National Environmental Research Institute
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NERI Technical Report No. 655, 2008

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Data sheet

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Abstract:	This report contains a description of models and background data for projection of SO_2, NO_X, NH_3, NMVOC, TSP, PM_{10} and $PM_{2.5}$ for Denmark. The emissions are projected to 2030 using basic scenarios together with the expected results of a few individual policy measures. Official Danish forecasts of activity rates are used in the models for those sectors for which the forecasts are available, i.e. the latest official forecast from the Danish Energy Authority. The emission factors refer to international guidelines and some are country-specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of plants. The projection models are based on the same structure and method as the Danish emission inventories in order to ensure consistency.

Keywords:	Acidifying gases, projections, emissions, SO_2, NO_X, NH_3, NMVOC, TSP, PM_{10} and $PM_{2.5}$
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Contents

Preface

This report contains a description of models and background data for projection of SO_2, NO_X, NMVOC, NH_3, TSP, PM_{10} and $PM_{2.5}$ for Denmark. The emissions are projected to 2030 using basic scenarios which include the estimated effects on Denmark's emissions of policies and measures implemented until June 2006 ('with measures' projections).

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

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

Ulrik Torp (chairman, EPA), Christian Lange Fogh (EPA), Erik Thomsen (EPA), Jørn L. Hansen (EPA), Rasmus Lassen (EPA), Dorte Kubel (EPA), Thomas Jensen (Danish Energy Authority), Lisa Bjergbakke (Trafikministeriet), Jytte Boll Illerup (project leader, NERI), Morten Winther (NERI), Ole-Kenneth Nielsen (NERI) and Mette Hjort Mikkelsen (NERI).

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The Energy Agency for providing the energy consumption forecast.

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Summary

Introduction

This report contains a description of the models and background data used for projection of the pollutants SO_2, NO_X, NMVOC, NH_3, TSP, PM_{10} and $PM_{2.5}$ for Denmark. The emissions are projected to 2030 using basic scenarios which include the estimated effects on emissions of policies and measures implemented until June 2006 ('with measures' projections). For activity rates, official Danish forecasts, e.g. the official forecast from the Danish Energy Authority, are used to provide activity rates in the models for those sectors for which these forecasts are available. The emission factors refer to international guidelines or are country-specific, referring to Danish legislation, Danish research reports or calculations based on emissions data from a considerable number of plants in Denmark. The projection models are based on the same structure and methodology as the Danish emission inventories in order to ensure consistency.

In Europe regional air pollution is regulated by a number of protocols under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). The objectives of the new protocol – the Gothenburg Protocol – are to control and reduce the emissions of SO_2, NO_X, NMVOC and NH_3. Contrary to the earlier protocols the parties to the convention are not obliged to comply with certain reduction percentages set in relation to a baseline year. Instead emission ceilings have been based on knowledge of critical loads and environmental impact on ecosystems within the geographical area of Europe. Table 1 shows the emission ceilings for Denmark in 2010. The same emission ceilings are given in the EU directive: Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

Table 1 Emission ceilings for Denmark in 2010 (tonnes)

Pollutants	SO_2	NO_X	NMVOC	NH_3*
Emission ceilings	55,000	127,000	85,000	69,000

* The NH_3 emission ceiling excludes the emission from straw treatment and crops.

Pollutant summary

NO_X

The projected NO_X emission of 135.8 ktonnes in 2010 is somewhat higher than the emission ceiling of 127 ktonnes. The three largest sources are transport (mainly road transport), energy industries and other mobile sources.

SO_2

The Danish SO_2 emission ceiling of 55 ktonnes in 2010 will be achieved according to the projection, which estimates the emission in 2010 to 20 ktonnes, approximately 64 % less than the emission ceiling. The largest source of the emission of SO_2 is energy industries, accounting for 43 % of the SO_2 emission in 2010.

NMVOC

The projected NMVOC emission of 92.8 ktonnes is somewhat higher than the emission ceiling of 85 ktonnes. The largest emission sources of NMVOC are use of solvents, transport, non-industrial combustion plants (mainly wood combustion in residential plants), other mobile sources and offshore activities.

NH_3

The projected emission in 2010 is estimated to be 65.5 ktonnes (excluding emissions from crops), compared with the emission ceilings of 69 ktonnes. This means that the Danish NH_3 emission is expected to be 5 % below the emission ceiling in 2010. Almost all emissions of NH_3 result from agricultural activities and the major part comes from livestock manure.

TSP

Particles are not included under the NEC directive, so no emission ceilings are established for TSP, PM_{10} or $PM_{2.5}$. The main sources of particle emission are agriculture and non-industrial combustion, mainly wood combustion in residential plants. These two sources are approximately the same size and account for 85 % of the total TSP emission in 2010.

PM_{10}

The main sources of the PM_{10} emission are non-industrial combustion, mainly wood combustion in residential plants, and agriculture. They account for 48 % and 34 % respectively.

$PM_{2.5}$

The main source by far of the $PM_{2.5}$ emission is non-industrial combustion, mainly wood combustion in residential plants, which accounts for 67 % of the total $PM_{2.5}$ emission in 2010. The other most important sectors are transport and agriculture.

Sammenfatning

Introduktion

Denne rapport indeholder en beskrivelse af de modeller og baggrundsdata der er benyttet til fremskrivning af SO_2, NO_X, NMVOC, NH_3, TSP, PM_{10} og $PM_{2.5}$. Emissionerne er fremskrevet til 2030 som basisscenarie, som inkluderer de estimerede effekter på emissionerne af vedtaget lovgivning inden juni 2006. For aktivitetsdata benyttes, hvor det er muligt, officielle danske fremskrivninger, f.eks. den officielle energifremskrivning fra Energistyrelsen. De anvendte emissionsfaktorer henviser enten til internationale guidelines eller nationale emissionsfaktorer, som refererer til dansk lovgivning, danske forskningsrapporter eller emissionsdata fra et betydeligt antal anlæg i Danmark. Fremskrivningsmodellerne er opbygget efter den samme struktur og benytter samme metodevalg som anvendes ved udarbejdelsen af de årlige emissionsopgørelser. Dette sikrer konsistens imellem de årlige opgørelser og fremskrivningen.

I Europa reguleres den regionale luftforurening af en række protokoller under FN's konvention om langtransporteret, grænseoverskridende luftforurening (United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution (CLRTAP)). Formålet med den nye protokol – Gøteborg-protokollen – er at kontrollere og reducere emissionerne af SO_2, NO_X, NMVOC og NH_3. I modsætning til de tidligere protokoller er parterne i protokollen ikke forpligtede til at reducere emissionerne med en bestemt procent i forhold til emissionerne i et basisår. I stedet er der for hvert land fastlagt emissionslofter, bestemt ud fra den viden der findes om kritiske belastninger og miljømæssige påvirkninger indenfor Europas geografiske område. Tabel 1 viser emissionslofterne for Danmark i 2010. De samme emissionslofter er givet i EU-direktivet: Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

Tabel 1. Emissionslofter for Danmark i 2010 (tons).

Stoffer	SO_2	NO_X	NMVOC	NH_3*
Emissionslofter	55.000	127.000	85.000	69.000

NH_3 emissionsloftet er eksklusiv emissioner fra afgrøder og ammoniakbehandlet halm.

Emissionsfremskrivninger

NO_X

Den fremskrevne NO_X emission er i 2010 estimeret til 135,8 kton, hvilket er ca. 7 % højere end emissionsloftet på 127 kton. De største kilder er transportsektoren, energisektoren og andre mobile kilder.

SO_2

Fremskrivningen af SO_2 emission er for 2010 estimeret til 20 kton, hvilket er markant under emissionsloftet på 55 kton. Den største kilde til SO_2 emission er energisektoren som bidrager med 43 % af den samlede SO_2 emission i 2010

NMVOC

Den fremskrevne NMVOC emission er i 2010 estimeret til 92,8 kton, hvilket er ca. 9 % højere end emissionsloftet på 85 kton. De vigtigste kilder til NMVOC emission er opløsningsmidler, transportsektoren, ikke-industrielle forbrændingsanlæg (hovedsageligt træafbrænding i husholdninger), andre mobile kilder og flygtige emissioner fra offshore sektoren.

NH_3

Den fremskrevne NH_3 emission er i 2010 estimeret til 65,5 kton (eksklusiv emission fra afgrøder) det er 5 % laverer end emissionsloftet på 69 kton. Stort set hele NH_3 emissionen stammer fra landbrugssektoren, herunder er det største bidrag fra husdyrgødning.

TSP

Partikler er ikke inkluderet under NEC direktivet, så der er ikke fastsat et emissionsloft for TSP, PM_{10} og $PM_{2.5}$. De vigtigste kilder til partikel-emission er landbrug og ikke-industriel forbrænding, hovedsageligt træafbrænding i husholdninger. Disse to kilder er omtrent lige store og udgør tilsammen 85 % af den totale TSP emission i 2010.

PM_{10}

De vigtigste kilder til PM_{10} emission er ikke-industriel forbrænding, hovedsageligt træafbrænding i husholdninger og landbrug. De udgør henholdsvis 48 og 34 % af den samlede emission.

$PM_{2.5}$

Hovedkilden til $PM_{2.5}$ emission er ikke-industriel forbrænding, hovedsageligt træafbrænding i husholdninger, som i 2010 udgør 67 % af den samlede $PM_{2.5}$ emission. Andre vigtige sektorer er transport og landbrug.

1 Introduction

In the MST project 'Projection models 2010' (Illerup et al., 2002) a number of sector-specific models were developed in order to project emissions of SO_2, NO_X, NMVOC and NH_3 to 2010. These models have been further developed in order to include TSP, PM_{10} and $PM_{2.5}$ and to project the emissions to 2030.

In this report projections have been made for stationary combustion, transport, other mobile sources and fugitive emissions. The calculation methods and activity data for these sectors are presented and the results are discussed.

Projection of NMVOC emission from solvents has been described in a separate report (Fauser and Illerup, 2007). The results and a brief summary are included in this report.

Projection of NH_3 and particles from the agricultural sector has been the subject of a separate report (Gyldenkærne and Mikkelsen, 2007). The results and a summary are included in this report.

Emissions from industrial processes have not been projected, instead historical data from 2004 (Illerup et al., 2006) has been applied for the entire time series.

1.1 Obligations

Regional air pollution is regulated by a number of protocols under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). The objectives of the most recent of these protocols – the Gothenburg Protocol – is to control and reduce emissions of SO_2, NO_X, NMCOV and NH_3 to reduce exceedence of critical loads with regard to acidification, eutrophication and the effect of photochemical air pollution (ozone). In contrast to the earlier protocols, the individual countries are not obliged to achieve a certain reduction target, but emission ceilings have been set in order to reduce exceedence of the critical loads, based on the knowledge of critical loads and effects on the ecosystems within the geographic area of Europe. Emission ceilings for Denmark in 2010 according to the Gothenburg Protocol are shown in Table 1.1

Table 1.1 Emission ceilings for Denmark in 2010 (tonnes)

Pollutants	SO_2	NO_X	NMVOC	NH_3*
Emission ceilings	55000	127000	85000	69000

* The NH_3 emission ceiling excludes emissions from ammonia-treated straw and crops.

These emission ceilings are also included in the EU directive: Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

According to the protocol and the directive, Denmark is obliged to report annual emissions of SO_2, NO_X, NMVOC and NH_3, as well as data on projected emissions and current reduction plans. The expected development in the emissions to 2010 can be illustrated using the projection models developed in the present project and, based on the projected emissions, it will be possible to decide whether it is necessary to implement further regulation of the emissions in the individual sectors.

1.2 Environmental problems

Emissions of SO_2, NO_x, NMVOC and NH_3 especially relate to regional environmental problems and may cause acidification, eutrophication or photochemical smog.

1.2.1 Acidification

Acid deposition of sulphur and nitrogen compounds stems mainly from SO_2, NO_x and NH_3 emissions. The effects of acidification are expressed in a number of ways, including defoliation and reduced vitality of trees, and declining fish stocks in acid-sensitive lakes and rivers (European Environmental Agency, 1998).

SO_2 and NO_x can be oxidised into sulphate (SO_4^{--}) and nitrate (NO_3^-), either in the atmosphere or after deposition, respectively resulting in the formation of two H^+-ions and one. NH_3 may react with H^+ to form ammonium (NH_4^+) and on nitrification in soil NH_4^+ is oxidised to NO_3^-, resulting in the formation of two H^+-ions (Wark and Warner, 1981).

The total emissions in terms of acid equivalents can be calculated by means of equation 1.1. Figure 1.1 shows the distribution of emissions of SO_2, NO_x and NH_3 for 2000 in terms of acid equivalents

eq 1.1 $$Total\ acid\ equivalents = \frac{m_{SO_2}}{M_{SO_2}} \cdot 2 + \frac{m_{NO_x}}{M_{NO_x}} + \frac{m}{M}$$

where m_i is the emission of pollutant i [tonnes], and M_i is the molecular weight [tonne/Mmole] of pollutant i.

The actual effect of the acidifying substances depends on a combination of two factors: the amount of acid deposition and the natural capacity of the terrestrial or aquatic ecosystem. In areas where the soil minerals easily weather or have a high chalk content, acid deposition will be relatively easily neutralised (Holten-Andersen, 1998).

1.2.2 Photochemical smog

Photochemical smog is caused primarily by NMVOC and NO_x and the main so-called secondary pollutant is ozone (O_3).

Nitrogen dioxide is highly active photochemically, and for solar radiation below 400 nm occurring in the lower atmosphere (troposphere), the gas dissociates to NO and the highly active-monoatomic oxygen O which combines with O_2 to form O_3 (Wark and Warner, 1981).

Presence of hydrocarbons increases the complexity of the atmospheric reactions. A small part of the atomic oxygen formed by the dissociation of NO_2 is capable of reacting with various organic compounds (NMVOC), forming very reactive products (free radicals), enhancing the formation of NO_2 and thereby the formation of O_3.

The photochemical reactions in the atmosphere are very complex, but overall it can be concluded that in a European context, nitrogen oxide emissions are responsible for much of the ozone formation in thinly populated areas of the countryside. In the more densely populated areas, especially close to towns, ozone formation is enhanced by NMVOC emissions (Holten-Andersen et al., 1998).

Photochemical smog constitutes, as does acidification, so-called transboundary air pollution. This means that ozone is spread across national borders in Europe. In pure air ozone has a lifespan of several weeks and can therefore mix into the air and disperse over virtually the whole of the northern hemisphere before it is chemically degraded or physically removed.

Harmful effects are seen both on vegetation and man. For Europe as a whole it was estimated that the critical concentration of ozone was exceeded in an area corresponding to 83 % of the total cultivated area of Europe. A large number of Danish crops have proven to be sensitive to ozone; among others, beans, clover, potatoes, spinach, tomatoes and wheat. In man, ozone is a respiratory tract and eye irritant. The critical concentration at street level suggested by the World Health Organisation is rarely exceeded in Danish towns (Holten-Andersen et al., 1998).

1.2.3 Eutrophication

Eutrophication expresses itself in enhanced nutrient loading on ecosystems such as forest, grasslands, fjords, lakes and open marine areas. The two main pollutants contributing to atmospheric deposition of nutrients are NH_3 and NO_X (Bach et al., 2001).

Eutrophication in marine waters may be caused both by leaching of nutrients from agriculture land and by atmospheric deposition of nitrogen compounds. The effects of enhanced nutrient loading are blooms of toxic plankton and oxygen deficit resulting in increasing fish mortality.

The greatest effect of atmospheric deposition of nitrogen compounds is seen on ecosystems vulnerable to nitrogen loading. Examples of such systems are heath bogs and dry grasslands.

Exceedence of critical loads with regard to eutrophication has resulted in altered composition of animal and plant species in these areas and in decreasing species numbers.

1.2.4 Particulate Matter

Air pollution containing particles results from atmospheric emission, dispersal and chemical and physical conversion. Generally we use the terms PM_{10}, i.e. particles up to a diameter of 10 µm (1/1000 mm), and $PM_{2.5}$, i.e. particles up to a diameter of 2.5 µm. Small particles (below

0.25 µm) are formed at high temperatures, for instance in combustion engines, power boilers or industrial processes. Some of the particles are soot particles, which originate primarily from diesel-powered cars and fireplaces/stoves. A number of studies show that – with their content of many different chemical compounds – soot particles are particularly harmful. Coarse, airborne particles are typically formed by a number of mechanical processes; for instance in dust from the soil and from roads which is whirled up by the wind, during gravelling and salting of slippery roads, in salty particles from the sea (drying into salt particles), as well as from volcanoes, vegetation (pollen), wear on tyres and road surfaces, traffic-related turbulence in streets, construction and industrial processes. Due to their weight, these particles only remain suspended for a short time, and thus have a short lifetime. Particle pollution is harmful to health, especially via respiratory and cardiovascular diseases. Much indicates that it is the small particles that present the most serious problem to health in relation to air pollution (Palmgren et al., 2005).

1.3 Historical emission data

The Danish historical emissions are estimated according to the CORINAIR method (EMEP/CORINAIR, 2004), and the SNAP (Selected Nomenclature for Air Pollution) sector categorization and nomenclature are used. The detailed level makes it possible to aggregate to the UNECE/EMEP nomenclature (NFR). The historical data are reported to the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the latest data are provided in Illerup et al. (2007).

1.3.1 Acidifying gases

Figure 2.1 shows the emission of Danish acidifying gases in terms of acid equivalents. In 1990, the relative contributions in acid equivalents were almost equal for the three gases. In 2005, the most important acidification factor in Denmark was ammonia nitrogen and the relative contributions for SO_2, NO_X and NH_3 were 7 %, 40 % and 53 %, respectively. However, with regard to long-range transport of air pollution, SO_2 and NO_X are still the most important pollutants.

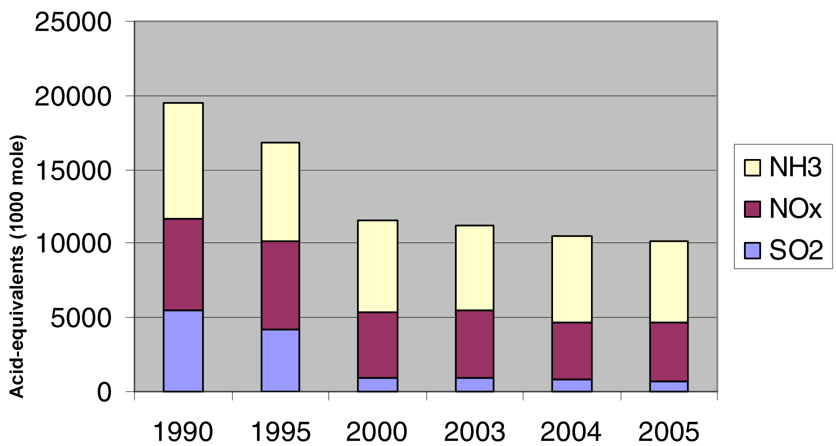


Figure 1.1 Emissions of NH_3, NO_X and SO_2 in acid equivalents

SO_2

The main part of the SO_2 emission originates from combustion of fossil fuels, i.e. mainly coal and oil, in public power and district heating plants. From 1980 to 2005, the total emission decreased by 95 %. The large reduction is largely due to installation of desulphurisation plant and use of fuels with lower content of sulphur in public power and district heating plants. Despite the large reduction in the SO_2 emission, energy industries still contribute 36 % of the total emission. Also emissions from industrial combustion plants, non-industrial combustion plants and other mobile sources are important. National sea traffic (navigation and fishing) contributes with about 12 % of the total SO_2 emission. This is due to the use of residual oil with high sulphur content.

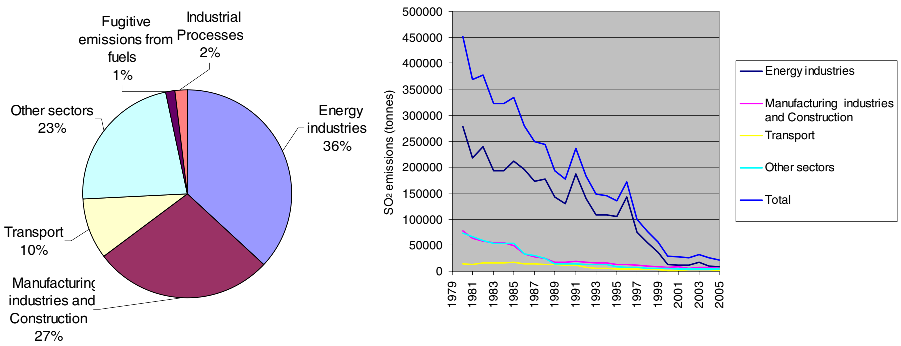


Figure 1.2 SO_2 emissions. Distribution by the main sectors (2005) and time series for 1990 to 2005

NO_X

The largest sources of emissions of NO_X are other mobile sources followed by road transport and combustion in energy industries (mainly public power and district heating plants). The transport sector is the sector contributing the most to the emission of NO_X and, in 2005, 35 % of the Danish emissions of NO_X stems from road transport, national navigation, railways and civil aviation. Also emissions from national fishing and off-road vehicles contribute significantly to the NO_X emission. For non-industrial combustion plants, the main sources are combustion of gas oil, natural gas and wood in residential plants. The emissions from public power plants and district heating plants have decreased by 61 % from 1985 to 2005. In the same period, the total emission decreased by 36 %. The reduction is due to the increasing use of catalyst cars and installation of low-NO_X burners and denitrifying units in power and district heating plants.

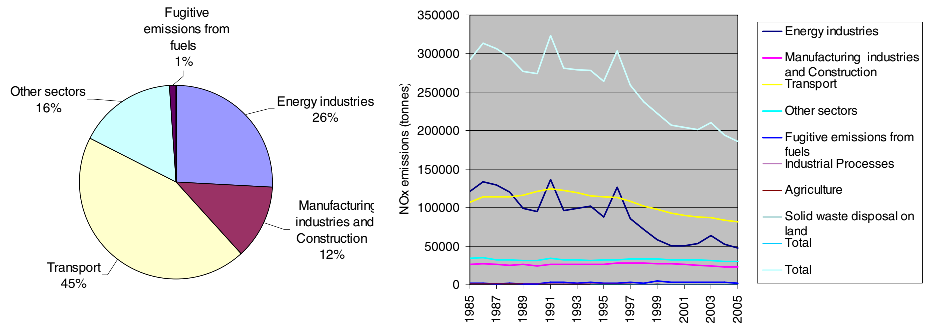
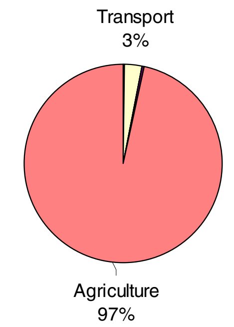


Figure 1.3 NO_X emissions. Distribution by main sectors (2005) and time-series for 1990 to 2005

NH_3

Almost all atmospheric emissions of NH_3 result from agricultural activities. Only a minor fraction originates from road transport. This fraction is, however, increasing due to increasing use of catalyst cars. The major part of the emission from agriculture stems from livestock manure (79 %), and the largest losses of ammonia occur during the handling of the manure in stables and in field application. Other contributions come from crops (15 %), use of mineral fertilisers (6 %), sewage sludge used as fertiliser and ammonia used for straw treatment (less than 1 %). The total ammonia emission decreased by 36 % from 1985 to 2005. This is due to active national environmental policy efforts over the past twenty years. Due to the action plans for the aquatic environment and the Ammonia Action Plan, a series of measures to prevent loss of nitrogen in agricultural production has been initiated. The measures have included requirements for improved utilisation of nitrogen in livestock manure, a ban against application of livestock manure in winter, prohibition of broad-spreading of manure, requirements for establishment of catch crops, regulation of the number of livestock per hectare, and a ceiling for the supply of nitrogen to crops. As a result, despite an increase in the production of pigs and poultry, the ammonia emission has been considerably reduced.



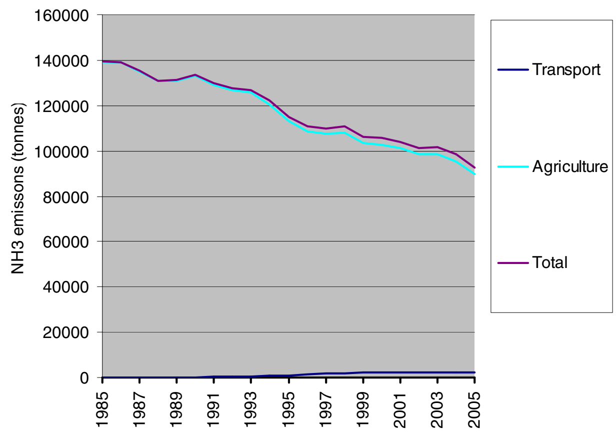
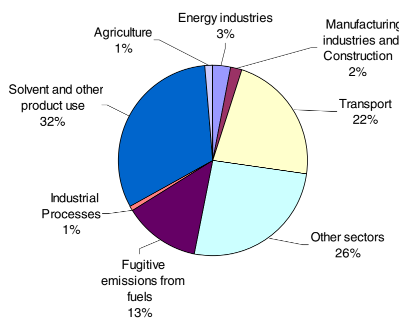


Figure1.4 NH_3 emissions. Distribution by the main sectors (2005) and time series for 1985 to 2005

1.3.2 Other air pollutants

NMVOC

Emissions of NMVOC originate from many different sources and can be divided into two main groups: incomplete combustion and evaporation. Road vehicles and other mobile sources such as national navigation vessels and off-road machinery are the main sources of NMVOC emissions from incomplete combustion processes. Road transportation vehicles are still the main contributors, even though the emissions have declined since the introduction of catalyst cars in 1990. The evaporative emissions mainly originate from the use of solvents. The emissions from the energy industries have increased during the 1990s due to the increasing use of stationary gas engines, which have much higher emissions of NMVOC than conventional boilers. The total anthropogenic emission has decreased by 31 % from 1985 to 2005, largely due to the increased use of catalyst cars and reduced emissions from use of solvents.



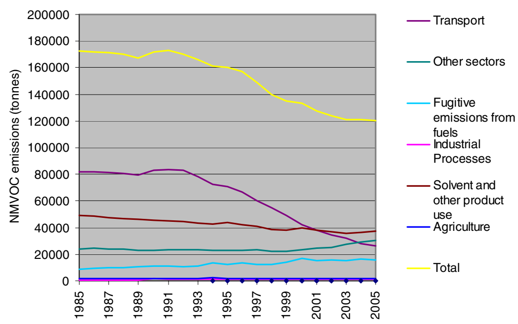


Figure 1.5 NMVOC emissions. Distribution by main sectors (2005) and time series for 1990 to 2005

Particulate Matter

The particulate matter (PM) emission inventory has been reported for the years 2000-2005. The inventory includes the total emission of particles TSP (Total Suspended Particles), emission of particles smaller than 10 µm (PM_{10}) and emission of particles smaller than 2.5 µm ($PM_{2.5}$).

The largest $PM_{2.5}$ emission sources are the residential sector (64 %), road traffic (15 %) and other mobile sources (7 %). For the latter, the most important source is off-road vehicles and machinery in the agricultural-/forestry sector (54 %). For the road transport sector, exhaust emissions account for the major part (77 %) of the emissions.

The largest TSP emission sources are the agricultural sector and the residential sector. TSP emissions from transport are also important and include both exhaust emissions and non-exhaust emissions from brake and tyre wear as well as road abrasion. The non-exhaust emissions account for 45 % of the TSP emission from road transport.

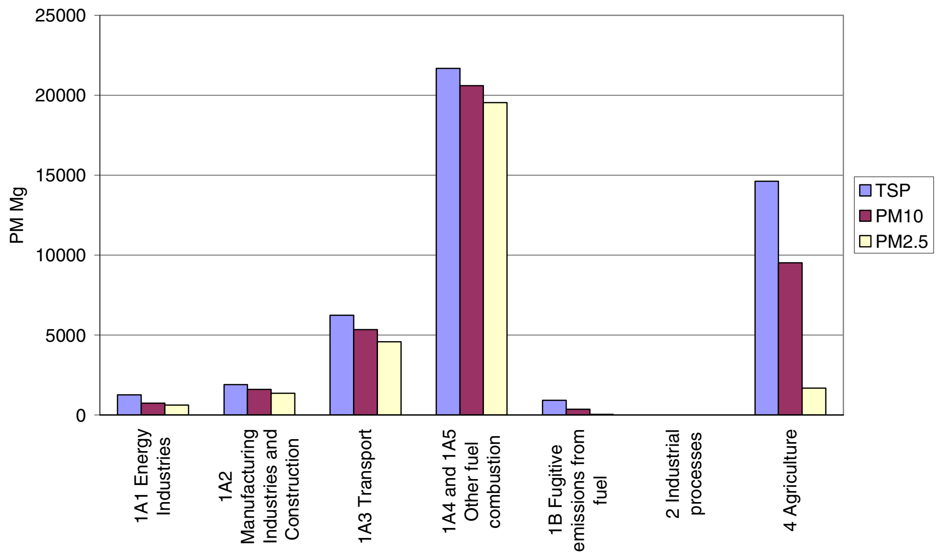


Figure 1.6 PM emissions for 2005

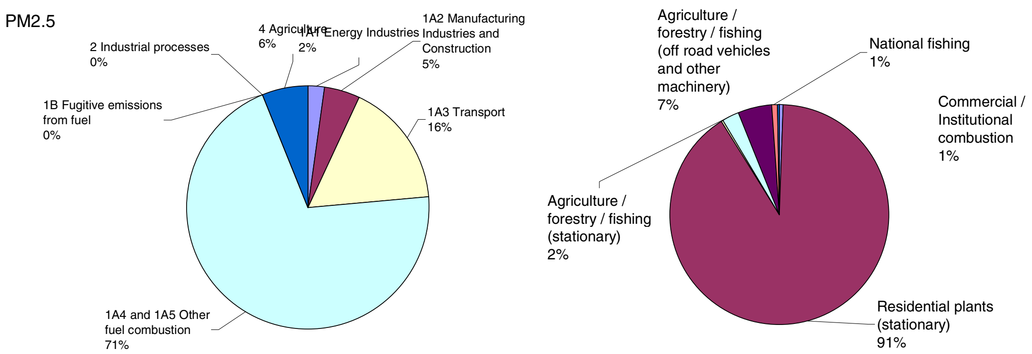


Figure 1.7 $PM_{2.5}$ emissions. Distribution by main sectors and by sub-sectors for other fuel combustion for 2005

1.4 Projection models

Projection of emissions can be considered as emission inventories for the future, in which the historical data is replaced by a number of assumption and simplifications. In the present project the emission factor method is used and the emission as a function of time for a given pollutant can be expressed as:

$$eq\ 1.2 \qquad E = \sum_s A_s(t) \cdot \bar{EF}_s(t)$$

where A_s is the activity for sector s for the year t and $EF_s(t)$ is the aggregated emission factor for sector s.

In order to model the emission development as a consequence of changes in technology and legislation, the activity rates and emission factors of the emission source should be aggregated at an appropriate level, at which relevant parameters such as process type, reduction targets and installation type can be taken into account. If detailed knowledge and information of the technologies and processes are available, the aggregated emission factor for a given pollutant and sector can be estimated from the weighted emission factors for relevant technologies as given in equation 1.3:

$$eq\ 1.3 \qquad \overline{EF}_s(t) = \sum_k P_{s,k}(t) \cdot EF_{s,k}(t)$$

where P is the activity share of a given technology within a given sector, $EF_{s,k}$ is the emission factor for a given technology and k is the type of technology.

Official Danish forecasts of activity rates are used in the models for those sectors for which these forecasts are available. For other sectors, projected activity rates are estimated in co-operation with relevant research institutes and other organisations. The emission factors are based on recommendations from the IPCC Guidelines (IPCC, 1997), IPCC Good Practice Guidance and Uncertainty Management (IPCC, 2000) and the Joint EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2004), as well as data from measurements carried out in Danish plants. The influence on the emission factors of legislation and ministerial orders has been estimated and included in the models.

The projection models are based on the same structure and methodology as the Danish emission inventories in order to ensure consistency. In Denmark the emissions are estimated according to the CORINAIR method (EMEP/CORINAIR, 2004), and the SNAP (Selected Nomenclature for Air Pollution) sector categorisation and nomenclature are used. The detailed level makes it possible to aggregate to both the UNECE/EMEP nomenclature (NFR) and the IPCC nomenclature (CRF).

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2 Stationary combustion

2.1 Methodology

Stationary combustion plants are included in the CRF emission sources 1A1 Energy Industries, 1A2 Manufacturing Industries and 1A4 Other sectors.

The methodology for emission projections is, just as the Danish emission inventory for stationary combustion plants, based on the CORINAIR system described in the EMEP/CORINAIR Guidebook (EMEP-/CORINAIR, 2003). The projections are based on official activity rates forecast from the Danish Energy Authority and on emission factors for different fuels, plants and sectors. For each of the fuels and categories (sector and e.g. type of plant), a set of general emission factors has been determined. Some emission factors refer to the IPPC Guidelines (IPCC, 1997) and the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2003), and some are country-specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of plants.

Some of the large plants, such as power plants and municipal waste incineration plants, are registered individually as large point sources and emission data from the actual plants are used. The CO_2 from incineration of the plastic part of municipal waste is included in the emission projections.

2.2 Sources

The combustion of fossil fuels is one of the most important sources of greenhouse gas emission and this chapter covers all sectors which use fuels for energy production, with the exception of the transport sector. Table 2.1 shows the sector categories used and the relevant classification.

Table 2.1 Sectors included in stationary combustion

Sector	IPCC	SNAP
Public power	1A1a	0101
District heating plants	1A1a	0102
Petroleum refining plants	1A1b	0103
Oil/gas extraction	1A1c	0105
Commercial and institutional plants	1A4a	0201
Residential plants	1A4b	0202
Plants in agriculture, forestry and aquaculture	1A4c	0203
Combustion in industrial plants	1A2	03
Flaring	1B2c	09

In Denmark, all municipal waste incineration is utilised for heat and power production. Thus, incineration of waste is included as stationary combustion in the IPCC Energy sector (source categories *1A1*, *1A2* and *1A4)*.

Fugitive emissions and emissions from flaring in oil refinery, and in gas and oil extraction are estimated in Chapter 3.

As seen in Figure 1.2 in section 1.3, the sector contributing most to the emission of SO_2 is public power and district heating plants.

2.3 Activity data

The fuel consumption data in the model is based on the general projection of the energy consumption by the Danish Energy Authority (DEA, 2006a), and the projection for large combustion plants, Ramses (DEA 2006b), from 2005 to 2030. For this report a projection from June 2006 has been utilised; and later in 2006 a new energy consumption projection was prepared by the DEA. The major change compared to the June version concerns wood consumption in residential plants. This will entail an increase in estimated emissions, especially for NMVOC and particles.

Industrial point sources, e.g. Aalborg Portland, are not included in Ramses; data for this source is therefore based on information from the companies and Statistics Denmark. The fuel consumption data used in the emission calculation, divided into sectors and fuel types for selected years is enclosed in Appendix 1.

For the purpose of emission calculation, data is split according to area and point sources. Point sources are plants larger than 25 MWe and the added industrial point sources. The fuel consumption for the area sources is calculated by subtracting the point sources and the mobile sources from the general energy projection from the DEA. The projection is based on the amount of fuel which is expected to be combusted in Danish plants, and therefore has not been corrected for any international trade in electricity.

Fuel consumption data distributed on fuel types is shown in Table 2.1 and Figure 2.1.

The two dominant fuel types for the entire time series are coal and natural gas. Coal consumption peaks in 2008, decreases significantly from 2009 to 2010, followed by a slight increase from 2010 to 2015. From 2015 to 2030 a continuous decrease is observed, along with a similar increase in the consumption of natural gas.

Table 2.1 Fuel consumption (PJ)

	1990	2000	2005	2010	2015	2020	2025	2030
Coal	254	165	102	153	173	142	138	105
Orimulsion	0	34	0	0	0	0	0	0
Natural gas	80	196	216	215	248	254	243	259
Waste	16	32	41	42	41	47	50	51
Wood	18	28	39	42	44	44	44	46
Residual oil	32	18	24	25	27	29	27	30
Gas oil	62	41	36	31	28	27	26	25
Straw	12	12	24	27	27	27	28	28
Refinery gas	14	16	17	17	17	17	17	17
Petroleum coke	5	7	8	8	8	8	8	8
Biogas	1	3	4	5	5	5	5	5
LPG	3	2	2	2	2	2	2	2
Coke	1	1	1	1	1	1	1	1
Kerosene	5	0	0	0	0	0	0	0
Total	503	555	513	567	621	603	588	578

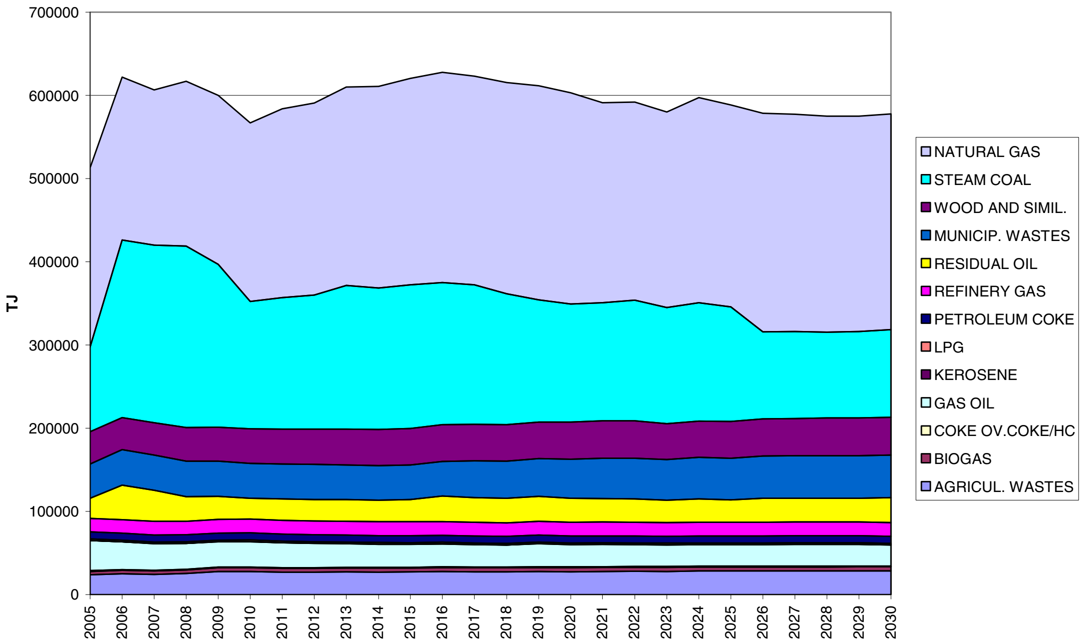

Figure 2.1 Fuel consumption distributed according to fuel type

Figure 2.2 shows fuel consumption for the different sectors. Public power and district heating plants account for between 50 % and 60 % of the total consumption, with, from 2015, an increasing amount of the fuel consumption taking place in gas turbines at the expense of conventional coal-fired plants. The projection shows a strong increase in fuel consumption in the offshore industry from c. 2008 to 2020.

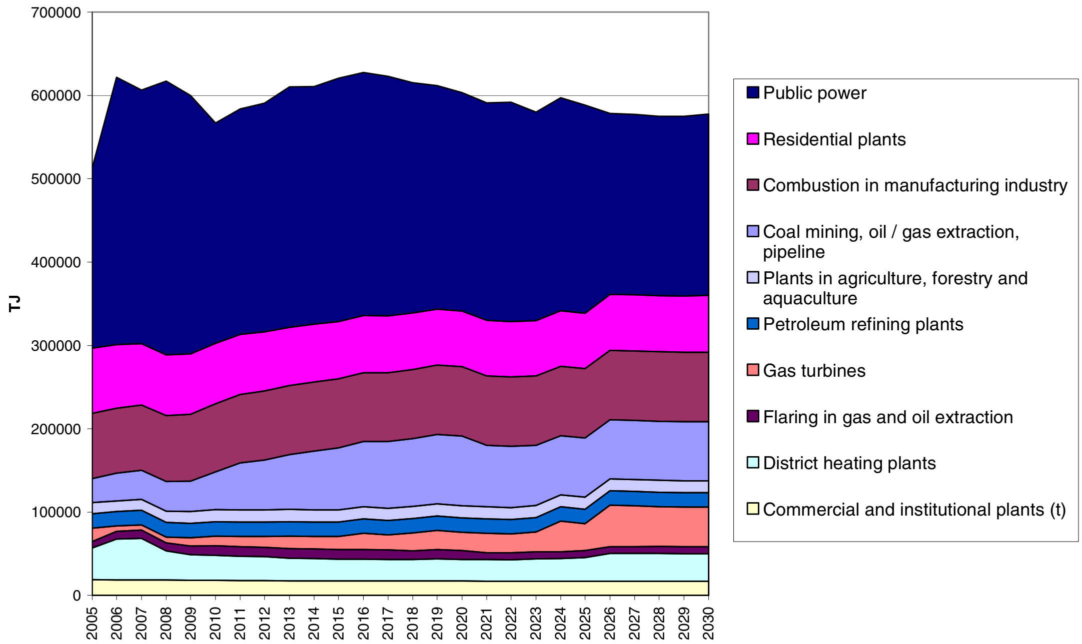

Figure 2.2 Fuel consumption distributed by sector

For power plants larger than 25 MWe, fuel consumption increases from 2005 to 2008, followed by a decrease from 2008 to 2010. From 2010 to 2030 fuel consumption in large point sources remains relatively constant, see Figure 2.3.

The share of fuel consumption relating to electricity export ranges between 5 % and 12 %, see Figure 2.4. In 2005 a net import is expected, this is the only year in the time series where a net import is projected. The large decrease in fuel consumption from 2008 to 2010 is mainly due to an assumption of lower export in these years.

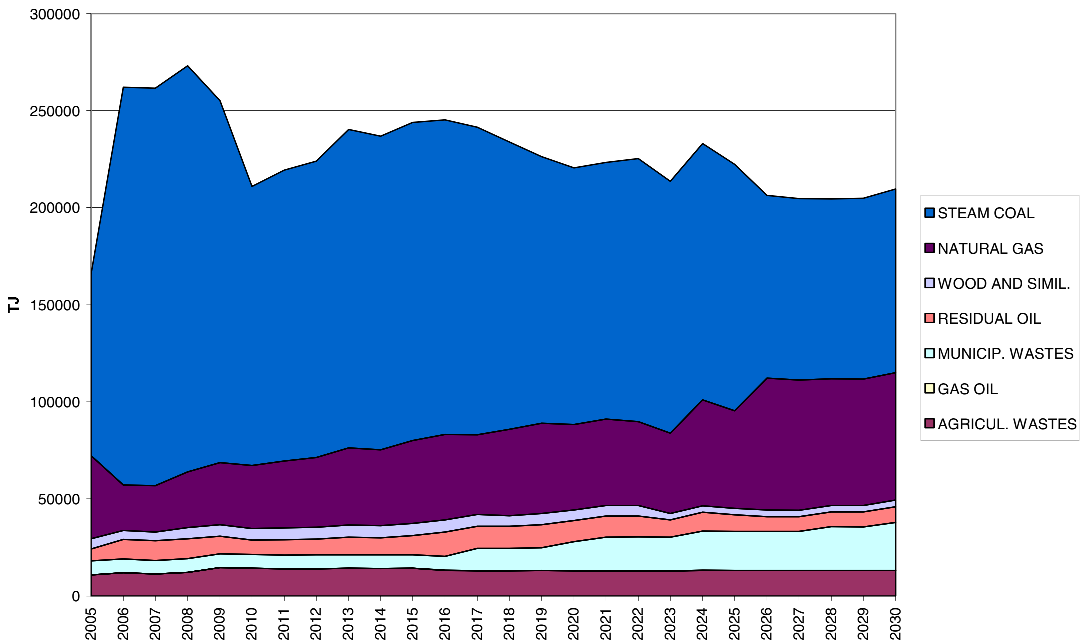

Figure 2.3 Fuel consumption for plants > 25 MWe

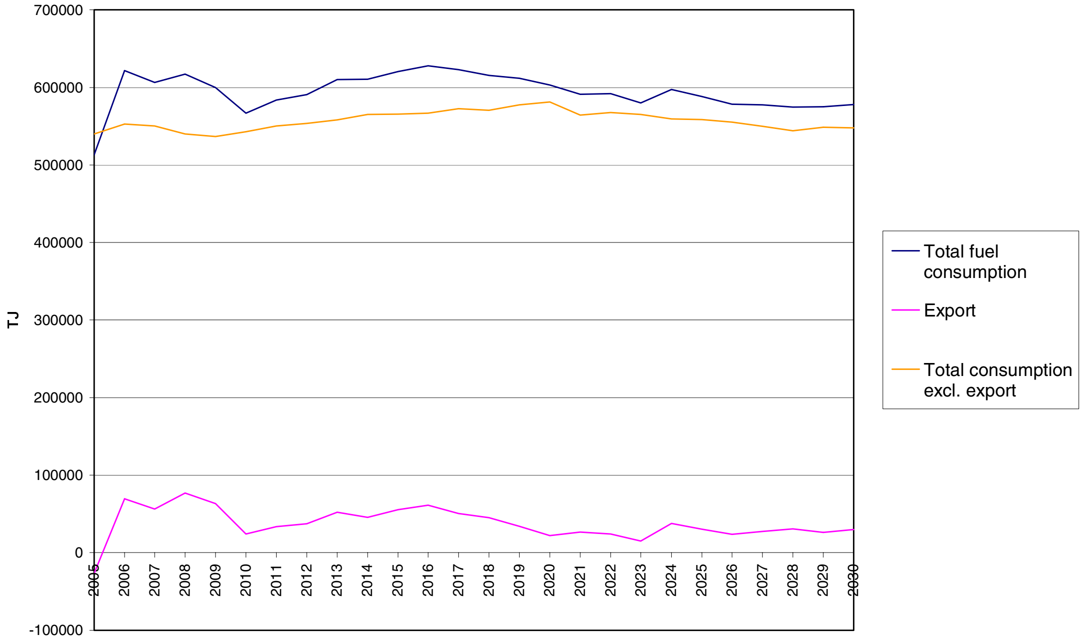

Figure 2.4 Total fuel consumption and fuel consumption for export

2.4 Emission factors

2.4.1 NO_X

NO_X emission factors for centralised power plants are based on information from DONG Energy, previously E2 and Elsam. For other power plants the same emission factors are used as in 'Emissioner af SO_2 og NO_X fra kraftværker' (Illerup & Bruun, 2003).

The NO_X emission factors for area sources are mainly based on the factors used for the 2004 inventory to the UNECE with the exception of flaring, where a much lower emission factor of 30 g/GJ has been used. Some of the emission factors used in the projection model are aggregated based on emission factors for different types of plants. The following future legislation has been incorporated:

'Bekendtgørelse om anlæg, der forbrænder affald' (Danish legislation) results in a lower emission factor from 2010 when the new emission limits have been fully incorporated.

'Bekendtgørelse om begrænsning af emission af nitrogenoxider, uforbrændte carbonhydrider og carbonmonooxid mv. fra motorer og turbiner' (Danish legislation) results in lower emission factors for natural gas powered engines and turbines (included from 2006), biogas powered engines (implemented in 2010 fully incorporated in 2013) and gas oil powered engines and turbines (included from 2016).

'Bekendtgørelse om begrænsning af visse luftforurenende emissioner fra store fyringsanlæg' (Danish legislation) results in a lower emission factor for large natural gas powered boilers from 2008.

'Luftvejledningen' results in a lower emission factor for small natural gas powered boilers (not residential), which is fully incorporated from 2018.

An estimation of the emission factor in 2010 has been applied for 2010-2018.

For point sources the following future legislation has been incorporated:

'Bekendtgørelse om begrænsning af visse luftforurenende emissioner fra store fyringsanlæg' (Danish legislation) results in lower emission factors for coal from 2016 onwards. Furthermore the emission factors for residual oil, gas oil and natural gas combusted in boilers have been established according to threshold limits for existing boilers > 500 MWth valid from 2008. These emission factors have been used for the entire time series.

'Bekendtgørelse om anlæg, der forbrænder affald' (Danish legislation) results in lower emission factors then in the historic inventories.

'Bekendtgørelse om begrænsning af emission af nitrogenoxider, uforbrændte carbonhydrider og carbonmonooxid mv. fra motorer og turbiner' (Danish legislation) results in lower emission factors for residual oil and gas oil powered gas turbines. Based on the life expectancy of gas turbines, NERI has assumed that the emission limit for new plants can be used from the year 2020. Furthermore, the emission factor for natural gas powered turbines has been determined for the entire time-series in accordance with the legislation.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations (Illerup et al. 2006).

2.4.2 SO_2

SO_2 emission factors for centralised power plants are based on information from DONG Energy, previously E2 and Elsam. For other power plants the same emission factors are used as in 'Emissioner af SO_2 og NO_X fra kraftværker' (Illerup & Bruun, 2003).

In the historic inventories the SO_2 emission factors are implemented directly. In the projection model the SO_2 emission factors are calculated based on the sulphur content of the fuel, heating value, sulphur content in ash, and degree of desulphurisation. However some of the emission factors used in the projection model are based on emission measurements or threshold values, i.e. without knowledge of input data. In these cases the variables mentioned above have been fitted to match the emission factor.

SO_2 emission factors for area sources mainly stem from the 2004 emission inventory. Some emission factors have been aggregated based on emission factors for different plant types. The following future legislation has been incorporated:

'Bekendtgørelse om anlæg, der forbrænder affald' (Danish legislation) results in a lower SO_2 emission factor for non electricity producing plants. For electricity producing plants the emission factor is already lower than the new legislative emission limit. The lower emission factor has been implemented from 2005 even though the legislation first enters fully into effect from 2006.

For point sources most of the emission factors comes from the 2004 inventory. However for central power plants plant-specific emission factors have been obtained from the major power plant operators in Denmark. The following future legislation has been incorporated:

'Bekendtgørelse om begrænsning af visse luftforurenende emissioner fra store fyringsanlæg' (Danish legislation) results in lower emission factors for residual oil. The new limit does not enter fully into effect until 2008, but in this projection it has been incorporated from 2005. For other fuel types the present emission factors are lower than the legislative limits.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations. (Illerup et al. 2006).

2.4.3 NMVOC

The emission factors for NMVOC are mainly based on the 2004 emission inventory. Some emission factors have been aggregated for several plant types. For residential wood combustion, research carried out by NERI has resulted in decreasing emission factors over time due to expected improvements in technology.

The following future legislation has been incorporated:

'Bekendtgørelse om anlæg, der forbrænder affald' (Danish legislation) results in a lower emission factor than in the historic inventories. The lower emission factor is utilised for the entire time-series even though the legislative limit first fully takes effect from 2006.

'Bekendtgørelse om begrænsning af emission af nitrogenoxider, uforbrændte carbonhydrider og carbonmonooxid mv. fra motorer og turbiner' (Danish legislation) results in a lower emission factor for natural gas powered engines from 2007. For biogas powered engines the emission factor is reduced from 2013, but the decrease is very small.

For point sources the emission factors are based on the 2004 inventory. These emission factors are lower than future legislative limits so no changes are made.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations. (Illerup et al. 2006).

2.4.4 TSP, PM_{10} & $PM_{2.5}$

The emission factors are mainly based on the 2004 emission inventory. Some emission factors have been aggregated for several different plant types. For residential wood combustion, research carried out by NERI has resulted in decreasing emission factors over time due to expected improvements in technology.

The following future legislation has been incorporated:

'Bekendtgørelse om anlæg, der forbrænder affald' (Danish legislation) results in a lower TSP emission factor for non electricity producing plants than in the 2004 inventory. This lower emission factor has been applied for the entire time series even though the legislative limit is not applicable for all plants until 2008. PM_{10} and $PM_{2.5}$ emission factors are established at the same ratio as in the historic emission inventories.

For point sources the emission factors are based on the 2004 inventory. These emission factors are lower than future legislative limits so no changes are made.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations (Illerup et al. 2006).

2.5 Emissions

Emissions are calculated using equation 2.1, where A is the fuel consumption for sector s in the year t. $EF_s(t)$ is the aggregated emission factor for a sector s in the year t.

$$Eq.\ 2.1 \quad E = \sum_s A_s(t) \cdot \bar{EF}_s(t)$$

2.5.1 NO_X

The estimated NO_X emission is shown in Table 2.12 and in Figure 2.5 and 2.6.

A detailed view of estimated emissions for selected years can be found in Appendix 1.

The total NO_X emission decreases from 2006 to 2010 due to decreasing fuel consumption, with coal experiencing the largest fall in consumption, and installation of $DeNO_X$ on some large power plants in 2008. From 2010 to 2016 the NO_X emission increases due to increasing fuel consumption, mainly natural gas. The decrease in emission during the remainder of the time series is caused by decreasing fuel consumption.

Table 2.12 NO_X emissions from stationary combustion (tonne)

	1990	2000	2005	2010	2015	2020	2025	2030
Public power	85250	39402	25945	24322	26079	23291	21801	19477
Gas turbines	314	2406	777,8	562,5	848,8	1377	1693	2607
District heating	5182	1178	3396	2725	2441	2451	2650	3167
Refineries	1616	1529	1871	1871	1871	1871	1871	1871
Oil/gas production	2376	6305	7163	11389	18604	20978	17720	17720
Commercial and institutional plants	1399	1095	1515	1175	1143	1134	1126	1116
Residential plants	4939	4657	4795	4681	4697	4723	4841	5035
Plants in agriculture, forestry & aquaculture	1180	1327	1455	1358	1369	1353	1346	1348
Combustion in manufacturing plants	13796	15381	11409	11091	11197	10985	11024	11024
Flaring, oil and gas production	1306	3050	240	350	343	319	249	249
Total	117358	76330	58568	59524	68591	68483	64321	63614

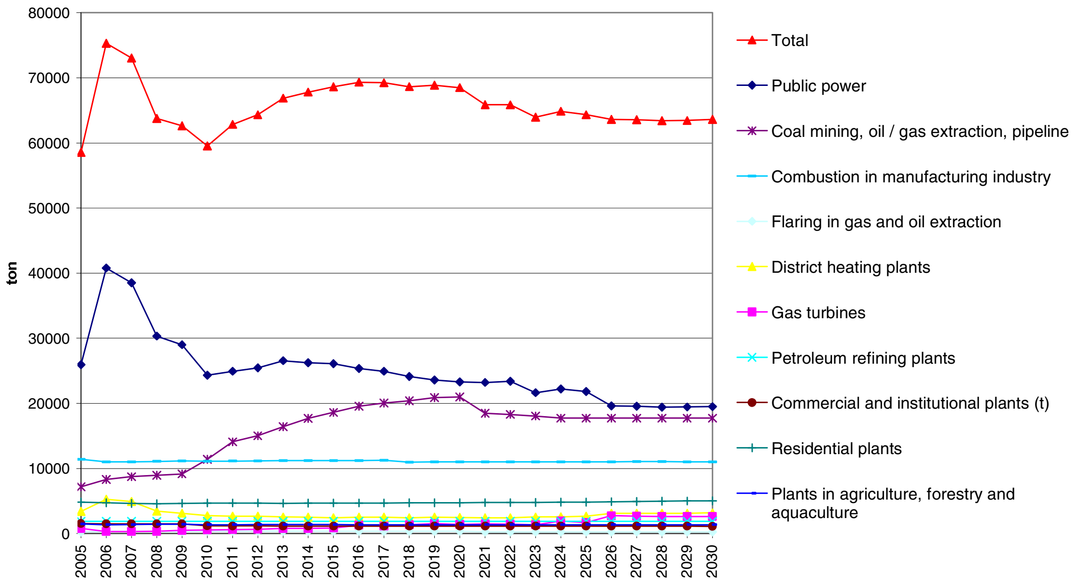

Figure 2.5 NO_X emissions by sector

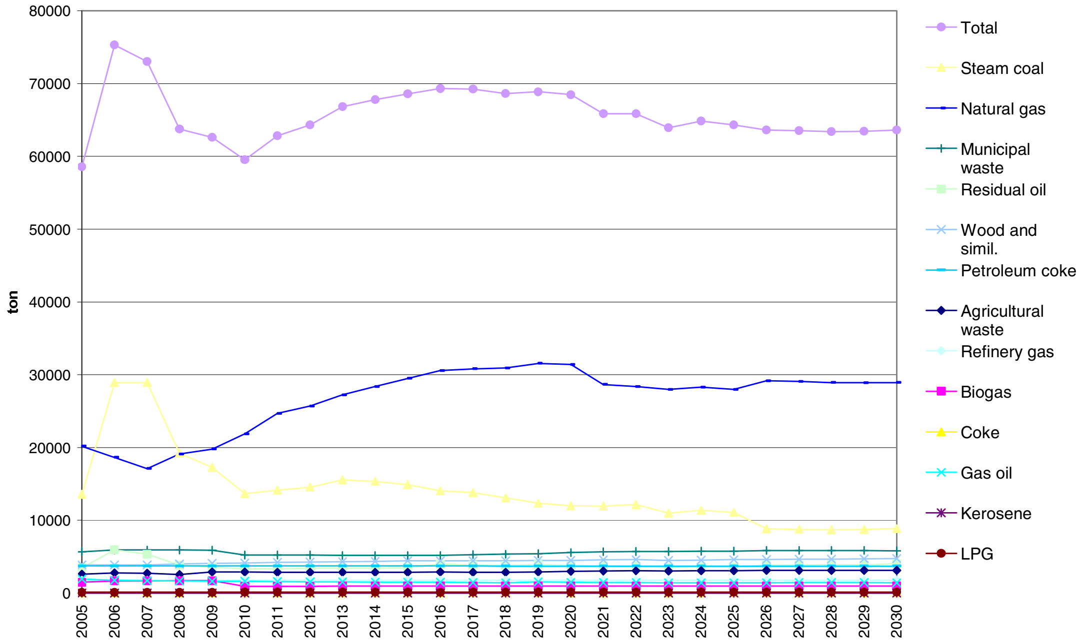

Figure 2.6 NO_X emissions by fuel type

A small decrease in the NO_X emission can be observed for centralised power plants (Table 2.13 and Figure 2.6).

The decrease is due to reduced coal consumption in the centralised power plants.

Table 2.13 NO_X-emissions from power plants > 25 MW_{el} (tonne)

	2005	2010	2015	2020	2025	2030
Coal	11359	11405	12739	9726	8735	6462
Natural gas	2304	1796	2378	2482	2700	3634
Waste	614	611	605	1268	1730	2147
Straw	1257	1544	1588	1508	1530	1544
Residual oil	662	594	802	1012	698	665
Wood	403	426	452	388	230	230
Gas oil			1	5	6	
Total	16598	16375	18565	16388	15629	14681

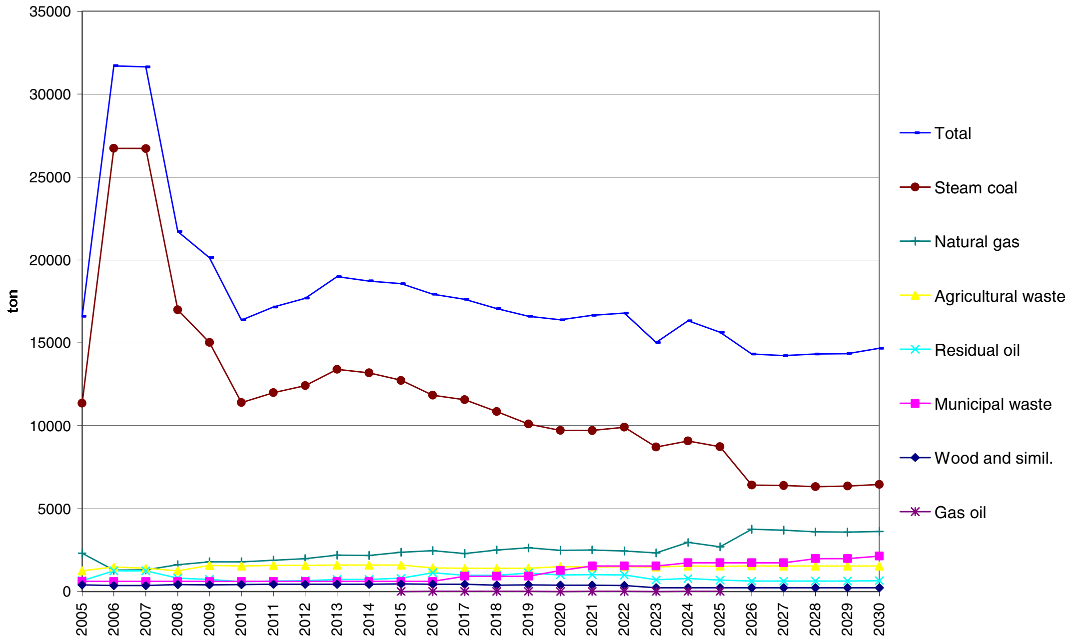

Figure 2.7 NO_X emissions by fuel type for large power plants

NO_X emissions from gas turbines used in the offshore sector increase significantly. From 2005 to 2015 the emission increases by 160 % due to increasing fuel consumption. The high emission factor and the increase in fuel consumption mean that the offshore sector will account for about 30 % of the total NO_X emission from stationary combustion in 2020.

Due to declining emission factors for natural gas the NO_X emission from the industrial sector remains practically constant despite an increase in fuel consumption.

2.5.2 SO_2

The estimated SO_2 emission is shown in Table 2.14 and in Figure 2.8 and 2.9.

A detailed view of estimated emissions for selected years can be found in Appendix 1.

The total SO_2 emission decreases from 2006 to 2010 due to decreasing consumption of coal and residual oil. From 2010 to 2030 the SO_2 emission increases slightly due to increasing fuel consumption, mainly in the industrial and district heating sectors.

Table 2.14 SO_2 emissions from stationary combustion (ton).

	1990	2000	2005	2010	2015	2020	2025	2030
Public power	119137	11074	3805	5004	5606	4641	4545	3968
Gas turbines	5	115	427	223	312	568	273	321
District heating	7045	902	3273	3002	2753	2973	3327	4523
Refineries	3411	613	455	455	455	455	455	455
Oil/gas production	3	8	12	19	31	35	30	30
Commercial and institutional plants	1884	349	304	290	282	281	281	280
Residential plants	6415	1898	1618	1552	1565	1577	1622	1691
Plants in agriculture, forestry & aquaculture	3192	1568	1572	1707	1761	1784	1800	1808
Combustion in manufacturing plants	16507	7405	5434	5737	6066	6546	6810	6955
Flaring, oil and gas production	1	3	3	5	5	4	4	4
Total	157600	23935	16903	17994	18837	18866	19147	20035

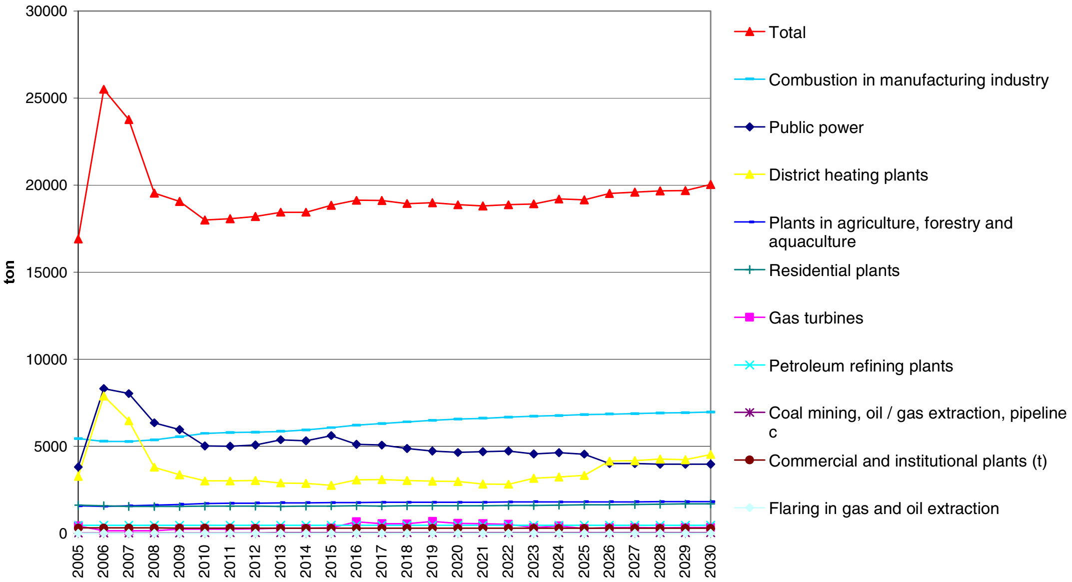

Figure 2.8 SO_2 emissions by sector.

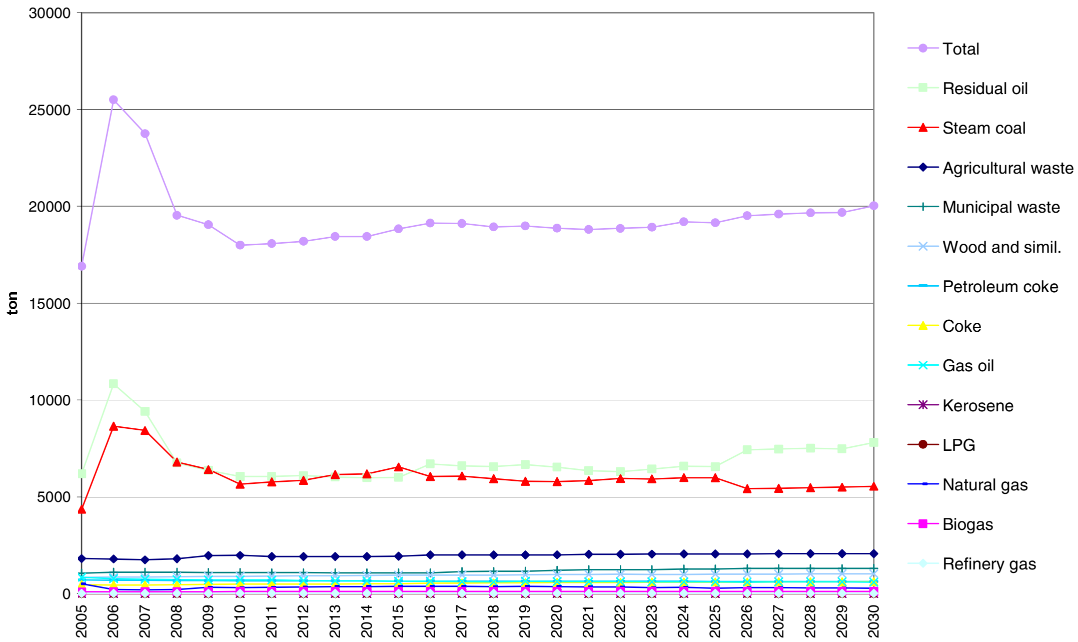

Figure 2.9 SO_2 emissions by fuel types

2.5.3 NMVOC

The estimated NMVOC emission is shown in Table 2.15 and in Figure 2.10 and 2.11.

A detailed view of estimated emissions for selected years can be found in Appendix 1.

The total NMVOC emission increases from 2005 to 2010 due to increasing wood combustion in residential plants. From 2010 to 2030 the NMVOC emission decreases due to a lower emission factor for wood combustion in residential plants. The residential sector accounts for between 59 % and 67 % of the total NMVOC emission from stationary combustion plants.

Table 2.15 NMVOC emissions from stationary combustion (tonne)

	1990	2000	2005	2010	2015	2020	2025	2030
Public power	422	3470	3582	3216	3315	3237	3008	2920
Gas turbines	3	33	22	16	23	35	47	69
District heating	575	410	925	737	661	618	653	701
Refineries	60	2	26	26	26	26	26	26
Oil/gas production	13	38	43	68	112	126	106	106
Commercial and institutional plants	193	628	785	773	759	739	720	707
Residential plants	8661	10548	12921	13593	12898	12318	11452	10328
Plants in agriculture, forestry & aquaculture	2142	1746	1704	1783	1792	1775	1775	1774
Combustion in manufacturing plants	627	712	865	879	902	915	920	914
Flaring, oil and gas production	13	33	24	35	34	32	25	25
Total	12709	17620	20897	21126	20521	19821	18733	17570

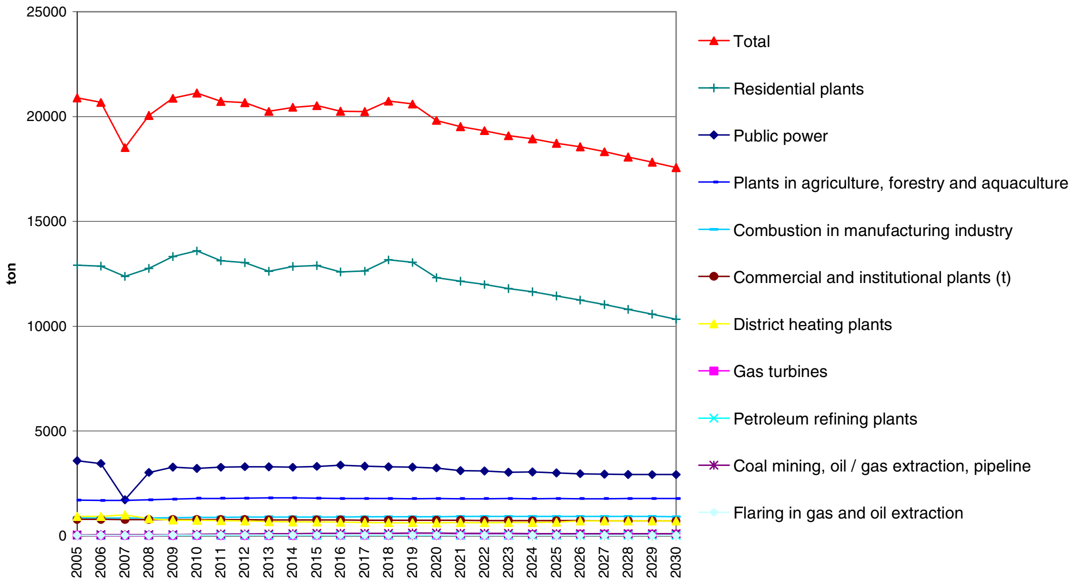

Figure 2.10 NMVOC emissions by sectors

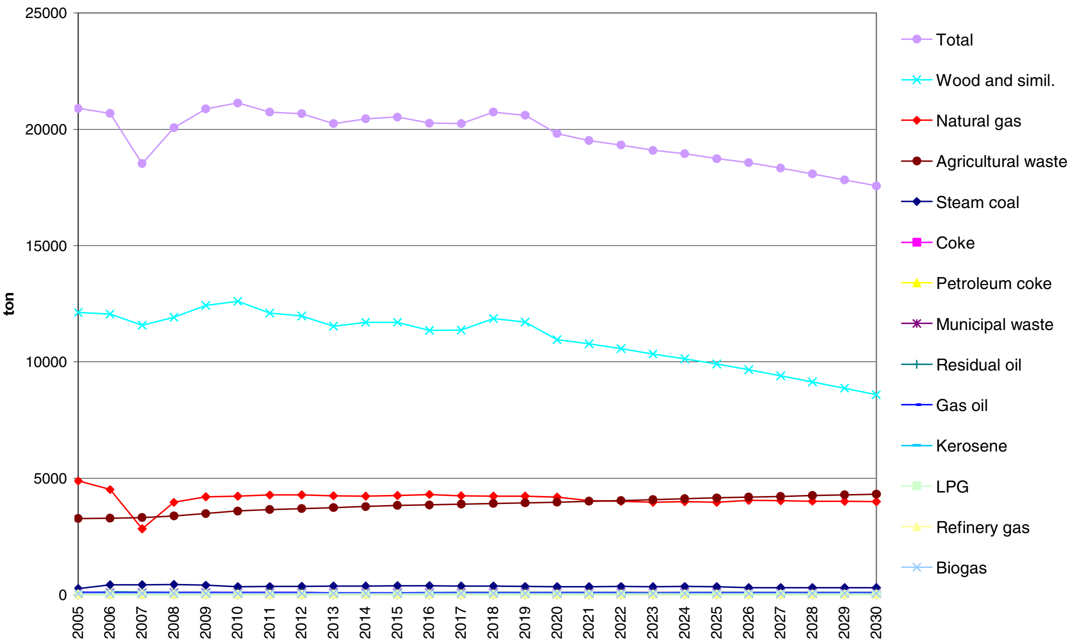

Figure 2.11 NMVOC emissions by fuel type

2.5.4 TSP, PM_{10}, $PM_{2.5}$

The estimated TSP emission is shown in Table 2.16 and in Figure 2.12 and 2.13.

A detailed view of estimated emissions for selected years can be found in Appendix 1.

The total TSP emission increases from 2005 to 2010 due to increasing wood combustion in residential plants. From 2010 to 2030, especially after 2020, the TSP emission decreases due to a lower emission factor for wood combustion in residential plants. The residential sector accounts for between 82 % and 86 % of the total TSP emission from stationary combustion plants.

Table 2.16 TSP emissions from stationary combustion (tonne)

	2000	2005	2010	2015	2020	2025	2030
Public power	846	491	666	730	637	616	518
Gas turbines	4	2	1	3	11	6	9
District heating	162	267	253	240	236	244	246
Refineries	144	124	124	124	124	124	124
Oil/gas production	3	3	5	7	8	7	7
Commercial and institutional plants	163	188	185	182	177	173	170
Residential plants	12111	12868	13640	12867	12177	11457	10346
Plants in agriculture, forestry & aquaculture	568	539	579	585	581	581	581
Combustion in manufacturing plants	1146	490	507	524	542	551	553
Flaring, oil and gas production	1	1	1	1	1	1	1
Total	15148	14972	15961	15262	14495	13759	12554

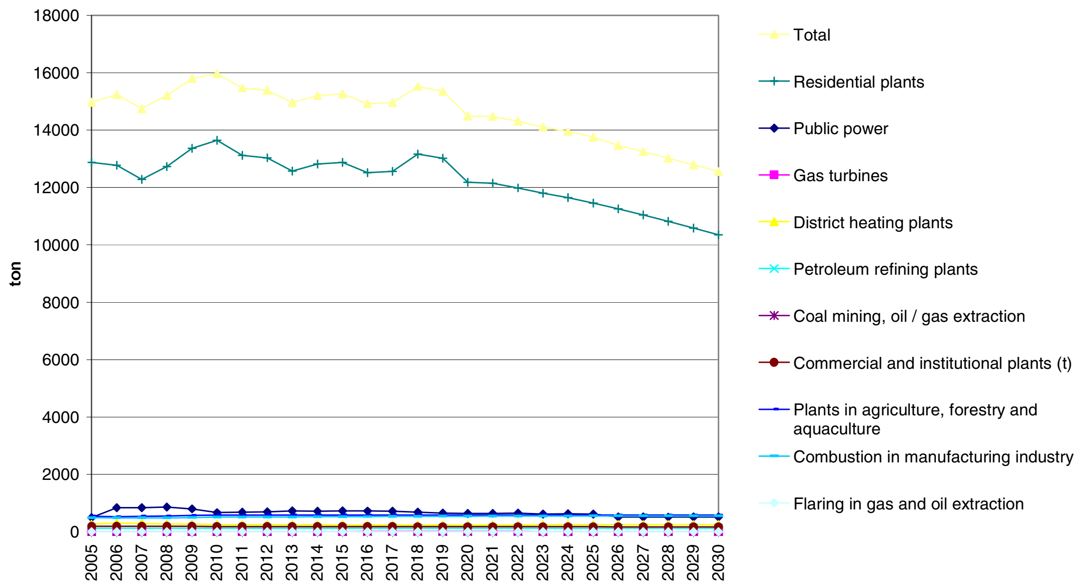

Figure 2.12 TSP emissions distributed by sector

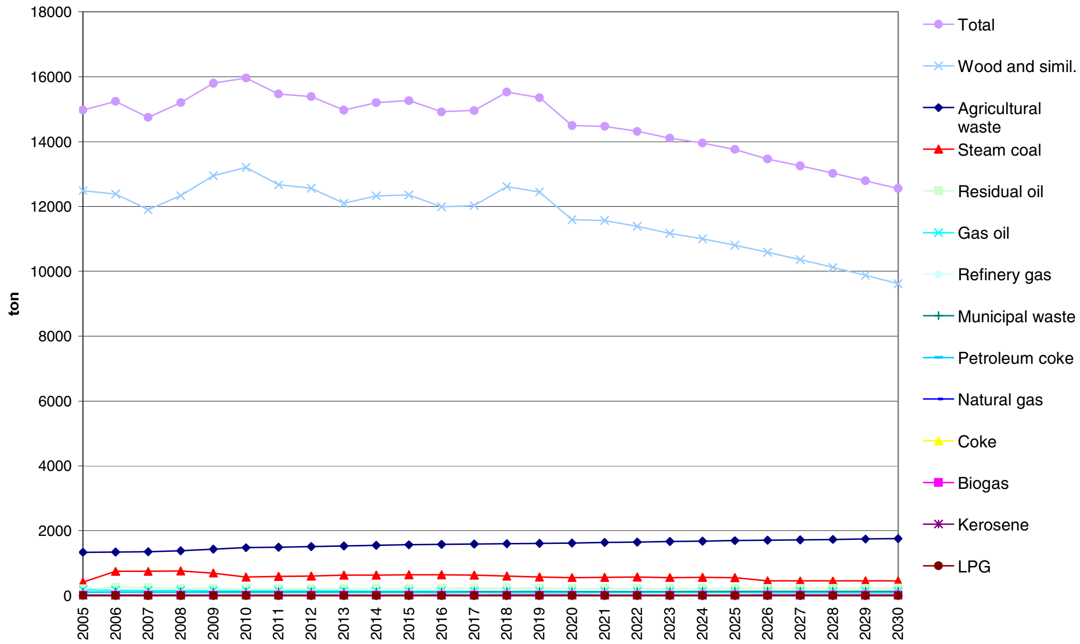

Figure 2.13 TSP emissions distributed by fuel type

The estimated PM_{10} emission is shown in Table 2.17 and in Figure 2.14 and 2.15.

A detailed view of estimated emissions for selected years can be found in Appendix 1.

The total PM_{10} emission increases from 2005 to 2010 due to increasing wood combustion in residential plants. From 2010 to 2030, especially from 2020, the PM_{10} emission decreases due to a lower emission factor for wood combustion in residential plants. The residential sector accounts for between 85 % and 88 % of the total PM_{10} emission from stationary combustion plants. The same trend that is observed for TSP can be seen for PM_{10}.

Table 2.17 PM_{10} emissions from stationary combustion (tonne)

	2000	2005	2010	2015	2020	2025	2030
Public power	690	328	465	522	441	427	341
Gas turbines	3	1	1	2	10	5	7
District heating	116	198	186	176	175	182	185
Refineries	131	115	115	115	115	115	115
Oil/gas production	2	3	5	7	8	7	7
Commercial and institutional plants	157	183	181	177	172	168	166
Residential plants	11499	12217	12951	12217	11562	10878	9823
Plants in agriculture, forestry & aquaculture	529	503	540	546	542	542	542
Combustion in manufacturing plants	843	353	366	379	392	398	400
Flaring, oil and gas production	1	1	1	1	1	1	1
Total	13970	13902	14812	14143	13419	12722	11586

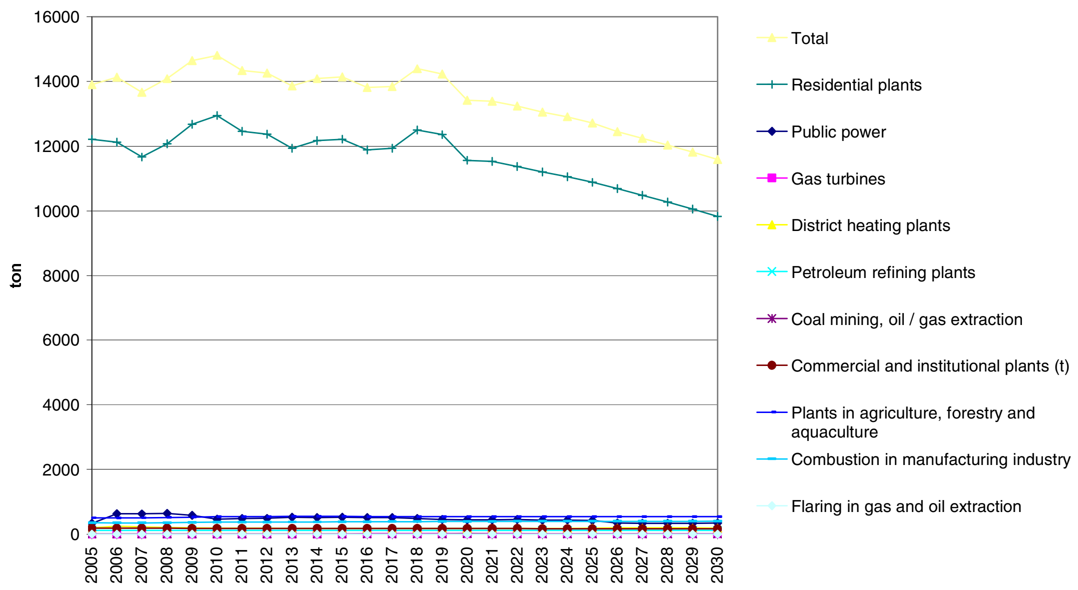

Figure 2.14 PM_{10} emissions by sector

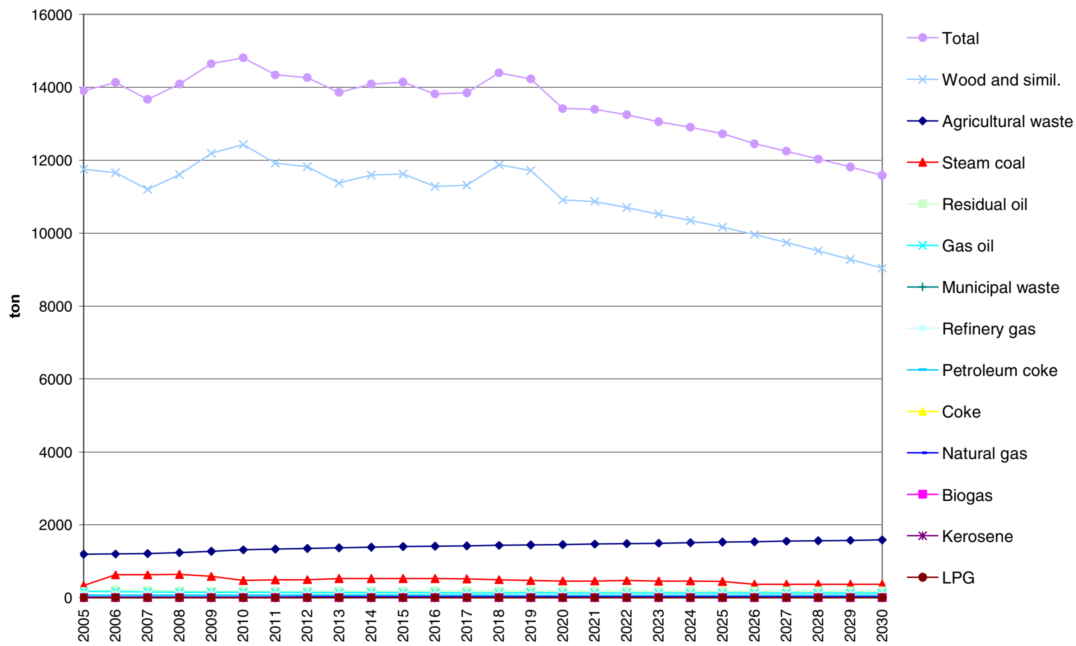

Figure 2.15 PM10 emissions by fuel type

The estimated $PM_{2.5}$ emission is shown in Table 2.18 and in Figure 2.16 and 2.17.

A detailed view of estimated emissions for selected years can be found in Appendix 1.

The total $PM_{2.5}$ emission increases from 2005 to 2010 due to increasing wood combustion in residential plants. From 2010 to 2030, especially from 2020, the $PM_{2.5}$ emission decreases due to a lower emission factor for wood combustion in residential plants. The residential sector accounts for between 86 % and 89 % of the total $PM_{2.5}$ emission from stationary combustion plants. The same trend that is observed for TSP and PM_{10} can be seen for $PM_{2.5}$.

Table 2.18 $PM_{2.5}$ emissions from stationary combustion (tonne)

	2000	2005	2010	2015	2020	2025	2030
Public power	584	271	382	428	363	353	283
Gas turbines	2	1	1	2	9	4	6
District heating	92	158	148	140	140	146	148
Refineries	124	111	111	111	111	111	111
Oil/gas production	1	3	5	7	8	7	7
Commercial and institutional plants	147	172	169	166	161	158	155
Residential plants	10881	11573	12267	11572	10952	10305	9306
Plants in agriculture, forestry & aquaculture	493	468	503	508	504	504	504
Combustion in manufacturing plants	500	233	243	252	260	264	265
Flaring, oil and gas production	1	1	1	1	1	1	1
Total	12826	12990	13830	13187	12511	11852	10786

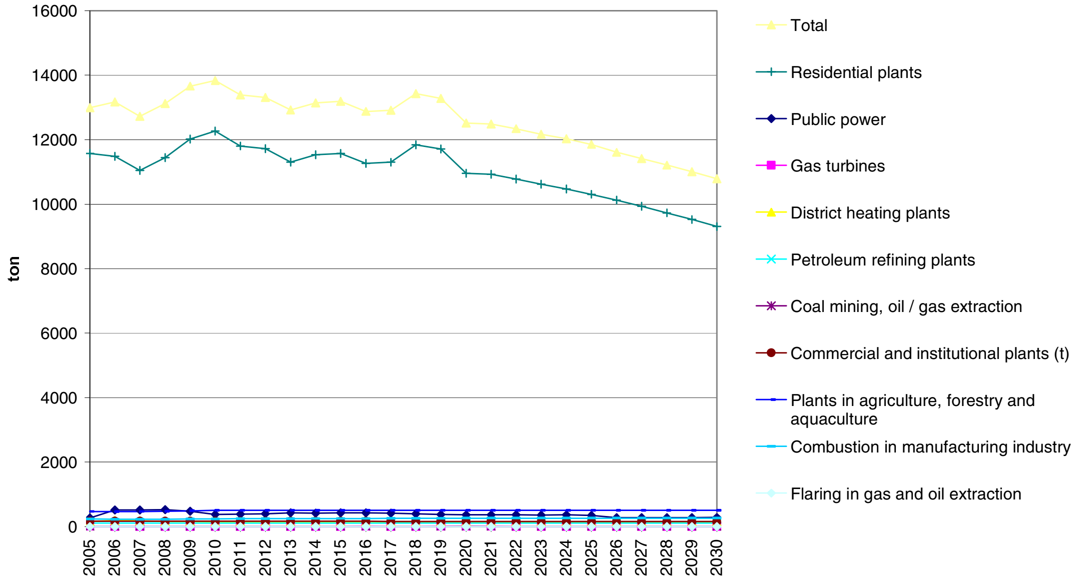

Figure 2.16 $PM_{2.5}$ emissions by sector

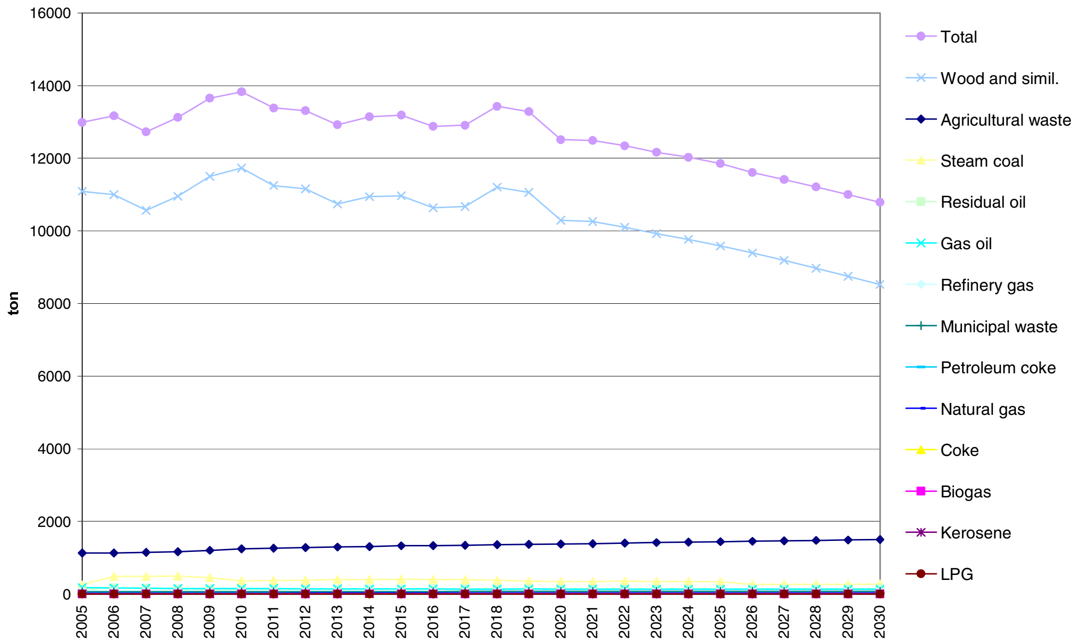

Figure 2.17 $PM_{2.5}$ emissions by fuel type

2.6 Model description

The software used for the energy model is Microsoft Access 2003, which is a Relational Database Management System (RDBMS) for creating databases. The database is called the 'Fremskrivning 2005-2030 model' and the overall construction of the database is shown in Figure 2.18.

The model consists of input data collected in tables containing fuel consumption and emission factors for combustion plants larger than 25 MWe and combustion plants smaller than 25 MWe. 'Area' and 'Point' in the model refer to small and large combustion plants, respectively. In Table 2.19 the names and the content of the tables are listed.

Table 2.19 Tables in the 'Fremskrivning2005-2030 model'

Name	Content
tblEmfArea	Emission factors for small combustion plants
tblActArea	Fuel consumption for small combustion plants
tblEmfPoint	Emission factors for large combustion plants
tblActPoint	Fuel consumption for large combustion plants

From the data in these tables a number of calculations and unions are created by means of queries. The names and the functions of the queries used for calculating the total emissions are shown in Table 2.20.

Table 2.20 Queries for calculating the total emissions

Name	Function
qEmissionArea	Calculation of the emissions from small combustion plants. Input: tblActArea and qEmfArea
qEmissionPoint	Calculation of the emissions from large combustion plants. Input: tblActPoint and qEmfPoint
qEmissionAll_a	Union of qEmissionArea and qEmissionPoint

Based on some of the queries a number of summation queries are available in the 'Fremskrivning2005-2030 model' (Figure 2.19). Output from the summation queries is in the form of Excel Pivot tables.

Table 2.21 Summation queries

Name	Output
qxlsEmissionAll	Table containing emissions for SNAP groups, Years and Pollutants
qxlsEmissionArea	Table containing emissions for small combustion plants for SNAP groups, Years and Pollutants
qxlsEmissionPoint	Table containing emissions for large combustion plants for SNAP groups, Years and Pollutants
qxlsActivityAll	Table containing fuel consumption for SNAP groups, Years and Pollutants
qxlsActivityPoint	Table containing fuel consumption for large combustion plants for SNAP groups, Years and Pollutants

All the tables and queries are connected and changes in one or more of the parameters in the tables result in changes in the output tables.

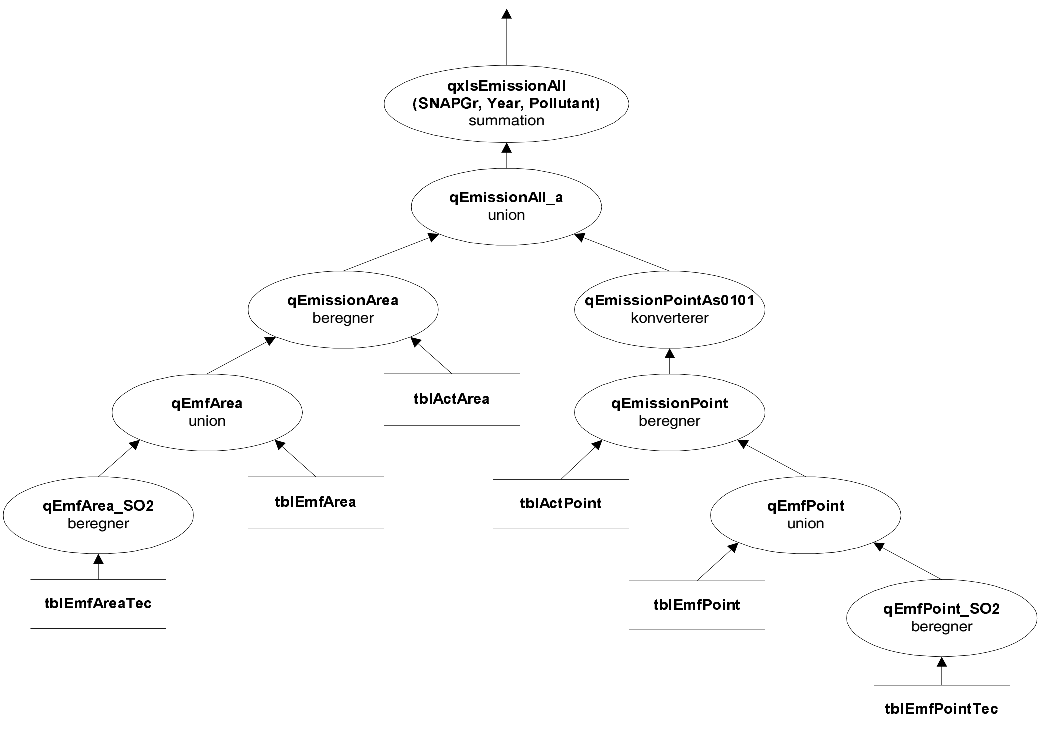

Figure 2.18 Overall construction of the database

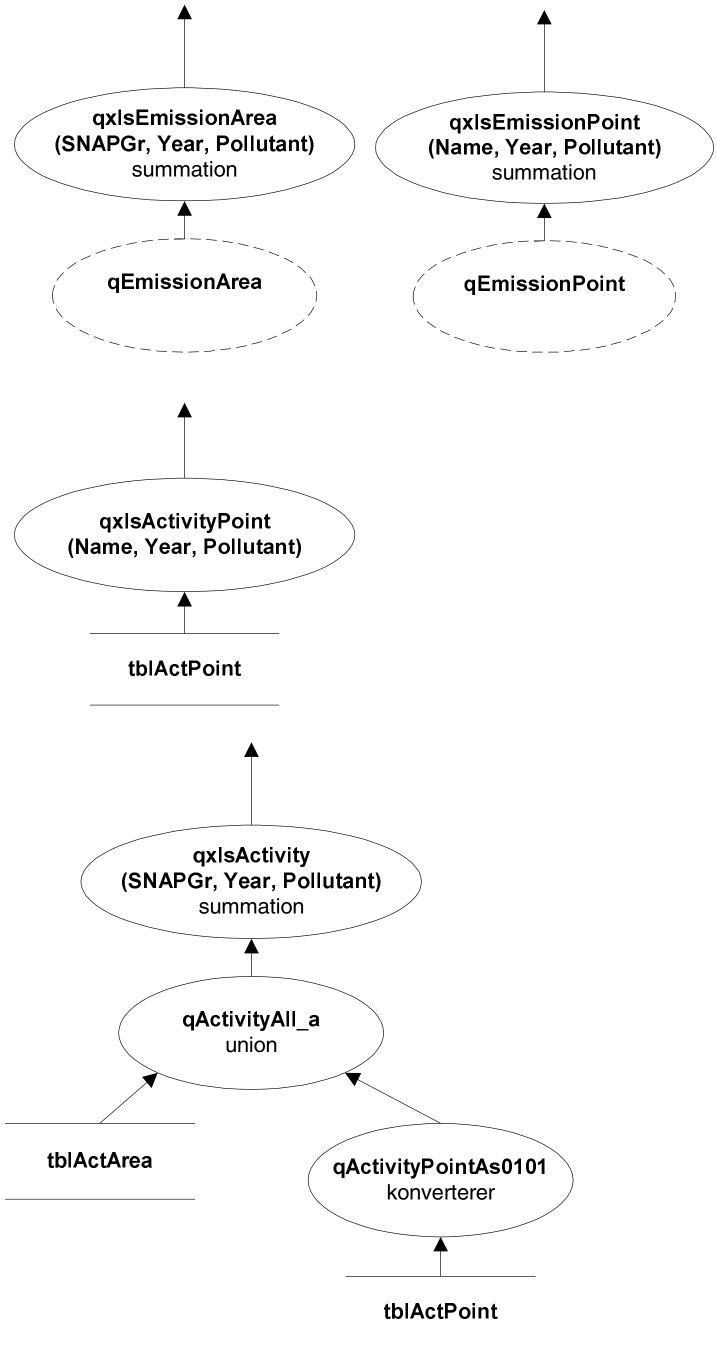

Figure 2.19 Summation queries

2.7 References

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3 Oil and gas extraction (Fugitive emissions)

3.1 Methodology

The total emission of VOCs from the extraction of oil and gas is expressed in Equation 3.1.

$$Eq\,3.1 \quad E_{total} = E_{extraction} + E_{GT} + E_{ship} + E_{pipeline} + E_{networks}$$

$E_{extraction}$ represents emissions from plant involved in offshore extraction of oil and gas and include emissions from venting, evaporation (fugitive loss) and flaring (refer to Equation 3.2).

$$Eq\,3.2 \quad E_{extraction} = E_{venting} + E_{fugitive} + E_{flaring}$$

In Denmark, the venting of gas is considered to be very limited as the controlled emission is flared. $E_{venting}$ is, therefore, set to zero.

According to the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2003), the total fugitive emission of VOC can be calculated by means of Equation 3.3:

$$Eq\,3.3 \quad E_{VOC,fugitive} = 40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}$$

where N_P is the number of platforms, P_{gas} (10^6 Nm^3) is the production of gas and P_{oil} (10^6 tonnes) is the production of oil. If it can be considered that the VOC emitted consists of 75 % methane and 25 % NMVOC, then the methane and NMVOC emission can be calculated by means of Equations 3.4 and 3.5:

$$Eq\,3.4 \quad E_{extraction,NMVOC} = E_{fugitive,NMVOC} + E_{flaring,NMVOC}$$
$$= 0.25(40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}) + F_P \cdot EMF_{flaring,NMVOC}$$

$$Eq\,3.5 \quad E_{extraction,CH4} = E_{fugitive,CH4} + E_{flaring,CH4}$$
$$= 0.75(40.2 \cdot N_P + 1.1 \cdot 10^{-2} P_{gas} + 8.5 \cdot 10^{-6} \cdot P_{oil}) + F_P \cdot EMF_{flaring,CH4}$$

where $EMF_{flaring}$ is the emission factor for flaring.

The emission from gas treatment and storage can be arrived at via Equation 3.6:

$$Eq\,3.6 \quad E_{GT} = E_{GT,fugitive} + EMF_{flaring} \cdot F_{GT}$$

where $E_{GT,fugitive}$ represents the fugitive emissions, $EMF_{flaring}$ represents the emission factor for flaring and F_{GT} is the amount of gas flared.

The loading of ships with oil is carried out both offshore and onshore and the emission is calculated by means of Equation 3.7:

$$Eq\ 3.7 \quad E_{ships} = EMF_{ships} \cdot L_{oil}$$

where EMF_{ships} is the emission factor for loading ships offshore and onshore and L_{oil} is the amount of oil loaded.

The emission of VOC from the transport of oil and gas in pipelines can be calculated by means of Equation 3.8:

$$Eq\ 3.8 \quad E_{pipelines} = EMF_{pipeline,gas} \cdot T_{gas} + EMF_{pipeline,oil} \cdot T_{oil}$$

where T_{gas} and T_{oil} represent the amount of gas and oil transported, respectively, and $EMF_{pipeline,gas}$ and $EMF_{pipeline,olie}$ are the associated emission factors.

Emissions from the storage of crude oil can be calculated by means of Equation 3.9:

$$Equation\ 3.9 \quad E_{tanks} = EMF_{tanks} \cdot T_{oil}$$

where EMF_{tanks} is the emission factor for storage of crude oil in tanks.

Emissions from the gas distribution network can be calculated by means of Equation 3.10:

$$Eq\ 3.10 \quad E_{networks} = EMF_{network} \cdot C_{gas}$$

where C_{gas} is the amount of gas transported and $EMF_{network}$ is the emission factor for the transport of gas via the gas distribution network.

3.2 Activity data

3.2.1 Historic

Activity data used in the calculation of the emissions is provided in Table 3.1 and stems either from the Danish Energy Authority's publications (Danish Energy Authority, 2005a and 2005b) or from DONG's environmental accounts ('grønne regnskaber') (DONG, 2005). The emissions from flaring are calculated in Chapter 2, 'Stationary Combustion'.

Table 3.1 Activity data for 2004

Activity	Symbol	Year 2005	Ref.
Number of platforms	N_p	48	Danish Energy Authority (2005a)
Gas produced (10^6Nm3)	P_{gas}	10 934	Danish Energy Authority (2005a)
Oil produced (10^3m3)	$P_{oil,vol}$	22 614	Danish Energy Authority (2005a)
Oil produced (10^3tonne)	P_{oil}	19 448	Danish Energy Authority (2005a)
Gas transported by pipeline (10^6Nm3)	T_{gas}	7 384	Danish Energy Authority (2005a)
Oil transported by pipeline (10^3m3)	T_{oil}	18 100	DONG (2005)
Oil transported by pipeline (10^3tonne)	T_{oil}	15 566	DONG (2005)
Oil loaded (10^3m3)	$L_{oil\ off\text{-}shore}$	4 774	Danish Energy Authority (2005a)
Oil loaded (10^3tonne)	$L_{oil\ off\text{-}shore}$	4 106	Danish Energy Authority (2005a)
Oil loaded (10^3m3)	$L_{oil\ on\text{-}shore}$	14 000	DONG (2005)
Oil loaded (10^3tonne)	$L_{oil\ on\text{-}shore}$	12 040	DONG (2005)
Volume gas consumed (10^6Nm3)	C_{gas}	3 248	Danish Energy Authority (2005b)

Mass weight crude oil = 0.86 tonne/m^3

3.2.2 Projection

The prognosis for the production of oil and gas shown in Figure 3.1 presents a path in which technological progress and new extraction possibilities are assumed (Danish Energy Authority, 2006). A decline in the extraction of oil and gas from 2004 to 2030 is foreseen in the prognosis.

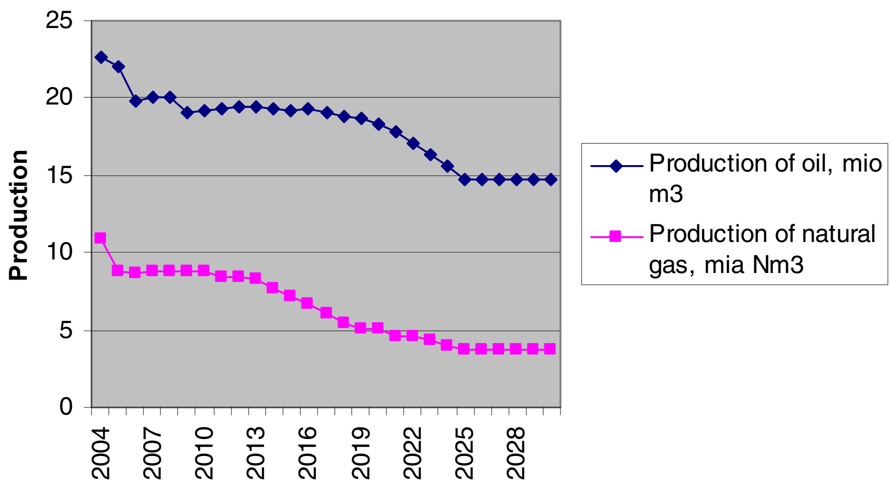

Figure 3.1 Prognosis for the production of oil and gas

3.3 Emission factors

In the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2003), the emission factors from different countries are provided. The Norwegian emission factors, which are also used in Norway's official emissions inventories (Flugsrud et al., 2000), have been selected for use in the projections (Table 3.2). The emissions from the storage of oil are stated in DONG's environmental accounts for 2004 (DONG, 2005) and the emission factor is calculated based on the amount of oil transported.

Table 3.2 Emission factors for 2005-2009.

	NMVOC	Unit	Ref.
Ships offshore	0.001	Fraction of loaded	EMEP/CORINAIR, 2003
Ships onshore	0.0002	Fraction of loaded	EMEP/CORINAIR, 2003
Pipeline, gas	3.66	kg/103m3	Karll, 2005
Oil tanks	249	kg/103m3	DONG, 2005
Network	3.47	kg/106m3	Karll, 2005

According to a local authority environmental department (Vejle Amt, 2005), stricter regulation of the emissions from oil tanks and onshore loading of ships is going to be introduced. The emission factors for these sources have therefore decreased by 99 % and 19 % from 2010. The emission factors from 2010 to 2030 are listed in Table 3.3.

Table 3.3 Emission factors for 2010-2030

	NMVOC	Unit	Ref.
Ships offshore	0.001	Fraction of loaded	EMEP/CORINAIR, 2003
Ships onshore	0.000162	Fraction of loaded	EMEP/CORINAIR, 2003 and Vejle Amt, 2005
Pipeline, gas	3.66	kg/103m3	Karll, 2005
Oil tanks	2,49	kg/103m3	DONG, 2005 and Vejle Amt 2005
Network	3.47	kg/106m3	Karll, 2005

3.4 Emissions

Table 3.4 NMVOC emissions (tonnes)

Extraction:	2004	2030
Fugitive		360
Gas treatment and storage:		
Fugitive + Flaring		0
Pipelines:		
Gas		11
Oil		i.e.
Network		4
Oil tanks		33
Total minus ships		408
Ships:		
Offshore		2976
Onshore		1414
Total		4797

The emissions for NMVOC are calculated based on the activity data in Table 4.1 and the emission factors in Tables 3.2 and 3.3.

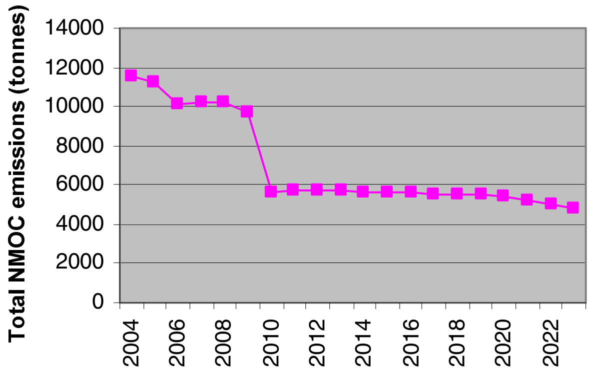

Figure 3.2 NMVOC emissions from oil and gas production

Table 3.5 MNVOC emissions (ktonnes)

IPCC name	IPCC code	1990	2000	2005	'2010'	2015'	2020	2025	2030
Fugitive emissions from oil	1B2a			11.24	5.60	5.61	5.36	4.78	4.78
Fugitive emissions from gas	1B2b			0.03	0.03	0.03	0.02	0.01	0.01
Total				11.27	5.63	5.64	5.37	4.80	4.80

The decline in emissions reflects the expected environmental regulation of emissions from oil tanks and onshore loading of ships, and the decreasing extraction of oil and gas. It has been assumed that the number of platforms falls in line with the decline in extraction. The emission factors are assumed to be the same as those used in the historic inventories, except in the case of oil tanks and onshore loading of ships.

3.5 Model description

The model for the offshore industry is created in Microsoft Excel and the worksheets used in the model are collected in the 'Offshore model'. The names and content of the tables are listed in Table 3.6.

Table 3.6 Tables in the 'Offshore model'

Name	Content
Activity data	Historical data for 2000 (Table 2.2.1) plus estimated activity rates for 2001 to 2010 based on data in table 'Projected production'
Projected production	Projected production of oil and gas for 2001 to 2010
EMF	Emission factors for NMVOC for all activities
Emissions	Projected emissions for 2001 to 2010 based on data in tables 'Activity data' and 'Emission factors'

Changing the data in the input data tables automatically updates the projected emissions.

3.6 References

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4 Transport

In the forecast model all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according to the CORINAIR system. The aggregation to the sector codes used for both the UNFCCC and UNECE Conventions is based on a correspondence list between SNAP and IPCC classification codes (CRF) shown in Table 4.1 (mobile sources only).

Table 4.1 SNAP – CRF correspondence table for transport

SNAP classification	IPCC classification
07 Road transport	1A3b Transport-Road
0801 Military	1A5 Other
0802 Railways	1A3c Railways
0803 Inland waterways	1A3d Transport-Navigation
080402 National sea traffic	1A3d Transport-Navigation
080403 National fishing	1A4c Agriculture/forestry/fisheries
080404 International sea traffic	1A3d Transport-Navigation (international)
080501 Dom. airport traffic (LTO < 1000 m)	1A3a Transport-Civil aviation
080502 Int. airport traffic (LTO < 1000 m)	1A3a Transport-Civil aviation (international)
080503 Dom. cruise traffic (> 1000 m)	1A3a Transport-Civil aviation
080504 Int. cruise traffic (> 1000 m)	1A3a Transport-Civil aviation (international)
0806 Agriculture	1A4c Agriculture/forestry/fisheries
0807 Forestry	1A4c Agriculture/forestry/fisheries
0808 Industry	1A2f Industry-Other
0809 Household and gardening	1A4b Residential

Military transport activities (land and air) refer to the CRF sector Other (1A5), while the Transport-Navigation sector (1A3d) comprises national sea transport (ship movements between two Danish ports) and recreational craft. Working machinery and materiel in industry are grouped in Industry-Other (1A2f), while agricultural and forestry machinery is accounted for in the Agriculture/forestry/fisheries (1A4c) sector together with fishing activities. The description of methodologies and references for the transport part of the Danish inventory is given in two sections; one for road transport and one for the other mobile sources.

4.1 Methodology and references for Road Transport

For road transport the emission calculations are made with a model developed by NERI, using the detailed methodology from the European COPERT III model. The latter model approach is explained by Ntziachristos et al. (2000) and EMEP/CORINAIR (2003). In COPERT III, fuel use and emission simulations can be made for operationally hot engines taking into account gradually stricter emission standards and emission degradation due to catalyst wear. Furthermore the emission effects of cold start and evaporation are simulated.

4.1.1 Vehicle fleet and mileage data

Corresponding to the COPERT fleet classification, all present and future vehicles in the Danish fleet are grouped into vehicle classes, sub-classes and layers. The layer classification is a further division of vehicle sub-classes into groups of vehicles with the same average fuel use and emission behaviour according to EU emission legislation levels. Table 4.2 gives an overview of the different model classes and sub-classes, and the layer level with implementation years are shown in Annex 4.I.

Table 4.2 Model vehicle classes and sub-classes, trip speeds and mileage split

			Trip speed [km/h]			Mileage split [%]		
Vehicle classes	Fuel type	Engine size/weight	Urban	Rural	Highway	Urban	Rural	Highway
PC	Gasoline	< 1.4 l.	40	70	100	35	46	19
PC	Gasoline	1.4 – 2 l.	40	70	100	35	46	19
PC	Gasoline	> 2 l.	40	70	100	35	46	19
PC	Diesel	< 2 l.	40	70	100	35	46	19
PC	Diesel	> 2 l.	40	70	100	35	46	19
PC	LPG		40	70	100	35	46	19
PC	2-stroke		40	70	100	35	46	19
LDV	Gasoline		40	65	80	35	50	15
LDV	Diesel		40	65	80	35	50	15
Trucks	Gasoline		35	60	80	32	47	21
Trucks	Diesel	3.5 – 7.5 tonnes	35	60	80	32	47	21
Trucks	Diesel	7.5 – 16 tonnes	35	60	80	32	47	21
Trucks	Diesel	16 – 32 tonnes	35	60	80	19	45	36
Trucks	Diesel	> 32 tonnes	35	60	80	19	45	36
Urban buses	Diesel		30	50	70	51	41	8
Coaches	Diesel		35	60	80	32	47	21
Mopeds	Gasoline		30	30	-	81	19	0
Motorcycles	Gasoline	2 stroke	40	70	100	47	39	14
Motorcycles	Gasoline	< 250 cc.	40	70	100	47	39	14
Motorcycles	Gasoline	250 – 750 cc.	40	70	100	47	39	14
Motorcycles	Gasoline	> 750 cc.	40	70	100	47	39	14

Information on the historical vehicle stock and annual mileage is obtained from the Danish Road Directorate (Ekman, 2005a). This covers data for the number of vehicles and annual mileage per first registration year for all vehicle sub-classes, and mileage split between urban, rural and highway driving and the respective average speeds. Additional data for the moped fleet and motorcycle fleet disaggregation information is given by the National Motorcycle Association (Markamp, 2005).

To support the emission projections carried out by Illerup et al. (2002) a vehicle fleet and mileage prognosis was produced by the Danish Road Directorate. The general approach was to assume new sales of vehicles and mean vehicle lifespan in the years during the forecast period, by means of historical data analyses and economic parameters. The prognosis data has subsequently been modified for later Danish emission forecast projects. The latest data adjustments were made by Ekman (2005b) as a part of the present emission forecast.

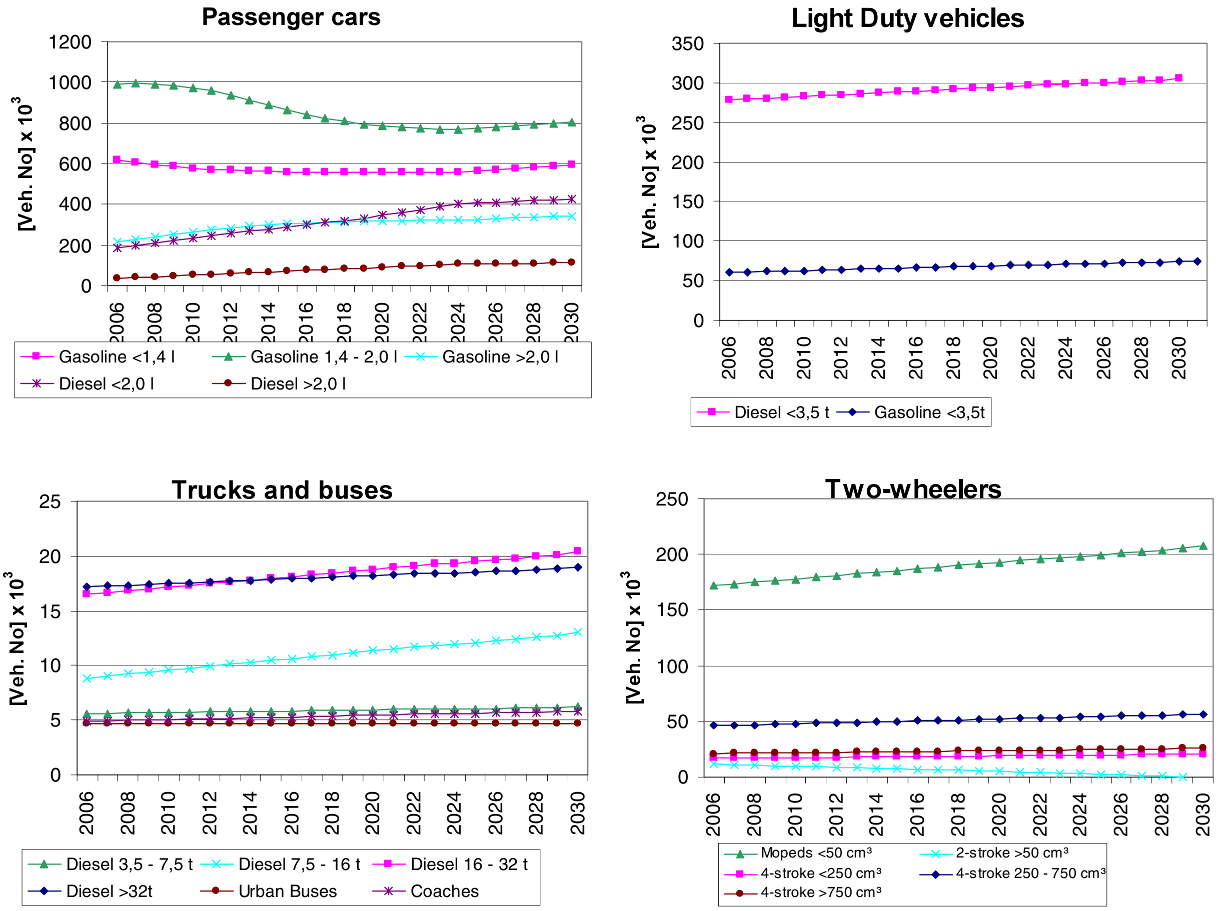

Figure 4.1 Number of vehicles in sub-classes in 2006-2030

The vehicle numbers per sub-class are shown in Figure 4.1. The engine size differentiation is associated with some uncertainty.

The vehicle numbers are summed up in layers for each year (Figure 4.2) by using the correspondence between layers and first registration year:

$$(eq\ 4.1) \quad N_{j,y} = \sum_{i=FYear(j)}^{LYear(j)} N_{i,y}$$

where N = number of vehicles, j = layer, y = year, i = first year of registration.

Weighted annual mileages per layer are calculated as the sum of all mileage driven per first registration year divided by the total number of vehicles in the specific layer.

$$eq\ 4.2 \quad M_{j,y} = \frac{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \cdot M_{i,y}}{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y}}$$

Vehicle numbers and weighted annual mileages per layer are shown in Annex 4.1 for 2006-2030. The trends in vehicle numbers per layer are also shown in Figure 4.2, which shows how vehicles complying with the gradually stricter EU emission levels (EURO I, II, III, etc.) are introduced into the Danish motor fleet over the forecast period.

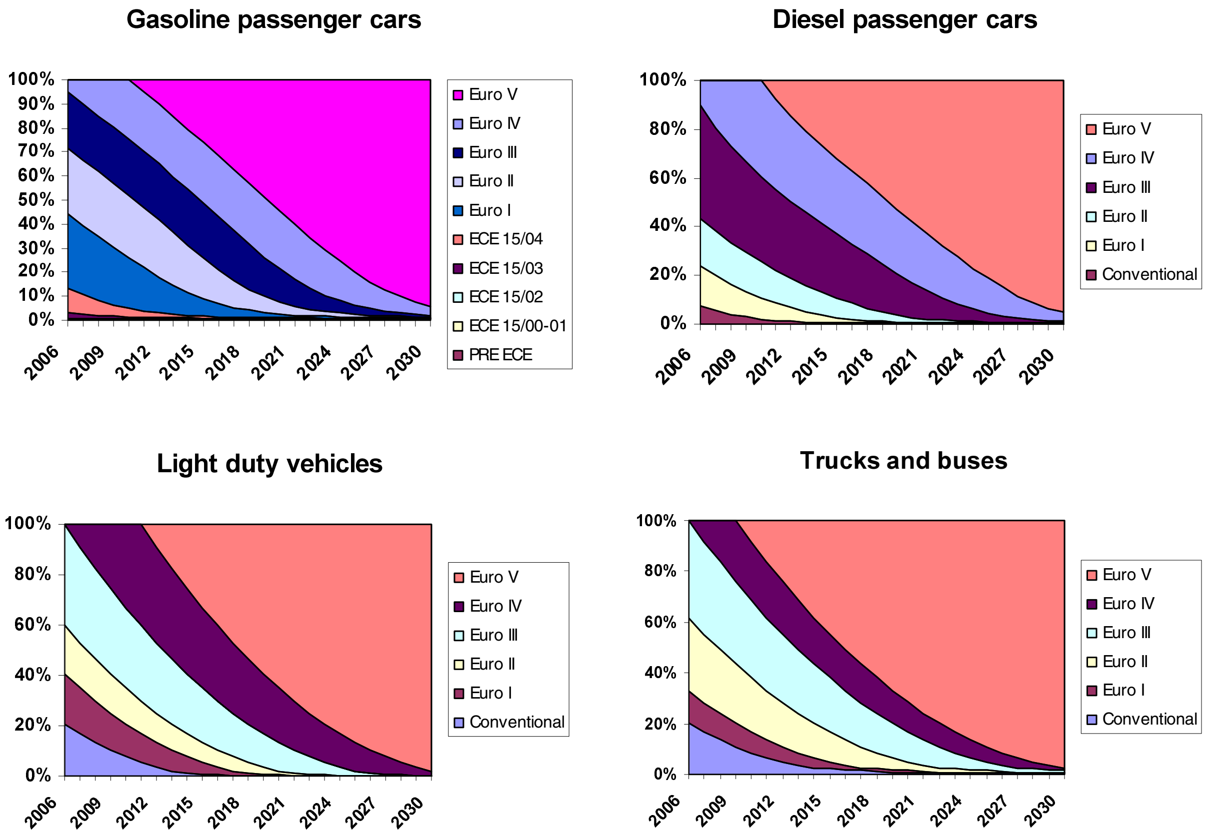

Figure 4.2 Layer distribution of vehicle numbers per vehicle type in 2006-2030

4.1.2 Fuel and emission legislation

For passenger cars and light duty vehicles the emission approval tests are made on a chassis dynamometer. The test cycle used in the EU for emission approval testing of Euro I-IV passenger cars and light duty vehicles is the EU NEDC (New European Driving Cycle (see Nørgaard and Hansen, 2004). The EU NEDC test is also used for fuel use measurements.

The NEDC cycle consists of two parts, the first part being a 4-time repetition (driving length: 4 km) of the ECE test cycle. The latter test cycle is the so-called urban driving cycle (average speed: 19 km/h). The second part of the test is the run-through of the EUDC (Extra Urban Driving Cycle) test driving segment, simulating fuel use under rural and highway driving conditions. The driving length of EUDC is 7 km at an average speed of 63 km/h. More information regarding the fuel measurement procedure can be found in the EU Directive 80/1268/EEC.

For NOx, VOC (NMVOC + CH4), CO and TSP, the emissions from road transport vehicles have to comply with the various EU directives listed in Table 3.24. The emission directives distinguish between three vehicle classes: passenger cars and light duty vehicles (<1305 kg), light duty vehicles (1305-1760 kg) and light duty vehicles (>1760 kg). The specific emission limits can be seen in Winther (2007).

Table 4.3 Overview of the existing EU emission directives for road transport vehicles

Vehicle category	Emission layer	EU Directive	First reg. year	
			Start	End
Private cars (gasoline)	PRE ECE		0	1969
	ECE 15/00-01	70/220 - 74/290	1970	1978
	ECE 15/02	77/102	1979	1980
	ECE 15/03	78/665	1981	1985
	ECE 15/04	83/351	1986	1990
	Euro I	91/441	1991	1996
	Euro II	94/12	1997	2000
	Euro III	98/69	2001	2005
	Euro IV	98/69	2006	9999
Private cars (diesel and LPG)		Conventional	0	1990
	Euro I	91/441	1991	1996
	Euro II	94/12	1997	2000
	Euro III	98/69	2001	2005
	Euro IV	98/69	2006	2010
	Euro V		2011	9999
Light duty veh. (gasoline and diesel)		Conventional	0	1994
	Euro I	93/59	1995	1998
	Euro II	96/69	1999	2001
	Euro III	98/69	2002	2006
	Euro IV	98/69	2007	9999
	Euro V		2012	9999
Heavy duty vehicles		Conventional	0	1993
	Euro I	91/542	1994	1996
	Euro II	91/542	1997	2001
	Euro III	1999/96	2002	2006
	Euro IV	1999/96	2007	2009
	Euro V	1999/96	2010	9999
Mopeds		Conventional	0	1999
	Euro I	97/24	2000	2002
	Euro II	97/24	2003	9999
Motor cycles		Conventional	0	1999
	Euro I	97/24	2000	2003
	Euro II	2002/51	2004	2006
	Euro III	2002/51	2007	9999

In practice, actual emissions from vehicles in traffic differ from the legislation limit values and therefore the latter figures are considered to be too inaccurate for total emission calculations. A major constraint is that the emission approval test conditions only to a limited degree reflect the large variety of emission-influencing factors in real traffic situations such as cumulated mileage driven, engine and exhaust after-treatment maintenance levels, and driving behaviour.

Therefore, in order to represent the Danish fleet and to support average national emission estimates, emission factors must be chosen which are derived from numerous emissions measurements, using a broad range of real-world driving patterns and sufficient numbers of test vehicles. It is similar important to have separate fuel use and emission data for cold start emission calculations and gasoline evaporation (hydrocarbons).

For heavy duty vehicles (trucks and buses) the emission limits are given in g/kWh, and the measurements are carried out for engines in a test bench, using the EU ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles, depending on Euro norm and installed exhaust gas after-treatment system. A description of the test cycles are given by Nørgaard and Hansen, 2004. Measurement results in g/kWh from emission approval tests cannot directly be used for inventory work. Instead, emission factors used for national estimates must be transformed into g/km, and derived from a sufficient number of measurements representing the different vehicle size classes, Euro engine levels, and real-world variations in driving behaviour.

In terms of the sulphur content in the fuels used by road transportation vehicles, the EU Directive 2003/17/EC describes the fuel quality standards agreed by the EU. In Denmark, the sulphur content in gasoline and diesel was reduced to 10 ppm in 2005 by means of a fuel tax reduction for fuels with 10 ppm sulphur content.

4.1.3 Fuel use and emission factors

Trip speed dependent base factors for fuel use and emissions are taken from the COPERT model, using trip speeds as shown in Table 4.2. The factors can be seen in Winther (2007). The scientific basis for COPERT III is fuel use figures and emission information from various European measurement programmes, transformed into trip speed dependent fuel use and emission factors for all vehicle categories and layers. For passenger cars and light duty vehicles, real measurement results lie behind the emission factors for Euro I and earlier vehicles, whereas computer-simulated emission factors form the experimental basis for Euro I and pre-Euro I heavy duty engines vehicles. In both cases, the emission factors for later engine technologies are produced using reduction factors (see Winther, 2007). The reduction factors are determined by assessing the EU emission limits and the relevant emission approval test conditions for each vehicle type and Euro class.

4.1.4 Fuel use and emission calculations

Fuel use and emissions are calculated for operationally hot engines and for engines during cold start, and a final fuel balance adjustment is made in order to account for the statistical fuel sold according to the Danish energy statistics.

The calculation procedure for hot engines is to combine base fuel use and emission factors (see Winther, 2007), number of vehicles and annual mileage figures (Annex 4.1), and mileage per road type shares (from Table 4.2). For further description of the hot and cold start calculations and fuel balance approach, please refer to Winther (2007).

Fuel use and emission results per layer and vehicle type, respectively, are shown in Annex 4.1 from 2006-2030. The layer-specific emission factors (km-based) for SO_2, NO_X, NMVOC, NH_3, TSP, PM_{10} and $PM_{2.5}$ derived from the base input data are also shown in Annex 4.1.

4.2 Other mobile sources

Other mobile sources are divided into several sub-sectors; sea transport, fishery, air traffic, railways, military, as well as the working machinery and materiel in industry, forestry, agriculture, and household and gardening sectors. The emission calculations are made using the detailed method as described in the EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 2003) for national sea transport (ferries only), air traffic and off road working machinery and equipment, while for the remaining sectors the simple method also described in these sources is used.

4.2.1 Activity data

Air traffic

For historical years, the activity data for air traffic consists of air traffic statistics provided by the Danish Civil Aviation Agency (CAA-DK) and Copenhagen Airport. For 2001-2004 records are given per flight by CAA-DK as data for aircraft type and origin and destination airports. For inventory years prior to 2001 detailed LTO/aircraft type statistics are obtained from Copenhagen Airport (for this airport only), while information on total number take-offs for other Danish airports is provided by CAA-DK. Fuel statistics for jet fuel use and aviation gasoline is obtained from the Danish energy statistics (DEA, 2005).

No forecast of air traffic movements is available as input to the emission projection calculations. Instead, a forecast of total fuel used by Danish domestic flights from 2006-2030 is used as activity data in the projection period.

Prior to emission calculation for historical years, the aircraft types are grouped into a smaller number of representative aircraft for which fuel use and emission data exist in the EMEP/CORINAIR databank. In this procedure the actual aircraft types are classified according to their overall aircraft type (jets, turbo props, helicopters and piston engines). Secondly, information on the aircraft MTOM (Maximum Take Off Mass) and number of engines is used to append a representative aircraft to the aircraft type in question. A more thorough explanation is given in Winther (2001a, b).

Non road working machinery and recreational craft

Non road working machinery and equipment are used in agriculture, forestry and industry as well as for household/gardening purposes, and recreational craft refer to the inventory group inland waterways. The specific machinery types comprised in the Danish inventory are shown in Table 4.4.

Table 4.3 Machinery types comprised in the Danish non road inventory

Sector	Diesel	Gasoline/LPG
Agriculture	Tractors, harvesters, machine pool, other	ATV's (All Terrain Vehicles), other
Forestry	Silv. tractors, harvesters, forwarders, chippers	-
Industry	Construction machinery, forklifts, building and construction, airport GSE, other	Forklifts (LPG), building and construction, other
Household/ gardening	-	Lawn & garden tractors, lawnmowers, chainsaws, cultivators, shrub clearers, hedge cutters, trimmers, other

Please refer to the report by Winther et al. (2007) for detailed information of the number of different types of machines, their load factors, engine sizes and annual working hours.

National sea transport

For sea transport the inventory basis is fuel sold in Danish ports, reported to the DEA (2005). Depending on the destination of the vessels in question, the traffic is defined either as national or international, as prescribed by the UNECE guidelines. A new Danish research project has carried out detailed calculations for Danish domestic ferries, and more information on ferry activity data can be obtained from Winther (2007). The latter project also comprises new emission estimates for small ferries (local ferries), other national sea transport, fisheries and international sea transport, using a more simple calculation approach.

The following Table 4.4 lists the most important ferry routes and service year in the period of 1990-2005.

Table 4.4 Most important domestic ferry routes in Denmark

Ferry service	Service period
Halsskov-Knudshoved	1990-1999
Hundested-Grenaa	1990-1996
Kalundborg-Juelsminde	1990-1996
Kalundborg-Samsø	1990-
Kalundborg-Århus	1990-
Korsør-Nyborg, DSB	1990-1997
Korsør-Nyborg, Vognmandsruten	1990-1999
København-Rønne	1990-2004
Køge-Rønne	2004-
Sjællands Odde - Ebeltoft	1990-
Sjællands Odde - Århus	1999-
Tårs-Spodsbjerg	1990-

Other sectors

The activity data for military, railways and fishery consists of fuel use information from the DEA (2005a).

For all other mobile sectors, fuel use figures are given in Annex 4.2 for the years 2006-2030 in both CollectER and NFR formats.

4.2.2 Emission legislation

For non road working machinery and equipment, recreational craft, railway locomotives/motor cars and ship engines, the emission directives list specific emission limit values (g/kWh) for CO, VOC, NO_X (or VOC + NO_X) and TSP, depending on engine size (kW for diesel, ccm for gasoline) and date of implementation (referring to the date the engine is placed on the market).

For diesel, Directives 1997/68/EC and 2004/26/EC relate to non road machinery other than agricultural and forestry tractors, and the directives have different implementation dates for machinery operating under transient and under constant loads. The latter directive also comprises emission limits for railway machinery. For tractors, the relevant directives are 2000/25/EC and 2005/13/EC. For gasoline, Directive 2002/88/EC distinguishes between handheld (SH) and non handheld (NS) machinery.

For engine type approval, the emissions (and fuel use) are measured using various test cycles (ISO 8178). Each test cycle consists of a number of measurement points for specific engine loads during constant operation. The specific test cycle used depends on the type of machinery in question, and the test cycles are described in more detail in the relevant directives.

Table 4.4 Overview of EU emission directives relevant for diesel fuelled non road machinery

Stage/Engine size [kW]	CO	VOC	NO_X	VOC+NO_X	PM	Diesel machinery EU directive	Diesel machinery Implement. date Transient	Diesel machinery Implement. date Constant	Tractors EU Directive	Tractors Implement. date
	[g/kWh]									
Stage I										
37<=P<75	6.5	1.3	9.2	-	0.85	97/68	1/4 1999	-	2000/25	1/7 2001
Stage II										
130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA										
130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB										
130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV										
130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014		2005/13	1/1 2014
56<=P<130	5	0.19	0.4	-	0.025		1/10 2014			1/10 2014

Table 4.5 Overview of the EU emission directive 2002/88 for gasoline fuelled non road machinery

	Category	Engine size [ccm]	CO [g/kWh]	HC [g/kWh]	NO_X [g/kWh]	HC+NO_X [g/kWh]	Implementation date
	Stage I						
Hand held	SH1	S<20	805	295	5.36	-	1/2 2005
	SH2	20=<S<50	805	241	5.36	-	1/2 2005
	SH3	50=<S	603	161	5.36	-	1/2 2005
Not hand held	SN3	100=<S<225	519	-	-	16.1	1/2 2005
	SN4	225=<S	519	-	-	13.4	1/2 2005
	Stage II						
Hand held	SH1	S<20	805	-	-	50	1/2 2008
	SH2	20=<S<50	805	-	-	50	1/2 2008
	SH3	50=<S	603	-	-	72	1/2 2009
Not hand held	SN1	S<66	610	-	-	50	1/2 2005
	SN2	66=<S<100	610	-	-	40	1/2 2005
	SN3	100=<S<225	610	-	-	16.1	1/2 2008
	SN4	225=<S	610	-	-	12.1	1/2 2007

For recreational craft, Directive 2003/44 comprises the emission legislation limits for diesel and for 2-stroke and 4-stroke gasoline engines, respectively. The CO and VOC emission limits depend on engine size (kW), and the inserted parameters given in the calculation formulas in Table 4.6. For NO_X, a constant limit value is given for each of the three engine types. For TSP, the constant emission limit regards diesel engines only.

Table 4.6 Overview of the EU emission directive 2003/44 for recreational craft

Engine type	Impl. date	$CO=A+B/P^n$			$HC=A+B/P^n$			NO_X	TSP
		A	B	n	A	B	n		
2-stroke gasoline	1/1 2007	150.0	600.0	1.0	30.0	100.0	0.75	10.0	-
4-stroke gasoline	1/1 2006	150.0	600.0	1.0	6.0	50.0	0.75	15.0	-
Diesel	1/1 2006	5.0	0.0	0	1.5	2.0	0.5	9.8	1.0

Table 4.7 Overview of the EU emission directive 2004/26 for railway locomotives and motor cars

	Engine size [kW]		CO [g/kWh]	HC [g/kWh]	NO_Xg /kWh]	HC+NO_X [g/kWh]	PM [g/kWh]	Implementation date
Locomotives	Stage IIIA							
	130<=P<560	RL A	3.5	-	-	4	0.2	1/1 2007
	560<P	RH A	3.5	0.5	6	-	0.2	1/1 2009
	2000<=P and piston displacement >= 5 l/cyl.	RH A	3.5	0.4	7.4	-	0.2	1/1 2009
	Stage IIIB	RB	3.5	-	-	4	0.025	1/1 2012
Motor cars	Stage IIIA							
	130<P	RC A	3.5	-	-	4	0.2	1/1 2006
	Stage IIIB							
	130<P	RC B	3.5	0.19	2	-	0.025	1/1 2012

For NO_X, the emission legislation is relevant for diesel engines with a power output greater than 130 kW installed on a ship constructed on or after 1 January 2000, and diesel engines with a power output greater than 130 kW which undergo major conversion on or after 1 January 2000. For engine type approval, the NO_X emissions are measured using a test cycle (ISO 8178) which consists of several steady-state modes with different weighting factors.

Figure 1 shows the NO_X emission limits for ship engines in relation to their rated engine speed (n) given in RPM (Revolutions Per Minute). The limits are as follows:

17 g/kWh, n < 130 RPM

45 x n-0.2 g/kWh, 130 ≤ n < 2000 RPM

9.8 g/kWh, n ≥ 2000 RPM

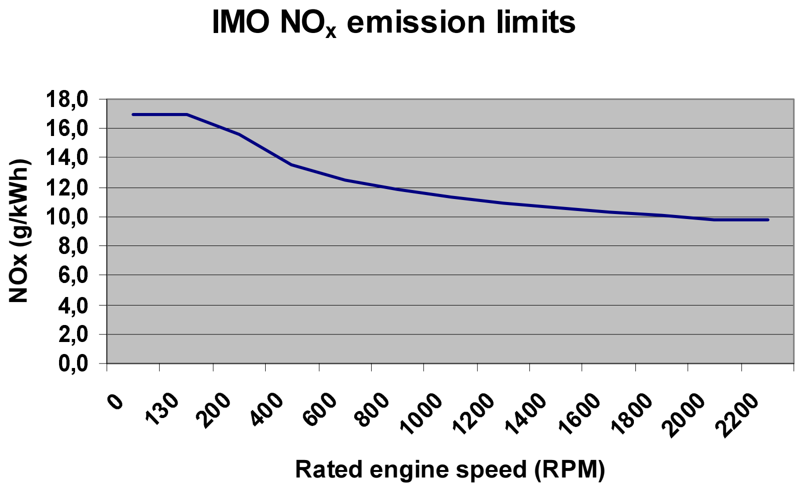

Figure 4.3 NO_X emission limits as a function of rated engine speed

Aircraft engine emissions of NO_X, CO, VOC and smoke are regulated by the ICAO (International Civil Aviation Organization). The legislation is relevant for aircraft engines with rated engine thrust larger than 26.7 kN. A further description of the emission legislation and emission limits is given in ICAO Annex 16 (1993).

Table 4.8 Current legislation in relation to marine fuel quality

Legislation		Heavy fuel oil S-%	Impl. date	Marine Gas oil S-%	Impl. date
EU-directive 1999/32		None		0.2	1.1.2000
EU-directive 2005/33	SECA - Baltic sea	1.5	11.08.2006	0.1	1.1.2008
	SECA - North sea	1.5	11.08.2007	0.1	1.1.2008
	Outside SECA's	None		0.1	1.1.2008
MARPOL Annex VI	SECA – Baltic sea	1.5	19.05.2006		
	SECA – North sea	1.5	21.11.2007		
	Outside SECA	4.5	19.05.2006		

For non road machinery, EU Directive 2003/17/EC gives a limit value of 50 ppm sulphur in diesel (from 2005).

4.2.3 Emission factors

The SO_2 emission factors are fuel related, and rely on the sulphur contents given in the relevant EU fuel directives or in the relevant Danish legislation. However, for jet fuel the default factor from the IPCC (1996) is used. Road transport diesel is assumed to be used by engines in military and railways, and road transport gasoline is assumed to be used by non road working machinery and recreational craft. Hence, these types of machinery have the same SO_2 emission factors as for road transport.

The NH_3 emission factors are taken from the EMEP/CORINAIR guidebook (CORINAIR, 2003).

For military ground machinery, aggregated emission factors (gasoline and diesel) are derived from the road traffic emission simulations (all emission components). For aviation gasoline (civil aviation and military), aggregated emission factors (fuel based) for conventional cars are used (all emission components).

For railways, specific Danish measurements from the Danish State Railways (DSB), see Næraa (2005), are used to calculate the emission factors for NO_X, VOC and PM in today's conditions, and a NMVOC/CH_4 split is made in the present analysis based on own judgment. For 2010 and 2020 DSB provides average emission factors, based on expectations relating to the machinery stock and the engine emission levels in these two years. Emission factor interpolations are made for the years in between, and for the years after 2020 the emission factors for 2020 are used.

For agriculture, forestry, industry, household gardening and inland waterways, the NO_X, VOC and PM emission factors are derived from various European measurement programmes, and factors for future years take into account the existing measurements and the future EU emission limits. For more details please refer to Winther et al. (2007). The NMVOC/CH_4 split is taken from USEPA (2004).

The source for civil and military aviation (jet fuel) and navigation emission factors is the EMEP/CORINAIR guidebook (CORINAIR, 2003).

For national sea transport, fisheries and international sea transport the NO_X emission factors come from MAN B&W (2006) and the Danish TEMA2000 emission model (Ministry of Transport, 2000). The latter model is also used as a source for VOC and PM. The NMVOC/CH_4 split is taken from CORINAIR (2003), and the PM_{10} and $PM_{2.5}$ ratios of total PM (TSP) come from MAN B&W (2006).

Emission factors are given in CollectER and CRF formats in Annex 4.2 for the years 2006-2030.

4.2.4 Calculation method

Air traffic

For aviation the estimates are made separately for landing and take-off (LTOs < 3000 ft) and cruise (> 3000 ft). The calculations furthermore distinguish between national and international flights. For more details regarding the calculation procedure please refer to Winther (2001a, 2001b and 2007).

Non-road working machinery and recreational craft

Fuel use and emissions are calculated as the product of the number of engines, annual working hours, average rated engine size, load factors, and fuel use/emission factors. For diesel and gasoline engines, the deterioration effects (due to engine ageing) are included in the emission calculation equation by using deterioration factors according to engine type, size, age, lifetime, and emission level. For diesel engines before Stage IIIB and IV, transient operational effects are also taken into consideration by using average transient factors. For more details regarding the calculation procedure please refer to Winther (2007).

National sea transport

For Danish ferries fuel use and emissions are calculated as the product of the number of round trips, sailing time per round trip, engine size, load factor, and fuel use/emission factors. The fuel use from ferries is estimated using a baseline 1996 figure and the relative difference in annual round trips as given in the activity data.

The difference between the DEA statistical fuel sales and the sum of estimated fuel use in local and regional ferries gives the amount of fuel allocated to the sub-sector other national sea. For years when this fuel amount becomes smaller than zero, no fuel is allocated to other national sea, and the ferry results are adjusted in order to obtain a fuel balance, as prescribed by convention rules.

Please refer to Winther (2007) for more details regarding the calculations for national sea transport.

Other sectors

For fishing vessels, military and railways, the emissions are estimated with the simple method using fuel-related emission factors and fuel use from the DEA.

4.3 Fuel use and emission results (SO_2, NO_X, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$)

An overview of the fuel use and emission results for all mobile sources in Denmark is given in Table 4.8. The ’2010’ and ’2015’ results are the average figures for the years 2008-2012 and 2013-2017, respectively.

Table 4.8 Summary table of fuel use and emissions for mobile sources in Denmark

Component	Category	NFR code	1990	2000	2005	2010	2015	2020	2025	2030
Energy	Industry	(1A2f)	12	12	12	12	12	12	12	12
	Civil Aviation	(1A3a)	3	2	2	2	2	2	2	3
	Road	(1A3b)	126	152	166	176	181	186	191	195
	Railways	(1A3c)	4	3	3	3	3	3	3	3
	Navigation	(1A3d)	7	6	6	6	6	6	6	6
	Residential	(1A4b)	2	2	4	4	4	4	4	4
	Ag./for./fish.	(1A4c)	28	23	22	21	21	21	21	21
	Military	(1A5)	2	2	2	2	2	2	2	2
	Navigation int.	(1A3d)	40	56	41	41	41	41	41	41
	Civil Aviation int.	(1A3a)	24	33	31	34	37	40	43	46
SO_2	Industry	(1A2f)	952	253	5	5	5	5	5	5
	Civil Aviation	(1A3a)	77	49	41	44	48	52	56	59
	Road	(1A3b)	5766	351	77	82	84	86	88	90
	Railways	(1A3c)	376	7	6	6	6	6	6	6
	Navigation	(1A3d)	5534	1712	2168	1360	1360	1360	1360	1360
	Residential	(1A4b)	4	5	2	2	2	2	2	2
	Ag./for./fish.	(1A4c)	2922	1108	753	380	379	379	379	379
	Military	(1A5)	48	27	2	2	2	2	2	2
	Navigation int.	(1A3d)	54300	65168	32112	16056	16056	16056	16056	16056
	Civil Aviation int.	(1A3a)	554	750	720	779	848	922	984	1050
NO_X	Industry	(1A2f)	11081	12096	10277	7733	6218	4845	4156	4077
	Civil Aviation	(1A3a)	1123	723	495	537	583	633	676	721
	Road	(1A3b)	102091	72515	56810	38133	24430	17279	14276	13505
	Railways	(1A3c)	4913	3727	3241	1216	653	90	90	90
	Navigation	(1A3d)	9326	7518	8500	8679	8761	8722	8680	8374
	Residential	(1A4b)	123	194	327	367	377	377	377	377
	Ag./for./fish.	(1A4c)	26548	24482	22162	19120	16437	14372	13146	12216
	Military	(1A5)	480	497	573	446	353	301	277	270
	Navigation int.	(1A3d)	84417	117148	72995	76174	78522	79297	78832	77895
	Civil Aviation int.	(1A3a)	7016	9446	9612	10406	11322	12317	13139	14015
NMVOC	Industry	(1A2f)	2266	1926	1586	1124	922	773	734	719
	Civil Aviation	(1A3a)	186	156	40	43	47	51	54	58
	Road	(1A3b)	79517	39042	28305	18408	12809	10206	9131	8527
	Railways	(1A3c)	321	253	205	79	41	4	4	4
	Navigation	(1A3d)	1848	1745	1345	839	646	639	641	644
	Residential	(1A4b)	4560	5209	8727	6976	5845	5721	5721	5721
	Ag./for./fish.	(1A4c)	6324	3474	2498	1889	1496	1354	1296	1229
	Military	(1A5)	56	64	66	53	45	41	39	39
	Navigation int.	(1A3d)	2259	3134	2378	2468	2549	2615	2660	2674
	Civil Aviation int.	(1A3a)	331	407	403	436	475	516	551	588
NH_3	Industry	(1A2f)	2	2	2	2	2	2	2	2
	Civil Aviation	(1A3a)	0	0	0	0	0	0	0	0
	Road	(1A3b)	70	2200	2698	3144	3236	3281	3351	3421
	Railways	(1A3c)	1	1	1	1	1	1	1	1
	Navigation	(1A3d)	0	0	0	0	0	0	0	0
	Residential	(1A4b)	0	0	0	0	0	0	0	0
	Ag./for./fish.	(1A4c)	3	3	3	3	3	3	3	3
	Military	(1A5)	0	0	0	0	0	0	0	0
	Navigation int.	(1A3d)	0	0	0	0	0	0	0	0
	Civil Aviation int.	(1A3a)	0	0	0	0	0	0	0	0
TSP	Industry	(1A2f)	1577	1135	977	643	471	315	273	257
	Civil Aviation	(1A3a)	5	3	2	2	2	3	3	3
	Road	(1A3b)	5702	3933	2963	1822	1048	677	473	397

Continued Component	Category	NFR code	1990	2000	2005	2010	2015	2020	2025	2030
	Road non exhaust	(1A3b)	1882	2258	2484	2643	2722	2804	2874	2933
	Railways	(1A3c)	202	141	108	16	8	0	0	0
	Navigation	(1A3d)	742	511	230	167	149	143	143	143
	Residential	(1A4b)	39	47	87	89	90	90	90	90
	Ag./for./fish.	(1A4c)	2910	1689	988	678	399	214	152	104
	Military	(1A5)	13	21	35	21	11	7	4	3
	Navigation int.	(1A3d)	6213	7614	1103	656	656	656	656	656
	Civil Aviation int.	(1A3a)	28	38	36	39	43	47	50	53
PM_{10}	Industry	(1A2f)	1577	1135	977	643	471	315	273	257
	Civil Aviation	(1A3a)	5	3	2	2	2	3	3	3
	Road	(1A3b)	5702	3933	2963	1822	1048	677	473	397
	Road non exhaust	(1A3b)	1228	1460	1607	1708	1759	1812	1856	1893
	Railways	(1A3c)	202	141	108	16	8	0	0	0
	Navigation	(1A3d)	711	493	229	167	149	142	142	142
	Residential	(1A4b)	39	47	87	89	90	90	90	90
	Ag./for./fish.	(1A4c)	2887	1671	987	678	399	214	151	104
	Military	(1A5)	13	21	35	21	11	7	4	3
	Navigation int.	(1A3d)	5903	7233	1092	649	649	649	649	649
	Civil Aviation int.	(1A3a)	28	38	36	39	43	47	50	53
$PM_{2.5}$	Industry	(1A2f)	1577	1135	977	643	471	315	273	257
	Civil Aviation	(1A3a)	5	3	2	2	2	3	3	3
	Road	(1A3b)	5702	3933	2963	1822	1048	677	473	397
	Road non exhaust	(1A3b)	662	792	873	928	956	985	1009	1029
	Railways	(1A3c)	202	141	108	16	8	0	0	0
	Navigation	(1A3d)	682	476	228	166	148	142	142	142
	Residential	(1A4b)	39	47	87	89	90	90	90	90
	Ag./for./fish.	(1A4c)	2865	1654	987	678	398	214	151	104
	Military	(1A5)	13	21	35	21	11	7	4	3
	Navigation int.	(1A3d)	5607	6871	1086	646	646	646	646	646
	Civil Aviation int.	(1A3a)	28	38	36	39	43	47	50	53

4.3.1 Road transport

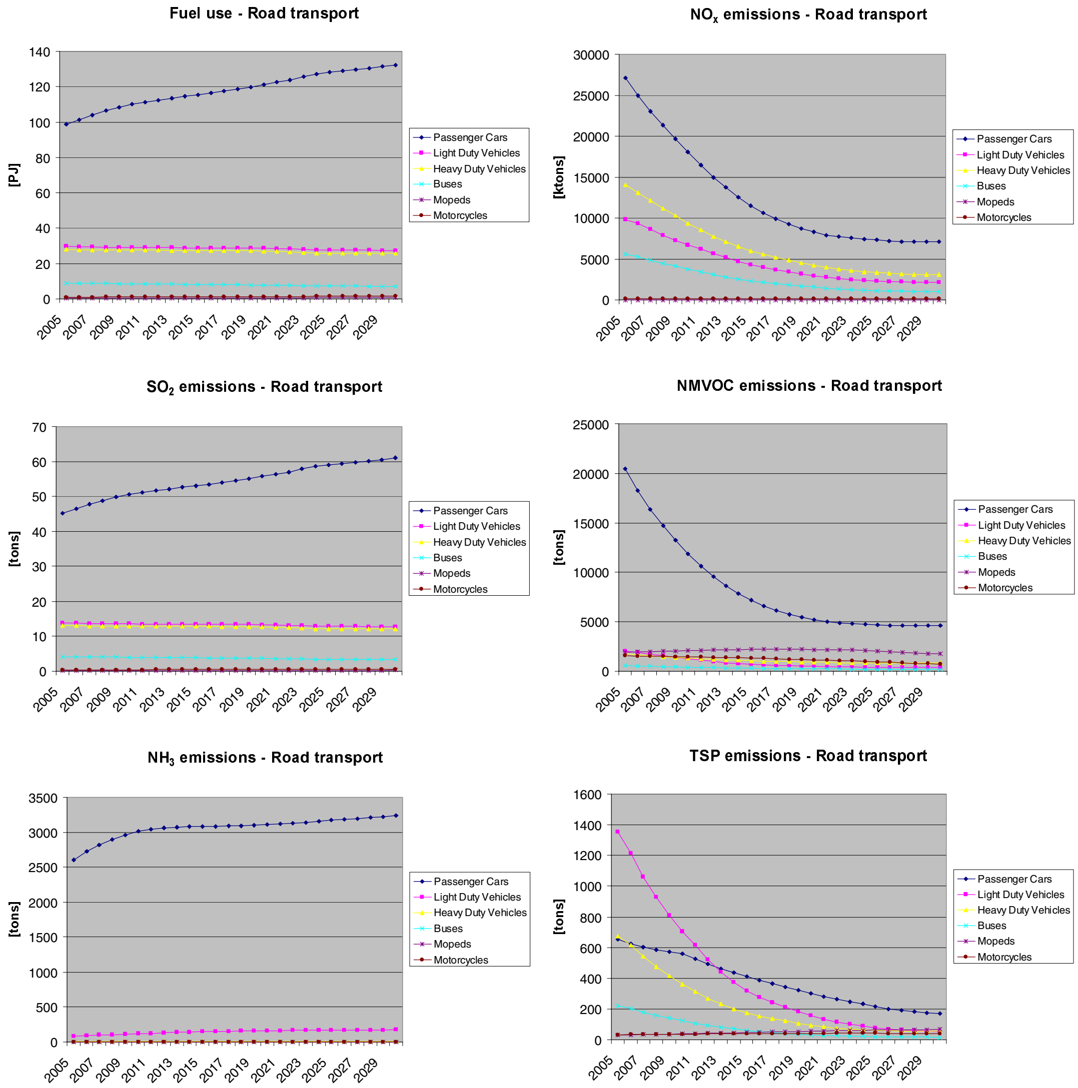

Figure 4.3 Fuel use, NO_X, SO_2, NMVOC, NH_3 and TSP emissions from 2005-2030 for road traffic

Total fuel use for road traffic increases by 17 % from 2005 to 2030. Passenger cars have the largest fuel use share, followed by heavy duty vehicles, light duty vehicles, buses and two-wheelers in decreasing order. Heavy duty vehicles and buses have almost similar fuel use totals, and the fuel use levels are considerably higher than those noted for busesand particularly two-wheelers. The SO_2 emission is dependent on the fuel sulphur content, which is constant for road transport gasoline and diesel. Hence the SO_2 emission trends follow the development in fuel use.

The majority of the NMVOC and NH_3 emission from road transport comes from gasoline passenger cars (Figure 4.3). The NMVOC emission decrease of 70 % from 2005 to 2030 is explained by the introduction of gradually more efficient catalytic converters for gasoline cars. The use of catalysts is also the main reason for the total NH_3 emission increase of 27 % over the same period. The NH_3 emission trend becomes very similar to the fuel use development when the phase-out rate of conventional gasoline cars reaches zero.

The NO_X emission for road transport declines by 76 % from 2005 to 2030, and for all vehicle categories significant emission reductions have been achieved due to the gradual strengthening of the EU emission standards over the course of the forecast period. As in the case of NMVOC, passenger cars are also the largest single source of NO_X; however, the emission contribution for heavy vehicles is only a little less than for passenger cars, when the emissions from trucks and buses are taken as a sum.

In terms of TSP, the total emission is expected to decline by 87 % from 2005 to 2030, and emission reductions are calculated for all vehicle types except for two-wheelers. In the beginning of the forecast period, light duty vehicles are the most dominant source of TSP emissions, but from 2013 passenger cars adopt this position. This is due to the increase in later years in the sale of new diesel passenger cars, which tends to mitigate the emission effect of the penetration of new technologies.

No TSP emission improvements are incorporated in the forecast model for two-wheelers and, due to this, by the end of the forecast period, mopeds are estimated to hold the second largest share of TSP emissions, and for motorcycles the emission share becomes larger than the emission share for buses.

4.3.2 Other mobile sources

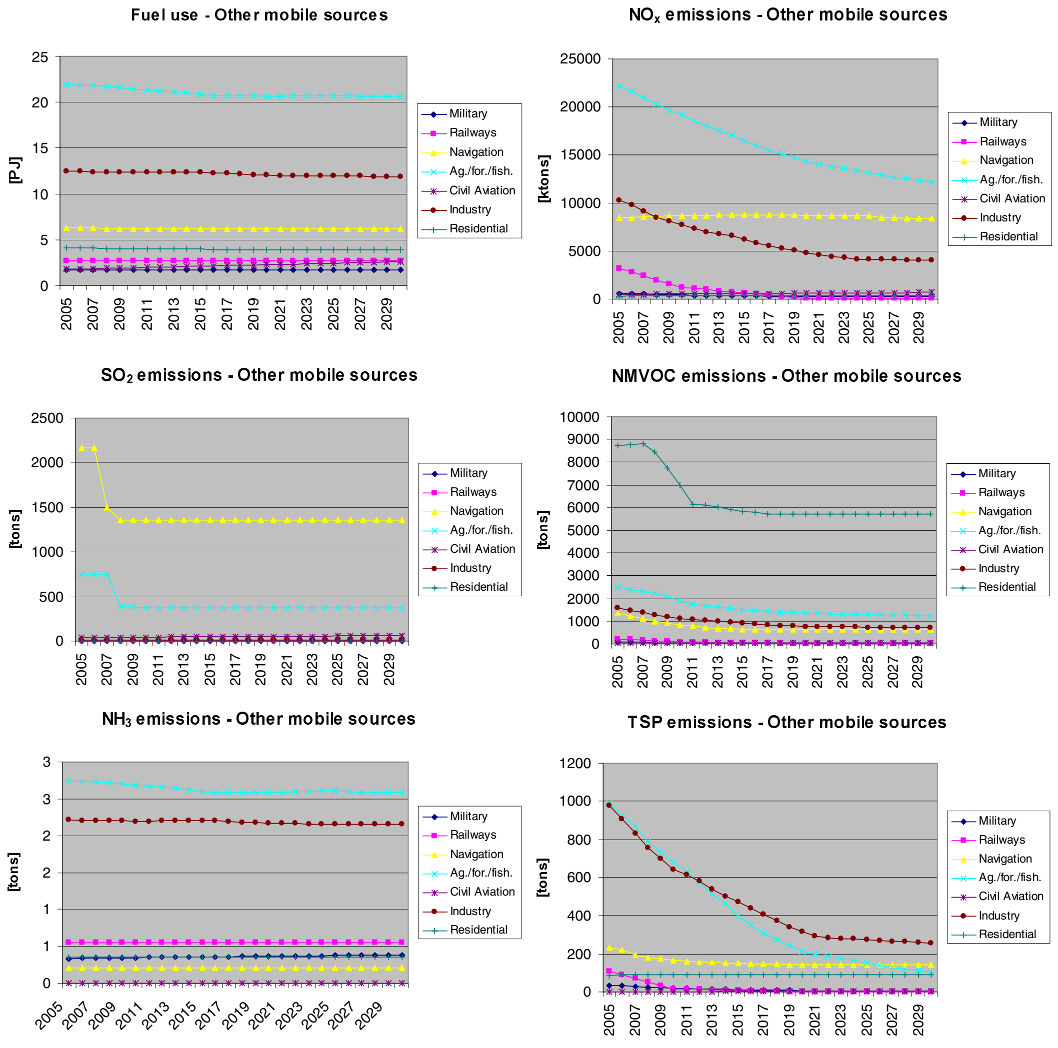

Figure 4.4 Fuel use, NO_X, SO_2, NMVOC, NH_3 and TSP emissions from 2005-2030 for other mobile sources

For other mobile sources fuel use for agriculture/forestry/fisheries (1A4c) decreases in the first part of the forecast period. The emission reduction is due to a shift towards a smaller number of agricultural tractors and harvesters with larger engines. For air traffic, the DEA energy projections assume a similar growth rate for domestic and international flights corresponding to a fuel use increase of 35 % from 2005 to 2030. The marginal fuel use decreases for industry (1A2f), residential (1A4b) and navigation (1A3d) are due to a gradual phase-out of old and less fuel efficient technologies.

The SO_2 emissions for other mobile sources are insignificant except for sea-going vessels. For navigation (1A3d) and agriculture/forestry-/fisheries (1A4c), the emission effect of the Baltic and North Sea SO_x emission control areas (SECAs) becomes visible from 2007, and from 2008 the sulphur content in marine gas oil is reduced by 50 %. For other mobile sources the NH_3 emissions are very small. The most important emission source is Agriculture/forestry/fisheries (1A4c), followed by Industry (1A2f).

By far the most of the NMVOC emission comes from gasoline gardening machinery (residential, 1A4b), whereas for railways (1A3c), domestic air traffic and military only small emission contributions are noted. The NMVOC emission reductions for residential (1A4b) and navigation (1A3d) are due to the introduction of the cleaner gasoline stage II emission technology (residential, 1A4b), and the gradual shift from 2-stroke to 4-stroke engines (navigation, 1A3d). For agriculture/forestry/-fisheries (1A4c) and industry (1A2f), the gradually stricter emission standards for diesel engines cause the NMVOC emission to decrease during the forecast period.

For TSP, agriculture/forestry/fisheries (1A4c) and industry (1A2f) are the major emission sources for much of the forecast period, and the emission contributions from these two sources remain similar until the mid 2010s. After this point the emissions from agriculture/forestry/-fisheries (1A4c) decrease more rapidly than the emissions from industry, mainly due to the decline in the number of agricultural tractors and harvesters, though these with larger engine size. The TSP emission from large ships is dependent on the fuel sulphur content of marine fuels, and the reductions in sulphur content achieved only bring moderate TSP emission reductions. As a result, by the end of the forecast period navigation becomes the second largest TSP emission source.

For NO_X, this shift in relative emission importance between industry (1A2f) and navigation (1A3d) takes place already at the beginning of the forecast period, since for navigation (1A3d) no strengthening in emission standards is in place during the forecast period. In all years, agriculture/forestry/fisheries (1A4c) is the largest source of NO_X emissions, and for this category, as well as for industry (1A2f) and railways (1A3c), substantial emission improvements are achieved due to the penetration of cleaner engine technologies, in compliance with future emission standards.

4.4 Model structure for NERI transport models

More detailed emission models for transport comprising road transport, air traffic, non road machinery and sea transport have been developed by NERI. The emission models are organised in databases. They comprise input data tables for fleet and operational data, and fuel sale figures; and output fuel use and emission results are obtained through linked database queries. A thorough documentation of the database input data, and data manipulation queries will be given in a NERI report in 2007, along with flow-chart diagrams.

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5 Agriculture

The projected emission from the agricultural sector includes ammonia (NH_3) and particulates (PM) given in PM_{10}, $M_{2.5}$ and TSP. Approx. 97 % of the ammonia emission is related to the agricultural sector, primarily animal husbandry, but includes emissions from use of fertiliser as well as sludge applied on fields. The remaining 3 % stems from industrial processes and the transport sector. In 2004 agricultural activities contributed with approx. 30 % of the total PM_{10} emission and thereby represent the second largest source for the PM_{10} emission.

The projection has to be considered as an update of the 2002 ammonia emission projection (Illerup et al. 2002). The projected developments have been discussed with contacts from the Danish Institute of Agricultural Science, Danish Agricultural Advisory Service, Danish Research Institute of Food Economics, National Committee for Pig Production and producers of stable and manure handling equipment.

It has to be pointed out that the historic ammonia emission in this report is not directly comparable with that in the Danish annual emission inventory. In the directive on national emission ceilings, the emission from crops and ammonia-treated straw is not taken into account and these emission sources are therefore not included in this projection either.

5.1 Assumptions

The projection includes all implemented and planned measures such as the Action Plan for the Aquatic Environment III (VMPIII), reform of the European Common Agricultural Policy Reform (CAP) and a newly launched law on animal husbandry entering into force by 1 January, 2007 (Law No. 1572, 20 December 2006). Furthermore, expected technological developments are taken into account - ammonia-reducing technologies in stables and investment in biogas plants. Stricter environmental requirements, especially in relation to expansion of livestock farming, will result in the implementation of various technical measures to reduce the ammonia emission. However, a high degree of uncertainty is embodied in the projection, as it is difficult to estimate which technologies will be used, and to what extent and where.

Assessment of technology implementation for the near future is based on expectations from the main producers and importers. In the longer term expectations based on the background material for new legislation in the area (http://www.skovognatur.dk/Nyheder/2006/Rapporter_husdyrlov.htm) will be used to estimate possible investments in buildings and technology. For example, it is estimated that farmers with pigs not housed according to Best Available Technique (BAT) will have to invest in ammonia-reducing technologies, and 30 % of these will select slurry acidification as a measure with the remaining 70 % choosing to invest in air-cleaning technologies. For dairy cows the most important investment in connection with new building is likely to be flooring with drainage.

Biogasification of slurry brings about a reduction in the ammonia emission from field application of slurry. Subsidies for building new biogas plants are restricted to a total energy production of 8 PJ according to the Danish action plan on energy. This represents twice the current actual production level. However, it may prove difficult to find suitable locations and financial investors. Hence, only a 30 % increase is assumed in the projection to 2010 and no further increase in gasification is projected thereafter.

The main part - nearly 80 % - of the ammonia emission from the agricultural sector relates to livestock production. The most important assumption in relation to the livestock production is briefly mentioned below.

It is assumed that average livestock feed efficiency in 2015 corresponds to the present-day level exhibited by 25 % of the best farms, both dairy and pig. From 2015 to 2025, a slight increase in feed efficiency is incorporated in the projection.

For dairy cows, an increase in milk yield of 180 kg milk per cow per year from 2003-2015 is expected. From 2015-2025 a lower growth rate of 100 kg milk per cow per year is assumed. The milk quota is expected to remain unaltered until 2006, at which point an increase of 1.5 % in the milk quota is expected. From 2006 to 2025 milk production is expected to remain at the same level.

N-excretion from dairy cattle is expected to increase from 132.8 kg N per cow in 2004 to 139.3 kg N per cow in 2015 and 150.1 kg N in 2025, due to an increased milk yield and a slightly increased feed efficiency (Aaes 2005).

Due to the recent constraints within Danish pig production the number of sows has been constant at 1.15 million sows since 2002. No further increase in the number of sows in Denmark is expected in the basic scenario, but due to an increased productivity of 0.3 piglets per sow per year the number of pigs produced will continue to expand. An increase in the export of piglets is expected until 2010 with a concomitant reduction in the number of fatteners produced in Denmark in the short term and a reduction in the associated ammonia emission. In 2005 a production level of 24.0 million pigs is estimated. In 2025 estimated production is 28.8 million pigs.

N-excretion from slaughter pigs is assumed to be reduced from 3.17 kg N per produced pig in 2004 to 2.70 kg N in 2015 and 2.60 in 2025 (Poulsen et al. 2004, Tybirk 2005).

93 % of pig slurry and 79 % of cattle slurry is currently applied during spring. No major seasonal changes are expected. 15 % of the pig slurry and 59 % of cattle slurry was injected in the soil in 2004 (Danish Agriculture, 2004). The low percentage figure for pig farms is due to a high share of winter green crops, where application takes place from hose trailing in growing crops. In 2015 50 % of pig slurry and 75 % of cattle

slurry is expected to be injected (T. Birkmose, 2005). From 2015 and onwards these percentages are kept constant in the projection.

Agricultural area is assumed to decrease by approximately 230,000 hectare from 2003 to 2025 – corresponding to 8 %. This is the result of 30,000 hectares of afforestation and establishment of wetlands as planned in VMPIII.

The ammonia emission is projected to 2025 and from 2025 to 2030 the emission is kept at the same level.

5.2 Methodology

The methodology is basically the same as that used in the Danish emission inventory (Mikkelsen et al. 2005), but it has been necessary to take into account some revisions made to calculations of the ammonia emission.

The calculation of the projected PM emission is based on the EMEP/CORINAIR Emission Inventory Guidebook – 2006 (EMEP 2006). The projected PM emission includes the emission from animal stables. Emission factors provided in the guidebook are used and these refer mainly to measurements undertaken in north-western European stables (Takai et al. 1998), including Danish stables. The PM emission from plant production is not taken into account due to considerable uncertainties present as well as lack of data. A first draft of guidelines is available but has not yet been reviewed and approved.

Due to new research carried out in Denmark, e.g. in connection with the VMPIII programme of research, an ongoing revision of the ammonia emission inventory system and emission factors is currently underway. This includes conversion from a total N-based system to a TAN-based system (Total Ammoniacal Nitrogen), the part of nitrogen that is volatile (N.J. Hutchings, DIAS, personal comm.). Another important revision is an updated emission factor relating to the application of manure (Sommer and Hansen, 2004). Although the revision is not yet complete, major effects on the emission estimates have been included in this projection in order to give a more comprehensive picture of the future ammonia emission. The revised model is a prototype which has to be validated further before it can be used in the official Danish ammonia inventory.

A more detailed description and more background information regarding the ammonia projection are given in Gyldenkærne and Mikkelsen (2007 – in press).

5.2.1 Model description

The emissions from the agricultural sector are calculated in a comprehensive agricultural model-based system called DIEMA (Danish Integrated Emission Model for Agriculture). This model-based system includes very detailed data and information covering emissions of ammonia, particulate matter and greenhouse gases from the agricultural sector. Figure 5.1 shows the unit which relates to the ammonia emission.

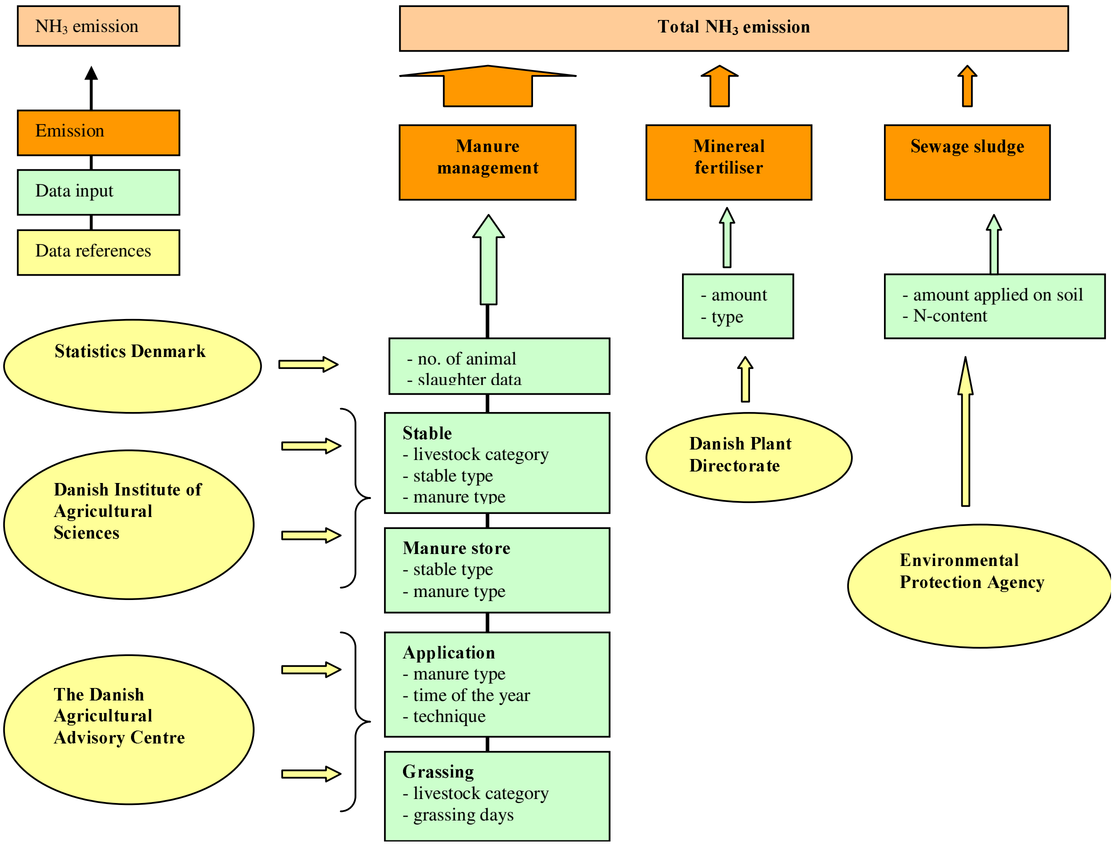

Figure 5.1 DIEMA – NH_3 unit (Danish Integrated Emission Model for Agriculture)

DIEMA operates with 30 different livestock categories according to livestock type, weight class and age. These categories are subdivided in to different stable type and manure type, which result in about 100 different combinations of livestock subcategories and stable types. For each of these combinations the emission is calculated and then aggregated to the main animal categories conforming with the NFR format (Nomenclature For Reporting), which is requested in the EMEP/CORINAIR guidelines.

The Danish Institute of Agricultural Sciences (DIAS) delivers Danish standards relating to feed consumption, manure type in different stable types, nitrogen content in manure, etc. The Danish normative system of standards for animal excretion is based on data from the Danish Agricultural Advisory Centre (DAAC). DAAC is the central office for all Danish agricultural advisory services. DAAC performs a great deal of research as well as collecting efficacy reports from the Danish farmers for dairy production, meat production, pig production, etc. to optimise productivity in Danish agriculture.

5.3 PM emission results

The PM emission from agriculture comprises particles in the form of dust from cattle, pig, poultry and horse stables. Approx. 55 % of the emission from the agricultural sector stems from poultry, 40 % from pigs and the remaining 5 % from cattle and horses. The PM emission is estimated from 2000. Until 2004 the emission of PM_{10} has decreased by 7% due to a fall in the production of broilers. No legislation has been introduced to reduce the PM emission.

The PM emission is expected to increase from 2005 to 2030. The PM_{10} emission is assumed to increase from 9,500 Mg in 2005 to 10,400 Mg in 2030 (+ 9 %) primarily due to the expected growth in pig production.

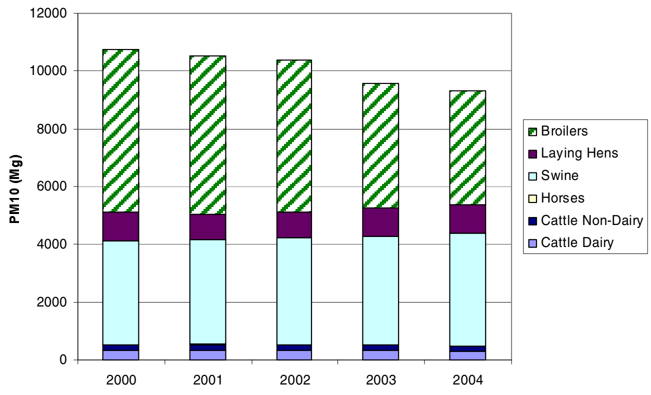

Figure 5.2a PM10 emission 2000 – 2004

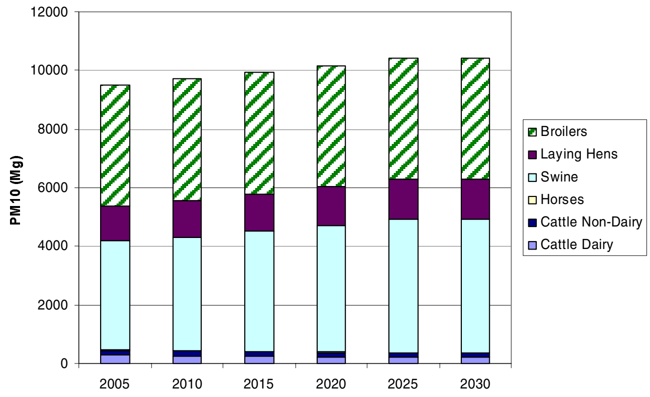

Figure 5.2b Projected PM10 emission 2005 – 2030

5.4 NH_3 emission results

5.4.1 Historic

The Danish emission from the agricultural sector, excluding the emission from growing crops and ammonia-treated straw, has been reduced from 107,000 tonnes NH_3/year to 80,200 tonnes NH_3/year from 1990 to 2004, corresponding to a reduction of 25 % (Figure 3). This development is due to active national environmental policies over the last twenty years, including the effect of the various Danish action plans for the aquatic environment and the Action Plan for Reducing the Ammonia Emission, as well as improved management practices, especially in pig production. A series of environmental policy measures to prevent loss of nitrogen from the agriculture to the aquatic environment has been introduced. The measures include improved utilisation of nitrogen in husbandry manure, stricter requirements with regard to storing and application of husbandry manure, increased area with winter green fields to 'catch' nitrogen, as well as ceilings with regard to livestock per hectare and maximum nitrogen application rates to agricultural crops.

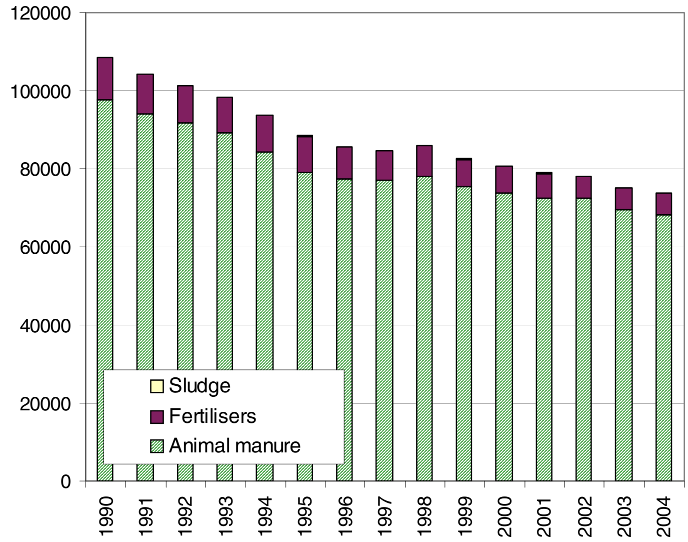

Figure 5.3 Ammonia emissions from the agricultural sector 1990 - 2004

5.4.2 Projected

New knowledge on emission factors for animal manure obtained in recent years has confirmed the need for revision of the emission estimates. In Figure 5.4 the ammonia emission from animal husbandry from 1985 to 2004 as currently reported in the emissions inventory is shown as well as the estimated ammonia emission to 2030 using the revised model. It is estimated that the currently used model overestimates the ammonia emission by approx. 6-7,000 tonnes NH_3/year, which corresponds to approximately 10 % of the total ammonia emission under the NEC Directive.

The lower ammonia emission in the revised model in relation to that currently used in the emissions inventory is due mainly to changes in the emission factors for manure application. Based on new investigations, an emission factor for each month during the season has been estimated (Sommer and Hansen, 2004). The emission from February to April appears to remain stable, but decreases considerably in May and June due to crop growth. Especially the emission estimates for manure application to growing crops with trailing hoses in spring have been overestimated in the currently used model. This has a relatively great effect on the total emission in 2004 because the majority of slurry is applied in spring – e.g. for pig slurry, 93 %.

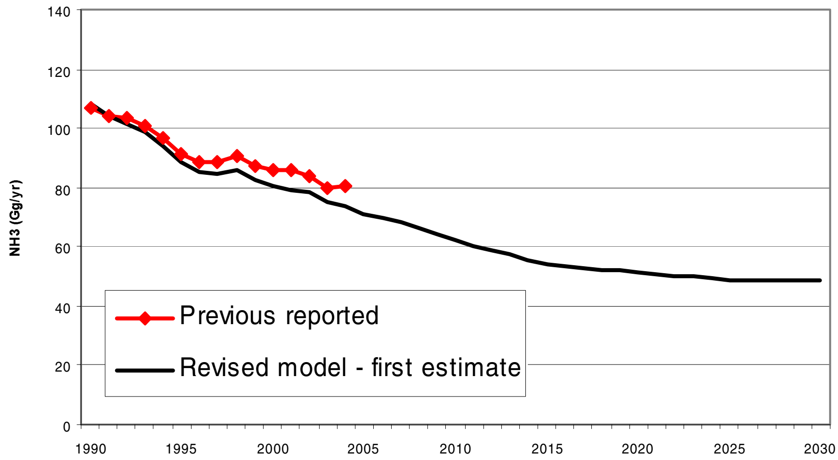

Figure 5.4 Ammonia emissions from the agricultural sector 1990 – 2004 and the expected emission 2005 - 2030

Livestock farming is moving towards larger operating units, which are expected to have higher productivity compared with today's average. This structural development, as well as the stronger environmental requirements, will promote better conditions for investment in new buildings and ammonia-reducing technologies. This will lead to a further increase in yield per livestock unit produced, better utilisation of feed, improved handling and utilisation of manure – measures which lead to a reduction in ammonia emissions. There is no doubt that the emission of ammonia from the agricultural sector will be reduced over time, despite expected growth in pig production, but it is more difficult to predict the rate at which this will occur and the limit for how much the emission can be reduced. The EU agricultural policy also plays a deciding role as do, of course, the conditions for export and import of agricultural products.

Based on the assumptions mentioned above, the revised model estimates an ammonia emission from the agricultural sector of 70,900 tonnes NH_3/year in 2005. A further reduction is expected to 62,100 NH_3/year in 2010 and 48,800 NH_3/year in 2030, which represents a reduction of 31 % since 2005.

The downward trend in the ammonia emission is largely due to investment in new ammonia-reducing technologies in stables and manure storage. Other important causal factors are manure application methods with increased injection, improved feed utilisation particularly for pigs, and a further reduction in the number of cattle.

Table 5.1 Expected ammonia emission 2005 to 2030 calculated with the revised model (tonnes NH_3/year)

	1990	2000	2005	2010	2020	2025	2030
Animal manure	97,860	73,843	65,418	56,789	46,608	44,289	44,289
Fertilisers	10,538	6,791	5,424	5,247	4,704	4,496	4,496
Sludge	71	83	78	69	50	50	50
Agriculture - total	108,469	80,717	70,920	62,105	51,362	48,836	48,836
Industry	541	560	268	268	268	268	268
Transport	74	2,205	2,705	3,150	3,287	3,358	3,428
Under NEC – total	109,084	83,482	73,893	65,523	54,917	52,462	52,523
Relative development	100	77	68	60	50	48	48

The emission from non-agricultural sources – industrial processes and transport – is expected to increase from 3,000 tonnes NH_3 in 2005 to 3,700 tonnes NH_3 in 2030. This is mainly due to increased use of cars with catalytic converters.

Denmark has ratified the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone under the Convention on Long-Range Transboundary Air Pollution (http://www.unece.org/env/lrtap/) and accepted the target to reduce the emission to 69,000 tonnes NH_3 by 2010. The same obligation is contained in the EU Directive on National Emission Ceilings (2001/81/EC) (NEC Directive). This ceiling includes all sources except the emission from crops and ammonia-treated straw. It is expected that Denmark is able to fulfil its reduction commitments for ammonia. The projected total NH_3 emissions are estimated at 65,500 tonnes NH_3 in 2010.

The Clean Air For Europe (CAFE) programme has worked out a policy scenario - the Thematic Strategy Scenario 2020 (Amann et al. 2005) – to outline its strategy for cleaner air in Europe, including revision of the NEC Directive. The Commission's aim for improvement of mortality effects, reduction of excess nitrogen and acid deposition, and reduction of human ozone exposure provided country-specific details on e.g. emission reductions. Analysis of the Thematic Strategic scenario 2020 suggested a Danish ammonia primarily emission ceiling for 2020 to 62,000 tonnes NH_3. The current Danish projected emission in 2020 is estimated at 54,900 tonnes NH_3 and below the result from the Thematic Strategic scenario.

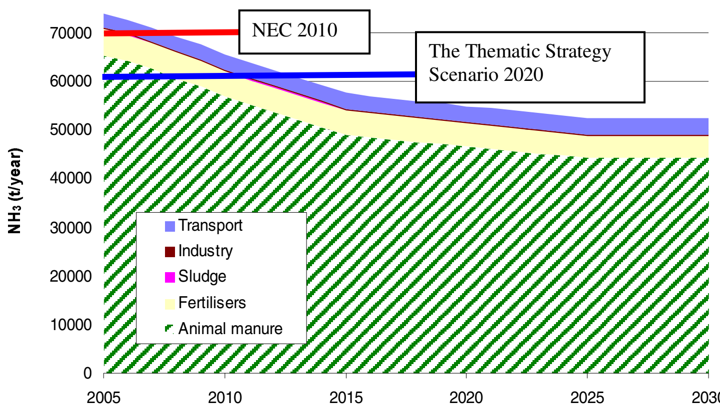

Figure 5.5 Projected ammonia emissions 2005 – 2030 compared to the National Emission Ceiling 2010 and the Thematic Strategy Scenario 2020

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6 Solvents

6.1 Summary of method

Solvent use constitutes non-methane VOC (NMVOC) emissions of approximately 33,000 tonnes in 2006, which is one third of the total NMVOC emissions in Denmark (Illerup et al., 2007). Many different chemicals are categorised as solvents and used in a variety of household products and industrial activities. The Danish NMVOC emission inventory for solvent use in industry and households is based on the detailed model as described in EMEP/CORINAIR (2004), and covers the following key issues:

1. Defining the chemicals to be included
2. Quantifying amounts consumed for each chemical
3. Distributing consumption figures across industry and household activities
4. Assigning emission factors to chemical use

The procedure is outlined in Figure 6.1. The inventory includes chemicals from a gross list of 650 different chemicals and chemical groups (NAI, 2000). Consumption figures for 427 NMVOCs are calculated from production, import and export figures derived from Statistics Denmark and of these, 44 NMVOCs constitute more than 95 % of the total amount consumed. These 44 NMVOCs are included in the solvent emissions inventory. Assignment of the amounts consumed to industrial activities and households is made using SPIN (2007), a database comprising information on chemical consumption in industrial categories and product use categories. Emission factors have been obtained from the literature and personal communication with experts. Given the high complexity and uncertainty of data, continuous refinements have been carried out and reported in the annual reports to the EU and UN (e.g. Illerup et al., 2007). In Table 1 the 31 NMVOCs with highest emissions are shown.

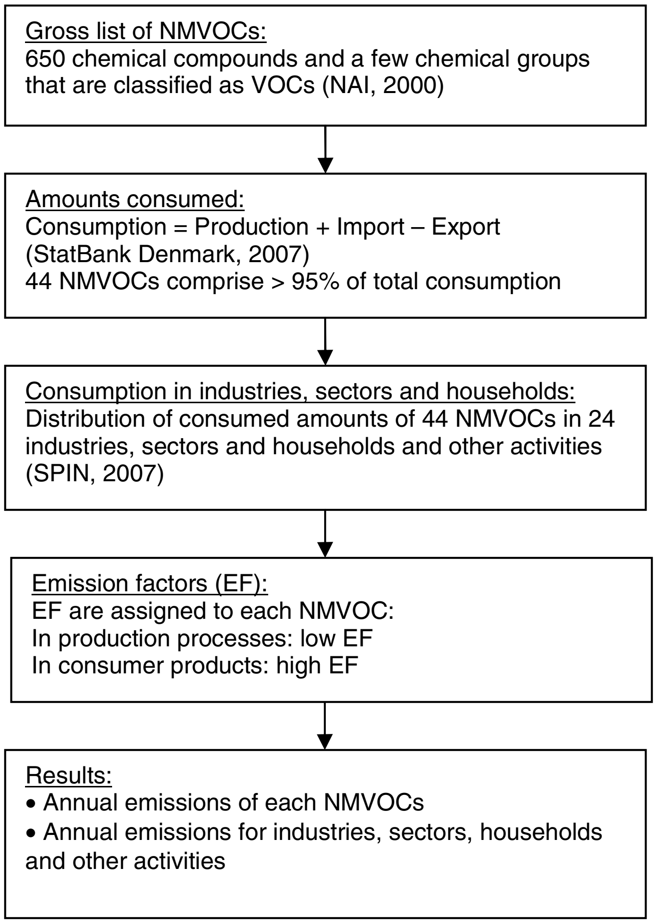

Figure 6.1 Procedure in the Danish NMVOC emission inventory for solvent use in industries and households

Table 6.1 NMVOCs with the highest emissions in the Danish 2006 solvent emission inventory (Illerup et al., 2007 with additional revisions). Consumption figures are from StatBank Denmark (2007) and emission factors are from various sources, e.g. Rypdal (1994).

Chemical	Emissions 2006 (tonnes/year)
methanol	4777
propylalcohol	4167
turpentine (white spirit: stoddard solvent and solvent naphtha)	3940
aminooxygengroups	2865
glycerol	2630
pentane	2331
ethanol	2166
naphthalene	1768
acetone	1297
propane	1000
butane	1000
butanone	676
glycolethers	622
ethylenglycol	610
formaldehyde	503
cyclohexanones	482
propylenglycol	479
1-butanol	240
butanoles	227
xylene	202
toluendiisocyanate	199
phenol	129
methyl methacrylate	74.8
toluene	66.6
acyclic aldehydes	65.1
dioctylphthalate	60.6
acyclic monoamines	51.3
styrene	49.6
tetrachloroethylene	26.1
triethylamine	11.9
diethylenglycol	10.3
diamines	0,018
Total 2005	**32726**

Figure 6.2 shows NMVOC emissions of the UNFCCC source categories Paint application (CRF sector 3A), Degreasing and dry cleaning (CRF sector 3B), Chemical products, manufacture and processing (CRF sector 3C) and Other (CRF sector 3D). Figure 6.3 shows NMVOC emissions from Danish industries, sectors and households.

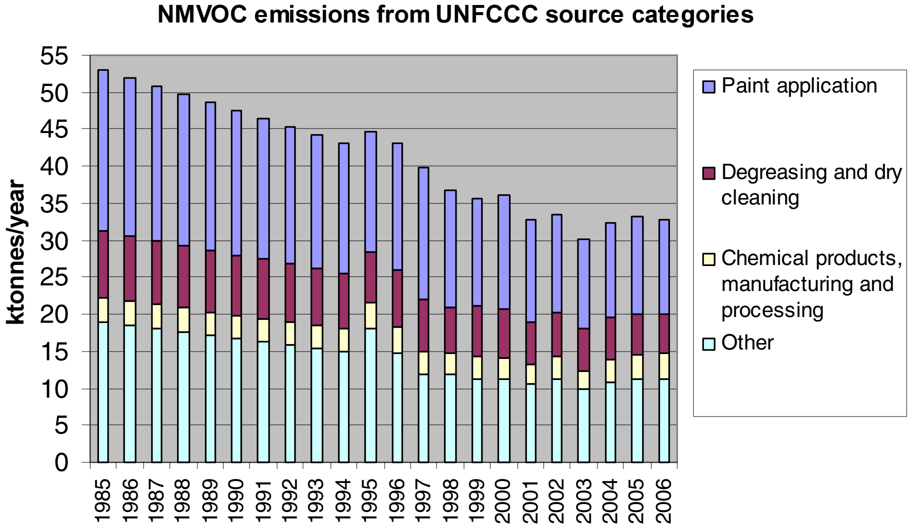

Figure 6.2 Danish NMVOC emissions for UNFCCC source categories. 1995 – 2006: NMVOC consumption figures are from StatBank Denmark (2007), emission factors are from various sources, e.g. Rypdal (1994) and distribution according to source category is based on the SPIN use categories (SPIN, 2007). 1985 – 1994 are linear extrapolations.

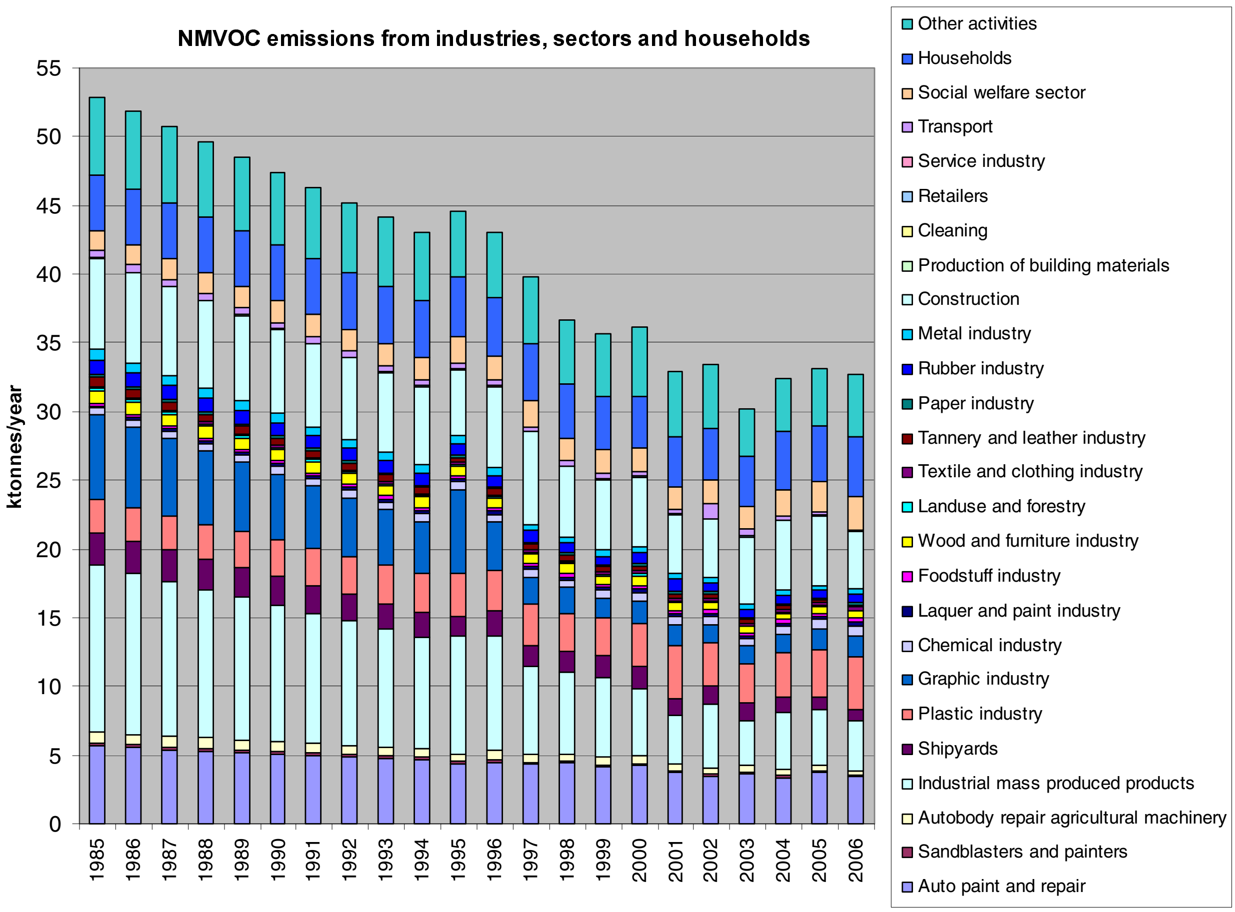

Figure 6.3 Danish NMVOC emissions from industries, sectors and households. 1995 – 2006: NMVOC consumption figures are from StatBank Denmark (2007), emission factors are from various sources, e.g. Rypdal (1994) and distribution on industries, sectors and households are from SPIN industrial categories (SPIN, 2007). 1985 – 1994 are linear extrapolations.

There is a 27 % decrease in total VOC emissions from 1995 to 2006. Of the 26 industries and sectors, nine show an increase. Households, construction, plastic industry, industrial mass-produced products and auto paint and repair and are the largest sources of the Danish VOC emission from solvent use, constituting 13 %, 13 %, 12 %, 11 % and 10 % of the total 2005 VOC emission, respectively. The most abundantly used solvents are methanol, propylalcohol and turpentine, or white spirit defined as a mixture of stoddard solvent and solvent naphtha. Methanol is primarily used as an intermediate (monomer) solvent in thinners, degreasers, etc, and as a disinfecting and conserving agent. Propylalcohol is used as a flux agent in soldering as well as solvent and thinner and as a windscreen washing agent. Turpentine is used as thinner for paints, lacquers and adhesives. Household emissions are dominated by propane and butane, which are used as aerosols in spray cans, primarily in cosmetic products.

Reasonable agreement is found between the calculations in the Danish model and the Regional Air Pollution INformation and Simulation (RAINS) model
(http://www.iiasa.ac.at/web-apps/tap/RainsWeb/RainsServlet1).
RAINS estimates historic emissions of air pollutants for each country in Europe based on information collected in available international emission inventories and on national information. For 2000 and 2005 deviations between the two models were 14 % and 8 %, respectively.

6.2 Emission projections

Emission projections have been made for four industrial sectors: 'Auto paint and repair', 'Plastic industry', 'Graphic industry' and 'Lacquer and paint industry'. Together these sectors account for approximately 28 % of the total NMVOC emission in 2006, and thus provide a suitable indication for overall Danish NMVOC emissions trends.

Production and use of products containing VOCs are regulated by two national directives: Directive no. 350 on the Limitation of Emissions of Volatile Organic Compounds from use of Organic Solvents in Certain Activities, also known as the VOC Directive, and Directive no. 1049 on Marketing and Labelling of Volatile Organic Compounds in Certain Paints and Lacquers and Products for Auto Repair Lacquering, also known as Directive 1049. The directives supplement each other, as the VOC Directive regulates activities with VOC consumption above a certain limit value, and Directive 1049 regulates activities with VOC consumption below the limit value.

Not all activities in the four sectors are regulated by the two directives, e.g. only the small amount of solvents used in surface treatment of plastic products is covered in the plastics industry. Projections on , e.g., solvent use for processing plastic are based on expert judgements on actual or planned emission reducing measures.

6.2.1 Auto paint and repair

Projections are based on fulfilment of the NMVOC limit values in auto paint and lacquer products stated in the VOC Directive and Directive

1049. For this sector the limit values are identical in the two directives and are also attained by means of a reduction program, outlined in the VOC Directive:

$$M = P * R = P * T * F \qquad (3)$$

where M is the target emission to be reached by 31 October 2007, P is the ratio between target emission and reference emission, T is the dry mass of surface coating, lacquers, adhesives and paints used in a year, F is the ratio between NMVOC emission and dry matter (T). R (= T * F) is the reference emission and represents the annual emission on 31 October 2007 that would occur if emission reduction measures had not been implemented.

P is found from the VOC Directive to be 0.4, the reference emission R is found from linear extrapolation of the 1995 – 2006 inventory data to be 3.23 ktonnes/year. It is estimated that a third of the solvent use is in paints and lacquers and the remaining two thirds are therefore not regulated by the directives:

31 October 2007 emission = 3.23 * (0.67 + 0.33 * 0.4) = 2.59 ktonnes/year

Projections to 2010 and 2020 are based on linear extrapolation of 1995 – 2006 emissions, from which the 2007 reductions are subtracted:

2010 emission = 2.90 – 3.23 * 0.33 * (1 – 0.4) = 2.26 ktonnes/year

2020 emission = 1.80 – 3.23 * 0.33 * (1 – 0.4) = 1.16 ktonnes/year

6.2.2 Graphic industry

The graphic industry covers heat-set web offset, magazine photogravure, other photogravure, flexography, serigraphy, lamination and lacquering. The VOC Directive regulates activities with VOC consumption above 20 tonnes/year. Activities with VOC consumption below 20 tonnes/year are, however, not regulated by Directive 1049, as this covers paints and lacquers for buildings only.

Larger industries (consumption of > 20 tonnes/year) use catalytic and thermic combustion of solvents, which reduce the NMVOC emission below the limit values in the VOC Directive. An emission factor of 5 % is estimated for emissions from solvent use in larger industries. Conservative emissions projections are made based on extrapolation of 2006 emissions. It is assumed that NMVOC use is divided equally between smaller (consumption of < 20 tonnes/year) and larger (consumption of > 20 tonnes/year) industries. This yields:

31 October 2007 emission = 2010 emission = 2020 emission =

1.51 * (0.5 * 0.05 + 0.5) = 0.79 ktonnes/year

6.2.3 Lacquer and paint industry

The lacquer and paint industry covers processing of surface coating, lacquers, adhesives and paints, e.g., through mixing of pigments, binders and adhesives with organic solvents and dissolving, dispersing, adjustment of viscosity, toning and tapping of the final products.

Emissions are mainly diffuse and are estimated in the emission inventory to be approximately 1 % of the NMVOC content of the products (Møller, 1995). The emission limit values are 3 % of the NMVOC content for activities with NMVOC consumption between 100 and 1000 tonnes/year, and 5 % of the NMVOC content for activities with NMVOC consumption > 1000 tonnes/year, according to the VOC Directive.

For the NMVOC consumption below 100 tonnes/year, limit values for NMVOC content in water-based and solvent-based paints, lacquers, primers and other surface coatings are stated in Directive 1049 and are to be reached by 2007 and 2010, respectively. These limit values are compared to estimates of NMVOC content in water- and solvent-based products derived from Møller (1995).

Directive 1049 limit values for water-based paints and lacquers (19% of the industry's NMVOC consumption) comply with the actual content, which is also the case for water based wood preservation (2% of NMVOC consumption) and part of the solvent based wood preservation (32% of the NMVOC consumption). For solvent based paints and lacquers (34% of the NMVOC consumption) the limit values are exceeded, which is also the case for part of the solvent based wood preservation (32% of the NMVOC consumption). The solvent content has decreased in paints and lacquers since 1995, which increases the amount of products that fulfil the limit values.

Linear extrapolation of 1995 – 2006 inventory data is used for projecting emissions:

31.10 2007 emission = 0.222 ktonnes/year

2010 emission = 0.226 ktonnes/year

2020 emission = 0.241 ktonnes/year

6.2.4 Plastics industry

The plastics industry covers three main activities; production of expanded polystyrene products (EPS-branch), production of fibreglass-reinforced polyester products (composite-branch) and production of polyurethane products (PUR-branch).

Production of plastic materials does not take place in Denmark, only manufacture and processing of plastic-containing products are relevant. E.g. polystyrene products are manufactured from imported polystyrene pellets. Apart from small amounts of solvent used in surface treatment of plastic products, the plastic industry is not regulated by the VOC Directive or Directive 1049.

A number of emission reducing measures are being implemented at present; a general shift from open to closed processes, replacing solvent-based with water-based cleaning agents, instalment of coal filters and combustion of solvent waste. It is not possible for the industry to predict the effects of these measures; therefore a static and conservative estimate with emissions constant at the 2006 level is made for 2007, 2010 and 2020.

6.3 Summary for solvents

Table 6.2 Summary of projected Danish NMVOC emissions for four selected sectors and total emissions (ktonnes/year)

	Auto paint and repair1)	Graphic industry2)	Lacquer and paint industry3)	Plastic industry4)	Total emissions5)
31.10.2007	2.59	0.79	0.222	3.87	28.8
2010	2.26	0.79	0.226	3.87	25.5
2020	1.16	0.79	0.241	3.87	25.5

1) Regulated by the VOC Directive and Directive 1049

2) Not covered by B1049. Reductions are estimated from catalytic and thermic combustion of solvent in larger plants

3) Linear projection

4) 2006 emissions are assumed for 2007, 2010 and 2020. Static and conservative estimate

5) Other sectors and industries from 2007 to 2010 are based on linear projections of 1995 – 2006 inventory data. Constant 2010 emissions are projected to 2030.

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7 Conclusions

The national emission ceilings for Denmark for 2010 for the four pollutants are listed in Table 7.1 together with historic emissions for 2005 and projected emissions for 2010 and 2020. The SO_2 emission already in 2005 is below the 2010 ceiling and is projected to remain at the same level in 2010 and 2020. The NH_3 emission is projected to decrease from 2005 to 2010 and to be below the ceiling. The emission is projected to further decrease from 2010 to 2020. Both the NOx emission and the NMVOC emission in 2010 are expected to coincide approximately with the ceiling limits.

Table 7.1 Emission ceilings for Denmark in 2010 (1000 tonnes)

Pollutants	SO_2	NO_X	NMVOC	NH_3*
Emissions 2005	20	161	116	74
Emission ceilings 2010	55	127	85	69
Projected emissions 2010	20	136	88	66
Projected emissions 2020	21	115	76	55

* The NH_3 emission ceiling excludes emission from straw treatment and crops

The projected emissions of SO_2, NO_x, NMVOC, NH_3 and particles are discussed below. The category 'other sectors stationary' mentioned is comprised of stationary plants in agriculture/forestry/aquaculture, residential & commercial/institutional sectors, the category 'other sectors mobile' is comprised of machinery in household/gardening & agriculture/forestry/fishing.

7.1 SO_2 emission

The SO_2 emission is shown in Figure 7.2. The total emission is projected to decrease from 2006 to 2010, mainly because of decreasing coal consumption in the energy industry sector. From 2010 to 2030 there is a slight increase in the SO_2 emission caused by increasing fuel consumption in the industrial sector. The historic SO_2 emission decreased significantly due to installation of desulphurisation plant and switching to fuels with lower sulphur content. The resulting decline in the total SO_2 emission from 1990 to 2005 was 89 %.

In 2010 the energy industry sector is expected to account for 43 % of the total SO_2 emission. The industrial sector and other stationary sectors represent the second and third largest sources of the SO_2 emission.

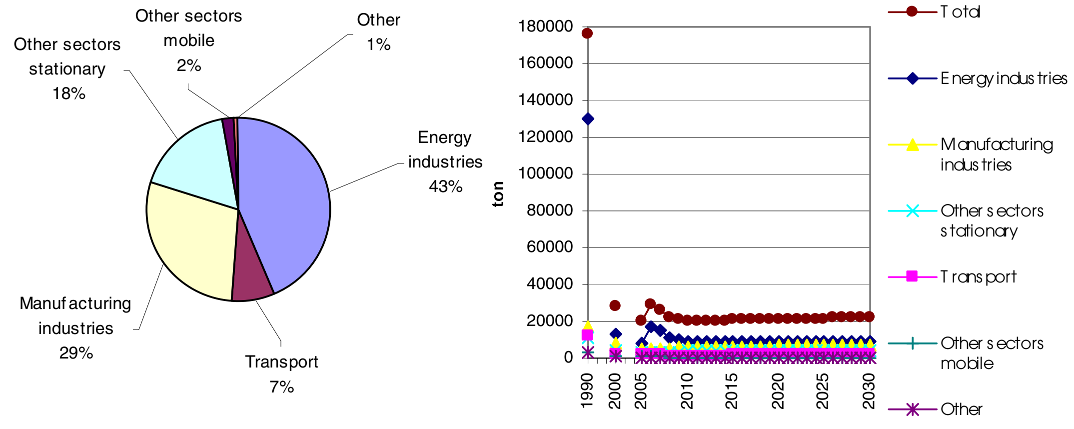

Figure 7.2 SO_2 emission. Distribution by main sectors (2010) and time series for1990, 2000 and 2005 to 2030

7.2 NO_x emission

From Figure 7.1 it can be seen that the NO_X emission decreases over the time series. The sectors responsible for the reduction are the transport sector and mobile sources in other sectors. Since 1990 there has been a significant decline in the NO_X emission from both the transport sector as well as from energy industries, due to the introduction of catalyst cars and $DeNO_X$ facilities in power plants. For the transport sector the decline is projected to continue to 2030 due to introduction of still stricter EU norms, whereas the NO_X emission from energy industries remains stable.

The projected NO_X emission of 136 ktonnes in 2010 is somewhat higher than the emission ceiling of 127 ktonnes. The three largest sources are transport (mainly road transport), energy industries and other mobile sources. The emissions from the transport sector are projected to account for 37 % of the total NO_X emission in 2010.

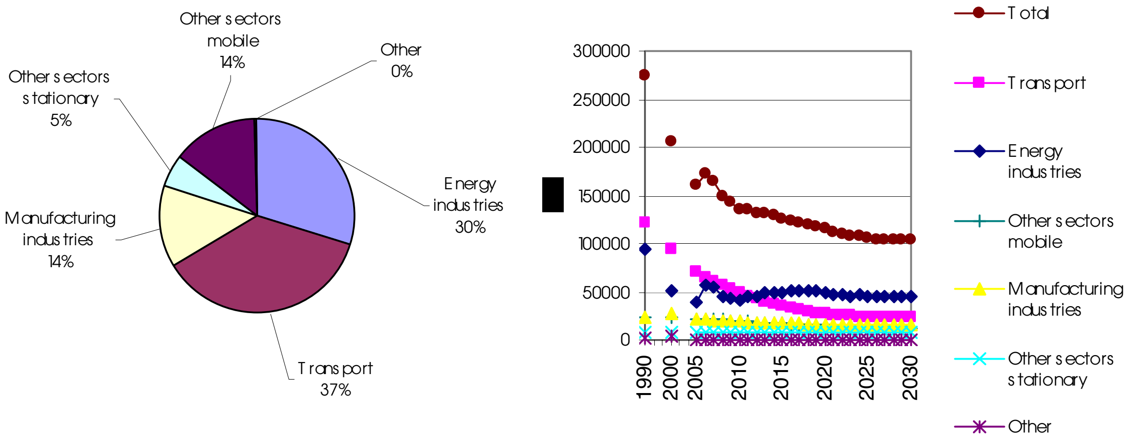

Figure 7.1 NO_X emissions. Distribution by main sectors (2010) and time series for 1990, 2000 and 2005 to 2030

7.3 NMVOC emissions

Figure 7.3 illustrates that the total NMVOC emission is expected to decrease during the course of the time series. The transport sector is responsible for the largest decrease in the emission. Fugitive emissions,

emissions from use of solvents as well as emissions from other sectors also decrease slightly.

The historical decrease since 1990 is due to the introduction of catalyst cars as well as reduced emissions from use of solvents and other product use.

In 2010 solvent and other product use is projected to account for 58 % of the total NMVOC emission. Transport and other stationary sectors are the second and third largest sources of the NMVOC emission. For other sectors it is primarily wood combustion in the residential sector that contributes heavily to the emission. From 2010 to 2030 the emissions decrease further for the transport sector due to implementation of still stricter EU norms.

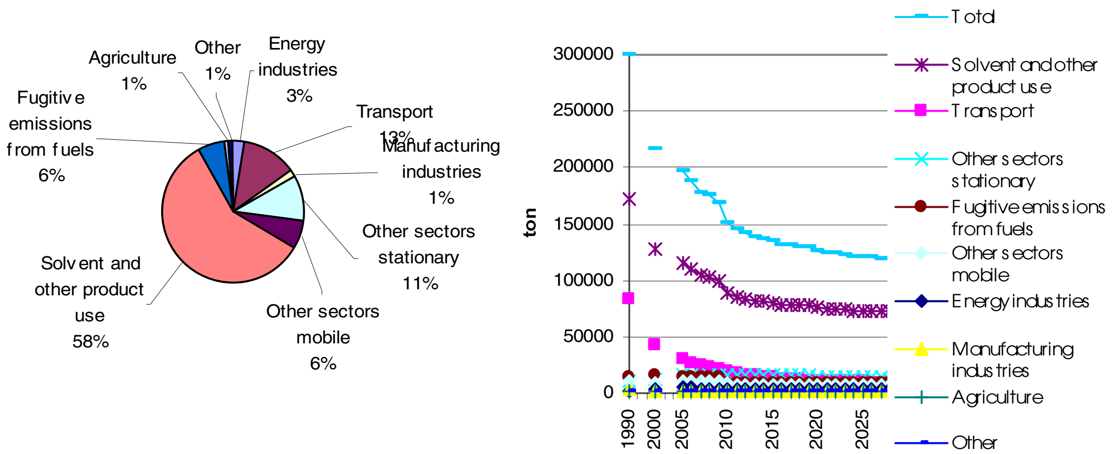

Figure 7.3 NMVOC emissions. Distribution by main sectors (2010) and time series for 1990, 2000 and 2005 to 2030

7.4 NH_3 emission

The NH_3 emission is shown in Figure 7.4 where it is apparent that the NH_3 emission decreases over the time series. The agricultural sector is by far the largest source and is also responsible for the main decrease in the emission. The decrease from 1990 to 2005 is due to higher fodder efficiency and changes in manure handling. The further decrease to 2030 is largely related to investment in new ammonia-reducing technologies in stables and manure storage. Other important causes are changes in manure application methodologies involving increased injection, improved feed utilisation (particularly for pigs) and a further reduction in the number of cattle.

In 2010 the agricultural sector is projected to account for 95 % of the total NH_3 emission. Transport contributes with roughly 5 % of the emission while a small emission comes from mobile sources in other sectors and industrial processes.

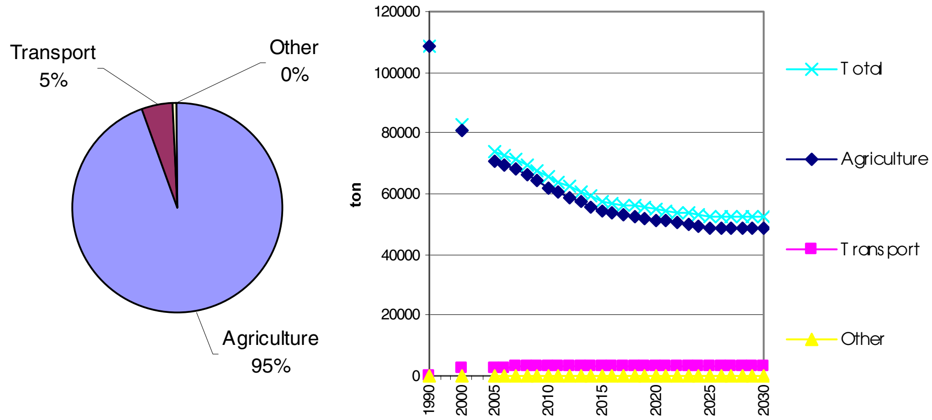

Figure 7.4 NH_3 emissions. Distribution by main sectors (2010) and time series for 1990, 2000 and 2005 to 2030

7.5 Particulate Matter (PM) emissions

The PM emission inventory data only dates back to 2000. The TSP, PM_{10} and $PM_{2.5}$ emissions are shown in Figures 7.5, 7.6 and 7.7. For all particle size fractions, total PM emissions decrease over the time series. The main sectors responsible for the reduction are the transport sector and other mobile sectors. In other stationary sectors the main source of the PM emission is residential wood combustion.

TSP

The largest TSP emission sources are the agricultural sector and the residential sector. In 2010 the agricultural sector is projected to account for 43 % of the total TSP emission, closely followed at 42 % by other sectors, stationary, in which residential wood combustion is the main sector.

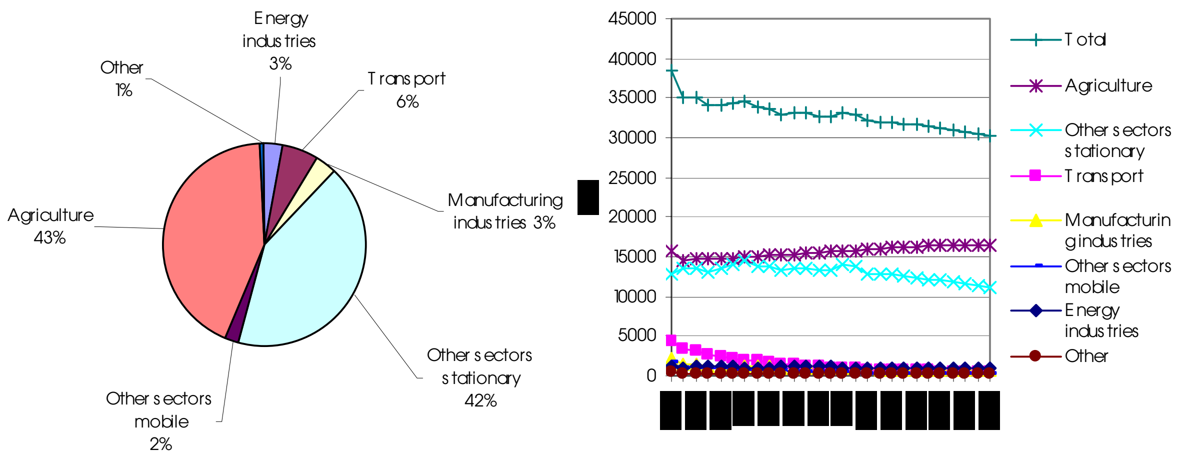

Figure 7.5 TSP emissions. Distribution by main sectors (2010) and time series for 2000 and 2005 to 2030

PM_{10}

As with TSP the largest PM_{10} emission sources are the residential sector and the agricultural sector. As mentioned above the PM_{10} emission decreases over the time series and the sectors responsible for the reduction are the transport sector and other sectors. In other sectors the main source of the PM_{10} emission is residential wood combustion. The decrease from 2000 to 2005 is caused by the decreasing emission from the transport sector and the agricultural sector.

In 2010 other stationary sectors account for 48 % of the total PM_{10} emission. Agriculture and transport are the second and third largest sources for the PM_{10} emission.

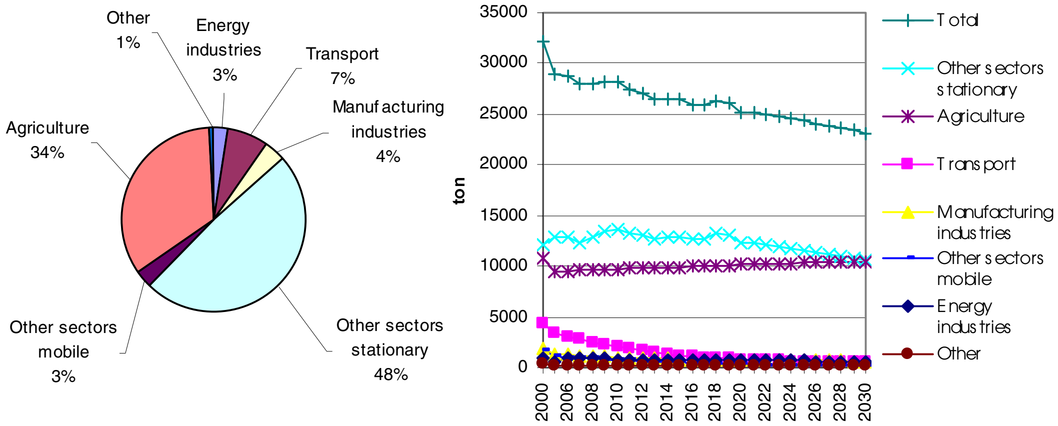

Figure 7.6 PM_{10} emissions. Distribution by to main sectors (2010) and time series for 2000 and 2005 to 2030

$PM_{2.5}$

The largest $PM_{2.5}$ emission sources are the residential sector, followed by road traffic and other mobile sources. For the latter, the most important source is off-road vehicles and machinery in the agricultural/forestry sector. For the road transport sector, exhaust emissions account for the major part of the emissions. The sectors responsible for the reduction are the transport sector and other sectors. The decrease from 2000 to 2005 is caused by decreasing emissions, mainly from the transport sector.

In 2010 other stationary sectors are expected to account for 67 % of the total $PM_{2.5}$ emission. Transport and agriculture are the second and third largest sources for the $PM_{2.5}$ emission.

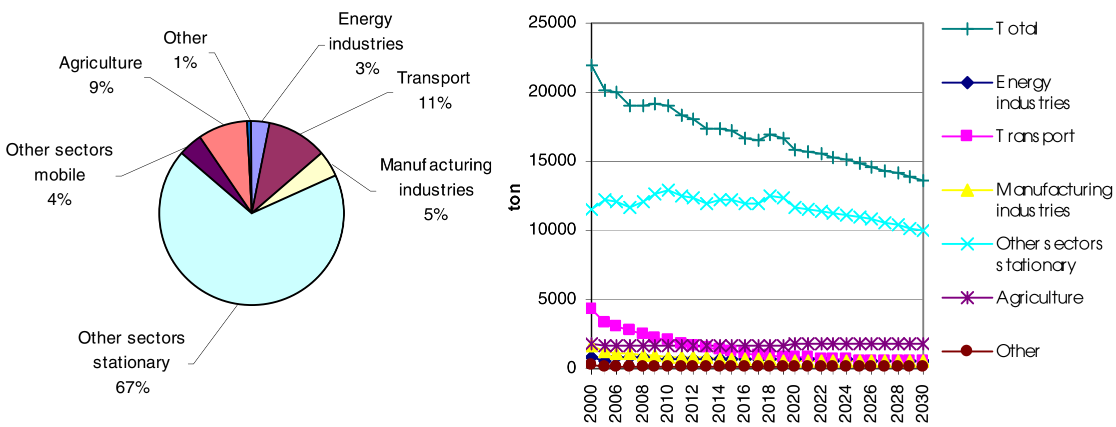

Figure 7.7 $PM_{2.5}$ emissions. Distribution by main sectors (2010) and time series for 2000 and 2005 to 2030

Table 7.2 to 7.8 list the emissions for 1990, 2000, 2005 and the projected emissions for 2015, 2020, 2025 and 2030.

Table 7.2 NO_X emissions in tonnes

SNAP	Sector	NFR	1990	2000	2005	2010	2015	2020	2025	2030
0101	Public power	1A1a	85250	39402	25945	24322	26079	23291	21801	19477
010104	Gas turbines	1A1a	314	2406	778	562	849	1377	1693	2607
0102	District heating plants	1A1a	5182	1178	3396	2725	2441	2451	2650	3167
0103	Petroleum refining plants	1A1b	1616	1529	1871	1871	1871	1871	1871	1871
0105	Coal mining, oil / gas extraction, pipeline	1A1c	2376	6305	7163	11389	18604	20978	17720	17720
0201	Commercial and institutional plants (t)	1A4a	1399	1095	1515	1175	1143	1134	1126	1116
0202	Residential plants	1A4b	4939	4750	4795	4681	4697	4723	4841	5035
0203	Plants in agriculture, forestry and aquaculture	1A4c	1180	1327	1455	1358	1369	1353	1346	1348
03	Combustion in manufacturing industry	1A2	12954	14918	11409	11091	11197	10985	11024	11024
04	Production processes	2A-G	842		30	30	30	30	30	30
0401	Processes in petroleum industries	1B2a								
0502	Extraction, 1st treatment and loading of liquid fuels	1B2a								
0506	Gas distribution networks	1B2b								
06	Solvent and other product use	3A-D								
07	Road	1A3b	105313	80695	56810	38133	24430	17279	14276	13505
0801	Military	1A5	494	549	573	446	353	301	277	270
0802	Railways	1A3c	4913	3727	3241	1216	653	90	90	90
0803	Navigation	1A3d	10138	7994	8500	8679	8761	8722	8680	8374
0805	Civil Aviation	1A3a	1123	723	495	537	583	633	676	721
0806-0807	Ag./for./fish.	1A4c	23339	24271	22162	19120	16437	14372	13146	12216
0808	Industry	1A2f	11081	12096	10277	7733	6218	4845	4156	4077
0809	Residential	1A4b	123	194	327	367	377	377	377	377
090206	Flaring in gas and oil extraction	1B2c	1306	3050	240	350	343	319	249	249
10	Agriculture	4A-G								
Total			273880	206209	160983	135785	126434	115132	106030	103276
0804	Navigation int.	1A3d	62285	96911	72995	76174	78522	79297	78832	77895
0805	Civil Aviation int.	1A3a	7016	9446	9612	10406	11322	12317	13139	14015

Table 7.3 SO_2-emissions in tonnes

SNAP	Sector	NFR	1990	2000	2005	2010	2015	2020	2025	2030
0101	Public power	1A1a	119137	11074	3805	5004	5606	4641	4545	3968
010104	Gas turbines	1A1a	5	115	427	223	312	568	273	321
0102	District heating plants	1A1a	7045	902	3273	3002	2753	2973	3327	4523
0103	Petroleum refining plants	1A1b	3411	613	455	455	455	455	455	455
0105	Coal mining, oil / gas extraction, pipeline	1A1c	3	8	12	19	31	35	30	30
0201	Commercial and institutional plants (t)	1A4a	1884	349	304	290	282	281	281	280
0202	Residential plants	1A4b	6415	1898	1618	1552	1565	1577	1622	1691
0203	Plants in agriculture, forestry and aquaculture	1A4c	3192	1568	1572	1707	1761	1784	1800	1808
03	Combustion in manufacturing industry	1A2	16507	7405	5434	5737	6066	6546	6810	6955
0401	Processes in petroleum industries	1B2a	3335	981	119	119	119	119	119	119
07	Road	1A3b	5766	351	77	82	84	86	88	90
0801	Military	1A5	48	27	2	2	2	2	2	2
0802	Railways	1A3c	376	7	6	6	6	6	6	6
0803	Navigation	1A3d	5257	1725	2168	1360	1360	1360	1360	1360
0805	Civil Aviation	1A3a	77	49	41	44	48	52	56	59
0806-0807	Ag./for./fish.	1A4c	2506	1129	753	380	379	379	379	379
0808	Industry	1A2f	952	253	5	5	5	5	5	5
0809	Residential	1A4b	4	5	2	2	2	2	2	2
090206	Flaring in gas and oil extraction	1B2c	1	3	3	5	5	4	4	4
Total			175922	28462	20076	19995	20842	20878	21164	22058
0804	Navigation int.	1A3d	42404	56634	32112	16056	16056	16056	16056	16056
0805	Civil Aviation int.	1A3a	554	750	720	779	848	922	984	1050

Table 7.4 NMVOC-emissions in tonnes

SNAP	Sector	NFR	1990	2000	2005	2010	2015	2020	2025	2030
0101	Public power	1A1a	422	3470	3582	3216	3315	3237	3008	2920
010104	Gas turbines	1A1a	3	33	22	16	23	35	47	69
0102	District heating plants	1A1a	575	410	925	737	661	618	653	701
0103	Petroleum refining plants	1A1b	60	2	26	26	26	26	26	26
0105	Coal mining, oil / gas extraction, pipeline	1A1c	13	38	43	68	112	126	106	106
0201	Commercial and institutional plants (t)	1A4a	193	628	785	773	759	739	720	707
0202	Residential plants	1A4b	8661	10548	12921	13593	12898	12318	11452	10328
0203	Plants in agriculture, forestry and aquaculture	1A4c	2142	1746	1704	1783	1792	1775	1775	1774
03	Combustion in manufacturing industry	1A2	627	712	865	879	902	915	920	914
04	Production processes	2A-G	1626	1090	1135	1135	1135	1135	1135	1135
0401	Processes in petroleum industries	1B2a	3667	4983	3732	3732	3732	3732	3732	3732
0502	Extraction, 1st treatment and loading of liquid fuels	1B2a	10754	10739	11238	5603	5611	5355	4782	4782
0506	Gas distribution networks	1B2b	81	66	31	31	25	18	15	15
06	Solvent and other product use	3A-D	45582	39712	34400	25500	25500	25500	25500	25500
07	Road	1A3b	81015	39795	28305	18408	12809	10206	9131	8527
0801	Military	1A5	54	57	66	53	45	41	39	39
0802	Railways	1A3c	321	253	205	79	41	4	4	4
0803	Navigation	1A3d	1545	1653	1345	839	646	639	641	644
0805	Civil Aviation	1A3a	186	156	40	43	47	51	54	58
0806-0807	Ag./for./fish.	1A4c	6255	3478	2498	1889	1496	1354	1296	1229
0808	Industry	1A2f	2266	1926	1586	1124	922	773	734	719
0809	Residential	1A4b	4560	5209	8727	6976	5845	5721	5721	5721
090206	Flaring in gas and oil extraction	1B2c	13	33	24	35	34	32	25	25
10	Agriculture	4A-G	1901	1678	1599	1599	1599	1599	1599	1599
Total			172521	128414	115802	88137	79973	75949	73117	71275
0804	Navigation int.	1A3d	2116	3126	2378	2468	2549	2615	2660	2674
0805	Civil Aviation int.	1A3a	331	407	403	436	475	516	551	588
	NMVOC storage (Transport sector)				1116	1182	1194	1207	1232	1256

Table 7.5 NH_3-emissions in tonnes

SNAP	Sector	NFR	1990	2000	2005	2010	2015	2020	2025	2030
04	Production processes	2A-G	49	61	268	268	268	268	268	268
07	Road	1A3b	70	2215	2698	3144	3236	3281	3351	3421
0801	Military	1A5	0,1	0,2	0,3	0,3	0,4	0,4	0,4	0,4
0802	Railways	1A3c	1	1	1	1	1	1	1	1
0803	Navigation	1A3d	0,1	0,2	0,2	0,2	0,2	0,2	0,2	0,2
0805	Civil Aviation	1A3a	0,2	0,2	0,0	0,0	0,0	0,0	0,0	0,0
0806-0807	Ag./for./fish.	1A4c	3	3	3	3	3	3	3	3
0808	Industry	1A2f	2	2	2	2	2	2	2	2
0809	Residential	1A4b	0,2	0,2	0,4	0,4	0,4	0,4	0,4	0,4
10	Animal manure	4A-G	97860	73843	65418	56789	49153	46608	44289	44289
	Mineral fertiliser		10538	6791	5424	5247	4921	4704	4496	4496
	Sludge		71	83	78	69	60	50	50	50
Total			108594	82999	73893	65523	57644	54917	52461	52531
10	Crops				13839	11125	10874	10687	10499	NE

Table 7.6 TSP-emissions in tonnes

SNAP	Sector	NFR	2000	2005	2010	2015	2020	2025	2030
0101	Public power	1A1a	846	491	666	730	637	616	518
010104	Gas turbines	1A1a	4	2	1	3	11	6	9
0102	District heating plants	1A1a	162	267	253	240	236	244	246
0103	Petroleum refining plants	1A1b	144	124	124	124	124	124	124
0105	Coal mining, oil / gas extraction, pipeline	1A1c	3	3	5	7	8	7	7
0201	Commercial and institutional plants (t)	1A4a	163	188	185	182	177	173	170
0202	Residential plants	1A4b	12111	12868	13640	12867	12177	11457	10346
0203	Plants in agriculture, forestry and aquaculture	1A4c	568	539	579	585	581	581	581
03	Combustion in manufacturing industry	1A2	1146	490	507	524	542	551	553
04	Production processes	2A-G	594	192	192	192	192	192	192
07	Road	1A3b	3721	2963	1822	1048	677	473	397
0801	Military	1A5	19	35	21	11	7	4	3
0802	Railways	1A3c	141	108	16	8	0	0	0
0803	Navigation	1A3d	385	230	167	149	143	143	143
0805	Civil Aviation	1A3a	3	2	2	2	3	3	3
0806-0807	Ag./for./fish.	1A4c	1566	988	678	399	214	152	104
0808	Industry	1A2f	1135	977	643	471	315	273	257
0809	Residential	1A4b	47	87	89	90	90	90	90
090206	Flaring in gas and oil extraction	1B2c	1	1	1	1	1	1	1
10	Agriculture	4A-G	15772	14621	14952	15415	15923	16432	16432
Total			38532	35175	34543	33048	32058	31520	30174
0804	Navigation int.	1A3d	8779	1103	2468	2549	2615	2660	2674
0805	Civil Aviation int.	1A3a	38	36	436	475	516	551	588
	Road non exhaust		2306	2484	2643	2722	2804	2874	2933

Table 7.7 PM_{10}-emissions in tonnes

SNAP	Sector	NFR	2000	2005	2010	2015	2020	2025	2030
0101	Public power	1A1a	690	328	465	522	441	427	341
010104	Gas turbines	1A1a	3	1	1	2	10	5	7
0102	District heating plants	1A1a	116	198	186	176	175	182	185
0103	Petroleum refining plants	1A1b	131	115	115	115	115	115	115
0105	Coal mining, oil / gas extraction, pipeline	1A1c	2	3	5	7	8	7	7
0201	Commercial and institutional plants (t)	1A4a	157	183	181	177	172	168	166
0202	Residential plants	1A4b	11499	12217	12951	12217	11562	10878	9823
0203	Plants in agriculture, forestry and aquaculture	1A4c	529	503	540	546	542	542	542
03	Combustion in manufacturing industry	1A2	843	353	366	379	392	398	400
04	Production processes	2A-G	377	153	153	153	153	153	153
07	Road	1A3b	3721	2963	1822	1048	677	473	397
0801	Military	1A5	19	35	21	11	7	4	3
0802	Railways	1A3c	141	108	16	8	0	0	0
0803	Navigation	1A3d	383	229	167	149	142	142	142
0805	Civil Aviation	1A3a	3	2	2	2	3	3	3
0806-0807	Ag./for./fish.	1A4c	1564	987	678	399	214	151	104
0808	Industry	1A2f	1135	977	643	471	315	273	257
0809	Residential	1A4b	47	87	89	90	90	90	90
090206	Flaring in gas and oil extraction	1B2c	1	1	1	1	1	1	1
10	Agriculture	4A-G	10742	9512	9700	9921	10163	10405	10405
Total			32102	28956	28101	26395	25183	24418	23139
0804	Navigation int.	1A3d	8691	1092	649	649	649	649	649
0805	Civil Aviation int.	1A3a	38	36	39	43	47	50	53
	Road non exhaust		1489	1607	1708	1759	1812	1856	1893

Table 7.8 $PM_{2.5}$-emissions in tonnes

SNAP	Sector	NFR	2000	2005	2010	2015	2020	2025	2030
0101	Public power	1A1a	584	271	382	428	363	353	283
010104	Gas turbines	1A1a	2	1	1	2	9	4	6
0102	District heating plants	1A1a	92	158	148	140	140	146	148
0103	Petroleum refining plants	1A1b	124	111	111	111	111	111	111
0105	Coal mining, oil / gas extraction, pipeline	1A1c	1	3	5	7	8	7	7
0201	Commercial and institutional plants (t)	1A4a	147	172	169	166	161	158	155
0202	Residential plants	1A4b	10881	11573	12267	11572	10952	10305	9306
0203	Plants in agriculture, forestry and aquaculture	1A4c	493	468	503	508	504	504	504
03	Combustion in manufacturing industry	1A2	500	233	243	252	260	264	265
04	Production processes	2A-G	250	115	115	115	115	115	115
07	Road	1A3b	3721	2963	1822	1048	677	473	397
0801	Military	1A5	19	35	21	11	7	4	3
0802	Railways	1A3c	141	108	16	8	0	0	0
0803	Navigation	1A3d	382	228	166	148	142	142	142
0805	Civil Aviation	1A3a	3	2	2	2	3	3	3
0806-0807	Ag./for./fish.	1A4c	1563	987	678	398	214	151	104
0808	Industry	1A2f	1135	977	643	471	315	273	257
0809	Residential	1A4b	47	87	89	90	90	90	90
090206	Flaring in gas and oil extraction	1B2c	1	1	1	1	1	1	1
10	Agriculture	4A-G	1838	1667	1692	1710	1742	1774	1774
Total			21925	20160	19073	17190	15815	14877	13670
0804	Navigation int.	1A3d	8647	1086	646	646	646	646	646
0805	Civil Aviation int.	1A3a	38	36	39	43	47	50	53
	Road non exhaust		808	873	928	956	985	1009	1029

Appendix 1

Sector	Fuel	Pollutant	Year	Emission	Value
Public power	Steam coal	NO_X	2010	11541,46	144721991
Public power	Wood and similar	NO_X	2010	489,85	6898440
Public power	Municipal waste	NO_X	2010	3603,16	33589307
Public power	Agricultural waste	NO_X	2010	2045,59	18031318
Public power	Residual oil	NO_X	2010	787,71	8900640
Public power	Natural gas	NO_X	2010	5204,26	49806330
Public power	Biogas	NO_X	2010	649,87	2538554
Gas turbines	Natural gas	NO_X	2010	562,48	11404359
District heating plants	Wood and similar	NO_X	2010	615,39	6837690
District heating plants	Municipal waste	NO_X	2010	437,21	3869129
District heating plants	Agricultural waste	NO_X	2010	338,22	3757987
District heating plants	Residual oil	NO_X	2010	912,04	6422840
District heating plants	Gas oil	NO_X	2010	63,41	975513
District heating plants	Natural gas	NO_X	2010	358,59	7968580
Petroleum refining plants	Residual oil	NO_X	2010	116,02	817024
Petroleum refining plants	Gas oil	NO_X	2010	0,20	3085
Petroleum refining plants	Refinery gas	NO_X	2010	1754,78	16554512
Coal mining, oil / gas extraction	Natural gas	NO_X	2010	11388,85	45555396
Commercial and institutional plants (t)	Petroleum coke	NO_X	2010	0,35	7000
Commercial and institutional plants (t)	Wood and similar	NO_X	2010	92,32	1025796
Commercial and institutional plants (t)	Municipal waste	NO_X	2010	308,00	2725691
Commercial and institutional plants (t)	Residual oil	NO_X	2010	31,55	222166
Commercial and institutional plants (t)	Gas oil	NO_X	2010	177,44	3412246
Commercial and institutional plants (t)	Kerosene	NO_X	2010	2,20	44000
Commercial and institutional plants (t)	Natural gas	NO_X	2010	389,71	9278713
Commercial and institutional plants (t)	LPG	NO_X	2010	12,28	173000
Commercial and institutional plants (t)	Biogas	NO_X	2010	160,77	1156590
Residential plants	Steam coal	NO_X	2010	1,66	17516
Residential plants	Coke	NO_X	2010	0,33	3484
Residential plants	Petroleum coke	NO_X	2010	9,60	192000
Residential plants	Wood and similar	NO_X	2010	2199,36	18328000
Residential plants	Agricultural waste	NO_X	2010	318,96	3544000
Residential plants	Residual oil	NO_X	2010	4,97	35000
Residential plants	Gas oil	NO_X	2010	1054,66	20282000
Residential plants	Kerosene	NO_X	2010	6,85	137000
Residential plants	Natural gas	NO_X	2010	1057,98	29388228
Residential plants	LPG	NO_X	2010	26,60	566000
Plants in agriculture, forestry and aquaculture	Steam coal	NO_X	2010	163,40	1720000
Plants in agriculture, forestry and aquaculture	Wood and similar	NO_X	2010	14,85	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	NO_X	2010	190,51	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	NO_X	2010	148,10	1042930
Plants in agriculture, forestry and aquaculture	Gas oil	NO_X	2010	136,01	2615592
Plants in agriculture, forestry and aquaculture	Kerosene	NO_X	2010	0,32	6397
Plants in agriculture, forestry and aquaculture	Natural gas	NO_X	2010	575,09	5990566
Plants in agriculture, forestry and aquaculture	LPG	NO_X	2010	6,68	94125
Plants in agriculture, forestry and aquaculture	Biogas	NO_X	2010	123,27	704401
Combustion in manufacturing industry	Steam coal	NO_X	2010	1971,13	6545623
Combustion in manufacturing industry	Coke	NO_X	2010	80,96	852213
Combustion in manufacturing industry	Petroleum coke	NO_X	2010	3720,70	8187958

Sector	Fuel	Pollutant	Year	Emission	Value
Combustion in manufacturing industry	Wood and similar	NO_X	2010	753,80	8375575
Combustion in manufacturing industry	Municipal waste	NO_X	2010	901,93	1984829
Combustion in manufacturing industry	Residual oil	NO_X	2010	1338,29	7626275
Combustion in manufacturing industry	Gas oil	NO_X	2010	212,44	3268338
Combustion in manufacturing industry	Kerosene	NO_X	2010	2,35	47000
Combustion in manufacturing industry	Natural gas	NO_X	2010	2001,27	43585196
Combustion in manufacturing industry	LPG	NO_X	2010	91,53	953428
Combustion in manufacturing industry	Biogas	NO_X	2010	16,41	231112
Flaring in gas and oil extraction	Natural gas	NO_X	2010	350,05	11668364
Public power	Steam coal	NO_X	2020	9726,02	132376804
Public power	Wood and similar	NO_X	2020	441,69	6321443
Public power	Municipal waste	NO_X	2020	4019,58	39248111
Public power	Agricultural waste	NO_X	2020	2118,92	17578665
Public power	Residual oil	NO_X	2020	860,04	9489941
Public power	Gas oil	NO_X	2020	8,17	48039
Public power	Natural gas	NO_X	2020	5458,16	54226331
Public power	Biogas	NO_X	2020	658,21	2571150
Gas turbines	Residual oil	NO_X	2020	372,97	2997336
Gas turbines	Gas oil	NO_X	2020	4,58	70500
Gas turbines	Natural gas	NO_X	2020	999,48	18718988
District heating plants	Wood and similar	NO_X	2020	563,61	6262375
District heating plants	Municipal waste	NO_X	2020	356,70	3156594
District heating plants	Agricultural waste	NO_X	2020	309,88	3443112
District heating plants	Residual oil	NO_X	2020	923,08	6500551
District heating plants	Gas oil	NO_X	2020	118,78	1827330
District heating plants	Natural gas	NO_X	2020	179,12	4713633
Petroleum refining plants	Residual oil	NO_X	2020	116,02	817024
Petroleum refining plants	Gas oil	NO_X	2020	0,20	3085
Petroleum refining plants	Refinery gas	NO_X	2020	1754,78	16554512
Coal mining, oil / gas extraction	Natural gas	NO_X	2020	20978,00	83912005
Commercial and institutional plants (t)	Petroleum coke	NO_X	2020	0,35	7000
Commercial and institutional plants (t)	Wood and similar	NO_X	2020	88,18	979796
Commercial and institutional plants (t)	Municipal waste	NO_X	2020	308,12	2726691
Commercial and institutional plants (t)	Residual oil	NO_X	2020	31,55	222166
Commercial and institutional plants (t)	Gas oil	NO_X	2020	160,28	3082246
Commercial and institutional plants (t)	Kerosene	NO_X	2020	1,95	39000
Commercial and institutional plants (t)	Natural gas	NO_X	2020	370,76	8827713
Commercial and institutional plants (t)	LPG	NO_X	2020	12,14	171000
Commercial and institutional plants (t)	Biogas	NO_X	2020	160,77	1156590
Residential plants	Steam coal	NO_X	2020	1,58	16682
Residential plants	Coke	NO_X	2020	0,32	3318
Residential plants	Petroleum coke	NO_X	2020	7,30	146000
Residential plants	Wood and similar	NO_X	2020	2610,24	21752000
Residential plants	Agricultural waste	NO_X	2020	378,54	4206000
Residential plants	Residual oil	NO_X	2020	3,69	26000
Residential plants	Gas oil	NO_X	2020	803,30	15448000
Residential plants	Kerosene	NO_X	2020	5,20	104000
Residential plants	Natural gas	NO_X	2020	891,08	24752228
Residential plants	LPG	NO_X	2020	22,18	472000
Plants in agriculture, forestry and aquaculture	Steam coal	NO_X	2020	179,08	1885000
Plants in agriculture, forestry and aquaculture	Wood and similar	NO_X	2020	14,85	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	NO_X	2020	190,51	2116800

Sector	Fuel	Pollutant	Year	Emission	Value
Plants in agriculture, forestry and aquaculture	Residual oil	NO_X	2020	140,57	989930
Plants in agriculture, forestry and aquaculture	Gas oil	NO_X	2020	137,88	2651474
Plants in agriculture, forestry and aquaculture	Kerosene	NO_X	2020	0,32	6397
Plants in agriculture, forestry and aquaculture	Natural gas	NO_X	2020	559,64	5829566
Plants in agriculture, forestry and aquaculture	LPG	NO_X	2020	6,87	96764
Plants in agriculture, forestry and aquaculture	Biogas	NO_X	2020	123,27	704401
Combustion in manufacturing industry	Steam coal	NO_X	2020	2075,44	7643663
Combustion in manufacturing industry	Coke	NO_X	2020	94,54	995173
Combustion in manufacturing industry	Petroleum coke	NO_X	2020	3720,70	8187958
Combustion in manufacturing industry	Wood and similar	NO_X	2020	795,02	8833575
Combustion in manufacturing industry	Municipal waste	NO_X	2020	901,93	1984829
Combustion in manufacturing industry	Residual oil	NO_X	2020	1368,82	7841275
Combustion in manufacturing industry	Gas oil	NO_X	2020	245,03	3769637
Combustion in manufacturing industry	Kerosene	NO_X	2020	2,45	49000
Combustion in manufacturing industry	Natural gas	NO_X	2020	1664,22	42602196
Combustion in manufacturing industry	LPG	NO_X	2020	99,59	1037348
Combustion in manufacturing industry	Biogas	NO_X	2020	17,63	248336
Flaring in gas and oil extraction	Natural gas	NO_X	2020	319,10	10636527
Public power	Steam coal	NO_X	2030	6540,86	95206012
Public power	Wood and similar	NO_X	2030	324,71	4694824
Public power	Municipal waste	NO_X	2030	4259,29	43501665
Public power	Agricultural waste	NO_X	2030	2199,14	18137046
Public power	Residual oil	NO_X	2030	738,10	7810577
Public power	Gas oil	NO_X	2030	23,51	138270
Public power	Natural gas	NO_X	2030	4731,22	45725374
Public power	Biogas	NO_X	2030	660,16	2578750
Gas turbines	Residual oil	NO_X	2030	77,12	1286941
Gas turbines	Natural gas	NO_X	2030	2530,26	46488501
District heating plants	Wood and similar	NO_X	2030	570,42	6337965
District heating plants	Municipal waste	NO_X	2030	327,41	2897419
District heating plants	Agricultural waste	NO_X	2030	297,83	3309258
District heating plants	Residual oil	NO_X	2030	1574,91	11090901
District heating plants	Gas oil	NO_X	2030	92,87	1428701
District heating plants	Natural gas	NO_X	2030	303,26	7980588
Petroleum refining plants	Residual oil	NO_X	2030	116,02	817024
Petroleum refining plants	Gas oil	NO_X	2030	0,20	3085
Petroleum refining plants	Refinery gas	NO_X	2030	1754,78	16554512
Coal mining, oil / gas extraction	Natural gas	NO_X	2030	17720,09	70880341
Commercial and institutional plants (t)	Petroleum coke	NO_X	2030	0,35	7000
Commercial and institutional plants (t)	Wood and similar	NO_X	2030	84,04	933796
Commercial and institutional plants (t)	Municipal waste	NO_X	2030	308,12	2726691
Commercial and institutional plants (t)	Residual oil	NO_X	2030	31,69	223166
Commercial and institutional plants (t)	Gas oil	NO_X	2030	158,92	3056246
Commercial and institutional plants (t)	Kerosene	NO_X	2030	1,95	39000
Commercial and institutional plants (t)	Natural gas	NO_X	2030	358,46	8534713
Commercial and institutional plants (t)	LPG	NO_X	2030	11,72	165000
Commercial and institutional plants (t)	Biogas	NO_X	2030	160,77	1156590
Residential plants	Steam coal	NO_X	2030	1,43	15014
Residential plants	Coke	NO_X	2030	0,28	2986
Residential plants	Petroleum coke	NO_X	2030	6,70	134000
Residential plants	Wood and similar	NO_X	2030	2974,92	24791000
Residential plants	Agricultural waste	NO_X	2030	431,46	4794000

Sector	Fuel	Pollutant	Year	Emission	Value
Residential plants	Residual oil	NO_X	2030	3,41	24000
Residential plants	Gas oil	NO_X	2030	736,11	14156000
Residential plants	Kerosene	NO_X	2030	4,80	96000
Residential plants	Natural gas	NO_X	2030	854,76	23743228
Residential plants	LPG	NO_X	2030	21,24	452000
Plants in agriculture, forestry and aquaculture	Steam coal	NO_X	2030	185,06	1948000
Plants in agriculture, forestry and aquaculture	Wood and similar	NO_X	2030	14,85	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	NO_X	2030	190,51	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	NO_X	2030	136,31	959930
Plants in agriculture, forestry and aquaculture	Gas oil	NO_X	2030	133,83	2573643
Plants in agriculture, forestry and aquaculture	Kerosene	NO_X	2030	0,27	5397
Plants in agriculture, forestry and aquaculture	Natural gas	NO_X	2030	557,05	5802566
Plants in agriculture, forestry and aquaculture	LPG	NO_X	2030	6,99	98505
Plants in agriculture, forestry and aquaculture	Biogas	NO_X	2030	123,27	704401
Combustion in manufacturing industry	Steam coal	NO_X	2030	2136,05	8281606
Combustion in manufacturing industry	Coke	NO_X	2030	102,43	1078230
Combustion in manufacturing industry	Petroleum coke	NO_X	2030	3720,70	8187958
Combustion in manufacturing industry	Wood and similar	NO_X	2030	783,32	8703575
Combustion in manufacturing industry	Municipal waste	NO_X	2030	901,93	1984829
Combustion in manufacturing industry	Residual oil	NO_X	2030	1366,41	7824275
Combustion in manufacturing industry	Gas oil	NO_X	2030	258,96	3983953
Combustion in manufacturing industry	Kerosene	NO_X	2030	2,40	48000
Combustion in manufacturing industry	Natural gas	NO_X	2030	1633,29	41809196
Combustion in manufacturing industry	LPG	NO_X	2030	101,46	1056856
Combustion in manufacturing industry	Biogas	NO_X	2030	17,49	246336
Flaring in gas and oil extraction	Natural gas	NO_X	2030	248,63	8287746
Public power	Steam coal	SO_2	2010	2798,71	144721991
Public power	Wood and similar	SO_2	2010	27,13	6898440
Public power	Municipal waste	SO_2	2010	788,02	33589307
Public power	Agricultural waste	SO_2	2010	755,79	18031318
Public power	Residual oil	SO_2	2010	549,64	8900640
Public power	Natural gas	SO_2	2010	22,69	49806330
Public power	Biogas	SO_2	2010	62,22	2538554
Gas turbines	Natural gas	SO_2	2010	223,35	11404359
District heating plants	Wood and similar	SO_2	2010	172,11	6837690
District heating plants	Municipal waste	SO_2	2010	101,44	3869129
District heating plants	Agricultural waste	SO_2	2010	489,83	3757987
District heating plants	Residual oil	SO_2	2010	2212,05	6422840
District heating plants	Gas oil	SO_2	2010	22,85	975513
District heating plants	Natural gas	SO_2	2010	3,37	7968580
Petroleum refining plants	Residual oil	SO_2	2010	438,96	817024
Petroleum refining plants	Gas oil	SO_2	2010	0,07	3085
Petroleum refining plants	Refinery gas	SO_2	2010	15,92	16554512
Coal mining, oil / gas extraction	Natural gas	SO_2	2010	19,24	45555396
Commercial and institutional plants (t)	Petroleum coke	SO_2	2010	4,24	7000
Commercial and institutional plants (t)	Wood and similar	SO_2	2010	25,82	1025796
Commercial and institutional plants (t)	Municipal waste	SO_2	2010	71,46	2725691
Commercial and institutional plants (t)	Residual oil	SO_2	2010	76,51	222166
Commercial and institutional plants (t)	Gas oil	SO_2	2010	79,91	3412246
Commercial and institutional plants (t)	Kerosene	SO_2	2010	0,20	44000
Commercial and institutional plants (t)	Natural gas	SO_2	2010	3,92	9278713
Commercial and institutional plants (t)	LPG	SO_2	2010	0,02	173000

Sector	Fuel	Pollutant	Year	Emission	Value
Commercial and institutional plants (t)	Biogas	SO_2	2010	28,35	1156590
Residential plants	Steam coal	SO_2	2010	10,05	17516
Residential plants	Coke	SO_2	2010	2,00	3484
Residential plants	Petroleum coke	SO_2	2010	116,18	192000
Residential plants	Wood and similar	SO_2	2010	461,32	18328000
Residential plants	Agricultural waste	SO_2	2010	461,94	3544000
Residential plants	Residual oil	SO_2	2010	12,05	35000
Residential plants	Gas oil	SO_2	2010	474,99	20282000
Residential plants	Kerosene	SO_2	2010	0,63	137000
Residential plants	Natural gas	SO_2	2010	12,41	29388228
Residential plants	LPG	SO_2	2010	0,07	566000
Plants in agriculture, forestry and aquaculture	Steam coal	SO_2	2010	986,57	1720000
Plants in agriculture, forestry and aquaculture	Wood and similar	SO_2	2010	4,15	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	SO_2	2010	275,91	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	SO_2	2010	359,19	1042930
Plants in agriculture, forestry and aquaculture	Gas oil	SO_2	2010	61,26	2615592
Plants in agriculture, forestry and aquaculture	Kerosene	SO_2	2010	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	SO_2	2010	2,53	5990566
Plants in agriculture, forestry and aquaculture	LPG	SO_2	2010	0,01	94125
Plants in agriculture, forestry and aquaculture	Biogas	SO_2	2010	17,27	704401
Combustion in manufacturing industry	Steam coal	SO_2	2010	1853,34	6545623
Combustion in manufacturing industry	Coke	SO_2	2010	488,82	852213
Combustion in manufacturing industry	Petroleum coke	SO_2	2010	550,06	8187958
Combustion in manufacturing industry	Wood and similar	SO_2	2010	210,81	8375575
Combustion in manufacturing industry	Municipal waste	SO_2	2010	133,34	1984829
Combustion in manufacturing industry	Residual oil	SO_2	2010	2399,92	7626275
Combustion in manufacturing industry	Gas oil	SO_2	2010	76,54	3268338
Combustion in manufacturing industry	Kerosene	SO_2	2010	0,22	47000
Combustion in manufacturing industry	Natural gas	SO_2	2010	18,30	43585196
Combustion in manufacturing industry	LPG	SO_2	2010	0,12	953428
Combustion in manufacturing industry	Biogas	SO_2	2010	5,66	231112
Flaring in gas and oil extraction	Natural gas	SO_2	2010	4,93	11668364
Public power	Steam coal	SO_2	2020	2216,28	132376804
Public power	Wood and similar	SO_2	2020	24,87	6321443
Public power	Municipal waste	SO_2	2020	923,31	39248111
Public power	Agricultural waste	SO_2	2020	731,64	17578665
Public power	Residual oil	SO_2	2020	657,36	9489941
Public power	Gas oil	SO_2	2020	1,13	48039
Public power	Natural gas	SO_2	2020	23,42	54226331
Public power	Biogas	SO_2	2020	63,02	2571150
Gas turbines	Residual oil	SO_2	2020	298,61	2997336
Gas turbines	Gas oil	SO_2	2020	1,65	70500
Gas turbines	Natural gas	SO_2	2020	267,72	18718988
District heating plants	Wood and similar	SO_2	2020	157,62	6262375
District heating plants	Municipal waste	SO_2	2020	82,76	3156594
District heating plants	Agricultural waste	SO_2	2020	448,79	3443112
District heating plants	Residual oil	SO_2	2020	2238,81	6500551
District heating plants	Gas oil	SO_2	2020	42,79	1827330
District heating plants	Natural gas	SO_2	2020	1,99	4713633
Petroleum refining plants	Residual oil	SO_2	2020	438,96	817024
Petroleum refining plants	Gas oil	SO_2	2020	0,07	3085
Petroleum refining plants	Refinery gas	SO_2	2020	15,92	16554512

Sector	Fuel	Pollutant	Year	Emission	Value
Coal mining, oil / gas extraction	Natural gas	SO_2	2020	35,45	83912005
Commercial and institutional plants (t)	Petroleum coke	SO_2	2020	4,24	7000
Commercial and institutional plants (t)	Wood and similar	SO_2	2020	24,66	979796
Commercial and institutional plants (t)	Municipal waste	SO_2	2020	71,49	2726691
Commercial and institutional plants (t)	Residual oil	SO_2	2020	76,51	222166
Commercial and institutional plants (t)	Gas oil	SO_2	2020	72,18	3082246
Commercial and institutional plants (t)	Kerosene	SO_2	2020	0,18	39000
Commercial and institutional plants (t)	Natural gas	SO_2	2020	3,73	8827713
Commercial and institutional plants (t)	LPG	SO_2	2020	0,02	171000
Commercial and institutional plants (t)	Biogas	SO_2	2020	28,35	1156590
Residential plants	Steam coal	SO_2	2020	9,57	16682
Residential plants	Coke	SO_2	2020	1,90	3318
Residential plants	Petroleum coke	SO_2	2020	88,34	146000
Residential plants	Wood and similar	SO_2	2020	547,50	21752000
Residential plants	Agricultural waste	SO_2	2020	548,23	4206000
Residential plants	Residual oil	SO_2	2020	8,95	26000
Residential plants	Gas oil	SO_2	2020	361,78	15448000
Residential plants	Kerosene	SO_2	2020	0,48	104000
Residential plants	Natural gas	SO_2	2020	10,46	24752228
Residential plants	LPG	SO_2	2020	0,06	472000
Plants in agriculture, forestry and aquaculture	Steam coal	SO_2	2020	1081,21	1885000
Plants in agriculture, forestry and aquaculture	Wood and similar	SO_2	2020	4,15	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	SO_2	2020	275,91	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	SO_2	2020	340,94	989930
Plants in agriculture, forestry and aquaculture	Gas oil	SO_2	2020	62,10	2651474
Plants in agriculture, forestry and aquaculture	Kerosene	SO_2	2020	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	SO_2	2020	2,46	5829566
Plants in agriculture, forestry and aquaculture	LPG	SO_2	2020	0,01	96764
Plants in agriculture, forestry and aquaculture	Biogas	SO_2	2020	17,27	704401
Combustion in manufacturing industry	Steam coal	SO_2	2020	2483,16	7643663
Combustion in manufacturing industry	Coke	SO_2	2020	570,82	995173
Combustion in manufacturing industry	Petroleum coke	SO_2	2020	550,06	8187958
Combustion in manufacturing industry	Wood and similar	SO_2	2020	222,34	8833575
Combustion in manufacturing industry	Municipal waste	SO_2	2020	133,34	1984829
Combustion in manufacturing industry	Residual oil	SO_2	2020	2473,96	7841275
Combustion in manufacturing industry	Gas oil	SO_2	2020	88,28	3769637
Combustion in manufacturing industry	Kerosene	SO_2	2020	0,23	49000
Combustion in manufacturing industry	Natural gas	SO_2	2020	17,88	42602196
Combustion in manufacturing industry	LPG	SO_2	2020	0,14	1037348
Combustion in manufacturing industry	Biogas	SO_2	2020	6,09	248336
Flaring in gas and oil extraction	Natural gas	SO_2	2020	4,49	10636527
Public power	Steam coal	SO_2	2030	1574,58	95206012
Public power	Wood and similar	SO_2	2030	3,90	4694824
Public power	Municipal waste	SO_2	2030	1025,42	43501665
Public power	Agricultural waste	SO_2	2030	742,71	18137046
Public power	Residual oil	SO_2	2030	533,82	7810577
Public power	Gas oil	SO_2	2030	3,24	138270
Public power	Natural gas	SO_2	2030	21,08	45725374
Public power	Biogas	SO_2	2030	63,21	2578750
Gas turbines	Residual oil	SO_2	2030	130,09	1286941
Gas turbines	Natural gas	SO_2	2030	191,09	46488501
District heating plants	Wood and similar	SO_2	2030	159,53	6337965

Sector	Fuel	Pollutant	Year	Emission	Value
District heating plants	Municipal waste	SO_2	2030	75,96	2897419
District heating plants	Agricultural waste	SO_2	2030	431,34	3309258
District heating plants	Residual oil	SO_2	2030	3819,74	11090901
District heating plants	Gas oil	SO_2	2030	33,46	1428701
District heating plants	Natural gas	SO_2	2030	3,37	7980588
Petroleum refining plants	Residual oil	SO_2	2030	438,96	817024
Petroleum refining plants	Gas oil	SO_2	2030	0,07	3085
Petroleum refining plants	Refinery gas	SO_2	2030	15,92	16554512
Coal mining, oil / gas extraction	Natural gas	SO_2	2030	29,94	70880341
Commercial and institutional plants (t)	Petroleum coke	SO_2	2030	4,24	7000
Commercial and institutional plants (t)	Wood and similar	SO_2	2030	23,50	933796
Commercial and institutional plants (t)	Municipal waste	SO_2	2030	71,49	2726691
Commercial and institutional plants (t)	Residual oil	SO_2	2030	76,86	223166
Commercial and institutional plants (t)	Gas oil	SO_2	2030	71,57	3056246
Commercial and institutional plants (t)	Kerosene	SO_2	2030	0,18	39000
Commercial and institutional plants (t)	Natural gas	SO_2	2030	3,61	8534713
Commercial and institutional plants (t)	LPG	SO_2	2030	0,02	165000
Commercial and institutional plants (t)	Biogas	SO_2	2030	28,35	1156590
Residential plants	Steam coal	SO_2	2030	8,61	15014
Residential plants	Coke	SO_2	2030	1,71	2986
Residential plants	Petroleum coke	SO_2	2030	81,08	134000
Residential plants	Wood and similar	SO_2	2030	623,99	24791000
Residential plants	Agricultural waste	SO_2	2030	624,87	4794000
Residential plants	Residual oil	SO_2	2030	8,27	24000
Residential plants	Gas oil	SO_2	2030	331,52	14156000
Residential plants	Kerosene	SO_2	2030	0,44	96000
Residential plants	Natural gas	SO_2	2030	10,03	23743228
Residential plants	LPG	SO_2	2030	0,06	452000
Plants in agriculture, forestry and aquaculture	Steam coal	SO_2	2030	1117,34	1948000
Plants in agriculture, forestry and aquaculture	Wood and similar	SO_2	2030	4,15	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	SO_2	2030	275,91	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	SO_2	2030	330,60	959930
Plants in agriculture, forestry and aquaculture	Gas oil	SO_2	2030	60,27	2573643
Plants in agriculture, forestry and aquaculture	Kerosene	SO_2	2030	0,02	5397
Plants in agriculture, forestry and aquaculture	Natural gas	SO_2	2030	2,45	5802566
Plants in agriculture, forestry and aquaculture	LPG	SO_2	2030	0,01	98505
Plants in agriculture, forestry and aquaculture	Biogas	SO_2	2030	17,27	704401
Combustion in manufacturing industry	Steam coal	SO_2	2030	2849,07	8281606
Combustion in manufacturing industry	Coke	SO_2	2030	618,46	1078230
Combustion in manufacturing industry	Petroleum coke	SO_2	2030	550,06	8187958
Combustion in manufacturing industry	Wood and similar	SO_2	2030	219,07	8703575
Combustion in manufacturing industry	Municipal waste	SO_2	2030	133,34	1984829
Combustion in manufacturing industry	Residual oil	SO_2	2030	2468,11	7824275
Combustion in manufacturing industry	Gas oil	SO_2	2030	93,30	3983953
Combustion in manufacturing industry	Kerosene	SO_2	2030	0,22	48000
Combustion in manufacturing industry	Natural gas	SO_2	2030	17,55	41809196
Combustion in manufacturing industry	LPG	SO_2	2030	0,14	1056856
Combustion in manufacturing industry	Biogas	SO_2	2030	6,04	246336
Flaring in gas and oil extraction	Natural gas	SO_2	2030	3,50	8287746
Public power	Steam coal	NMVOC	2010	217,08	144721991
Public power	Wood and similar	NMVOC	2010	22,76	6898440
Public power	Municipal waste	NMVOC	2010	32,92	33589307

Sector	Fuel	Pollutant	Year	Emission	Value
Public power	Agricultural waste	NMVOC	2010	14,43	18031318
Public power	Residual oil	NMVOC	2010	26,70	8900640
Public power	Natural gas	NMVOC	2010	2867,49	49806330
Public power	Biogas	NMVOC	2010	34,27	2538554
Gas turbines	Natural gas	NMVOC	2010	15,97	11404359
District heating plants	Wood and similar	NMVOC	2010	328,21	6837690
District heating plants	Municipal waste	NMVOC	2010	19,35	3869129
District heating plants	Agricultural waste	NMVOC	2010	187,90	3757987
District heating plants	Residual oil	NMVOC	2010	19,27	6422840
District heating plants	Gas oil	NMVOC	2010	1,95	975513
District heating plants	Natural gas	NMVOC	2010	180,09	7968580
Petroleum refining plants	Residual oil	NMVOC	2010	2,45	817024
Petroleum refining plants	Gas oil	NMVOC	2010	0,00	3085
Petroleum refining plants	Refinery gas	NMVOC	2010	23,18	16554512
Coal mining, oil / gas extraction	Natural gas	NMVOC	2010	68,33	45555396
Commercial and institutional plants (t)	Petroleum coke	NMVOC	2010	0,01	7000
Commercial and institutional plants (t)	Wood and similar	NMVOC	2010	615,48	1025796
Commercial and institutional plants (t)	Municipal waste	NMVOC	2010	13,63	2725691
Commercial and institutional plants (t)	Residual oil	NMVOC	2010	0,67	222166
Commercial and institutional plants (t)	Gas oil	NMVOC	2010	10,24	3412246
Commercial and institutional plants (t)	Kerosene	NMVOC	2010	0,13	44000
Commercial and institutional plants (t)	Natural gas	NMVOC	2010	122,48	9278713
Commercial and institutional plants (t)	LPG	NMVOC	2010	0,35	173000
Commercial and institutional plants (t)	Biogas	NMVOC	2010	10,41	1156590
Residential plants	Steam coal	NMVOC	2010	0,26	17516
Residential plants	Coke	NMVOC	2010	0,05	3484
Residential plants	Petroleum coke	NMVOC	2010	0,29	192000
Residential plants	Wood and similar	NMVOC	2010	11139,06	18328000
Residential plants	Agricultural waste	NMVOC	2010	2126,40	3544000
Residential plants	Residual oil	NMVOC	2010	0,11	35000
Residential plants	Gas oil	NMVOC	2010	60,85	20282000
Residential plants	Kerosene	NMVOC	2010	0,41	137000
Residential plants	Natural gas	NMVOC	2010	264,49	29388228
Residential plants	LPG	NMVOC	2010	1,13	566000
Plants in agriculture, forestry and aquaculture	Steam coal	NMVOC	2010	25,80	1720000
Plants in agriculture, forestry and aquaculture	Wood and similar	NMVOC	2010	99,00	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	NMVOC	2010	1265,85	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	NMVOC	2010	3,13	1042930
Plants in agriculture, forestry and aquaculture	Gas oil	NMVOC	2010	7,85	2615592
Plants in agriculture, forestry and aquaculture	Kerosene	NMVOC	2010	0,02	6397
Plants in agriculture, forestry and aquaculture	Natural gas	NMVOC	2010	373,81	5990566
Plants in agriculture, forestry and aquaculture	LPG	NMVOC	2010	0,19	94125
Plants in agriculture, forestry and aquaculture	Biogas	NMVOC	2010	7,11	704401
Combustion in manufacturing industry	Steam coal	NMVOC	2010	98,18	6545623
Combustion in manufacturing industry	Coke	NMVOC	2010	12,78	852213
Combustion in manufacturing industry	Petroleum coke	NMVOC	2010	12,28	8187958
Combustion in manufacturing industry	Wood and similar	NMVOC	2010	402,03	8375575
Combustion in manufacturing industry	Municipal waste	NMVOC	2010	17,86	1984829
Combustion in manufacturing industry	Residual oil	NMVOC	2010	22,88	7626275
Combustion in manufacturing industry	Gas oil	NMVOC	2010	4,90	3268338
Combustion in manufacturing industry	Kerosene	NMVOC	2010	0,14	47000
Combustion in manufacturing industry	Natural gas	NMVOC	2010	304,81	43585196
Combustion in manufacturing industry	LPG	NMVOC	2010	1,91	953428

Sector	Fuel	Pollutant	Year	Emission	Value
Combustion in manufacturing industry	Biogas	NMVOC	2010	1,55	231112
Flaring in gas and oil extraction	Natural gas	NMVOC	2010	35,01	11668364
Public power	Steam coal	NMVOC	2020	198,57	132376804
Public power	Wood and similar	NMVOC	2020	20,86	6321443
Public power	Municipal waste	NMVOC	2020	38,46	39248111
Public power	Agricultural waste	NMVOC	2020	14,06	17578665
Public power	Residual oil	NMVOC	2020	28,47	9489941
Public power	Gas oil	NMVOC	2020	2,79	48039
Public power	Natural gas	NMVOC	2020	2899,81	54226331
Public power	Biogas	NMVOC	2020	34,45	2571150
Gas turbines	Residual oil	NMVOC	2020	8,99	2997336
Gas turbines	Gas oil	NMVOC	2020	0,14	70500
Gas turbines	Natural gas	NMVOC	2020	26,21	18718988
District heating plants	Wood and similar	NMVOC	2020	300,59	6262375
District heating plants	Municipal waste	NMVOC	2020	15,78	3156594
District heating plants	Agricultural waste	NMVOC	2020	172,16	3443112
District heating plants	Residual oil	NMVOC	2020	19,50	6500551
District heating plants	Gas oil	NMVOC	2020	3,65	1827330
District heating plants	Natural gas	NMVOC	2020	106,53	4713633
Petroleum refining plants	Residual oil	NMVOC	2020	2,45	817024
Petroleum refining plants	Gas oil	NMVOC	2020	0,00	3085
Petroleum refining plants	Refinery gas	NMVOC	2020	23,18	16554512
Coal mining, oil / gas extraction	Natural gas	NMVOC	2020	125,87	83912005
Commercial and institutional plants (t)	Petroleum coke	NMVOC	2020	0,01	7000
Commercial and institutional plants (t)	Wood and similar	NMVOC	2020	587,88	979796
Commercial and institutional plants (t)	Municipal waste	NMVOC	2020	13,63	2726691
Commercial and institutional plants (t)	Residual oil	NMVOC	2020	0,67	222166
Commercial and institutional plants (t)	Gas oil	NMVOC	2020	9,25	3082246
Commercial and institutional plants (t)	Kerosene	NMVOC	2020	0,12	39000
Commercial and institutional plants (t)	Natural gas	NMVOC	2020	116,53	8827713
Commercial and institutional plants (t)	LPG	NMVOC	2020	0,34	171000
Commercial and institutional plants (t)	Biogas	NMVOC	2020	10,41	1156590
Residential plants	Steam coal	NMVOC	2020	0,25	16682
Residential plants	Coke	NMVOC	2020	0,05	3318
Residential plants	Petroleum coke	NMVOC	2020	0,22	146000
Residential plants	Wood and similar	NMVOC	2020	9523,57	21752000
Residential plants	Agricultural waste	NMVOC	2020	2523,60	4206000
Residential plants	Residual oil	NMVOC	2020	0,08	26000
Residential plants	Gas oil	NMVOC	2020	46,34	15448000
Residential plants	Kerosene	NMVOC	2020	0,31	104000
Residential plants	Natural gas	NMVOC	2020	222,77	24752228
Residential plants	LPG	NMVOC	2020	0,94	472000
Plants in agriculture, forestry and aquaculture	Steam coal	NMVOC	2020	28,28	1885000
Plants in agriculture, forestry and aquaculture	Wood and similar	NMVOC	2020	99,00	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	NMVOC	2020	1265,85	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	NMVOC	2020	2,97	989930
Plants in agriculture, forestry and aquaculture	Gas oil	NMVOC	2020	7,95	2651474
Plants in agriculture, forestry and aquaculture	Kerosene	NMVOC	2020	0,02	6397
Plants in agriculture, forestry and aquaculture	Natural gas	NMVOC	2020	363,76	5829566
Plants in agriculture, forestry and aquaculture	LPG	NMVOC	2020	0,19	96764
Plants in agriculture, forestry and aquaculture	Biogas	NMVOC	2020	7,04	704401
Combustion in manufacturing industry	Steam coal	NMVOC	2020	114,65	7643663

Sector	Fuel	Pollutant	Year	Emission	Value
Combustion in manufacturing industry	Coke	NMVOC	2020	14,93	995173
Combustion in manufacturing industry	Petroleum coke	NMVOC	2020	12,28	8187958
Combustion in manufacturing industry	Wood and similar	NMVOC	2020	424,01	8833575
Combustion in manufacturing industry	Municipal waste	NMVOC	2020	17,86	1984829
Combustion in manufacturing industry	Residual oil	NMVOC	2020	23,52	7841275
Combustion in manufacturing industry	Gas oil	NMVOC	2020	5,65	3769637
Combustion in manufacturing industry	Kerosene	NMVOC	2020	0,15	49000
Combustion in manufacturing industry	Natural gas	NMVOC	2020	297,83	42602196
Combustion in manufacturing industry	LPG	NMVOC	2020	2,07	1037348
Combustion in manufacturing industry	Biogas	NMVOC	2020	1,66	248336
Flaring in gas and oil extraction	Natural gas	NMVOC	2020	31,91	10636527
Public power	Steam coal	NMVOC	2030	142,81	95206012
Public power	Wood and similar	NMVOC	2030	15,49	4694824
Public power	Municipal waste	NMVOC	2030	42,63	43501665
Public power	Agricultural waste	NMVOC	2030	14,51	18137046
Public power	Residual oil	NMVOC	2030	23,43	7810577
Public power	Gas oil	NMVOC	2030	8,03	138270
Public power	Natural gas	NMVOC	2030	2638,91	45725374
Public power	Biogas	NMVOC	2030	34,56	2578750
Gas turbines	Residual oil	NMVOC	2030	3,86	1286941
Gas turbines	Natural gas	NMVOC	2030	65,08	46488501
District heating plants	Wood and similar	NMVOC	2030	304,22	6337965
District heating plants	Municipal waste	NMVOC	2030	14,49	2897419
District heating plants	Agricultural waste	NMVOC	2030	165,46	3309258
District heating plants	Residual oil	NMVOC	2030	33,27	11090901
District heating plants	Gas oil	NMVOC	2030	2,86	1428701
District heating plants	Natural gas	NMVOC	2030	180,36	7980588
Petroleum refining plants	Residual oil	NMVOC	2030	2,45	817024
Petroleum refining plants	Gas oil	NMVOC	2030	0,00	3085
Petroleum refining plants	Refinery gas	NMVOC	2030	23,18	16554512
Coal mining, oil / gas extraction	Natural gas	NMVOC	2030	106,32	70880341
Commercial and institutional plants (t)	Petroleum coke	NMVOC	2030	0,01	7000
Commercial and institutional plants (t)	Wood and similar	NMVOC	2030	560,28	933796
Commercial and institutional plants (t)	Municipal waste	NMVOC	2030	13,63	2726691
Commercial and institutional plants (t)	Residual oil	NMVOC	2030	0,67	223166
Commercial and institutional plants (t)	Gas oil	NMVOC	2030	9,17	3056246
Commercial and institutional plants (t)	Kerosene	NMVOC	2030	0,12	39000
Commercial and institutional plants (t)	Natural gas	NMVOC	2030	112,66	8534713
Commercial and institutional plants (t)	LPG	NMVOC	2030	0,33	165000
Commercial and institutional plants (t)	Biogas	NMVOC	2030	10,41	1156590
Residential plants	Steam coal	NMVOC	2030	0,23	15014
Residential plants	Coke	NMVOC	2030	0,04	2986
Residential plants	Petroleum coke	NMVOC	2030	0,20	134000
Residential plants	Wood and similar	NMVOC	2030	7193,70	24791000
Residential plants	Agricultural waste	NMVOC	2030	2876,40	4794000
Residential plants	Residual oil	NMVOC	2030	0,07	24000
Residential plants	Gas oil	NMVOC	2030	42,47	14156000
Residential plants	Kerosene	NMVOC	2030	0,29	96000
Residential plants	Natural gas	NMVOC	2030	213,69	23743228
Residential plants	LPG	NMVOC	2030	0,90	452000
Plants in agriculture, forestry and aquaculture	Steam coal	NMVOC	2030	29,22	1948000
Plants in agriculture, forestry and aquaculture	Wood and similar	NMVOC	2030	99,00	165000

Sector	Fuel	Pollutant	Year	Emission	Value
Plants in agriculture, forestry and aquaculture	Agricultural waste	NMVOC	2030	1265,85	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	NMVOC	2030	2,88	959930
Plants in agriculture, forestry and aquaculture	Gas oil	NMVOC	2030	7,72	2573643
Plants in agriculture, forestry and aquaculture	Kerosene	NMVOC	2030	0,02	5397
Plants in agriculture, forestry and aquaculture	Natural gas	NMVOC	2030	362,08	5802566
Plants in agriculture, forestry and aquaculture	LPG	NMVOC	2030	0,20	98505
Plants in agriculture, forestry and aquaculture	Biogas	NMVOC	2030	7,04	704401
Combustion in manufacturing industry	Steam coal	NMVOC	2030	124,22	8281606
Combustion in manufacturing industry	Coke	NMVOC	2030	16,17	1078230
Combustion in manufacturing industry	Petroleum coke	NMVOC	2030	12,28	8187958
Combustion in manufacturing industry	Wood and similar	NMVOC	2030	417,77	8703575
Combustion in manufacturing industry	Municipal waste	NMVOC	2030	17,86	1984829
Combustion in manufacturing industry	Residual oil	NMVOC	2030	23,47	7824275
Combustion in manufacturing industry	Gas oil	NMVOC	2030	5,98	3983953
Combustion in manufacturing industry	Kerosene	NMVOC	2030	0,14	48000
Combustion in manufacturing industry	Natural gas	NMVOC	2030	292,20	41809196
Combustion in manufacturing industry	LPG	NMVOC	2030	2,11	1056856
Combustion in manufacturing industry	Biogas	NMVOC	2030	1,65	246336
Flaring in gas and oil extraction	Natural gas	NMVOC	2030	24,86	8287746
Public power	Steam coal	TSP	2010	434,17	144721991
Public power	Wood and similar	TSP	2010	54,50	6898440
Public power	Municipal waste	TSP	2010	67,85	33589307
Public power	Agricultural waste	TSP	2010	71,58	18031318
Public power	Residual oil	TSP	2010	26,70	8900640
Public power	Natural gas	TSP	2010	4,98	49806330
Public power	Biogas	TSP	2010	6,68	2538554
Gas turbines	Natural gas	TSP	2010	1,14	11404359
District heating plants	Wood and similar	TSP	2010	129,92	6837690
District heating plants	Municipal waste	TSP	2010	19,35	3869129
District heating plants	Agricultural waste	TSP	2010	78,92	3757987
District heating plants	Residual oil	TSP	2010	19,27	6422840
District heating plants	Gas oil	TSP	2010	4,88	975513
District heating plants	Natural gas	TSP	2010	0,80	7968580
Petroleum refining plants	Residual oil	TSP	2010	40,85	817024
Petroleum refining plants	Gas oil	TSP	2010	0,02	3085
Petroleum refining plants	Refinery gas	TSP	2010	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	TSP	2010	4,56	45555396
Commercial and institutional plants (t)	Petroleum coke	TSP	2010	0,70	7000
Commercial and institutional plants (t)	Wood and similar	TSP	2010	146,69	1025796
Commercial and institutional plants (t)	Municipal waste	TSP	2010	13,63	2725691
Commercial and institutional plants (t)	Residual oil	TSP	2010	3,11	222166
Commercial and institutional plants (t)	Gas oil	TSP	2010	17,06	3412246
Commercial and institutional plants (t)	Kerosene	TSP	2010	0,22	44000
Commercial and institutional plants (t)	Natural gas	TSP	2010	0,93	9278713
Commercial and institutional plants (t)	LPG	TSP	2010	0,03	173000
Commercial and institutional plants (t)	Biogas	TSP	2010	3,04	1156590
Residential plants	Steam coal	TSP	2010	0,30	17516
Residential plants	Coke	TSP	2010	0,06	3484
Residential plants	Petroleum coke	TSP	2010	19,20	192000
Residential plants	Wood and similar	TSP	2010	12686,03	18328000
Residential plants	Agricultural waste	TSP	2010	829,30	3544000
Residential plants	Residual oil	TSP	2010	0,11	35000

Sector	Fuel	Pollutant	Year	Emission	Value
Residential plants	Gas oil	TSP	2010	101,41	20282000
Residential plants	Kerosene	TSP	2010	0,69	137000
Residential plants	Natural gas	TSP	2010	2,94	29388228
Residential plants	LPG	TSP	2010	0,11	566000
Plants in agriculture, forestry and aquaculture	Steam coal	TSP	2010	29,24	1720000
Plants in agriculture, forestry and aquaculture	Wood and similar	TSP	2010	23,60	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	TSP	2010	495,33	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	TSP	2010	14,81	1042930
Plants in agriculture, forestry and aquaculture	Gas oil	TSP	2010	13,08	2615592
Plants in agriculture, forestry and aquaculture	Kerosene	TSP	2010	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	TSP	2010	0,60	5990566
Plants in agriculture, forestry and aquaculture	LPG	TSP	2010	0,02	94125
Plants in agriculture, forestry and aquaculture	Biogas	TSP	2010	1,85	704401
Combustion in manufacturing industry	Steam coal	TSP	2010	111,28	6545623
Combustion in manufacturing industry	Coke	TSP	2010	14,49	852213
Combustion in manufacturing industry	Petroleum coke	TSP	2010	81,88	8187958
Combustion in manufacturing industry	Wood and similar	TSP	2010	159,14	8375575
Combustion in manufacturing industry	Municipal waste	TSP	2010	11,91	1984829
Combustion in manufacturing industry	Residual oil	TSP	2010	106,77	7626275
Combustion in manufacturing industry	Gas oil	TSP	2010	16,34	3268338
Combustion in manufacturing industry	Kerosene	TSP	2010	0,24	47000
Combustion in manufacturing industry	Natural gas	TSP	2010	4,36	43585196
Combustion in manufacturing industry	LPG	TSP	2010	0,19	953428
Combustion in manufacturing industry	Biogas	TSP	2010	0,61	231112
Flaring in gas and oil extraction	Natural gas	TSP	2010	1,17	11668364
Public power	Steam coal	TSP	2020	397,13	132376804
Public power	Wood and similar	TSP	2020	49,94	6321443
Public power	Municipal waste	TSP	2020	79,28	39248111
Public power	Agricultural waste	TSP	2020	69,79	17578665
Public power	Residual oil	TSP	2020	28,47	9489941
Public power	Gas oil	TSP	2020	0,24	48039
Public power	Natural gas	TSP	2020	5,42	54226331
Public power	Biogas	TSP	2020	6,76	2571150
Gas turbines	Residual oil	TSP	2020	8,99	2997336
Gas turbines	Gas oil	TSP	2020	0,35	70500
Gas turbines	Natural gas	TSP	2020	1,87	18718988
District heating plants	Wood and similar	TSP	2020	118,99	6262375
District heating plants	Municipal waste	TSP	2020	15,78	3156594
District heating plants	Agricultural waste	TSP	2020	72,31	3443112
District heating plants	Residual oil	TSP	2020	19,50	6500551
District heating plants	Gas oil	TSP	2020	9,14	1827330
District heating plants	Natural gas	TSP	2020	0,47	4713633
Petroleum refining plants	Residual oil	TSP	2020	40,85	817024
Petroleum refining plants	Gas oil	TSP	2020	0,02	3085
Petroleum refining plants	Refinery gas	TSP	2020	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	TSP	2020	8,39	83912005
Commercial and institutional plants (t)	Petroleum coke	TSP	2020	0,70	7000
Commercial and institutional plants (t)	Wood and similar	TSP	2020	140,11	979796
Commercial and institutional plants (t)	Municipal waste	TSP	2020	13,63	2726691
Commercial and institutional plants (t)	Residual oil	TSP	2020	3,11	222166
Commercial and institutional plants (t)	Gas oil	TSP	2020	15,41	3082246
Commercial and institutional plants (t)	Kerosene	TSP	2020	0,20	39000

Sector	Fuel	Pollutant	Year	Emission	Value
Commercial and institutional plants (t)	Natural gas	TSP	2020	0,88	8827713
Commercial and institutional plants (t)	LPG	TSP	2020	0,03	171000
Commercial and institutional plants (t)	Biogas	TSP	2020	3,04	1156590
Residential plants	Steam coal	TSP	2020	0,28	16682
Residential plants	Coke	TSP	2020	0,06	3318
Residential plants	Petroleum coke	TSP	2020	14,60	146000
Residential plants	Wood and similar	TSP	2020	11097,12	21752000
Residential plants	Agricultural waste	TSP	2020	984,20	4206000
Residential plants	Residual oil	TSP	2020	0,08	26000
Residential plants	Gas oil	TSP	2020	77,24	15448000
Residential plants	Kerosene	TSP	2020	0,52	104000
Residential plants	Natural gas	TSP	2020	2,48	24752228
Residential plants	LPG	TSP	2020	0,09	472000
Plants in agriculture, forestry and aquaculture	Steam coal	TSP	2020	32,05	1885000
Plants in agriculture, forestry and aquaculture	Wood and similar	TSP	2020	23,60	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	TSP	2020	495,33	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	TSP	2020	14,06	989930
Plants in agriculture, forestry and aquaculture	Gas oil	TSP	2020	13,26	2651474
Plants in agriculture, forestry and aquaculture	Kerosene	TSP	2020	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	TSP	2020	0,58	5829566
Plants in agriculture, forestry and aquaculture	LPG	TSP	2020	0,02	96764
Plants in agriculture, forestry and aquaculture	Biogas	TSP	2020	1,85	704401
Combustion in manufacturing industry	Steam coal	TSP	2020	129,94	7643663
Combustion in manufacturing industry	Coke	TSP	2020	16,92	995173
Combustion in manufacturing industry	Petroleum coke	TSP	2020	81,88	8187958
Combustion in manufacturing industry	Wood and similar	TSP	2020	167,84	8833575
Combustion in manufacturing industry	Municipal waste	TSP	2020	11,91	1984829
Combustion in manufacturing industry	Residual oil	TSP	2020	109,78	7841275
Combustion in manufacturing industry	Gas oil	TSP	2020	18,85	3769637
Combustion in manufacturing industry	Kerosene	TSP	2020	0,25	49000
Combustion in manufacturing industry	Natural gas	TSP	2020	4,26	42602196
Combustion in manufacturing industry	LPG	TSP	2020	0,21	1037348
Combustion in manufacturing industry	Biogas	TSP	2020	0,65	248336
Flaring in gas and oil extraction	Natural gas	TSP	2020	1,06	10636527
Public power	Steam coal	TSP	2030	285,62	95206012
Public power	Wood and similar	TSP	2030	37,09	4694824
Public power	Municipal waste	TSP	2030	87,87	43501665
Public power	Agricultural waste	TSP	2030	72,00	18137046
Public power	Residual oil	TSP	2030	23,43	7810577
Public power	Gas oil	TSP	2030	0,69	138270
Public power	Natural gas	TSP	2030	4,57	45725374
Public power	Biogas	TSP	2030	6,78	2578750
Gas turbines	Residual oil	TSP	2030	3,86	1286941
Gas turbines	Natural gas	TSP	2030	4,65	46488501
District heating plants	Wood and similar	TSP	2030	120,42	6337965
District heating plants	Municipal waste	TSP	2030	14,49	2897419
District heating plants	Agricultural waste	TSP	2030	69,49	3309258
District heating plants	Residual oil	TSP	2030	33,27	11090901
District heating plants	Gas oil	TSP	2030	7,14	1428701
District heating plants	Natural gas	TSP	2030	0,80	7980588
Petroleum refining plants	Residual oil	TSP	2030	40,85	817024
Petroleum refining plants	Gas oil	TSP	2030	0,02	3085

Sector	Fuel	Pollutant	Year	Emission	Value
Petroleum refining plants	Refinery gas	TSP	2030	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	TSP	2030	7,09	70880341
Commercial and institutional plants (t)	Petroleum coke	TSP	2030	0,70	7000
Commercial and institutional plants (t)	Wood and similar	TSP	2030	133,53	933796
Commercial and institutional plants (t)	Municipal waste	TSP	2030	13,63	2726691
Commercial and institutional plants (t)	Residual oil	TSP	2030	3,12	223166
Commercial and institutional plants (t)	Gas oil	TSP	2030	15,28	3056246
Commercial and institutional plants (t)	Kerosene	TSP	2030	0,20	39000
Commercial and institutional plants (t)	Natural gas	TSP	2030	0,85	8534713
Commercial and institutional plants (t)	LPG	TSP	2030	0,03	165000
Commercial and institutional plants (t)	Biogas	TSP	2030	3,04	1156590
Residential plants	Steam coal	TSP	2030	0,26	15014
Residential plants	Coke	TSP	2030	0,05	2986
Residential plants	Petroleum coke	TSP	2030	13,40	134000
Residential plants	Wood and similar	TSP	2030	9136,23	24791000
Residential plants	Agricultural waste	TSP	2030	1121,80	4794000
Residential plants	Residual oil	TSP	2030	0,07	24000
Residential plants	Gas oil	TSP	2030	70,78	14156000
Residential plants	Kerosene	TSP	2030	0,48	96000
Residential plants	Natural gas	TSP	2030	2,37	23743228
Residential plants	LPG	TSP	2030	0,09	452000
Plants in agriculture, forestry and aquaculture	Steam coal	TSP	2030	33,12	1948000
Plants in agriculture, forestry and aquaculture	Wood and similar	TSP	2030	23,60	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	TSP	2030	495,33	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	TSP	2030	13,63	959930
Plants in agriculture, forestry and aquaculture	Gas oil	TSP	2030	12,87	2573643
Plants in agriculture, forestry and aquaculture	Kerosene	TSP	2030	0,03	5397
Plants in agriculture, forestry and aquaculture	Natural gas	TSP	2030	0,58	5802566
Plants in agriculture, forestry and aquaculture	LPG	TSP	2030	0,02	98505
Plants in agriculture, forestry and aquaculture	Biogas	TSP	2030	1,85	704401
Combustion in manufacturing industry	Steam coal	TSP	2030	140,79	8281606
Combustion in manufacturing industry	Coke	TSP	2030	18,33	1078230
Combustion in manufacturing industry	Petroleum coke	TSP	2030	81,88	8187958
Combustion in manufacturing industry	Wood and similar	TSP	2030	165,37	8703575
Combustion in manufacturing industry	Municipal waste	TSP	2030	11,91	1984829
Combustion in manufacturing industry	Residual oil	TSP	2030	109,54	7824275
Combustion in manufacturing industry	Gas oil	TSP	2030	19,92	3983953
Combustion in manufacturing industry	Kerosene	TSP	2030	0,24	48000
Combustion in manufacturing industry	Natural gas	TSP	2030	4,18	41809196
Combustion in manufacturing industry	LPG	TSP	2030	0,21	1056856
Combustion in manufacturing industry	Biogas	TSP	2030	0,65	246336
Flaring in gas and oil extraction	Natural gas	TSP	2030	0,83	8287746
Public power	Steam coal	PM_{10}	2010	376,28	144721991
Public power	Wood and similar	PM_{10}	2010	13,38	6898440
Public power	Municipal waste	PM_{10}	2010	37,82	33589307
Public power	Agricultural waste	PM_{10}	2010	2,40	18031318
Public power	Residual oil	PM_{10}	2010	26,70	8900640
Public power	Natural gas	PM_{10}	2010	4,98	49806330
Public power	Biogas	PM_{10}	2010	3,81	2538554
Gas turbines	Natural gas	PM_{10}	2010	0,70	11404359
District heating plants	Wood and similar	PM_{10}	2010	88,89	6837690
District heating plants	Municipal waste	PM_{10}	2010	16,12	3869129

Sector	Fuel	Pollutant	Year	Emission	Value
District heating plants	Agricultural waste	PM_{10}	2010	56,37	3757987
District heating plants	Residual oil	PM_{10}	2010	19,27	6422840
District heating plants	Gas oil	PM_{10}	2010	4,88	975513
District heating plants	Natural gas	PM_{10}	2010	0,80	7968580
Petroleum refining plants	Residual oil	PM_{10}	2010	32,68	817024
Petroleum refining plants	Gas oil	PM_{10}	2010	0,02	3085
Petroleum refining plants	Refinery gas	PM_{10}	2010	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	PM_{10}	2010	4,56	45555396
Commercial and institutional plants (t)	Petroleum coke	PM_{10}	2010	0,42	7000
Commercial and institutional plants (t)	Wood and similar	PM_{10}	2010	146,69	1025796
Commercial and institutional plants (t)	Municipal waste	PM_{10}	2010	11,36	2725691
Commercial and institutional plants (t)	Residual oil	PM_{10}	2010	2,33	222166
Commercial and institutional plants (t)	Gas oil	PM_{10}	2010	17,06	3412246
Commercial and institutional plants (t)	Kerosene	PM_{10}	2010	0,22	44000
Commercial and institutional plants (t)	Natural gas	PM_{10}	2010	0,93	9278713
Commercial and institutional plants (t)	LPG	PM_{10}	2010	0,03	173000
Commercial and institutional plants (t)	Biogas	PM_{10}	2010	1,73	1156590
Residential plants	Steam coal	PM_{10}	2010	0,21	17516
Residential plants	Coke	PM_{10}	2010	0,04	3484
Residential plants	Petroleum coke	PM_{10}	2010	11,52	192000
Residential plants	Wood and similar	PM_{10}	2010	12047,29	18328000
Residential plants	Agricultural waste	PM_{10}	2010	786,77	3544000
Residential plants	Residual oil	PM_{10}	2010	0,11	35000
Residential plants	Gas oil	PM_{10}	2010	101,41	20282000
Residential plants	Kerosene	PM_{10}	2010	0,69	137000
Residential plants	Natural gas	PM_{10}	2010	2,94	29388228
Residential plants	LPG	PM_{10}	2010	0,11	566000
Plants in agriculture, forestry and aquaculture	Steam coal	PM_{10}	2010	20,64	1720000
Plants in agriculture, forestry and aquaculture	Wood and similar	PM_{10}	2010	23,60	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	PM_{10}	2010	469,93	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	PM_{10}	2010	11,06	1042930
Plants in agriculture, forestry and aquaculture	Gas oil	PM_{10}	2010	13,08	2615592
Plants in agriculture, forestry and aquaculture	Kerosene	PM_{10}	2010	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	PM_{10}	2010	0,60	5990566
Plants in agriculture, forestry and aquaculture	LPG	PM_{10}	2010	0,02	94125
Plants in agriculture, forestry and aquaculture	Biogas	PM_{10}	2010	1,06	704401
Combustion in manufacturing industry	Steam coal	PM_{10}	2010	78,55	6545623
Combustion in manufacturing industry	Coke	PM_{10}	2010	10,23	852213
Combustion in manufacturing industry	Petroleum coke	PM_{10}	2010	57,32	8187958
Combustion in manufacturing industry	Wood and similar	PM_{10}	2010	108,88	8375575
Combustion in manufacturing industry	Municipal waste	PM_{10}	2010	9,92	1984829
Combustion in manufacturing industry	Residual oil	PM_{10}	2010	80,08	7626275
Combustion in manufacturing industry	Gas oil	PM_{10}	2010	16,34	3268338
Combustion in manufacturing industry	Kerosene	PM_{10}	2010	0,24	47000
Combustion in manufacturing industry	Natural gas	PM_{10}	2010	4,36	43585196
Combustion in manufacturing industry	LPG	PM_{10}	2010	0,19	953428
Combustion in manufacturing industry	Biogas	PM_{10}	2010	0,35	231112
Flaring in gas and oil extraction	Natural gas	PM_{10}	2010	1,17	11668364
		PM_{10}			
Public power	Steam coal	PM_{10}	2020	344,18	132376804
Public power	Wood and similar	PM_{10}	2020	12,26	6321443
Public power	Municipal waste	PM_{10}	2020	44,19	39248111
Public power	Agricultural waste	PM_{10}	2020	2,34	17578665

Sector	Fuel	Pollutant	Year	Emission	Value
Public power	Residual oil	PM_{10}	2020	28,47	9489941
Public power	Gas oil	PM_{10}	2020	0,24	48039
Public power	Natural gas	PM_{10}	2020	5,42	54226331
Public power	Biogas	PM_{10}	2020	3,86	2571150
Gas turbines	Residual oil	PM_{10}	2020	8,99	2997336
Gas turbines	Gas oil	PM_{10}	2020	0,35	70500
Gas turbines	Natural gas	PM_{10}	2020	1,14	18718988
District heating plants	Wood and similar	PM_{10}	2020	81,41	6262375
District heating plants	Municipal waste	PM_{10}	2020	13,15	3156594
District heating plants	Agricultural waste	PM_{10}	2020	51,65	3443112
District heating plants	Residual oil	PM_{10}	2020	19,50	6500551
District heating plants	Gas oil	PM_{10}	2020	9,14	1827330
District heating plants	Natural gas	PM_{10}	2020	0,47	4713633
Petroleum refining plants	Residual oil	PM_{10}	2020	32,68	817024
Petroleum refining plants	Gas oil	PM_{10}	2020	0,02	3085
Petroleum refining plants	Refinery gas	PM_{10}	2020	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	PM_{10}	2020	8,39	83912005
Commercial and institutional plants (t)	Petroleum coke	PM_{10}	2020	0,42	7000
Commercial and institutional plants (t)	Wood and similar	PM_{10}	2020	140,11	979796
Commercial and institutional plants (t)	Municipal waste	PM_{10}	2020	11,36	2726691
Commercial and institutional plants (t)	Residual oil	PM_{10}	2020	2,33	222166
Commercial and institutional plants (t)	Gas oil	PM_{10}	2020	15,41	3082246
Commercial and institutional plants (t)	Kerosene	PM_{10}	2020	0,20	39000
Commercial and institutional plants (t)	Natural gas	PM_{10}	2020	0,88	8827713
Commercial and institutional plants (t)	LPG	PM_{10}	2020	0,03	171000
Commercial and institutional plants (t)	Biogas	PM_{10}	2020	1,73	1156590
Residential plants	Steam coal	PM_{10}	2020	0,20	16682
Residential plants	Coke	PM_{10}	2020	0,04	3318
Residential plants	Petroleum coke	PM_{10}	2020	8,76	146000
Residential plants	Wood and similar	PM_{10}	2020	10538,38	21752000
Residential plants	Agricultural waste	PM_{10}	2020	933,73	4206000
Residential plants	Residual oil	PM_{10}	2020	0,08	26000
Residential plants	Gas oil	PM_{10}	2020	77,24	15448000
Residential plants	Kerosene	PM_{10}	2020	0,52	104000
Residential plants	Natural gas	PM_{10}	2020	2,48	24752228
Residential plants	LPG	PM_{10}	2020	0,09	472000
Plants in agriculture, forestry and aquaculture	Steam coal	PM_{10}	2020	22,62	1885000
Plants in agriculture, forestry and aquaculture	Wood and similar	PM_{10}	2020	23,60	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	PM_{10}	2020	469,93	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	PM_{10}	2020	10,49	989930
Plants in agriculture, forestry and aquaculture	Gas oil	PM_{10}	2020	13,26	2651474
Plants in agriculture, forestry and aquaculture	Kerosene	PM_{10}	2020	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	PM_{10}	2020	0,58	5829566
Plants in agriculture, forestry and aquaculture	LPG	PM_{10}	2020	0,02	96764
Plants in agriculture, forestry and aquaculture	Biogas	PM_{10}	2020	1,06	704401
Combustion in manufacturing industry	Steam coal	PM_{10}	2020	91,72	7643663
Combustion in manufacturing industry	Coke	PM_{10}	2020	11,94	995173
Combustion in manufacturing industry	Petroleum coke	PM_{10}	2020	57,32	8187958
Combustion in manufacturing industry	Wood and similar	PM_{10}	2020	114,84	8833575
Combustion in manufacturing industry	Municipal waste	PM_{10}	2020	9,92	1984829
Combustion in manufacturing industry	Residual oil	PM_{10}	2020	82,33	7841275
Combustion in manufacturing industry	Gas oil	PM_{10}	2020	18,85	3769637
Combustion in manufacturing industry	Kerosene	PM_{10}	2020	0,25	49000

Sector	Fuel	Pollutant	Year	Emission	Value
Combustion in manufacturing industry	Natural gas	PM_{10}	2020	4,26	42602196
Combustion in manufacturing industry	LPG	PM_{10}	2020	0,21	1037348
Combustion in manufacturing industry	Biogas	PM_{10}	2020	0,37	248336
Flaring in gas and oil extraction	Natural gas	PM_{10}	2020	1,06	10636527
Public power	Steam coal	PM_{10}	2030	247,54	95206012
Public power	Wood and similar	PM_{10}	2030	9,11	4694824
Public power	Municipal waste	PM_{10}	2030	48,98	43501665
Public power	Agricultural waste	PM_{10}	2030	2,41	18137046
Public power	Residual oil	PM_{10}	2030	23,43	7810577
Public power	Gas oil	PM_{10}	2030	0,69	138270
Public power	Natural gas	PM_{10}	2030	4,57	45725374
Public power	Biogas	PM_{10}	2030	3,87	2578750
Gas turbines	Residual oil	PM_{10}	2030	3,86	1286941
Gas turbines	Natural gas	PM_{10}	2030	2,84	46488501
District heating plants	Wood and similar	PM_{10}	2030	82,39	6337965
District heating plants	Municipal waste	PM_{10}	2030	12,07	2897419
District heating plants	Agricultural waste	PM_{10}	2030	49,64	3309258
District heating plants	Residual oil	PM_{10}	2030	33,27	11090901
District heating plants	Gas oil	PM_{10}	2030	7,14	1428701
District heating plants	Natural gas	PM_{10}	2030	0,80	7980588
Petroleum refining plants	Residual oil	PM_{10}	2030	32,68	817024
Petroleum refining plants	Gas oil	PM_{10}	2030	0,02	3085
Petroleum refining plants	Refinery gas	PM_{10}	2030	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	PM_{10}	2030	7,09	70880341
Commercial and institutional plants (t)	Petroleum coke	PM_{10}	2030	0,42	7000
Commercial and institutional plants (t)	Wood and similar	PM_{10}	2030	133,53	933796
Commercial and institutional plants (t)	Municipal waste	PM_{10}	2030	11,36	2726691
Commercial and institutional plants (t)	Residual oil	PM_{10}	2030	2,34	223166
Commercial and institutional plants (t)	Gas oil	PM_{10}	2030	15,28	3056246
Commercial and institutional plants (t)	Kerosene	PM_{10}	2030	0,20	39000
Commercial and institutional plants (t)	Natural gas	PM_{10}	2030	0,85	8534713
Commercial and institutional plants (t)	LPG	PM_{10}	2030	0,03	165000
Commercial and institutional plants (t)	Biogas	PM_{10}	2030	1,73	1156590
Residential plants	Steam coal	PM_{10}	2030	0,18	15014
Residential plants	Coke	PM_{10}	2030	0,04	2986
Residential plants	Petroleum coke	PM_{10}	2030	8,04	134000
Residential plants	Wood and similar	PM_{10}	2030	8676,22	24791000
Residential plants	Agricultural waste	PM_{10}	2030	1064,27	4794000
Residential plants	Residual oil	PM_{10}	2030	0,07	24000
Residential plants	Gas oil	PM_{10}	2030	70,78	14156000
Residential plants	Kerosene	PM_{10}	2030	0,48	96000
Residential plants	Natural gas	PM_{10}	2030	2,37	23743228
Residential plants	LPG	PM_{10}	2030	0,09	452000
Plants in agriculture, forestry and aquaculture	Steam coal	PM_{10}	2030	23,38	1948000
Plants in agriculture, forestry and aquaculture	Wood and similar	PM_{10}	2030	23,60	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	PM_{10}	2030	469,93	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	PM_{10}	2030	10,18	959930
Plants in agriculture, forestry and aquaculture	Gas oil	PM_{10}	2030	12,87	2573643
Plants in agriculture, forestry and aquaculture	Kerosene	PM_{10}	2030	0,03	5397
Plants in agriculture, forestry and aquaculture	Natural gas	PM_{10}	2030	0,58	5802566
Plants in agriculture, forestry and aquaculture	LPG	PM_{10}	2030	0,02	98505
Plants in agriculture, forestry and aquaculture	Biogas	PM_{10}	2030	1,06	704401

Sector	Fuel	Pollutant	Year	Emission	Value
Combustion in manufacturing industry	Steam coal	PM_{10}	2030	99,38	8281606
Combustion in manufacturing industry	Coke	PM_{10}	2030	12,94	1078230
Combustion in manufacturing industry	Petroleum coke	PM_{10}	2030	57,32	8187958
Combustion in manufacturing industry	Wood and similar	PM_{10}	2030	113,15	8703575
Combustion in manufacturing industry	Municipal waste	PM_{10}	2030	9,92	1984829
Combustion in manufacturing industry	Residual oil	PM_{10}	2030	82,15	7824275
Combustion in manufacturing industry	Gas oil	PM_{10}	2030	19,92	3983953
Combustion in manufacturing industry	Kerosene	PM_{10}	2030	0,24	48000
Combustion in manufacturing industry	Natural gas	PM_{10}	2030	4,18	41809196
Combustion in manufacturing industry	LPG	PM_{10}	2030	0,21	1056856
Combustion in manufacturing industry	Biogas	PM_{10}	2030	0,37	246336
Flaring in gas and oil extraction	Natural gas	PM_{10}	2030	0,83	8287746
Public power	Steam coal	$PM_{2,5}$	2010	303,92	144721991
Public power	Wood and similar	$PM_{2,5}$	2010	8,49	6898440
Public power	Municipal waste	$PM_{2,5}$	2010	36,41	33589307
Public power	Agricultural waste	$PM_{2,5}$	2010	1,84	18031318
Public power	Residual oil	$PM_{2,5}$	2010	22,25	8900640
Public power	Natural gas	$PM_{2,5}$	2010	4,98	49806330
Public power	Biogas	$PM_{2,5}$	2010	3,81	2538554
Gas turbines	Natural gas	$PM_{2,5}$	2010	0,58	11404359
District heating plants	Wood and similar	$PM_{2,5}$	2010	68,38	6837690
District heating plants	Municipal waste	$PM_{2,5}$	2010	12,90	3869129
District heating plants	Agricultural waste	$PM_{2,5}$	2010	45,10	3757987
District heating plants	Residual oil	$PM_{2,5}$	2010	16,06	6422840
District heating plants	Gas oil	$PM_{2,5}$	2010	4,88	975513
District heating plants	Natural gas	$PM_{2,5}$	2010	0,80	7968580
Petroleum refining plants	Residual oil	$PM_{2,5}$	2010	28,60	817024
Petroleum refining plants	Gas oil	$PM_{2,5}$	2010	0,02	3085
Petroleum refining plants	Refinery gas	$PM_{2,5}$	2010	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	$PM_{2,5}$	2010	4,56	45555396
Commercial and institutional plants (t)	Petroleum coke	$PM_{2,5}$	2010	0,21	7000
Commercial and institutional plants (t)	Wood and similar	$PM_{2,5}$	2010	138,48	1025796
Commercial and institutional plants (t)	Municipal waste	$PM_{2,5}$	2010	9,09	2725691
Commercial and institutional plants (t)	Residual oil	$PM_{2,5}$	2010	1,56	222166
Commercial and institutional plants (t)	Gas oil	$PM_{2,5}$	2010	17,06	3412246
Commercial and institutional plants (t)	Kerosene	$PM_{2,5}$	2010	0,22	44000
Commercial and institutional plants (t)	Natural gas	$PM_{2,5}$	2010	0,93	9278713
Commercial and institutional plants (t)	LPG	$PM_{2,5}$	2010	0,03	173000
Commercial and institutional plants (t)	Biogas	$PM_{2,5}$	2010	1,73	1156590
Residential plants	Steam coal	$PM_{2,5}$	2010	0,12	17516
Residential plants	Coke	$PM_{2,5}$	2010	0,02	3484
Residential plants	Petroleum coke	$PM_{2,5}$	2010	5,76	192000
Residential plants	Wood and similar	$PM_{2,5}$	2010	11408,55	18328000
Residential plants	Agricultural waste	$PM_{2,5}$	2010	747,78	3544000
Residential plants	Residual oil	$PM_{2,5}$	2010	0,09	35000
Residential plants	Gas oil	$PM_{2,5}$	2010	101,41	20282000
Residential plants	Kerosene	$PM_{2,5}$	2010	0,69	137000
Residential plants	Natural gas	$PM_{2,5}$	2010	2,94	29388228
Residential plants	LPG	$PM_{2,5}$	2010	0,11	566000
Plants in agriculture, forestry and aquaculture	Steam coal	$PM_{2,5}$	2010	12,04	1720000
Plants in agriculture, forestry and aquaculture	Wood and similar	$PM_{2,5}$	2010	22,28	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	$PM_{2,5}$	2010	446,64	2116800

Sector	Fuel	Pollutant	Year	Emission	Value
Plants in agriculture, forestry and aquaculture	Residual oil	$PM_{2,5}$	2010	7,40	1042930
Plants in agriculture, forestry and aquaculture	Gas oil	$PM_{2,5}$	2010	13,08	2615592
Plants in agriculture, forestry and aquaculture	Kerosene	$PM_{2,5}$	2010	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	$PM_{2,5}$	2010	0,60	5990566
Plants in agriculture, forestry and aquaculture	LPG	$PM_{2,5}$	2010	0,02	94125
Plants in agriculture, forestry and aquaculture	Biogas	$PM_{2,5}$	2010	1,06	704401
Combustion in manufacturing industry	Steam coal	$PM_{2,5}$	2010	45,82	6545623
Combustion in manufacturing industry	Coke	$PM_{2,5}$	2010	5,97	852213
Combustion in manufacturing industry	Petroleum coke	$PM_{2,5}$	2010	24,56	8187958
Combustion in manufacturing industry	Wood and similar	$PM_{2,5}$	2010	83,76	8375575
Combustion in manufacturing industry	Municipal waste	$PM_{2,5}$	2010	7,94	1984829
Combustion in manufacturing industry	Residual oil	$PM_{2,5}$	2010	53,38	7626275
Combustion in manufacturing industry	Gas oil	$PM_{2,5}$	2010	16,34	3268338
Combustion in manufacturing industry	Kerosene	$PM_{2,5}$	2010	0,24	47000
Combustion in manufacturing industry	Natural gas	$PM_{2,5}$	2010	4,36	43585196
Combustion in manufacturing industry	LPG	$PM_{2,5}$	2010	0,19	953428
Combustion in manufacturing industry	Biogas	$PM_{2,5}$	2010	0,35	231112
Flaring in gas and oil extraction	Natural gas	$PM_{2,5}$	2010	1,17	11668364
Public power	Steam coal	$PM_{2,5}$	2020	277,99	132376804
Public power	Wood and similar	$PM_{2,5}$	2020	7,78	6321443
Public power	Municipal waste	$PM_{2,5}$	2020	42,54	39248111
Public power	Agricultural waste	$PM_{2,5}$	2020	1,79	17578665
Public power	Residual oil	$PM_{2,5}$	2020	23,72	9489941
Public power	Gas oil	$PM_{2,5}$	2020	0,24	48039
Public power	Natural gas	$PM_{2,5}$	2020	5,42	54226331
Public power	Biogas	$PM_{2,5}$	2020	3,86	2571150
Gas turbines	Residual oil	$PM_{2,5}$	2020	7,49	2997336
Gas turbines	Gas oil	$PM_{2,5}$	2020	0,35	70500
Gas turbines	Natural gas	$PM_{2,5}$	2020	0,95	18718988
District heating plants	Wood and similar	$PM_{2,5}$	2020	62,62	6262375
District heating plants	Municipal waste	$PM_{2,5}$	2020	10,52	3156594
District heating plants	Agricultural waste	$PM_{2,5}$	2020	41,32	3443112
District heating plants	Residual oil	$PM_{2,5}$	2020	16,25	6500551
District heating plants	Gas oil	$PM_{2,5}$	2020	9,14	1827330
District heating plants	Natural gas	$PM_{2,5}$	2020	0,47	4713633
Petroleum refining plants	Residual oil	$PM_{2,5}$	2020	28,60	817024
Petroleum refining plants	Gas oil	$PM_{2,5}$	2020	0,02	3085
Petroleum refining plants	Refinery gas	$PM_{2,5}$	2020	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	$PM_{2,5}$	2020	8,39	83912005
Commercial and institutional plants (t)	Petroleum coke	$PM_{2,5}$	2020	0,21	7000
Commercial and institutional plants (t)	Wood and similar	$PM_{2,5}$	2020	132,27	979796
Commercial and institutional plants (t)	Municipal waste	$PM_{2,5}$	2020	9,09	2726691
Commercial and institutional plants (t)	Residual oil	$PM_{2,5}$	2020	1,56	222166
Commercial and institutional plants (t)	Gas oil	$PM_{2,5}$	2020	15,41	3082246
Commercial and institutional plants (t)	Kerosene	$PM_{2,5}$	2020	0,20	39000
Commercial and institutional plants (t)	Natural gas	$PM_{2,5}$	2020	0,88	8827713
Commercial and institutional plants (t)	LPG	$PM_{2,5}$	2020	0,03	171000
Commercial and institutional plants (t)	Biogas	$PM_{2,5}$	2020	1,73	1156590
Residential plants	Steam coal	$PM_{2,5}$	2020	0,12	16682
Residential plants	Coke	$PM_{2,5}$	2020	0,02	3318
Residential plants	Petroleum coke	$PM_{2,5}$	2020	4,38	146000
Residential plants	Wood and similar	$PM_{2,5}$	2020	9979,65	21752000

Sector	Fuel	Pollutant	Year	Emission	Value
Residential plants	Agricultural waste	$PM_{2,5}$	2020	887,47	4206000
Residential plants	Residual oil	$PM_{2,5}$	2020	0,07	26000
Residential plants	Gas oil	$PM_{2,5}$	2020	77,24	15448000
Residential plants	Kerosene	$PM_{2,5}$	2020	0,52	104000
Residential plants	Natural gas	$PM_{2,5}$	2020	2,48	24752228
Residential plants	LPG	$PM_{2,5}$	2020	0,09	472000
Plants in agriculture, forestry and aquaculture	Steam coal	$PM_{2,5}$	2020	13,20	1885000
Plants in agriculture, forestry and aquaculture	Wood and similar	$PM_{2,5}$	2020	22,28	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	$PM_{2,5}$	2020	446,64	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	$PM_{2,5}$	2020	7,03	989930
Plants in agriculture, forestry and aquaculture	Gas oil	$PM_{2,5}$	2020	13,26	2651474
Plants in agriculture, forestry and aquaculture	Kerosene	$PM_{2,5}$	2020	0,03	6397
Plants in agriculture, forestry and aquaculture	Natural gas	$PM_{2,5}$	2020	0,58	5829566
Plants in agriculture, forestry and aquaculture	LPG	$PM_{2,5}$	2020	0,02	96764
Plants in agriculture, forestry and aquaculture	Biogas	$PM_{2,5}$	2020	1,06	704401
Combustion in manufacturing industry	Steam coal	$PM_{2,5}$	2020	53,51	7643663
Combustion in manufacturing industry	Coke	$PM_{2,5}$	2020	6,97	995173
Combustion in manufacturing industry	Petroleum coke	$PM_{2,5}$	2020	24,56	8187958
Combustion in manufacturing industry	Wood and similar	$PM_{2,5}$	2020	88,34	8833575
Combustion in manufacturing industry	Municipal waste	$PM_{2,5}$	2020	7,94	1984829
Combustion in manufacturing industry	Residual oil	$PM_{2,5}$	2020	54,89	7841275
Combustion in manufacturing industry	Gas oil	$PM_{2,5}$	2020	18,85	3769637
Combustion in manufacturing industry	Kerosene	$PM_{2,5}$	2020	0,25	49000
Combustion in manufacturing industry	Natural gas	$PM_{2,5}$	2020	4,26	42602196
Combustion in manufacturing industry	LPG	$PM_{2,5}$	2020	0,21	1037348
Combustion in manufacturing industry	Biogas	$PM_{2,5}$	2020	0,37	248336
Flaring in gas and oil extraction	Natural gas	$PM_{2,5}$	2020	1,06	10636527
Public power	Steam coal	$PM_{2,5}$	2030	199,93	95206012
Public power	Wood and similar	$PM_{2,5}$	2030	5,77	4694824
Public power	Municipal waste	$PM_{2,5}$	2030	47,16	43501665
Public power	Agricultural waste	$PM_{2,5}$	2030	1,85	18137046
Public power	Residual oil	$PM_{2,5}$	2030	19,53	7810577
Public power	Gas oil	$PM_{2,5}$	2030	0,69	138270
Public power	Natural gas	$PM_{2,5}$	2030	4,57	45725374
Public power	Biogas	$PM_{2,5}$	2030	3,87	2578750
Gas turbines	Residual oil	$PM_{2,5}$	2030	3,22	1286941
Gas turbines	Natural gas	$PM_{2,5}$	2030	2,37	46488501
District heating plants	Wood and similar	$PM_{2,5}$	2030	63,38	6337965
District heating plants	Municipal waste	$PM_{2,5}$	2030	9,66	2897419
District heating plants	Agricultural waste	$PM_{2,5}$	2030	39,71	3309258
District heating plants	Residual oil	$PM_{2,5}$	2030	27,73	11090901
District heating plants	Gas oil	$PM_{2,5}$	2030	7,14	1428701
District heating plants	Natural gas	$PM_{2,5}$	2030	0,80	7980588
Petroleum refining plants	Residual oil	$PM_{2,5}$	2030	28,60	817024
Petroleum refining plants	Gas oil	$PM_{2,5}$	2030	0,02	3085
Petroleum refining plants	Refinery gas	$PM_{2,5}$	2030	82,77	16554512
Coal mining, oil / gas extraction	Natural gas	$PM_{2,5}$	2030	7,09	70880341
Commercial and institutional plants (t)	Petroleum coke	$PM_{2,5}$	2030	0,21	7000
Commercial and institutional plants (t)	Wood and similar	$PM_{2,5}$	2030	126,06	933796
Commercial and institutional plants (t)	Municipal waste	$PM_{2,5}$	2030	9,09	2726691
Commercial and institutional plants (t)	Residual oil	$PM_{2,5}$	2030	1,56	223166
Commercial and institutional plants (t)	Gas oil	$PM_{2,5}$	2030	15,28	3056246

Sector	Fuel	Pollutant	Year	Emission	Value
Commercial and institutional plants (t)	Kerosene	$PM_{2,5}$	2030	0,20	39000
Commercial and institutional plants (t)	Natural gas	$PM_{2,5}$	2030	0,85	8534713
Commercial and institutional plants (t)	LPG	$PM_{2,5}$	2030	0,03	165000
Commercial and institutional plants (t)	Biogas	$PM_{2,5}$	2030	1,73	1156590
Residential plants	Steam coal	$PM_{2,5}$	2030	0,11	15014
Residential plants	Coke	$PM_{2,5}$	2030	0,02	2986
Residential plants	Petroleum coke	$PM_{2,5}$	2030	4,02	134000
Residential plants	Wood and similar	$PM_{2,5}$	2030	8216,22	24791000
Residential plants	Agricultural waste	$PM_{2,5}$	2030	1011,53	4794000
Residential plants	Residual oil	$PM_{2,5}$	2030	0,06	24000
Residential plants	Gas oil	$PM_{2,5}$	2030	70,78	14156000
Residential plants	Kerosene	$PM_{2,5}$	2030	0,48	96000
Residential plants	Natural gas	$PM_{2,5}$	2030	2,37	23743228
Residential plants	LPG	$PM_{2,5}$	2030	0,09	452000
Plants in agriculture, forestry and aquaculture	Steam coal	$PM_{2,5}$	2030	13,64	1948000
Plants in agriculture, forestry and aquaculture	Wood and similar	$PM_{2,5}$	2030	22,28	165000
Plants in agriculture, forestry and aquaculture	Agricultural waste	$PM_{2,5}$	2030	446,64	2116800
Plants in agriculture, forestry and aquaculture	Residual oil	$PM_{2,5}$	2030	6,82	959930
Plants in agriculture, forestry and aquaculture	Gas oil	$PM_{2,5}$	2030	12,87	2573643
Plants in agriculture, forestry and aquaculture	Kerosene	$PM_{2,5}$	2030	0,03	5397
Plants in agriculture, forestry and aquaculture	Natural gas	$PM_{2,5}$	2030	0,58	5802566
Plants in agriculture, forestry and aquaculture	LPG	$PM_{2,5}$	2030	0,02	98505
Plants in agriculture, forestry and aquaculture	Biogas	$PM_{2,5}$	2030	1,06	704401
Combustion in manufacturing industry	Steam coal	$PM_{2,5}$	2030	57,97	8281606
Combustion in manufacturing industry	Coke	$PM_{2,5}$	2030	7,55	1078230
Combustion in manufacturing industry	Petroleum coke	$PM_{2,5}$	2030	24,56	8187958
Combustion in manufacturing industry	Wood and similar	$PM_{2,5}$	2030	87,04	8703575
Combustion in manufacturing industry	Municipal waste	$PM_{2,5}$	2030	7,94	1984829
Combustion in manufacturing industry	Residual oil	$PM_{2,5}$	2030	54,77	7824275
Combustion in manufacturing industry	Gas oil	$PM_{2,5}$	2030	19,92	3983953
Combustion in manufacturing industry	Kerosene	$PM_{2,5}$	2030	0,24	48000
Combustion in manufacturing industry	Natural gas	$PM_{2,5}$	2030	4,18	41809196
Combustion in manufacturing industry	LPG	$PM_{2,5}$	2030	0,21	1056856
Combustion in manufacturing industry	Biogas	$PM_{2,5}$	2030	0,37	246336
Flaring in gas and oil extraction	Natural gas	$PM_{2,5}$	2030	0,83	8287746
Combustion in manufacturing industry	Biogas	$PM_{2,5}$	2030	0,37	246336
Flaring in gas and oil extraction	Natural gas	$PM_{2,5}$	2030	0,83	8287746

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