791
Heavy-duty Vehicles	Gasoline >3,5 t	Conventional	0	9999	257	22009	0,400	0,400	0,400	0,724	1,063	0,475
Heavy-duty Vehicles	Diesel 3,5 - 7,5 t	Conventional	0	1993	2406	34246	0,369	0,252	0,206	9,728	9,760	3,558
Heavy-duty Vehicles	Diesel 3,5 - 7,5 t	Euro I - 91/542/EEC Stage I	1994	1996	1057	34246	0,240	0,164	0,134	2,778	2,787	1,016
Heavy-duty Vehicles	Diesel 3,5 - 7,5 t	Euro II - 91/542/EEC Stage II	1997	2001	1703	34246	0,148	0,101	0,082	2,754	2,763	1,007
Heavy-duty Vehicles	Diesel 7,5 - 16 t	Conventional	0	1993	5085	37550	0,727	0,492	0,399	44,427	44,124	15,999
Heavy-duty Vehicles	Diesel 7,5 - 16 t	Euro I - 91/542/EEC Stage I	1994	1996	2235	37550	0,473	0,320	0,259	12,692	12,606	4,571
Heavy-duty Vehicles	Diesel 7,5 - 16 t	Euro II - 91/542/EEC Stage II	1997	2001	3600	37550	0,182	0,123	0,100	7,863	7,810	2,832

Heavy-duty Vehicles	Diesel 16 - 32 t	Conventional	0	1993	7933	64092	0,871	0,594	0,484	84,132	135,864	88,598
Heavy-duty Vehicles	Diesel 16 - 32 t	Euro I - 91/542/EEC Stage I	1994	1996	3486	64092	0,566	0,386	0,315	24,031	38,807	25,306
Heavy-duty Vehicles	Diesel 16 - 32 t	Euro II - 91/542/EEC Stage II	1997	2001	5616	64092	0,218	0,148	0,121	14,890	24,046	15,680
Heavy-duty Vehicles	Diesel >32t	Conventional	0	1993	7361	64092	0,929	0,638	0,522	83,238	135,474	88,713
Heavy-duty Vehicles	Diesel >32t	Euro I - 91/542/EEC Stage I	1994	1996	3234	64092	0,604	0,415	0,340	23,770	38,688	25,334
Heavy-duty Vehicles	Diesel >32t	Euro II - 91/542/EEC Stage II	1997	2001	5211	64092	0,232	0,160	0,131	14,731	23,976	15,701
Buses	Urban Buses	Conventional	0	1993	2319	95765	0,643	0,442	0,345	72,843	40,209	6,125
Buses	Urban Buses	Euro I - 91/542/EEC Stage I	1994	1996	852	95765	0,418	0,287	0,224	17,396	9,602	1,463
Buses	Urban Buses	Euro II - 91/542/EEC Stage II	1997	2001	1345	95765	0,257	0,177	0,138	16,899	9,328	1,421
Buses	Coaches	Conventional	0	1993	2724	77850	0,676	0,454	0,367	45,851	45,259	16,357
Buses	Coaches	Euro I - 91/542/EEC Stage I	1994	1996	1001	77850	0,439	0,295	0,239	10,952	10,810	3,907
Buses	Coaches	Euro II - 91/542/EEC Stage II	1997	2001	1579	77850	0,169	0,114	0,092	6,644	6,559	2,370
Mopeds	<50 cm³	Conventional	0	1999	150522	1614	0,120	0,120		23,612	5,539	0,000
Mopeds	<50 cm³	97/24/EC Stage I	2000	2002	9478	1614	0,120	0,120		1,487	0,349	0,000
Motorcycles	2-stroke >50 cm³	Conventional	0	1999	11054	6029	0,120	0,120	0,120	3,759	3,119	1,120
Motorcycles	4-stroke <250 cm³	Conventional	0	1999	11916	6029	0,040	0,040	0,040	1,351	1,121	0,402
Motorcycles	4-stroke <250 cm³	97/24/EC	2000	2003	613	6029	0,040	0,040	0,040	0,069	0,058	0,021
Motorcycles	4-stroke 250 - 750 cm³	Conventional	0	1999	32768	6029	0,040	0,040	0,040	3,714	3,082	1,106
Motorcycles	4-stroke 250 - 750 cm³	97/24/EC	2000	2003	1685	6029	0,040	0,040	0,040	0,191	0,158	0,057
Motorcycles	4-stroke >750 cm³	Conventional	0	1999	14894	6029	0,040	0,040	0,040	1,688	1,401	0,503
Motorcycles	4-stroke >750 cm³	97/24/EC	2000	2003	766	6029	0,040	0,040	0,040	0,087	0,072	0,026

Appendix 2.2 Fuel use, emission factors and total emissions for other mobile sources in 2000

Category	Fuel type	Fuel use [GJ]	TSP [g/GJ]	PM: [g/GJ]	$PM_{2.5}$ [g/GJ]	TSP [tonnes]	PM_{10} [tonnes]	$PM_{2.5}$ [tonnes]
Military	DIESEL OIL	368508	46.6	46.6	46.6	17	17	17
Military	MOTOR GASOLINE	887	4.4	4.4	4.4	0	0	0
Military	AVIAT. GASOLINE	8894	10.0	10.0	10.0	0	0	0
Military	JET FUEL	114645	1.2	1.2	1.2	0	0	0
Military	JET FUEL	1031806	1.2	1.2	1.2	1	1	1
Railways	DIESEL OIL	3078730	52.5	52.5	52.5	162	162	162
Railways	MOTOR GASOLINE	7720	4.4	4.4	4.4	0	0	0
Inland waterways	MOTOR GASOLINE	533361.7	23.3	23.3	23.3	12	12	12
Inland waterways	DIESEL OIL	363329.4	164.8	156.6	148.8	60	57	54
National sea traffic	RESIDUAL OIL	1508806	139.4	132.4	125.8	210	200	190
National sea traffic	GAS OIL	3367109	42.2	40.0	38.0	142	135	128
National sea traffic	KEROSENE	626	97.6	92.7	88.0	0	0	0
National sea traffic	LPG	138	12.4	12.4	12.4	0	0	0
National fishing	GAS OIL	9346878	42.2	40.0	38.0	394	374	356
National fishing	KEROSENE	24708	97.6	92.7	88.0	2	2	2
National fishing	MOTOR GASOLINE	66587	23.3	23.3	23.3	2	2	2
National fishing	LPG	12742	12.4	12.4	12.4	0	0	0
International sea traffic	RESIDUAL OIL	33185389	200.5	190.5	181.0	6654	6321	6005
International sea traffic	GAS OIL	22872342	42.2	40.0	38.0	964	916	870
Domestic LTO	JET FUEL	591311	1.2	1.2	1.2	2	2	2
Domestic LTO	AVIAT. GASOLINE	101400.4	10.0	10.0	10.0	2	2	2
International LTO	JET FUEL	3299387	1.2	1.2	1.2	4	4	4
International LTO	AVIAT. GASOLINE	8705.594	10.0	10.0	10.0	0	0	0
Domestic cruise	JET FUEL	1648114	1.2	1.2	1.2	1	1	1
International cruise	JET FUEL	29719188	1.2	1.2	1.2	34	34	34
Agriculture	DIESEL OIL	16931053	127.7	121.3	115.3	2162	2054	1952
Agriculture	MOTOR GASOLINE	509036.1	23.3	23.3	23.3	12	12	12
Forestry	DIESEL OIL	4896.27	142.3	135.2	128.4	1	1	1
Forestry	MOTOR GASOLINE	59089	23.3	23.3	23.3	1	1	1
Industry	DIESEL OIL	9650646	115.3	109.5	104.0	1113	1057	1004
Industry	MOTOR GASOLINE	139893.5	23.3	23.3	23.3	3	3	3
Industry	LPG	2375942	12.4	12.4	12.4	30	30	30
Household and gardening	MOTOR GASOLINE	1162275	23.3	23.3	23.3	27	27	27

Appendix 2.3 Emissions of exhaust particulate matter (tonnes) for road transport 2002-2010

SectorID	Year	Urban	Rural	Highway	Total
Passenger Cars	2002	267	182	104	553
Passenger Cars	2003	248	164	97	509
Passenger Cars	2004	230	148	90	468
Passenger Cars	2005	215	133	84	432
Passenger Cars	2006	197	118	77	392
Passenger Cars	2007	183	107	71	361
Passenger Cars	2008	170	97	66	333
Passenger Cars	2009	159	89	62	310
Passenger Cars	2010	150	82	59	291
Light Duty Vehicles	2002	810	643	218	1671
Light Duty Vehicles	2003	754	596	204	1554
Light Duty Vehicles	2004	699	549	190	1438
Light Duty Vehicles	2005	646	504	177	1327
Light Duty Vehicles	2006	595	461	164	1220
Light Duty Vehicles	2007	536	413	149	1097
Light Duty Vehicles	2008	481	368	134	983
Light Duty Vehicles	2009	430	326	121	877
Light Duty Vehicles	2010	384	289	109	782
Heavy-duty Vehicles	2002	308	448	270	1026
Heavy-duty Vehicles	2003	288	419	252	959
Heavy-duty Vehicles	2004	269	390	234	893
Heavy-duty Vehicles	2005	250	363	217	830
Heavy-duty Vehicles	2006	232	336	201	769
Heavy-duty Vehicles	2007	208	301	180	689
Heavy-duty Vehicles	2008	186	268	159	613
Heavy-duty Vehicles	2009	165	237	141	542
Heavy-duty Vehicles	2010	145	208	123	477
Buses	2002	162	115	30	307
Buses	2003	153	109	28	290
Buses	2004	144	102	26	272
Buses	2005	135	96	25	255
Buses	2006	127	89	23	239
Buses	2007	115	81	21	216
Buses	2008	103	73	19	194
Buses	2009	92	65	17	174
Buses	2010	82	58	15	155
Mopeds	2002	24	6	0	29
Mopeds	2003	24	6	0	30
Mopeds	2004	25	6	0	31
Mopeds	2005	26	6	0	31
Mopeds	2006	26	6	0	32
Mopeds	2007	27	6	0	33
Mopeds	2008	27	6	0	34
Mopeds	2009	28	6	0	34
Mopeds	2010	28	7	0	34
Motorcycles	2002	11	9	3	23
Motorcycles	2003	11	9	3	24

Motorcycles	2004	11	9	3	24
Motorcycles	2005	12	10	3	25
Motorcycles	2006	12	10	4	25
Motorcycles	2007	12	10	4	26
Motorcycles	2008	12	10	4	26
Motorcycles	2009	12	10	4	26
Motorcycles	2010	12	10	4	27

Appendix 2.4 Total emissions of TSP, PM_{10} and $PM_{2.5}$ (tonnes) for other mobile sources

TSP

Category	Military	Railways	Inland waterways	National sea	National fishing	Civil aviation	Agriculture	Forestry	Industry	House-hold	Total
2001	39	150	72	348	376	4	2.167	2	1.106	27	4.291
2002	41	84	73	258	393	3	2.143	2	1.068	27	4.091
2003	38	84	74	245	393	3	2.147	2	1.029	28	4.042
2004	34	83	76	233	393	3	2.117	2	974	28	3.943
2005	32	83	77	221	393	3	2.089	2	918	29	3.846
2006	29	83	78	221	393	3	2.056	2	859	29	3.752
2007	26	83	79	221	393	3	2.021	2	797	30	3.654
2008	23	83	81	221	393	3	1.983	2	733	30	3.552
2009	21	83	82	221	393	3	1.943	2	695	31	3.472
2010	18	83	83	221	393	3	1.901	2	656	31	3.390

PM_{10}

Category	Military	Railways	Inland waterways	National sea	National fishing	Civil aviation	Agriculture	Forestry	Industry	House-hold	Total
2001	39	150	69	330	357	4	2.060	2	1.052	27	4.091
2002	41	84	70	245	373	3	2.036	2	1.016	27	3.897
2003	38	84	71	233	373	3	2.040	2	979	28	3.851
2004	34	83	72	221	373	3	2.012	2	927	28	3.757
2005	32	83	74	209	373	3	1.985	2	874	29	3.664
2006	29	83	75	209	373	3	1.954	2	818	29	3.575
2007	26	83	76	209	373	3	1.920	2	759	30	3.482
2008	23	83	77	209	373	3	1.885	2	699	30	3.384
2009	21	83	78	209	373	3	1.846	2	662	31	3.309
2010	18	83	79	209	373	3	1.807	2	625	31	3.231

$PM_{2.5}$

Category	Military	Railways	Inland waterways	National sea	National fishing	Civil aviation	Agriculture	Forestry	Industry	House-hold	Total
2001	39	150	67	314	340	4	1.958	2	1.002	27	3.902
2002	41	84	67	233	355	3	1.936	2	968	27	3.715
2003	38	84	68	222	355	3	1.940	2	933	28	3.671
2004	34	83	70	210	355	3	1.913	2	883	28	3.581
2005	32	83	71	199	355	3	1.888	2	833	29	3.493
2006	29	83	72	199	355	3	1.858	2	779	29	3.409
2007	26	83	73	199	355	3	1.826	2	723	30	3.320
2008	23	83	74	199	355	3	1.792	2	666	30	3.227
2009	21	83	75	199	355	3	1.756	2	631	31	3.155
2010	18	83	76	199	355	3	1.718	2	596	31	3.081

Appendix 2.5

Category	Fore-castYear	Source	TSPU	TSPR	TSPH	$PM_{10}U$	$PM_{10}R$	$PM_{10}H$	$PM_{2.5}U$	$PM_{2.5}R$	$PM_{2.5}H$
Passenger cars	2002	Road abrasion	1822	2395	989	92	121	50	0	0	0
Passenger cars	2003	Road abrasion	1868	2454	1014	94	124	51	0	0	0
Passenger cars	2004	Road abrasion	1906	2506	1035	96	126	52	0	0	0
Passenger cars	2005	Road abrasion	1948	2560	1057	98	129	53	0	0	0
Passenger cars	2006	Road abrasion	1987	2611	1078	100	131	54	0	0	0
Passenger cars	2007	Road abrasion	2022	2658	1098	102	134	55	0	0	0
Passenger cars	2008	Road abrasion	2054	2699	1115	103	136	56	0	0	0
Passenger cars	2009	Road abrasion	2081	2735	1130	105	138	57	0	0	0
Passenger cars	2010	Road abrasion	2096	2755	1138	106	139	57	0	0	0
Light duty vehicles	2002	Road abrasion	592	845	254	30	42	13	0	0	0
Light duty vehicles	2003	Road abrasion	606	866	260	30	43	13	0	0	0
Light duty vehicles	2004	Road abrasion	618	883	265	31	44	13	0	0	0
Light duty vehicles	2005	Road abrasion	631	901	270	32	45	14	0	0	0
Light duty vehicles	2006	Road abrasion	642	917	275	32	46	14	0	0	0
Light duty vehicles	2007	Road abrasion	653	933	280	33	47	14	0	0	0
Light duty vehicles	2008	Road abrasion	663	948	284	33	47	14	0	0	0
Light duty vehicles	2009	Road abrasion	674	963	289	34	48	14	0	0	0
Light duty vehicles	2010	Road abrasion	684	977	293	34	49	15	0	0	0
Heavy-duty vehicles	2002	Road abrasion	502	1044	751	25	52	38	0	0	0
Heavy-duty vehicles	2003	Road abrasion	512	1064	766	26	53	38	0	0	0
Heavy-duty vehicles	2004	Road abrasion	520	1081	778	26	54	39	0	0	0
Heavy-duty vehicles	2005	Road abrasion	529	1099	791	26	55	40	0	0	0
Heavy-duty vehicles	2006	Road abrasion	536	1114	802	27	56	40	0	0	0
Heavy-duty vehicles	2007	Road abrasion	543	1129	812	27	57	41	0	0	0
Heavy-duty vehicles	2008	Road abrasion	550	1143	822	28	57	41	0	0	0
Heavy-duty vehicles	2009	Road abrasion	557	1157	832	28	58	42	0	0	0
Heavy-duty vehicles	2010	Road abrasion	563	1171	843	28	59	42	0	0	0
Buses	2002	Road abrasion	299	316	103	15	16	5	0	0	0
Buses	2003	Road abrasion	303	320	105	15	16	5	0	0	0
Buses	2004	Road abrasion	306	323	106	15	16	5	0	0	0
Buses	2005	Road abrasion	309	326	107	15	16	5	0	0	0
Buses	2006	Road abrasion	311	329	108	16	16	5	0	0	0
Buses	2007	Road abrasion	313	331	109	16	17	5	0	0	0
Buses	2008	Road abrasion	315	334	110	16	17	5	0	0	0
Buses	2009	Road abrasion	317	336	111	16	17	6	0	0	0
Buses	2010	Road abrasion	318	338	111	16	17	6	0	0	0
Mopeds	2002	Road abrasion	7	2	0	0	0	0	0	0	0
Mopeds	2003	Road abrasion	7	2	0	0	0	0	0	0	0
Mopeds	2004	Road abrasion	8	2	0	0	0	0	0	0	0
Mopeds	2005	Road abrasion	8	2	0	0	0	0	0	0	0
Mopeds	2006	Road abrasion	8	2	0	0	0	0	0	0	0
Mopeds	2007	Road abrasion	8	2	0	0	0	0	0	0	0
Mopeds	2008	Road abrasion	8	2	0	0	0	0	0	0	0
Mopeds	2009	Road abrasion	8	2	0	0	0	0	0	0	0
Mopeds	2010	Road abrasion	8	2	0	0	0	0	0	0	0
Motorcycles	2002	Road abrasion	15	13	5	1	1	0	0	0	0
Motorcycles	2003	Road abrasion	16	13	5	1	1	0	0	0	0
Motorcycles	2004	Road abrasion	16	14	5	1	1	0	0	0	0

Motorcycles	2005	Road abrasion	17	14	5	1	1	0	0	0	0
Motorcycles	2006	Road abrasion	17	14	5	1	1	0	0	0	0
Motorcycles	2007	Road abrasion	18	15	5	1	1	0	0	0	0
Motorcycles	2008	Road abrasion	18	15	5	1	1	0	0	0	0
Motorcycles	2009	Road abrasion	19	15	6	1	1	0	0	0	0
Motorcycles	2010	Road abrasion	19	16	6	1	1	0	0	0	0

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Appendix 3 Emission of particulate matter from the agricultural sector

Contents

Emission of particulate matter from the agricultural sector

Recently, there has been an increasing interest in evaluating the particulate emission from the agricultural sector. Investigations have shown that farmers as well as the livestock increase the chance of developing lung- and respiratory related diseases by this particulate emission (Hartung & Seedorf, 1999) since the particles are able to carry bacteria, viruses and other organic compounds. This is especially a problem in relation to the indoor working environment. This paper is the first approach to evaluate the particulate emission from the Danish agricultural sector.

1 Methods and assumptions

The calculation of this emission inventory is based on the CEPMEIP database established by TNO (http://www.air.sk/tno/cepmeip/). The data background for particulate emission is primarily based on investigations of North European stables (Takai et al., 1998). Due to the lack of data this inventory only includes emission from stables. Even these data are uncertain. Subsequently, it is planned to incorporate particulate emission from arable farming – i.e. harvesting and field preparation by machines.

The particle emission includes primary particles in the form of dust from stables. Three main types of stables, cattle-, pigs- and poultry stable, are included in this inventory. Furthermore poultry is divided into two categories – "poultry, chickens" and "poultry, other".

2 References – sources of information

The number of animals is based on Statistics Denmark, Agricultural Statistic (www.dst.dk). The emission factor for cattle, pigs and "poultry, chickens" is based on Takai et al. (1998), and for "poultry, other" the value from CEPMEIP database has been used.

3 Emission

The emission is calculated as the summary of activity (a) multiplied by the emission factor (ef) for each activity. The emission is estimated as Total Suspended Particulate (TSP):

$$E_{total,\,TSP} = \sum a_i \bullet ef_i$$

In Takai, et al. (1998), dust emission from stables is estimated as "Inhalable dust". This is defined as particles that can be transported into the body by the respiratory system. Approximately, "inhalable dust" is equal to TSP (Hinz, T., 2002 and ISO/CEN, 1993).

For each source of emission, the proportion of $PM_{2.5}$ and PM_{10} is estimated – i.e. particles with a diameter smaller than 2,5 µm and 10 µm, respectively. The distribution of particle size is based on CEPMEIP database. Here, $PM_{2.5}$ constitute 10% of TSP and PM_{10} constitute 45% of TSP. This distribution is in accordance with measurements from an investigation made in Finland on 15 pig stables (Louhekainen et al., 1987a).

In 2001 the particle emission from agricultural activities is estimated to 14.200 tonnes (E_{TSP-}) – see Table A3-1. The main part of the emission originates from pig stables, whereas emission from poultry and cattle are minor sources.

Table A3-1. Emission factors used to estimate the PM emission from agricultural activities

PM Emission from animal production 2001	No. of animal	Emission factor			Emission		
	1000 head	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP
		g/head/ year			Mg/year	Mg/year	Mg/year
Animal category							
Poultry, chickens [1)]	19329	47.3	10.5	105.1	914	203	2031
Poultry, other poultry [2)]	889	249.2	55.3	553.1	222	49	492
Stock, cattle [3)]	1907	433.6	96.4	963.6	827	184	1838
Livestock, pigs [4)]	10110	437.6	97.2	972.4	4424	983	9831
Emission, total					6387	1419	14191

1Laying hens and broilers;
2Turkey, geese and duck;
3Dairy cattle and non-dairy (heifer, bulls, calves and suckling cattle);
4 Sows and slaughter pigs (Weaners under and over 50 kg)

In the period of 1990 to 2001, using the same method for consecutive years, it is seen that the total emission of particles (E_{TSP}) has increased with 13% (Figure A3-1). The increment is due to an increase in the livestock production – especially the pig production.

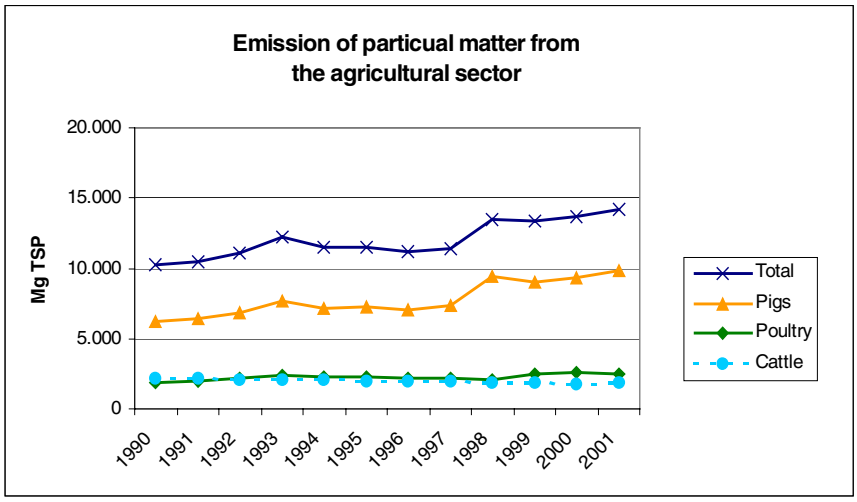

Figure A3-1. Particle emission from agricultural activities

The main part of the dust emission from stables originates from feeding and bedding. A smaller part originates from hair, skin, insects and grain pollen (Klimont et al., 2002). The amount of emission depends of the type of livestock, animal density and the age and activity of the animals. Furthermore, feeding strategy, the stable system and the physical conditions like ventilation, temperature, light and humidity has an effect on the amount of particle emission. Therefore, the emission from different types of stable systems can vary considerably (Takai et al., 1998, Klimont et al., 2002). For example, high humidity in pig- and cattle stables with deep litter reduces the dust emission. Therefore the emission from theses stable types is smaller than stables with tied-up systems.

So far, the method to estimate the particle emission only depends of the number of animals. However, it is necessary to take into account the variation in emission from different stable systems. Nevertheless, at this

stage it is necessary to gain more knowledge on this issue before it is taken into account.

Experiments have shown that the dust emission can be reduced markedly by adding lipids into the feed as well as by spraying the stables with an oil-water mixture. In this way, the emission can be reduced by up to 85% (Takai and Pedersen, 2000).

4 Uncertainties

The estimation of the particle emission is connected with high uncertainty in the order of several 100%. One reason is that the number of measurements of dust in stables is very limited and that the few existing measurements vary considerably. Likewise, the contribution of $PM_{2.5}$ and PM_{10} is uncertain.

5 Information of quality assurance/quality control (QA/QC)

In the preparation of this emission inventory the Danish Institute of Agricultural Science (DIAS) was consulted. They have been involved in the measurements of the dust emission from stables. DIAS has confirmed that the emission factors used in the inventory are the most reliable estimates. DIAS points out the necessity of including emission data from different stable system as soon as they are available.

When using the CEPMEIP database, the total emission from the agricultural sector is estimated to a lower value than the Danish calculation. Unfortunately, it has not been possible to look into the basis of the emission factor estimates in CEPMEIP database. It is apparent that, there is a discrepancy in the aggregation of the number of animals for each category. However, considering the uncertainties this distinction is insignificant.

Table A3-2. Emission of PM difference in use of methods

Emission inventory	PM emission tonnes TPS 2001
CEPMEIP	13,800
DK	14,200

In a report prepared by TNO, the particulate emission from 15 European countries has been estimated (Berdowski et al. 1997). Here it appears that the emission from the agricultural sector con-tribute approximately 5% of the total emission. In Denmark the emission from agricultural activities makes up about 24% of the total emission. The higher emission is due to the fact that the agricultural production is relatively big compared with the size of the country.

6 Improvements

In future, it is planned to include dust emission from arable farming. Inventories from Finland show that dust emission from arable farming contributes approximately 25% of the total emission from the agricultural sector (Karvosenoja et al., 2001 and Louhekainen et al., 1987b). The particle emission from this source is substantial and it is therefore important to include this in future emission inventories.

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