PROJECTION OF SO_2, NO_X, NH_3 AND PARTICLE EMISSIONS 2010-2030

Technical Report from DCE – Danish Centre for Environment and Energy No. 7 2012

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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 Agency. The emission factors refer either to international guidelines or 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 sulphur dioxide (SO_2), nitrogen oxides (NO_X), non methane volatile organic compounds (NMVOC), ammonia (NH_3), total suspended particulate matter (TSP) and particulate matter with an aerodynamic diameter below 10 µm and 2,5 µm (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 agreed upon or implemented until April 2011 ('with measures' projections).

The Department of Environmental Science and DCE - Danish Center for Environment and Energy at Aarhus University has carried out the work. The project has been financed by the Danish Environmental Protection Agency (EPA).

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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 April 2011 ('with measures' projections). Official Danish forecasts, e.g. the official forecast from the Danish Energy Agency, 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 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 this protocol 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 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 (the NEC directive).

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 growing crops; the NMVOC emission ceiling excludes the emission from growing crops.

Annual emissions are available for the years until 2009, while the presented emissions for 2010 are projections. As a consequence, the 2010 emissions are preliminary and are therefore not decisive as to whether Denmark fulfils its obligations with regards to the NEC Directive.

Pollutant summary

The historical emissions in the latest historical year, 2009, are shown in Table 2 together with the projected emissions for 2020 and 2030. The results of the projection indicate, that emissions of SO_2, NO_x, NMVOC and particulate matter decrease from the latest historical inventory year (2009) to the projection year 2020. From 2020 to 2030 the projection indicates a further decrease of emissions of the same pollutants, except SO_2, which is expected to show a slight increase.

Table 2 Historical emissions for 2009 and projected emissions for 2020 and 2030.

Pollutant	2009	2020	2030
SO_2, tonnes	14 791	15 270	15 773
NO_x, tonnes	131 784	84 571	70 323
NMVOC, tonnes *	93 456	69 989	64 231
NH_3, tonnes *	71 350	57 781	55 092
TSP, tonnes	39 179	30 860	28 591
PM_{10}, tonnes	30 645	22 682	19 970
$PM_{2.5}$, tonnes	24 451	16 892	13 853

* The NH_3 emissions are without emission from straw treatment and growing crops and the NMVOC emissions are excluding emission from growing crops according to the definitions in the NEC Directive.

Nitrogen oxides, NO_X

The largest sources are road transport, other mobile sources, and energy industries, accounting for 35 %, 32 % and 15 % of the NO_x emission in 2009, respectively.

The NO_x emission in 2009 of 131.8 ktonnes was somewhat higher than the emission ceiling of 127 ktonnes.

The NO_x emission is expected to decrease 36 % (47%) from 2009 to 2020 (2030). The decrease is mainly related to road transport and other mobile sources due to the introduction of stricter demands at EU level (new EURO norms).

Sulphur dioxide, SO_2

The largest sources of SO_2 emissions are energy industries and manufacturing industries, accounting for 31 % and 19 % respectively of the national SO_2 emission in 2009.

The SO_2 emission in 2009 of 14.8 ktonnes was significant below the emission ceiling of 55 ktonnes.

The SO_2 emission is expected to increase 3 % (7 %) from 2009 to 2020 (2030). The emission from other mobile sources and public power is expected to show a marked decrease, while emissions from combustion in manufacturing industries and district heating plants are expected to increase.

Non methane volatile organic compounds, NMVOC

The largest sources to emissions of NMVOC are solvents and other product use followed by residential plants, road transport, extraction, storage and refining of oil and gas, and industrial processes in food and drinks production. These sources account for 29 %, 17 %, 14 %, 12 % and 10 %, respectively of the total NMVOC emission in 2009.

The NMVOC emission is expected to decrease 25 % (31 %) from 2009 to 2020 (2030). The largest decrease is expected for residential plants and solvent and other product use, but pronounced decreases are also expected for road transport, fugitive emissions from fuels and other mobile sources.

Ammonia, NH_3

The predominant source of NH_3 emissions is agricultural activities (96 %) and the major part comes from livestock manure.

The NH_3 emission is expected to decrease 19 % (23 %) from 2009 to 2020 (2030). The major decrease is expected in relation to manure management (19 % and 21 %, respectively). The decreased emission is mainly a result of fall in emission from the animal housing and in particular from the pig housing, which is due to implementation of NH_3 reducing technology.

Total suspended particulate matter, 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 non-industrial combustion, mainly wood combustion in residential plants and agriculture, accounting for 49 % and 29 %, respectively, of the total TSP emission in 2009.

The TSP emission is 2009 was 39.2 ktonnes. The emission is projected to decrease by 21 % (27 %) from 2009 to 2020 (2030). The largest decrease is expected for emissions from residential plants of 36 % and 45 % from 2009 to respectively 2020 and 2030.

Particulate matter with diameter less than 10 µm - PM_{10}

The main sources of the PM_{10} emission are non-industrial combustion, mainly wood combustion in residential plants, and agriculture. In 2009 these sources accounted for 58 % and 19 %, respectively.

The emission projection estimates the PM_{10} emission to decrease by 26 % (35 %) from 2009 to 2020 (2030). The main decrease is expected for residential plants, but the PM_{10} emissions from road transport and other mobile sources are expected to decrease in the projection period as well.

Particulate matter with diameter less than 2.5 µm - $PM_{2.5}$

The single major source of the $PM_{2.5}$ emission is non-industrial combustion, mainly wood combustion in residential plants, which accounted for 71 % of the national $PM_{2.5}$ emission in 2009. Other important sources are road transport, other mobile sources and agriculture with 10 %, 9 % and 5 %, respectively

The $PM_{2.5}$ emission is expected to decrease by 31 % (43 %) from 2009 to 2020 (2030) mainly due to decreasing emission from residential plants caused by the introduction of new technologies with lower emissions and other mobile sources. The emission from agriculture is expected to increase slightly (16 % and 17 % from 2009 to 2020 and 2030, respectively).

Key uncertainties and future challenges

In a projection the activity data are naturally associated with some uncertainty. To the extent possible, this projection has been based on official projections, e.g. the fuel consumption projection made by the Danish Energy Agency.

Generally, the most uncertain pollutant is particulate matter. There are still several sources of PM that is not included in the emission inventory and therefore also not part of the projection. For the other pollutants the largest uncertainty relates to NMVOC, due to the wide variety of sources and the larger uncertainties associated with e.g. solvent use. Other uncertainties include emission factors for biomass fired plants, which are not subject to continuous monitoring. The projected increased use of biomass underlines the importance of establishing better emission factors for these installations.

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 april 2011. 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 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 inkluderet 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 (NEC Direktivet).

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; NMVOC-emissionsloftet er eksklusiv emissioner fra afgrøder.

Årlige emissioner er tilgængelige for årene frem til 2009, mens de præsenterede emissioner for 2010 er fremskrivninger. Det påpeges derfor, at 2010 emissionerne er foreløbige og ikke afgør, hvorvidt Danmark opfylder sine forpligtelser i henhold til NEC-direktivet.

Emissionsfremskrivninger

De historiske emissioner for det seneste historiske år, 2009, er vist i Tabel 2 sammen med de fremskrevne emissioner for 2020 og 2030. Resultatet af fremskrivningen indikerer, at emissionerne af SO_2, NO_x, NMVOC og partikler falder fra det seneste historiske år (2009) til fremskrivningsåret 2020. Fra 2020 til 2030 indikerer fremskrivningen et yderligere fald i emissionerne for de samme stoffer, undtagen for SO_2, der forventes at udvise en lille stigning fra 2020 til 2030.

Tabel 2 Historiske emissioner for 2009 og fremskrevne emissioner for 2020 og 2030.

Stoffer	2009	2020	2030
SO_2, ton	14 791	15 270	15 773
NO_x, ton	131 784	84 571	70 323
NMVOC, ton *	93 456	69 989	64 231
NH_3, ton *	71 350	57 781	55 092
TSP, ton	39 179	30 860	28 591
PM_{10}, ton	30 645	22 682	19 970
$PM_{2.5}$, ton	24 451	16 892	13 853

* NH_3-emissionerne er eksklusiv bidrag fra ammoniakbehandlet halm og fra afgrøder og NMVOC-emissionerne er eksklusiv bidrag fra afgrøder jf. definitionerne i NEC-direktivet.

Kvælstofoxider, NO_X

Den største kilde er vejtransport, andre mobile kilder og energiproduktion, der udgør hhv. 35 %, 32 % og 15 % af den samlede NO_x-emission i 2009.

NO_x-emissionen forventes at falde 36 % (47 %) fra 2009 til 2020 (2030). Faldet sker hovedsageligt for vejtransport og andre mobile kilder.

Svovldioxid, SO_2

De største kilder til SO_2-emission er energiproduktion og fremstillingsvirksomhed, der udgør hhv. 31 % og 19 % af den nationale SO_2-emission i 2009.

SO_2-emissionen i 2009 på 14,8 kton er signifikant lavere end emissionsloftet på 55 kton. Den fremskrevne emission i 2010 er 16,3 kton, der trods en mindre stigning stadig forventes at være markant lavere end emissionsloftet.

SO_2-emissionen forventes at falde 3 % (7 %) fra 2009 til 2020 (2030). Emissionerne fra andre mobile kilder og fra el- og varmeproduktion forventes at falde væsentligt, mens emissionerne fra forbrænding i fremstillingsvirksomhed og husholdninger forventes at stige.

Andre flygtige organiske forbindelser end metan, NMVOC

De største kilder til emissioner af NMVOC er brug af opløsningsmidler, efterfulgt af husholdninger, vejtransport, udvinding, lagring og raffinering af olie og gas og industrielle processer i føde- og drikkevareindustrien. Disse kilder udgør hhv. 29 %, 17 %, 14 %, 12 %, og 10 % af den totale NMVOC emission i 2009.

NMVOC-emissionen forventes at falde 25 % (31 %) fra 2009 til 2002 (2030). De største fald forventes for forbrænding i husholdninger og anvendelse af opløsningsmidler, men væsentlige fald forventes også for vejtransport, flygtige emissioner samt for andre mobile kilder.

Ammoniak, NH_3

Den altdominerende kilde til NH_3-emissioner er landbrugssektoren (96 %) og den største andel herfra kommer fra husdyrgødning.

NH_3-emissionen forventes at falde 19 % (23 %) fra 2009 til 2020 (2030). De største fald forventes for kilder relateret til håndtering af husdyrgødning (hhv. 19 % og 21 % frem til 2020 og 2030).

Total mængde svævestøv, TSP

Partikelemissioner er ikke omfattet af NEC-direktivet, og der er ikke opsat et emissionsloft for TSP, PM_{10} og $PM_{2,5}$. De største kilder til emissioner af partikler er ikke-industriel forbrænding, hovedsageligt afbrænding af træ i husholdninger og landbrug, der udgør hhv. 49 % og 29 % af den samlede TSP-emission i 2009.

TSP-emissionen i 2009 er 39,2 kton. I fremskrivningen forventes et fald på 21 % (27 %) fra 2009 til 2020 (2030). Det største fald forventes for emissioner fra husholdninger på 36 % og 45 % fra 2009 til hhv. 2020 og 2030.

Svævestøv med diameter mindre end 10 μm - PM_{10}

De største kilder til PM_{10}-emissioner er ikke-industriel forbrænding, hovedsageligt afbrænding af træ i husholdninger, og landbrug. I 2009 udgjorde disse kilder hhv. 58 % og 19 %.

Fremskrivningen estimerer et fald i PM_{10}-emissionen på 26 % (35 %) fra 2009 til 2020 (2030). Det største fald forventes for husholdninger, men PM_{10}-emissionerne fra vejtransport og andre mobile kilder forventes ligeledes at falde i fremskrivningsperioden.

Svævestøv med diameter mindre end 2.5 μm - $PM_{2.5}$

Den altovervejende kilde til emissioner af $PM_{2,5}$ er ikke-industriel forbrænding, hovedsageligt afbrænding af træ i husholdninger, der udgør 71 % af den nationale $PM_{2,5}$-emission i 2009. Andre væsentlige kilder er vejtransport, andre mobile kilder og landbrug med hhv. 10 %, 9 % og 5 %. $PM_{2,5}$-emissionen forventes at falde med 31 % (43 %) fra 2009 til 2020 (2030) hovedsageligt på grund af faldende emissioner fra husholdninger og andre mobile kilder. For emissionen fra landbrugssektoren forventes en mindre stigning på 16 % (17 %) fra 2009 til 2020 (2030).

Væsentligste usikkerheder og fremtidige udfordringer

Fremskrivninger af aktivitetsdata er altid behæftet med usikkerhed. I denne fremskrivning er der så vidt muligt taget udgangspunkt i officielle fremskrivninger, f.eks. den officielle energifremskrivning fra Energistyrelsen.

Fremskrivningen for partikler er mere usikker end for de øvrige stoffer. Der er stadig flere kilder til emissioner af partikler, der ikke er inkluderet i emissionsopgørelsen og derfor heller ikke indgår i fremskrivningen. For de øvrige stoffer er de største usikkerheder for NMVOC, pga. stor variation mellem kilderne og store usikkerheder knyttet til f.eks. anvendelse af opløsningsmidler. Andre usikkerheder er emissionsfaktorer for værker, der anvender biomasse, og ikke måles kontinuert. Forventningen om øget brug af biomasse i fremskrivningen understreger vigtigheden af bedre emissionsfaktorer for disse anlæg.

1 Introduction

In the 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 were further developed in a project published in 2008 (Illerup et al., 2008) in order to include TSP, PM_{10} and $PM_{2.5}$ and to project the emissions to 2030. This project has updated the projection models taking into account changes in projected activity data and emission factors.

Projections have been made for all anthropogenic sources of emissions included in the Danish emission inventory. The calculation methods and activity data for these sectors are presented and the results are discussed.

1.1 Obligations

Regional air pollution is regulated by a number of protocols under the UN-ECE 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 exceedance 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 exceedance 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 the emission from straw treatment and growing crops, the NMVOC emission ceiling excludes the emission from growing 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.

At the moment negotiations are on-going regarding an update of the Gothenburg Protocol to include emission ceilings for 2020 and a revision of the National Emission Ceilings Directive is expected to be initiated in 2013.

According to the protocol and the directive, Denmark is obligated 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 2030 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.

The main development in the projection of activity data towards 2030 is an expected large increase in the use of biomass. The emission factors for biomass fired plants are based on a very limited number of measurements and are therefore highly uncertain. The most uncertain pollutant is particulate matter. There are still several sources of PM (and a few of NMVOC) that is not included in the emission inventory and therefore also is not part of the projection. For the other pollutants the largest uncertainty is for NMVOC, due to the wide variety of sources and the large uncertainties associated with e.g. solvent use.

Annual emissions are available for the years until 2009, while the presented emissions for 2010 are projections. As a result the 2010 emissions are preliminary and can not be used to determine whether Denmark will fulfil its obligations due to the NEC Directive.

1.2 Environmental problems

Emissions of SO_2, NO_x, NMVOC, NH_3 and PM 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 H^+-ion. NH_3 may react with H^+ to form ammonium (NH_4^+) and by 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 selected years in terms of acid equivalents.

eq 1.1
$$Total\ acid\ equivalents = \frac{m_{SO_2}}{M_{SO_2}} \cdot 2 + \frac{m_{NO_x}}{M_{NO_x}} + \frac{m_{NH_3}}{M_{NH_3}}$$

where m_i is the emission of pollutant i [tonnes], and M_i is the molecular weight [tonne per 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 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 shows 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, 2006), 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 Nielsen et al. (2011).

1.3.1 Acidifying gases

Figure 1.1 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 2009, the most important acidification factor in Denmark was ammonia nitrogen and the relative contributions for SO_2, NO_X and NH_3 were 6 %, 36 % and 58 %, respectively. However, with regard to long-range transport of air pollution, SO_2 and NO_X are still the most important pollutants.

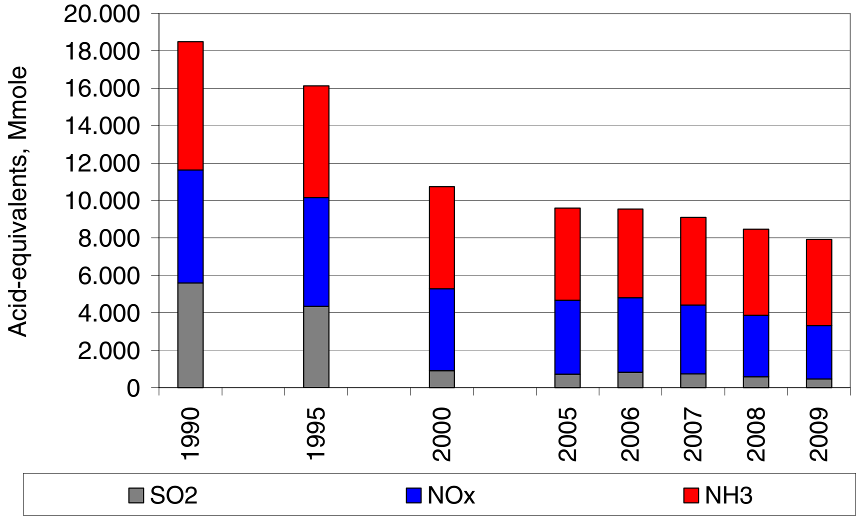

Figure 1.1 Emissions of NH_3, NO_X and SO_2 in acid equivalents.

SO_2

The main part of the SO_2 emission originates from combustion of fossil fuels, i.e. mainly coal and oil. From 1980 to 2009, the total emission decreased by 96.7 %. The large reduction is largely due to installation of desulphurisation units in public power and district heating plants and use of fuels with lower content of sulphur. Despite the large reduction, energy industries still contribute 33 % of the total emission of SO_2. Also emissions from industrial combustion plants, non-industrial combustion plants and transport are important. National sea traffic (navigation and fishing) contributes with about 13 % of the total SO_2 emission. This is due to the use of residual oil with high sulphur content.

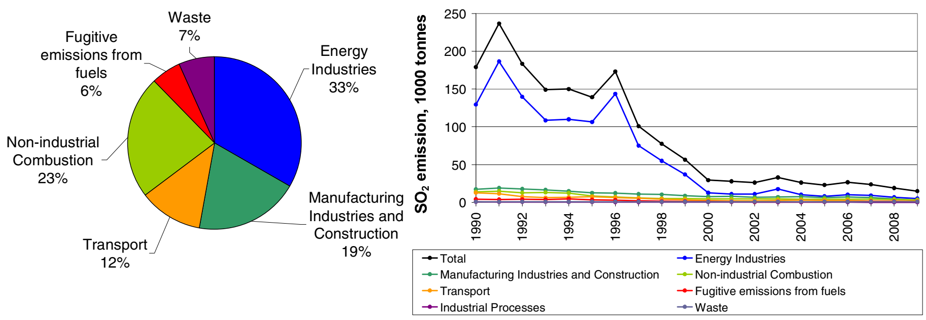

Figure 1.2 SO_2 emissions. Distribution by the main sectors (2009) and time-series for 1990 to 2009.

NO_X

The largest sources of emissions of NO_X are the transport sector (mainly road transport), non-industrial combustion (stationary and mobile sources in households and agriculture and fishing) 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 2009, 46 % 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 77 % from 1985 to 2009. In the same period, the total emission decreased by 56 %. 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.

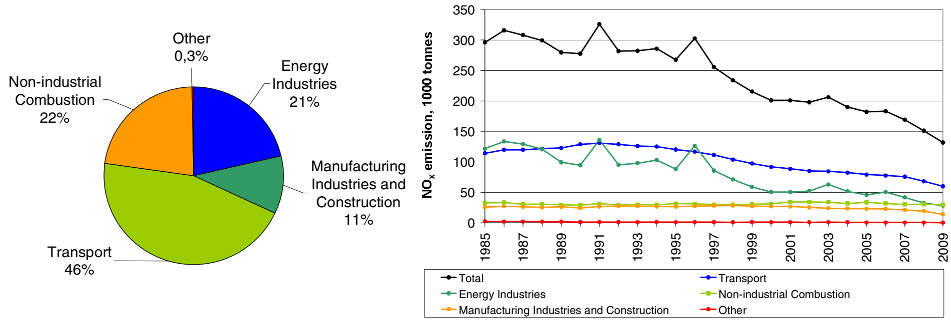

Figure 1.3 NO_X emissions. Distribution by main sectors (2009) and time-series for 1985 to 2009.

NH_3

The vast majority of atmospheric emissions of NH_3 result from agricultural activities. Only small emissions originate from stationary combustion and road transport. Due to increasing use of catalyst cars the contribution from road transport has been increasing. The major part of the emission from agriculture stems from livestock manure (80 %), and the largest losses of ammonia occur during the handling of the manure in stables and in field application. Other contributions come from crops (7 %), use of mineral fertilisers (6 %), N-excretion on pasture, range and paddock (3 %), sewage sludge used as fertiliser, field burning and ammonia used for straw treatment (less than 1 %). The total ammonia emission decreased by 36 % from 1985 to 2009. 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.

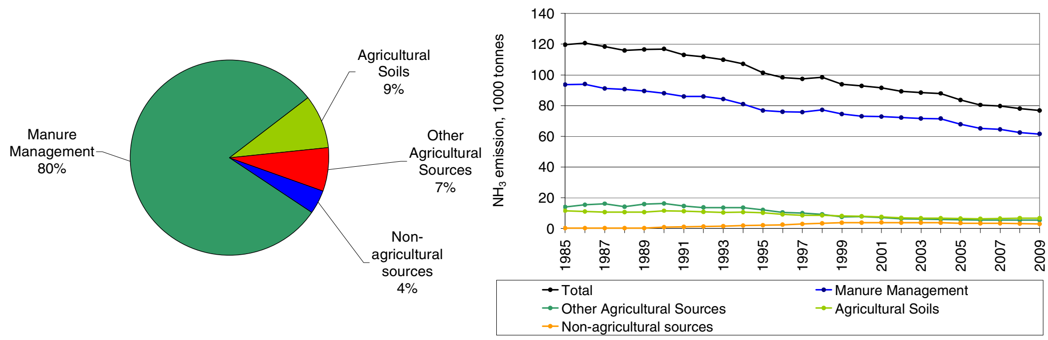

Figure1.4 NH_3 emissions. Distribution by the main sectors (2009) and time-series for 1985 to 2009.

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. Another large contributor is wood stoves and boilers in the residential sector. The evaporative emissions mainly originate from the use of solvents and in connection with extraction, transport and storage of oil and gas. 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. However, in later years the use of gas engines has declined due to structural changes in the Danish electricity market. The total anthropogenic emission has decreased by 50 % from 1985 to 2009, largely due to the increased use of catalyst cars and reduced emissions from use of solvents.

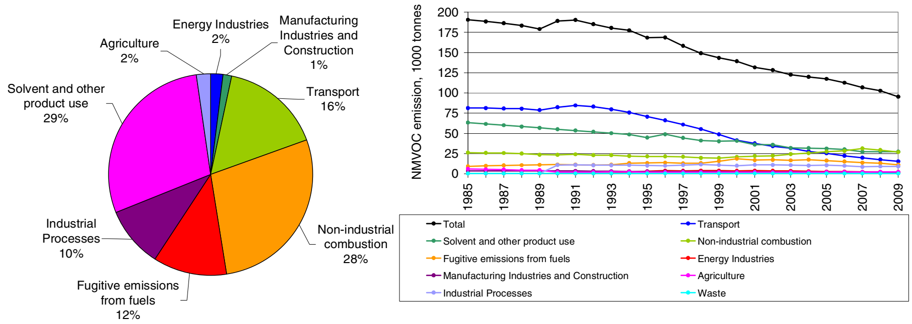

Figure 1.5 NMVOC emissions. Distribution by main sectors (2009) and time-series for 1985 to 2009.

Particulate Matter

The particulate matter (PM) emission inventory has been reported for the years 2000-2009. 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.

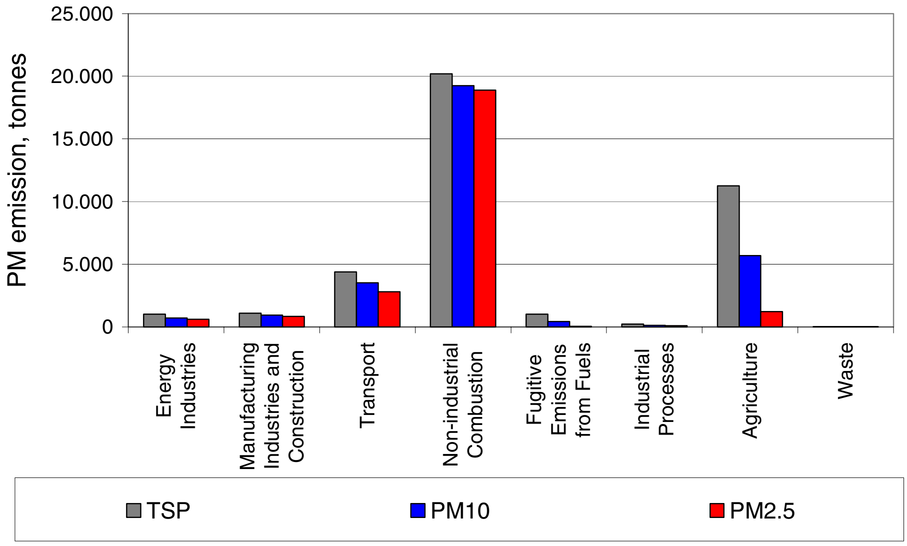

Figure 1.6 PM emissions for 2009.

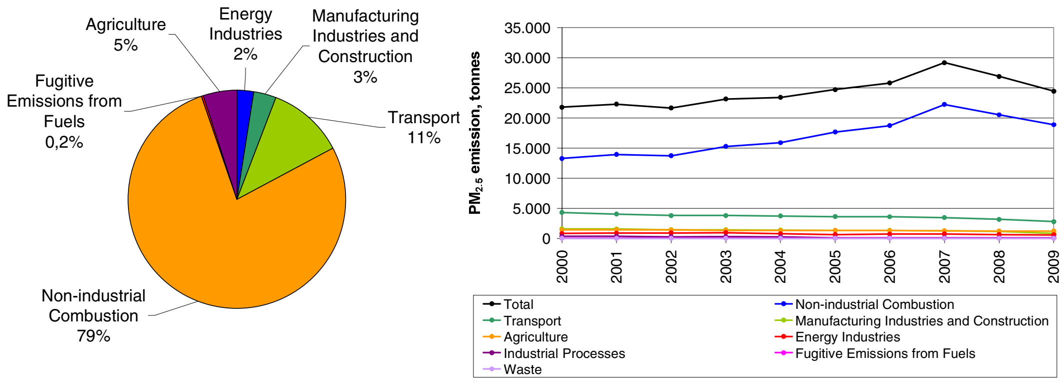

Figure 1.7 $PM_{2.5}$ emissions. Distribution by main sectors (2009) and time-series for 2000 to 2009.

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 assumptions 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
$$E = \sum_{s} A_s(t) \cdot \overline{EF}_s(t)$$

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 know-ledge 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 $$\overline{EF}_s(t) = \sum_k P_{s,k}(t) \cdot EF_{s,k}(t)$$

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 primarily country-specific, based on default emission factors from the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2006) now the EMEP/EEA Guidebook (EEA, 2009), as well as data from measurements carried out at 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, 2006), 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).

1.5 References

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2 Stationary combustion

Annual emissions are available for the years until 2009, while the presented emissions for 2010 are projections. In consequence the 2010 emissions are preliminary and cannot determine if Denmark fulfil its obligations under the NEC Directive.

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, 2002). The projections are based on official activity rates forecast from the Danish Energy Agency (DEA) 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 IPCC Guidelines (IPCC, 1997) and the EMEP/EEA Guidebook (EMEP/EEA, 2009), 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.

2.2 Sources

The combustion of fossil fuels is one of the most important sources of emission of SO_2, NO_x, NMVOC and PM. This chapter covers all sectors, which use fuels for energy production, with the exception of mobile combustion. Table 2.1 shows the sector categories used and the relevant classification.

Table 2.1 Sectors included in stationary combustion.

Sector	NFR	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

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

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

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 Agency (DEA, 2011a), and the projection for large combustion plants, Ramses (DEA 2011b), from 2010 to 2030. For this report a projection from 2011 has been utilised.

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.

For the purpose of emission calculation, data is split according to area and point sources. Point sources are plants larger than 25 MW_e and selected 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 according to fuel types is shown in Table 2.1 and Figure 2.1.

Through 2020, natural gas and coal are the most important fuels, followed by wood and municipal waste. The largest variations are seen for coal use and renewable energy use. Coal use peaks in 2010 and decreases significantly until 2030. For wood, the projected consumption increases throughout the period as a whole and from 2024 onwards the consumption of wood is projected to be higher than the consumption of coal. The projection of the future energy consumption is highly dependent on the development in fuel prices as well as structural changes in the Nordic electricity market. The decrease in fuel consumption from 2010 to 2015 is mainly caused by a significant increase in the share of renewable energy, primarily wind power.

Table 2.1 Fuel consumption for stationary combustion (TJ).

	2010	2015	2020	2025	2030
Natural gas	184 078	148 116	140 081	135 449	138 356
Steam coal	171 662	98 266	107 352	78 775	77 949
Wood and simil.	70 485	77 142	84 370	95 205	107 419
Municipal waste	38 733	42 279	42 932	46 613	48 520
Gas oil	31 235	27 783	26 191	25 364	26 915
Agricultural waste	20 920	19 038	18 731	18 443	18 124
Refinery gas	15 419	15 419	15 419	15 419	15 419
Residual oil	12 188	9 455	10 669	10 227	11 100
Petroleum coke	5 341	5 821	6 056	6 220	6 633
Biogas	4 480	8 224	17 788	17 657	17 556
LPG	1 628	1 726	1 772	1 815	1 891
Coke	616	601	616	626	659
Kerosene	117	117	117	118	120
Total	556 903	453 987	472 097	451 931	470 661

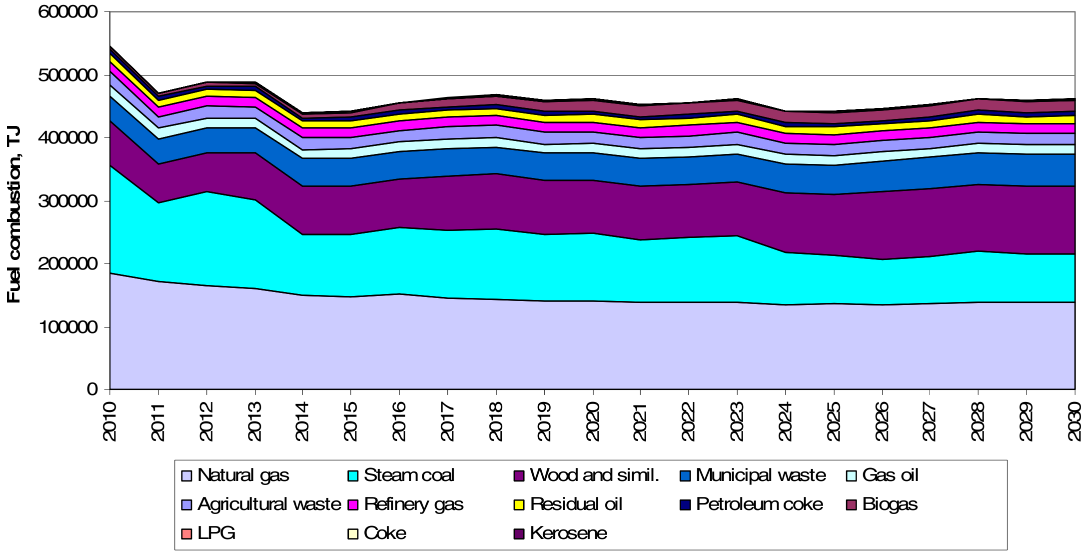

Figure 2.1 Fuel consumption distributed according to fuel type.

The sectors consuming the most fuel are public power, residential, manufacturing industries, off-shore and district heating. According to the energy projection the fuel consumption in the off-shore sector will increase by almost 39 % from 2010 to 2030.

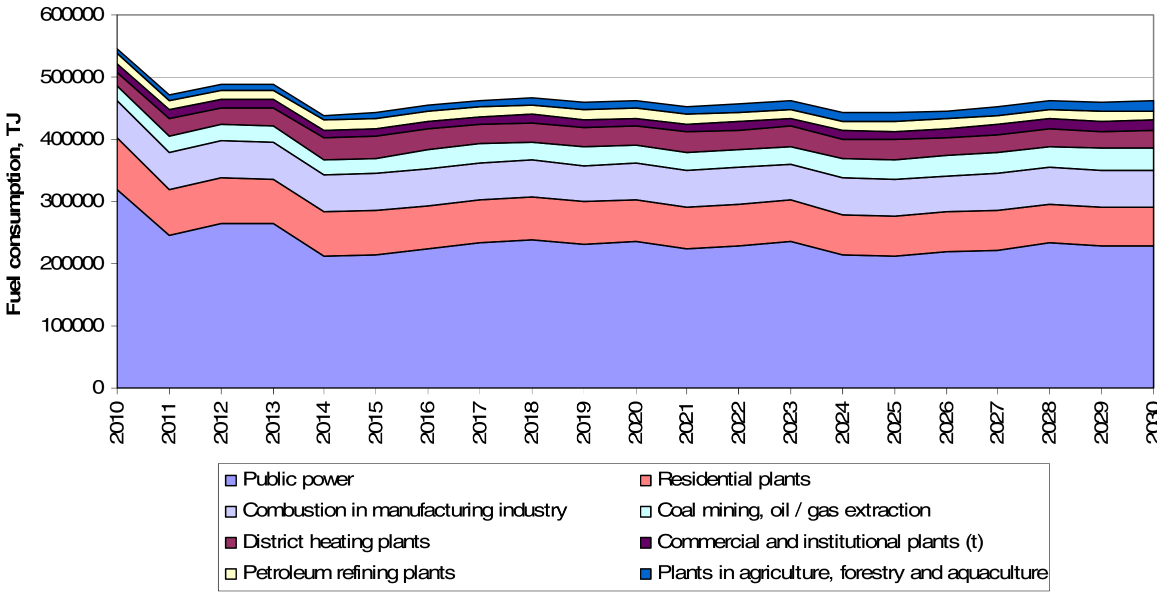

Figure 2.2 Fuel consumption distributed by sector.

Power plants larger than 25 MWe use between 36 % and 50 % of total fuel. The fuel consumption in these sources is expected to decline from 2010 to 2014, thereafter the consumption increases slightly and then remain relatively stable. The consumption at large point sources is to a large extent dependent on expected import/export of electricity and major changes to the Scandinavian energy market, e.g. new wind farms or new nuclear power plants. This is the reasons behind the projected decrease in fuel consumption from 2010 to 2014. The amount of wood combusted by large point sources is expected to increase whereas the coal and natural gas consumption decreases. The share of fuel use comprised by exported/imported electricity constitutes 0.6-7.8 % of total fuel consumption over the period 2010 to 2030 (Figure 2.4). The large decrease in fuel consumption for electricity export from 2011 to 2013 is due to structural changes in the Nordic electricity market, e.g. the expected phasing in of new wind turbines.

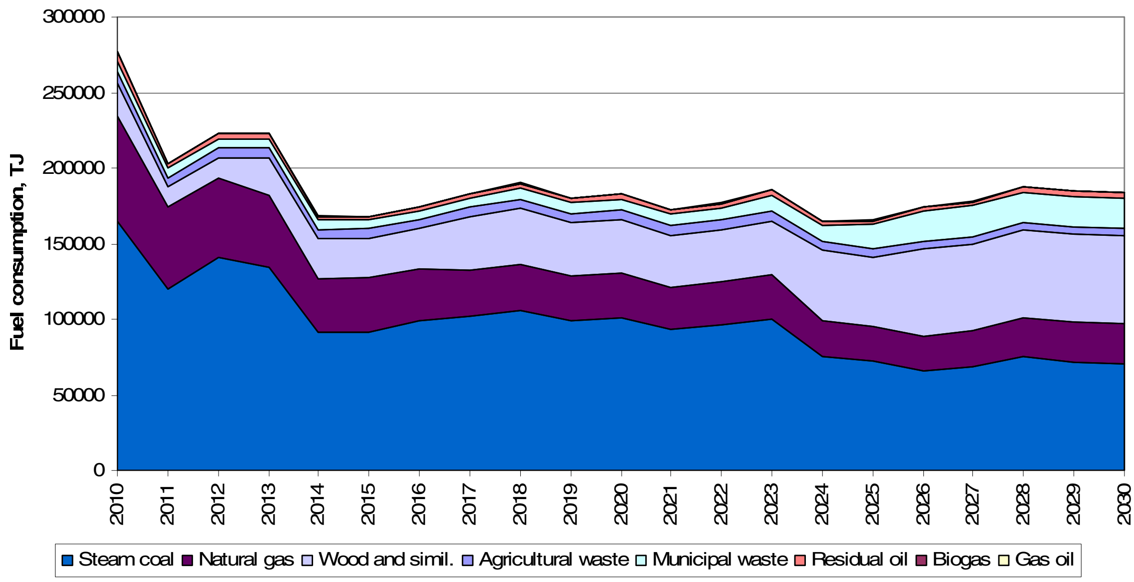

Figure 2.3 Fuel consumption for plants > 25 MWe.

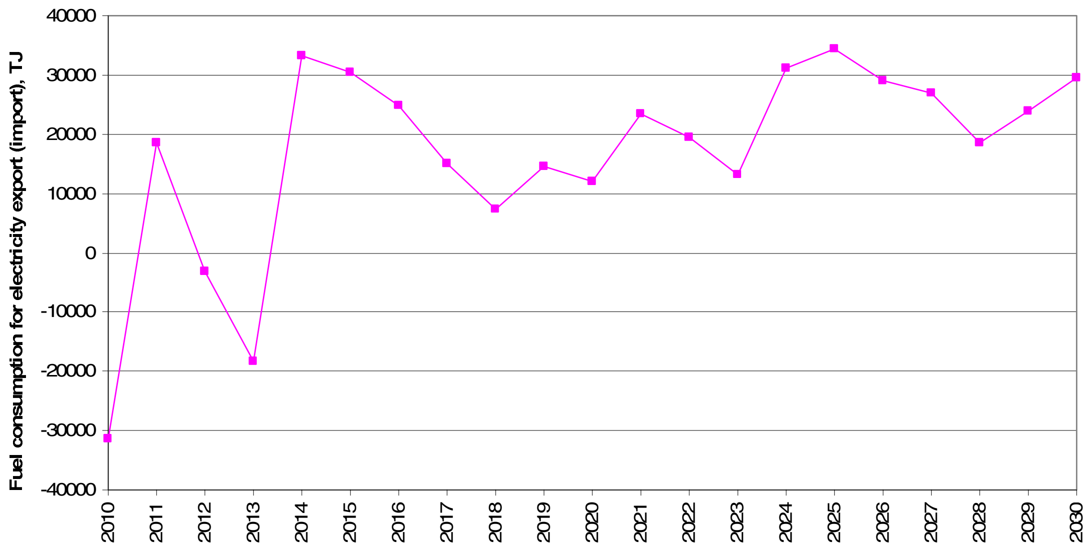

Figure 2.4 Total fuel consumption and fuel consumption for export.

2.4 Emission factors

2.4.1 NO_X

NO_X emission factors for centralised power plants are based on plant specific information from DONG Energy and Vattenfall. For other plants > 50 MW NO_x data are also plant specific. Both data sets refer to Nielsen et al. (2011). The emission factor for cement producer Aalborg Portland is based on plant specific data for the year 2010.

The NO_X emission factors for area sources are mainly based on the factors used for the 2009 inventory to the UNECE. Some of the emission factors used in the projection model are aggregated based on emission factors for different types of plants.

The following legislation that will result in decreasing emission factors has been incorporated:

'Bekendtgørelse om begrænsning af emission af nitrogenoxider, uforbrændte carbonhydrider og carbonmonooxid mv. fra motorer og turbiner' (Danish legislation on limiting NO_x, NMVOC and CO from engines and turbines, 1998) results in lower emission factors for biogas powered engines (implemented in 2010 fully incorporated in 2013). The current NO_x emission factor is however below the future limit. The emission limit for gas oil powered engines and turbines only applies to plants installed from 2006 and the emission factors have been included from 2016 onwards.

'Bekendtgørelse om begrænsning af visse luftforurenende emissioner fra store fyringsanlæg' (Danish legislation on limitting air pollution from large combustion plants, 2003) results in a lower emission factor for large natural gas powered boilers from 2008. Both the future and historic emission factor have been updated according to the lower emission factor.

'Luftvejledningen' (2001) results in a lower emission factor for small natural gas powered boilers (not residential, 120 kW – 50 MW). The emission limit value for new plants has been applied for 2020 onwards[1].

Some of the emission limits in the EU directive on industrial emissions are below the current emission factors.

- District heating plants > 100MW combusting coal: The current emission factor is above the limit in the Directive. However, the consumption of coal in district heating plants (without electricity production) was very low in 2009 and the energy projection does not include any consumption.
- Residual oil > 50 MW combusting residual oil: The current emission factor is above the future limit. However, all NO_x data for large plants are plant specific and the emission factor has not been applied in the projection.
- Combustion of biomass in plants > 50MW: The 2009 emission factor is above the future emission limit. However, the plant specific emission factors for most plants are below the future limit. The emission limit value for wood and straw has been applied for 2020-2030 for public power producing plants included as point sources. Other plants are in general below 50MW.
- Combustion of natural gas in boilers > 50MW: The 2009 emission factor is above the future emission limit. The emission limit value for natural gas has been applied for 2020-2030 for the public power producing plants included as point sources. Other plants are in general below 50MW.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations (Nielsen et al., 2011).

2.4.2 SO_2

SO_2 emission factors for centralised power plants are based on fuel specific emission factors 2009 that have been estimated based on plant specific data from DONG Energy and Vattenfall. The emission factors for cement production is an implied emission factor based on 2009 emission data.

[1] The 2009 emission factor for boilers in non-industrial plants is almost identical to the emission limit for new plants and thus this emission factor have been applied for the whole time-series.

In general SO_2 emission factors refer to the 2009 emission inventory. Emission factors for biogas have been aggregated based on emission factors for engines and other plants respectively. The emission factor for residual oil applied in power plants > 50 MW have been based on plant specific emission data 2009, assuming that all SO_2 is emitted from the consumption of coal and residual oil. This assumption gives a better estimate than applying the emission factor that is estimated for plants that only applies residual oil[2].

Some of the emission limits in the EU directive on industrial emissions are below the current emission factors.

- District heating plants > 50MW combusting coal: The current emission factor is above the future limit. However, the consumption of coal in district heating plants (without electricity production) was very low in 2009 and the energy projection does not include any consumption.
- Residual oil > 50 MW combusting residual oil: The current emission factor is above the future limit. However, the main part of residual oil combustion in large boilers takes place as secondary fuel in combination with another main fuel. Thus, the emission factor for residual oil might continue to be above the future emission limit for liquid fuels.

There is no other legislation in effect at the moment that will reduce the SO_2 emission further.

References to and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations (Nielsen et al., 2011).

2.4.3 NMVOC

The emission factors for NMVOC are mainly based on the 2009 emission inventory. Some emission factors have been aggregated for several plant types. For residential wood combustion a decreasing time-series have been estimated based on the gradual implementation of units with improved technology.

Implementation of current legislation will not significantly reduce the NMVOC emission further.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations. (Nielsen et al., 2011).

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

The emission factors for PM are mainly based on the 2009 emission inventory. Some emission factors have been aggregated for several plant types. For residential wood combustion decreasing time-series have been estimated based on the gradual implementation of units with improved technology.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations (Nielsen et al., 2011).

[2] Most residual oil applied in power plants is combusted in plants with another primary fuel.

2.4.5 NH_3

Stationary combustion is only a small source category for NH_3 emission. The emission factors for NH_3 all refer to the 2009 emission inventory. The NH_3 emission is only estimated for waste incineration and residential combustion of coal, coke, wood and straw.

References for and the assumptions behind the historic emission factors can be seen in Denmark's annual reporting to the United Nations (Nielsen et al., 2011).

Residential wood combustion

The inventory for wood combustion in residential plants distinguishes between four different types of stoves (old, new, modern and eco-stoves), fireplaces and old and new boilers with and without accumulation tank.

The projection of emissions from residential wood consumption has been made using the following assumptions:

- Constant number of wood stoves and boilers
- Replacement of 25000 wood stoves annually
- Replacement of 5 % of wood boilers annually. 80 % of new boilers assumed to be automatic
- 90 % of the new stoves is assumed to be modern eco-stoves (Svanemærkede)
- Until 2020 the assumption is that 60 % of the replaced stoves are from the category "old" while 30 % falls in the category "new"
- From 2020 the assumption is that the majority of replacements will happen in the category "new", as it is assumed that a few number of old stoves will remain

The replacement of old technologies with new technologies results in a decreasing aggregated emission factor for NMVOC and particulate matter, which causes the emissions from residential wood combustion to decrease substantially from 2010 to 2030.

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.

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

2.5.1 NO_X

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

The total NO_X emission decreases from 2010 to 2025 due to decreasing fuel consumption, with coal experiencing the largest fall in consumption. The projected decrease in emission from CHP plants and residential plants is counteracted by increasing emissions from energy consumption from oil and gas extraction and the agricultural sector. The increase in this sector is caused by a projected increase in fuel consumption.

The increase in NO_x emission from public power from 2009 to 2010 is caused by an increase in the projected fuel consumption. Overall a 10 % increase in fuel consumption is projected; the increase is highest for wood, straw, natural gas and biogas.

Table 2.12 NO_X emissions from stationary combustion (tonnes).

Sector	1990	1995	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	85 306	79 605	40 462	35 753	22 243	17 585	21 425	14 132	15 703	14 985	15 959
District heating plants	5 177	3 632	2 254	1 851	2 022	2 210	1 861	2 561	2 310	2 295	2 067
Petroleum refining plants	1 616	1 949	1 393	1 284	1 423	1 610	1 414	1 414	1 414	1 414	1 414
Oil/gas extraction	2 295	3 226	6 285	6 982	7 033	6 686	6 398	6 325	7 173	7 890	8 860
Commercial and institutional plants	1 188	1 514	1 304	1 104	831	812	682	646	634	697	839
Residential plants	4 939	5 213	4 723	5 815	6 226	6 192	6 197	5 673	5 544	5 420	5 252
Plants in agriculture, forestry and aquaculture	1 144	1 383	1 399	1 141	751	702	772	920	1 287	1 350	1 613
Combustion in industrial plants	13 277	14 678	14 922	12 324	9 228	6 764	5 359	5 361	4 934	4 938	5 083
Total	116 931	113 196	74 741	68 260	51 766	44 571	46 117	39 048	41 019	41 013	43 117

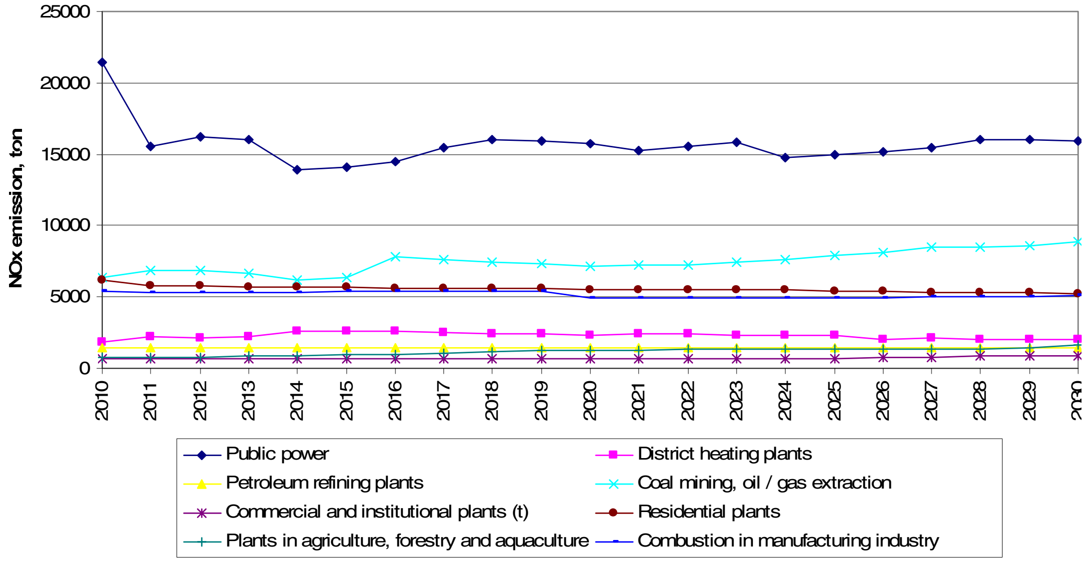

Figure 2.5 Projected NO_X emissions by sector.

NO_X emissions from gas turbines used in the offshore sector are projected to increase significantly. From 2010 to 2030 the emission increases by 38 % due to increasing fuel consumption. The high emission factor and the projected increase in fuel consumption mean that the offshore sector will account for about 21 % of the total NO_X emission from stationary combustion in 2030.

2.5.2 SO_2

The estimated SO_2 emission is shown in Table 2.14 and in Figure 2.6.

The total SO_2 emission remains relatively constant throughout the projection period. The emission from industrial plants is expected to increase due to increases in the projected use of coal and oil. The SO_2 emission from public power and heat production decreases due to decreasing consumption of coal and residual oil. For manufacturing industries the SO_2 emission increases due to slight increases in the projected consumption of fuels with higher SO_2 emission factor, e.g. coal, coke and residual oil.

Table 2.14 SO_2 emissions from stationary combustion (tonnes).

Sector	1990	1995	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	119 007	100 721	10 386	6 819	5 570	3 669	3 436	2 326	2 660	2 306	2 456
District heating plants	7 045	3 606	1 635	965	805	920	1 117	1 435	1 452	1 399	1 158
Petroleum refining plants	3 411	2 048	598	267	380	341	57	57	57	57	57
Oil/gas extraction	3	4	8	8	8	8	8	8	9	10	11
Commercial and institutional plants	1 874	779	356	283	191	130	62	59	57	84	144
Residential plants	6 415	2 324	1 522	1 653	1 633	1 636	1 576	1 434	1 412	1 390	1 340
Plants in agriculture, forestry and aquaculture	3 192	2 906	1 619	1 551	1 527	1 219	1 410	1 459	1 659	1 774	1 944
Combustion in industrial plants	16 296	11 520	7 421	6 230	4 534	2 847	4 983	5 037	5 268	5 450	5 962
Total	157 242	123 907	23 543	17 777	14 648	10 771	12 648	11 814	12 574	12 468	13 072

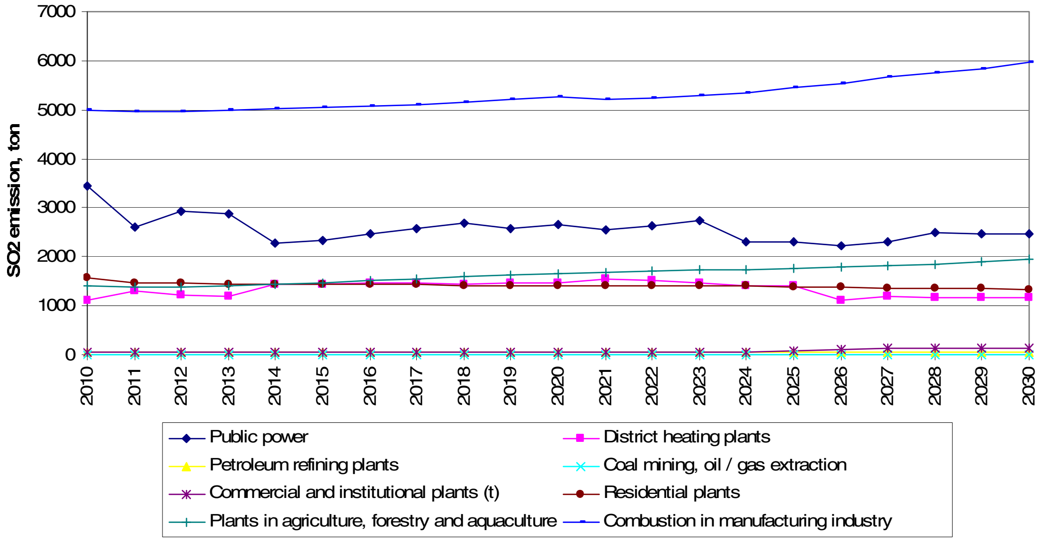

Figure 2.6 Projected SO_2 emissions by sector.

2.5.3 NMVOC

The estimated NMVOC emission is shown in Table 2.15 and in Figure 2.7.

The NMVOC emission increase projected from 2009 to 2010 for residential plants is caused by a change in methodology. This will be corrected for the next submission of annual inventories. From 2010 to 2030 the NMVOC emission is projected to decrease due to a lower emission factor for wood combustion in residential plants. This is due to the replacement of old wood stoves and boilers with new technologies that have considerably lower emissions. The residential sector will account for between 69 % and 83 % of the total NMVOC emission from stationary combustion plants.

Table 2.15 NMVOC emissions from stationary combustion (tonnes).

Sector	1990	1995	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	312	2 800	3 462	2 503	2 074	1 822	2 880	1 602	1 581	1 356	1 550
District heating plants	112	100	79	91	105	116	103	132	124	130	122
Petroleum refining plants	23	35	18	23	23	23	22	22	22	22	22
Oil/gas extraction	13	18	36	40	40	38	36	35	40	44	50
Commercial and institutional plants	125	219	305	266	285	275	258	235	226	228	240
Residential plants	12 098	11 615	11 521	15 745	17 904	16 245	17 652	14 258	11 421	9 204	7 132
Plants in agriculture, forestry and aquaculture	820	778	789	664	506	444	596	637	722	784	900
Combustion in industrial plants	1 131	702	545	439	357	295	315	311	312	310	322
Total	14 634	16 268	16 754	19 771	21 292	19 259	21 861	17 232	14 448	12 079	10 338

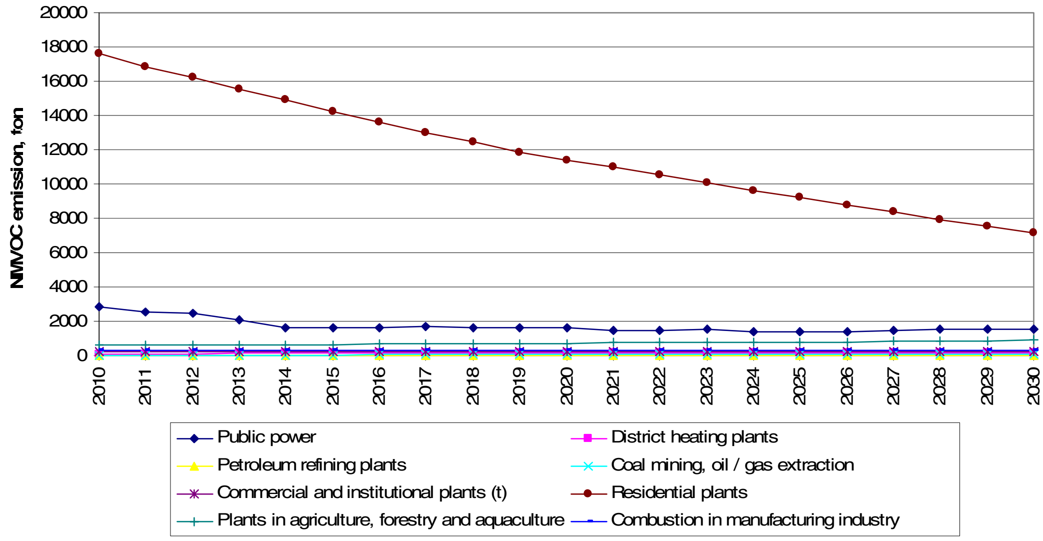

Figure 2.7 Projected NMVOC emissions by sectors.

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

The estimated TSP emission is shown in Table 2.16 and in Figure 2.8.

The TSP emission has increased in the historic years due to increasing wood combustion in residential plants. However, from 2010 to 2030 the TSP emission is expected to decrease due to a lower emission factor for wood combustion in residential plants. This is due to the replacement of old wood stoves and boilers with new technologies that have considerably lower emissions. The residential sector will account for between 77 % and 90 % of the total TSP emission from stationary combustion plants in the period 2010-2030 with the share being highest in the beginning of the period.

Table 2.16 TSP emissions from stationary combustion (tonnes).

Sector	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	834	946	652	634	808	623	747	767	890
District heating plants	187	222	248	269	262	299	291	288	279
Petroleum refining plants	144	111	119	113	81	81	81	81	81
Oil/gas extraction	3	3	3	3	3	3	3	3	4
Commercial and institutional plants	164	158	180	172	138	122	115	118	128
Residential plants	12 001	17 021	20 232	18 533	18 406	14 363	11 947	10 253	8 677
Plants in agriculture, forestry and aquaculture	465	413	399	389	585	645	730	810	915
Combustion in industrial plants	1090	851	818	498	288	293	297	298	313
Total	14 888	19 726	22 650	20 610	20 570	16 426	14 211	12 617	11 287

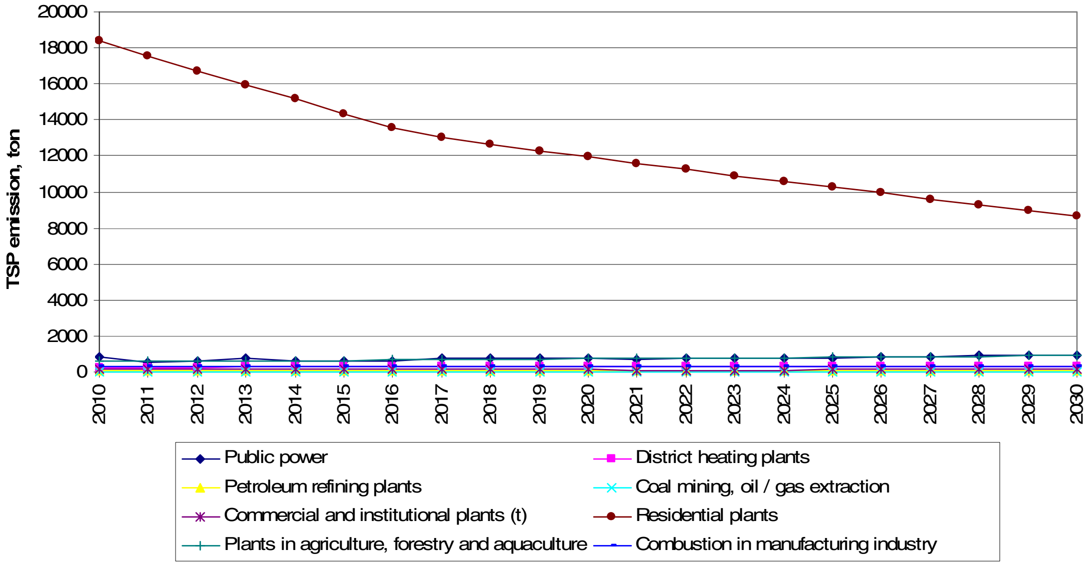

Figure 2.8 Projected TSP emissions distributed by sector.

The estimated PM_{10} emission is shown in Table 2.17 and in Figure 2.9.

The PM_{10} emission has increased in the historic years due to increasing wood combustion in residential plants. However, from 2010 to 2030 the PM_{10} emission is expected to decrease due to a lower emission factor for wood combustion in residential plants. This is due to the replacement of old wood stoves and boilers with new technologies that have considerably lower emissions. The residential sector will account for between 82 % and 92 % of the total PM_{10} emission from stationary combustion plants in the period 2010-2030 with the share being highest in the beginning of the period. This is the same trend as projected for TSP.

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

Sector	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	677	497	490	416	517	323	367	312	338
District heating plants	137	159	177	192	186	215	210	205	197
Petroleum refining plants	131	104	110	106	80	80	80	80	80
Oil/gas extraction	2	2	2	2	2	2	2	2	2
Commercial and institutional plants	158	151	175	170	136	120	113	116	126
Residential plants	11 421	16 217	19 265	17 629	17 525	13 682	11 386	9 776	8 278
Plants in agriculture, forestry and aquaculture	428	380	368	361	546	602	679	755	854
Combustion in industrial plants	800	557	581	359	218	221	225	225	236
Total	13 753	18 068	21 168	19 234	19 210	15 245	13 062	11 472	10 113

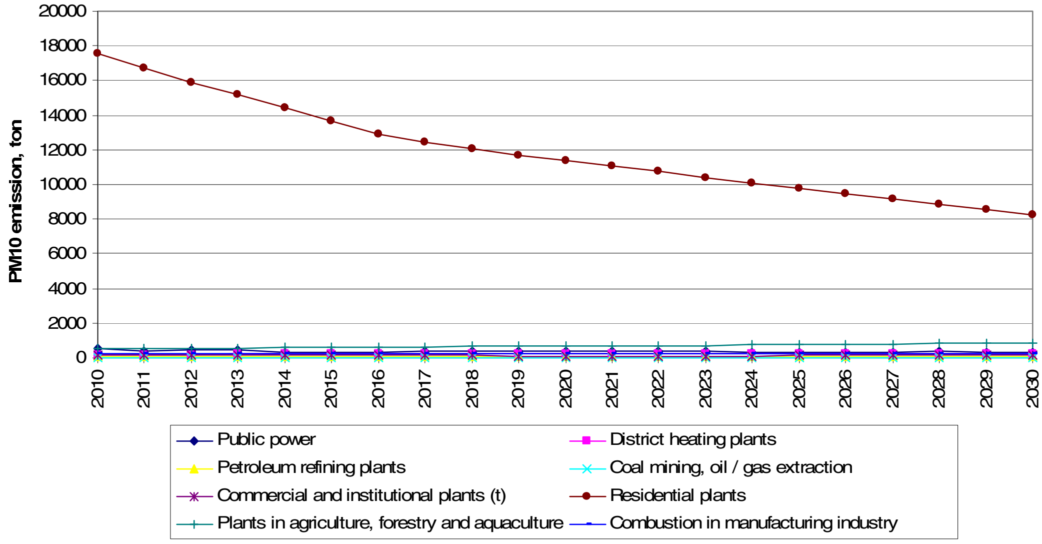

Figure 2.9 Projected PM_{10} emissions by sector.

The estimated $PM_{2.5}$ emission is shown in Table 2.18 and in Figure 2.10.

The $PM_{2.5}$ emission has increased in the historic years due to increasing wood combustion in residential plants. However, from 2010 to 2030 the $PM_{2.5}$ emission is expected to decrease due to a lower emission factor for wood combustion in residential plants. This is due to the replacement of old wood stoves and boilers with new technologies that have considerably lower emissions. The residential sector will account for between 84 % and 93 % of the total $PM_{2.5}$ emission from stationary combustion plants in the period 2010-2030 with the share being highest in the beginning of the period. 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 (tonnes).

Sector	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	573	402	405	343	413	254	286	238	255
District heating plants	110	127	142	154	149	174	170	165	158
Petroleum refining plants	124	101	105	103	80	80	80	80	80
Oil/gas extraction	1	1	1	1	1	1	1	2	2
Commercial and institutional plants	147	141	164	161	128	112	106	109	120
Residential plants	11 167	15 866	18 888	17 296	17 271	13 542	11 280	9675	8181
Plants in agriculture, forestry and aquaculture	396	351	339	335	511	563	636	707	801
Combustion in industrial plants	471	322	340	233	137	139	141	141	148
Total	12 989	17 310	20 385	18 625	18 690	14 866	12 701	11 117	9744

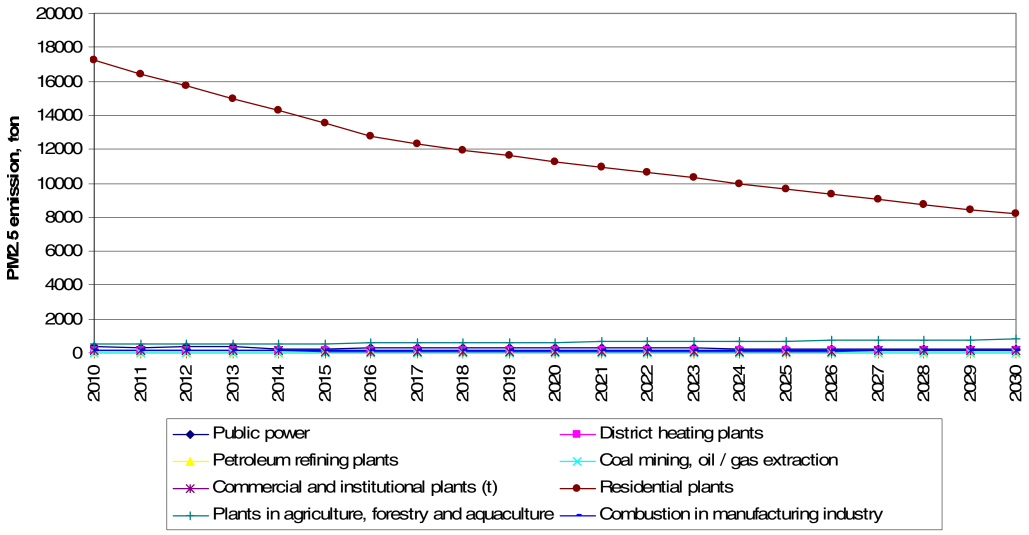

Figure 2.10 Projected $PM_{2.5}$ emissions by sector.

2.5.5 NH_3

The estimated NH_3 emission is shown in Table 2.19.

The total NH_3 emission remains relatively constant in the projection compared with recent historical years. The NH_3 emission from stationary combustion mainly originates from wood combustion in residential plants. Other small contributions are from waste incineration and coal and coke combustion in residential plants.

Table 2.19 NH_3 emissions from stationary combustion (tonne).

Sector	1990	1995	2000	2005	2008	2009	2010	2015	2020	2025	2030
Public power	0	3	6	8	9	8	11	12	12	13	13
District heating plants	0	0	1	1	1	1	0	0	0	0	0
Residential plants	67	76	85	143	183	178	181	181	179	178	178
Combustion in industrial plants	0	0	0	0	0	0	1	1	1	1	1
Total	67	79	93	152	193	187	193	193	192	192	192

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 2010-2030 model' and the overall construction of the database is shown in Figure 2.11.

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 2.20 the names and the content of the tables are listed.

Table 2.20 Tables in the 'Fremskrivning2010-2030 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 2.21.

Table 2.21 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 'Fremskrivning2010-2030 model' (Figure 2.12). Output from the summation queries is in the form of Excel Pivot tables.

Table 2.22 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.

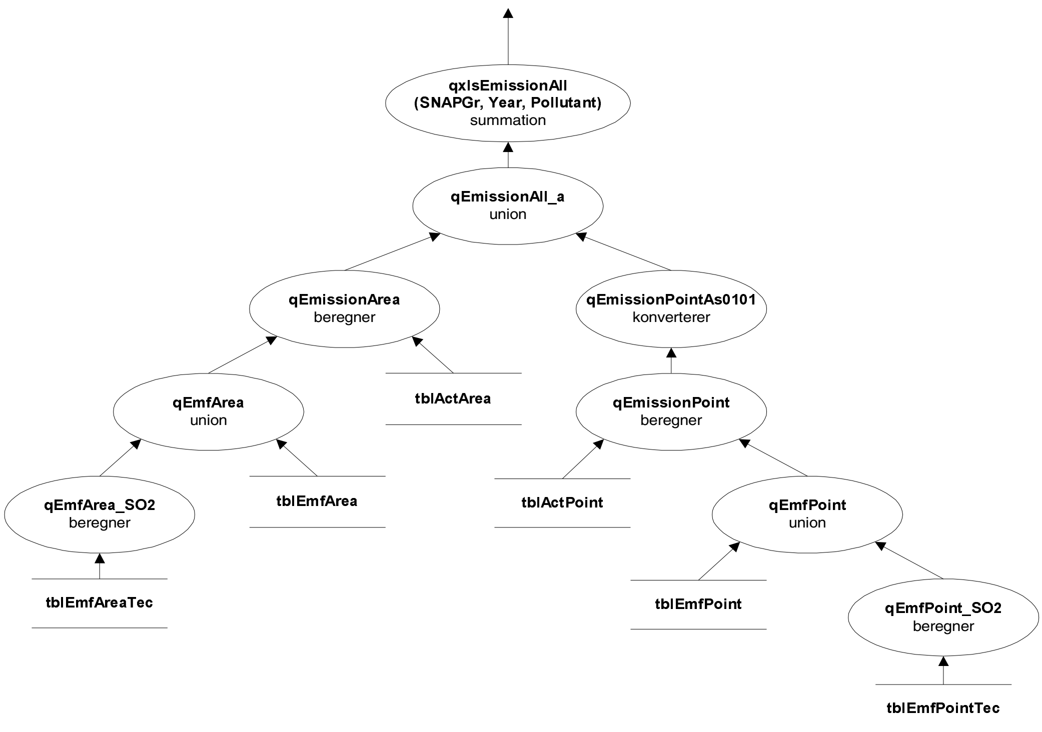

Figure 2.11 Overall construction of the database.

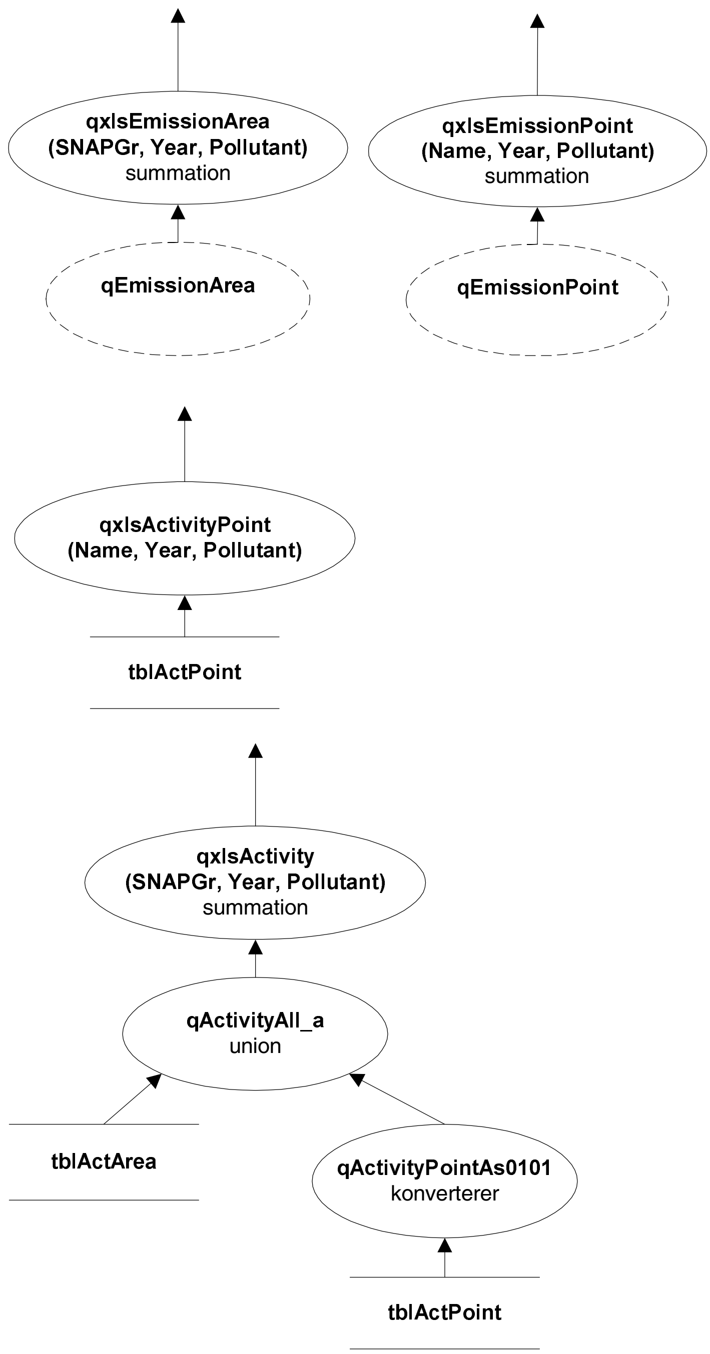

Figure 2.12 Summation queries.

2.7 References

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3 Oil and gas extraction (Fugitive emissions)

This chapter includes fugitive emissions in the CRF sector 1B. The sources included in the Danish emission inventory and in this projection are listed in Table 3.1. The following chapters describe the methodology, activity data, emission factors and emissions in the projection. For a detailed description of the emission inventory for the historical years, please refer to Plejdrup et al. (2009) and Nielsen et al. (2011).

Table 3.1 List of the SNAP codes and corresponding NFR sectors for the categories included in the Danish emission inventory model for greenhouse gases.

SNAP code	SNAP name	Activity	NFR sectors
04	Production processes		
040101	Petroleum products processing	Oil	1B2a iv
040103	Other	Oil	1B2a iv
05	Extraction and distribution of fossil fuels and geothermal energy		
050103	Storage of solid fuels	Coal	1B1a
050201	Land-based activities	Oil	1B2a i
050202 *	Off-shore activities	Oil	1B2a i
050503	Service stations		1B2a v
050601	Pipelines	Natural gas/Transmission	1B2b
050603	Distribution networks	Natural gas/Distribution	1B2b
050699	Venting in gas storage	Venting and flaring	1B2c
09	Waste treatment and disposal		
090203	Flaring in oil refinery	Venting and flaring	1B2c
090206	Flaring in oil and gas extraction	Venting and flaring	1B2c

*In the Danish inventory emissions from extraction of gas are united under “Extraction, 1st treatment and loading of liquid fossil fuels/off-shore activities” (1B2a i / SNAP 050202).

3.1 Methodology

The methodology for the emission projection correspond the methodology in the annual emission inventory, based on the EMEP/EEA Guidebook (EMEP/EEA, 2009).

Activity data are based on official forecasts by the Danish Energy Agency on fuel consumption (the energy consumption prognosis; DEA, 2011a) and on offshore production and flaring of oil and natural gas (the oil and gas prognosis; DEA, 2011b)).

Emission factors are either based on the EMEP/EEA guidelines (EMEP/EEA, 2009) or are country-specific based on data for one or more of the historical years.

3.2 Activity data

Activity data from the prognosis for the production of oil and gas (DEA, 2011b) is shown in Figure 3.1. The production is assumed to decrease over the projection years 2010-2030. The prognosis includes reserves (production at existing facilities and including justified projects for development), technological resources (estimated additional production due to new technological initiatives, e.g. CO_2 injection) and prospective resources (estimated production from new discoveries). Further, the production prognosis includes offshore flaring. The flaring amounts are expected to decrease over the projection period as well.

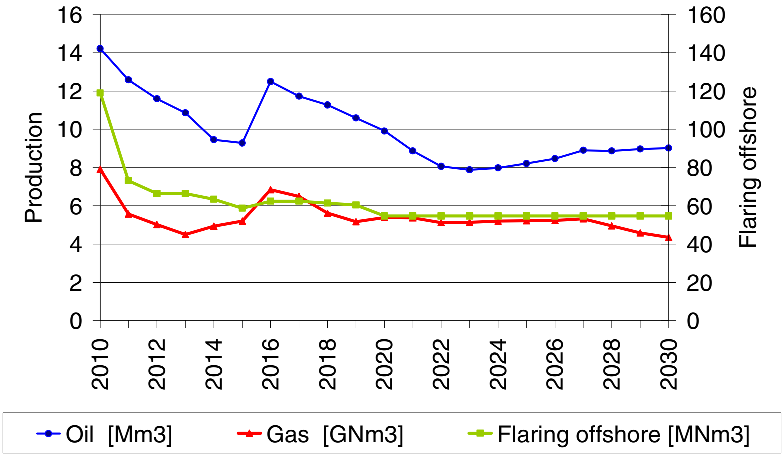

Figure 3.1 Prognosis for the production of oil and gas (DEA, 2011b).

The DEA prognosis of the production of oil and gas are used in projection of a number of sources: extraction of oil and natural gas, transport of oil in pipelines, onshore and offshore loading of ships and offshore flaring.

Data from the energy consumption prognosis by the DEA (2011a) are applied in the projection of fugitive emissions from fuels. Consumption of natural gas is used as proxy to project transmission of natural gas. Consumption of refinery gas and flaring in refineries are included in the energy consumption prognosis and applied in the projection. Summarised gasoline and coal consumptions for all sectors are used as proxy to project emissions from service stations and storage of solid fuels, respectively.

3.3 Emission factors

For a number of sources the emission factors are based on the EMEP/EEA Guidebook (EMEP/EEA, 2009), e.g. for exploration, loading of ships and offshore flaring in oil and natural gas exploration. For loading of ships the guidebook provide emission factors for different countries and the Norwegian emission factors are applied in the Danish projection. The NMVOC emission factor for onshore loading given in the guidebook has been reduced by 25 % in the projection years due to introduction of new vapour recovery unit (VRU) at the Danish raw oil terminal (Miljøcenter Odense, 2010). Further, a new degassing system has been built and taken into use in 2009. This has reduced the NMVOC emissions from oil tanks by 79 % (DONG Oil Pipe, 2010; Spectrasyne Ltd, 2010). The NMVOC emission factors for the projection years 2010 to 2030 are listed in Table 3.2.

The emission factor for service stations are the summarised factors for reloading of tanker trucks and refuelling of cars based on the EMEP/EEA Guidebook (EMEP/EEA, 2009). The NMVOC emission factor for service stations is listed in Table 3.2.

Table 3.1 NMVOC emission factors for 2010-2030.

	NMVOC	Unit	Ref.
Ships offshore	0.001	Fraction of loaded	EMEP/EEA, 2009
Ships onshore	0.00015	Fraction of loaded	EMEP/EEA, 2009 and Miljøcenter Odense, 2010
Oil tanks	10.4	Kg pr 103m3	DONG Energy, 2010 and Spectrasyne Ltd, 2010
Service stations	0.703	Kg NMVOC pr Mg gasoline	EMEP/EEA, 2009

Emission factors for offshore flaring are listed in Table 3.3. The SO_2 emissions are calculated using a country specific SO_2 emission factor for Danish natural gas. The emission factor for NO_x is based on a survey by the Danish Environmental Protection Agency (Danish EPA, 2008). Emission factors for NMVOC and PM are based on the EMEP/EEA Guidebook (2009). The NMVOC and PM emission factors are applied for flaring in refineries as well, while country specific emission factors are applied for SO_2 and NO_x.

Table 3.3 SO_2, NO_x and PM emission factors for offshore flaring.

Pollutant	Emission factor	Unit	Ref.
SO_2	0.014	g pr Nm^3	EMEP/EEA, 2009
NO_x	1.227	g pr Nm^3	Danish EPA, 2008
NMVOC	0.100	g pr Nm^3	EMEP/EEA, 2009
TSP	0.042	g pr Nm^3	EMEP/EEA, 2009
PM_{10}	0.042	g pr Nm^3	EMEP/EEA, 2009
$PM_{2.5}$	0.042	g pr Nm^3	EMEP/EEA, 2009

Emissions of particulate matter (PM) from coal storage are estimated by the emission factors used in the emission inventory of Poland (Olendry´nski et al., 2004). The emission factors are listed in Table 3.4.

Table 3.4 Emission factors for PM emissions from coal storage.

Emission factor	TSP	PM_{10}	$PM_{2.5}$
Emission factor, g pr Mg	150	60	6

3.4 Emissions

The majority of the emissions are calculated by the standard formula (Equation 3.1) while the emissions in the last historical year, given in e.g. annual reports, are adopted for the remaining sources.

Eq 3.1 $$E_{s,t} = AD_{s,t} * EF_{s,t}$$

where E is the emission, AD is the activity data and EF is the emission factor for the source s in the year t.

Table 3.5 includes NMVOC emission on sub-sector level for selected years from 1990 to 2030.

Table 3.5 NMVOC emissions, Mg.

	1990	1995	2000	2005	2009
Refining	3 667	5 885	4 983	3 550	3 994
Oil, onshore activities	2 404	3 913	6 183	6 994	3 818
Oil, offshore activities	236	330	4 476	3 873	2 018
Gasoline distribution	4 856	3 016	2 616	1 742	1 171
Gas, transmission and distribution	96	192	111	95	34
Venting and flaring	45	77	78	67	62
Total	11 304	13 413	18 447	16 321	11 097
Continued	2010	2015	2020	2025	2030
Refining	3 994	3 994	3 994	3 994	3 994
Oil, onshore activities	3 174	2 208	1 867	1 437	1 301
Oil, offshore activities	1 891	1 234	1 318	1 094	1 198
Gasoline distribution	1 111	1 018	980	980	1 016
Gas, transmission and distribution	34	29	26	23	22
Venting and flaring	67	61	61	61	61
Total	10 271	8 545	8 245	7 589	7 591

The total fugitive NMVOC emission is expected to decrease in the projection period, mainly due to technical improvements at the raw oil terminal leading to decreasing emissions from storage of oil in tanks and from loading of ships at the harbour terminal. Emissions from oil and natural gas exploration are also calculated to decrease in the projection years, as the exploration amounts are assumed to decrease. Emissions from refining are kept at the level of the latest historical year (2009) as the fugitive NMVOC emission may vary largely and unpredictably from year to year.

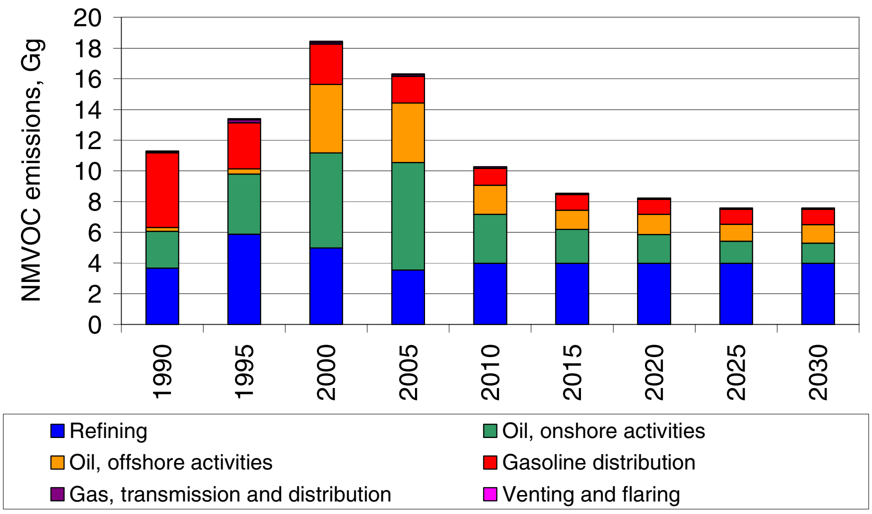

Figure 3.2 NMVOC emissions in selected historical years and projection years.

Emissions of SO_2 are assumed constant over the projection years in line with the assumption in the Energy projections by the Danish Energy Authority (DEA, 2011a), where the annual amount of crude oil for refining is assumed constant. Emissions of NO_x decrease from 2010 to 2020 as the offshore flaring amounts are assumed to decrease. From 2020 to 2030 offshore flaring amounts are assumed constant. PM emissions decrease in the projection period according to the decreasing coal consumption for power and heat production. Emissions of SO_2, NO_x and PM_{10} are shown in Figure 3.3.

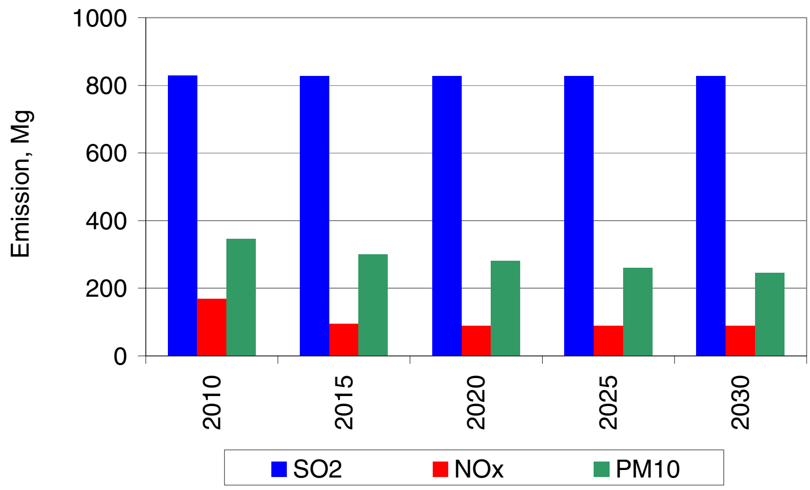

Figure 3.2 SO_2, NO_x and PM_{10} emissions in selected projection years.

3.5 Model description

The model for projection of fugitive emissions from fuels, the "Offshore model", is created in Microsoft Excel. Refineries and transmission/distribution of gas are treated in separate workbooks ("Refineries" and "Gas losses") and the results are imported to the workbook "Exploration" holding the remaining part of the fugitive sector. The names and content of the sub models are listed in Table 3.4.

Table 3.4 Tables in the 'Offshore model'.

Name	Content
Refineries	Activity data and emission factors for refining and flaring in refineries for the historical years 1990-2009.
Gas losses	Activity data and emission factors for transmission and distribution of natural gas and town gas for the historical years 1990-2009.
Exploration	Activity data and emission factors for extraction of oil and gas, loading of ships and storage in oil tanks at the oil terminal for the historical years 1990 to 2009 plus prognosis and projected activity rates and emission factors for the projection years 2010 to 2030. Further, the resulting emission the projection years for all sources in the fugitive sector are stored in the worksheet "Projected emissions".

Activity data, emission factors, calculations and results are kept in separate sheets in the sub models. Changing the data in the input data tables or emission factor tables will automatically update 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 CFR/NFR classification codes shown in Table 4.1 (mobile sources only).

Table 4.1 SNAP – CRF/NFR correspondence table for transport.

SNAP classification	CRF/NFR 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
0811 Commercial and institutional	1A4a Commercial and institutional

Military transport activities (land and air) refer to the CRF/NFR sector Other (1A5), while the Transport-Navigation sector (1A3d) comprises national sea transport (ship movements between two Danish ports) and recreational crafts (SNAP code 0803). For aviation, LTO (Landing and Take Off)[3] refers to the part of flying, which is below 1000 m. The working machinery and equipment in industry (SNAP code 0808) is grouped in Industry-Other (1A2f), while agricultural and forestry non-road machinery (SNAP codes 0806 and 0807) 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 detailed methodology is used to make annual estimates of the Danish emissions, as described in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2009). The actual calculations are made with a model using the European COPERT IV model methodology. The latter model approach is explained in (EMEP/EEA, 2009). In COPERT, fuel consumption and emission simulations can be made for operationally hot engines, taking into account gradually stricter emission standards and emis-

[3] A LTO cycle consists of the flying modes approach/descent, taxiing, take off and climb out. In principle the actual times-in-modes rely on the actual traffic circumstances, the airport configuration, and the aircraft type in question.

sion 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 traffic 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 consumption 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.

Vehicle classes	Fuel type	Engine size/weight
PC	Gasoline	< 1.4 l.
PC	Gasoline	1.4 – 2 l.
PC	Gasoline	> 2 l.
PC	Diesel	< 2 l.
PC	Diesel	> 2 l.
PC	LPG	
PC	2-stroke	
LDV	Gasoline	
LDV	Diesel	
LDV	LPG	
Trucks	Gasoline	
Trucks	Diesel	Diesel RT 3,5 - 7,5t
Trucks	Diesel	Diesel RT 7,5 - 12t
Trucks	Diesel	Diesel RT 12 - 14 t
Trucks	Diesel	Diesel RT 14 - 20t
Trucks	Diesel	Diesel RT 20 - 26t
Trucks	Diesel	Diesel RT 26 - 28t
Trucks	Diesel	Diesel RT 28 - 32t
Trucks	Diesel	Diesel RT >32t
Trucks	Diesel	Diesel TT/AT 14 - 20t
Trucks	Diesel	Diesel TT/AT 20 - 28t
Trucks	Diesel	Diesel TT/AT 28 - 34t
Trucks	Diesel	Diesel TT/AT 34 - 40t
Trucks	Diesel	Diesel TT/AT 40 - 50t
Trucks	Diesel	Diesel TT/AT 50 - 60t
Trucks	Diesel	Diesel TT/AT >60t
Buses	Gasoline	Gasoline Urban Buses
Buses	Diesel	Diesel Urban Buses <15t
Buses	Diesel	Diesel Urban Buses 15 - 18t
Buses	Diesel	Diesel Urban Buses >18t
Buses	Gasoline	Gasoline Coaches
Buses	Diesel	Diesel Coaches <15t
Buses	Diesel	Diesel Coaches 15 - 18t
Buses	Diesel	Diesel Coaches >18t
Mopeds	Gasoline	
Motorcycles	Gasoline	2 stroke
Motorcycles	Gasoline	< 250 cc.
Motorcycles	Gasoline	250 – 750 cc.
Motorcycles	Gasoline	> 750 cc.

To support the emission projections a project has been carried out by DTU Transport in order to provide fleet and annual mileage data for the vehicle categories present in COPERT IV (Jensen & Kveiborg, 2010). For information on the historical vehicle stock and annual mileage, please refer to Nielsen et al. (2011).

In addition new data prepared by DTU Transport for the Danish Infrastructure Commission has provided information of the total mileage driven by foreign trucks on Danish roads for rigid trucks and truck-trailer/articulated truck combinations, respectively. This mileage contribution has been added to the total mileage for Danish trucks on Danish roads, for trucks in comparable gross vehicle weight size classes. The data from DTU Transport was estimated for the years 1999-2009 and by using appropriate assumptions the mileage has been back-casted to 1985 and forecasted to 2030.

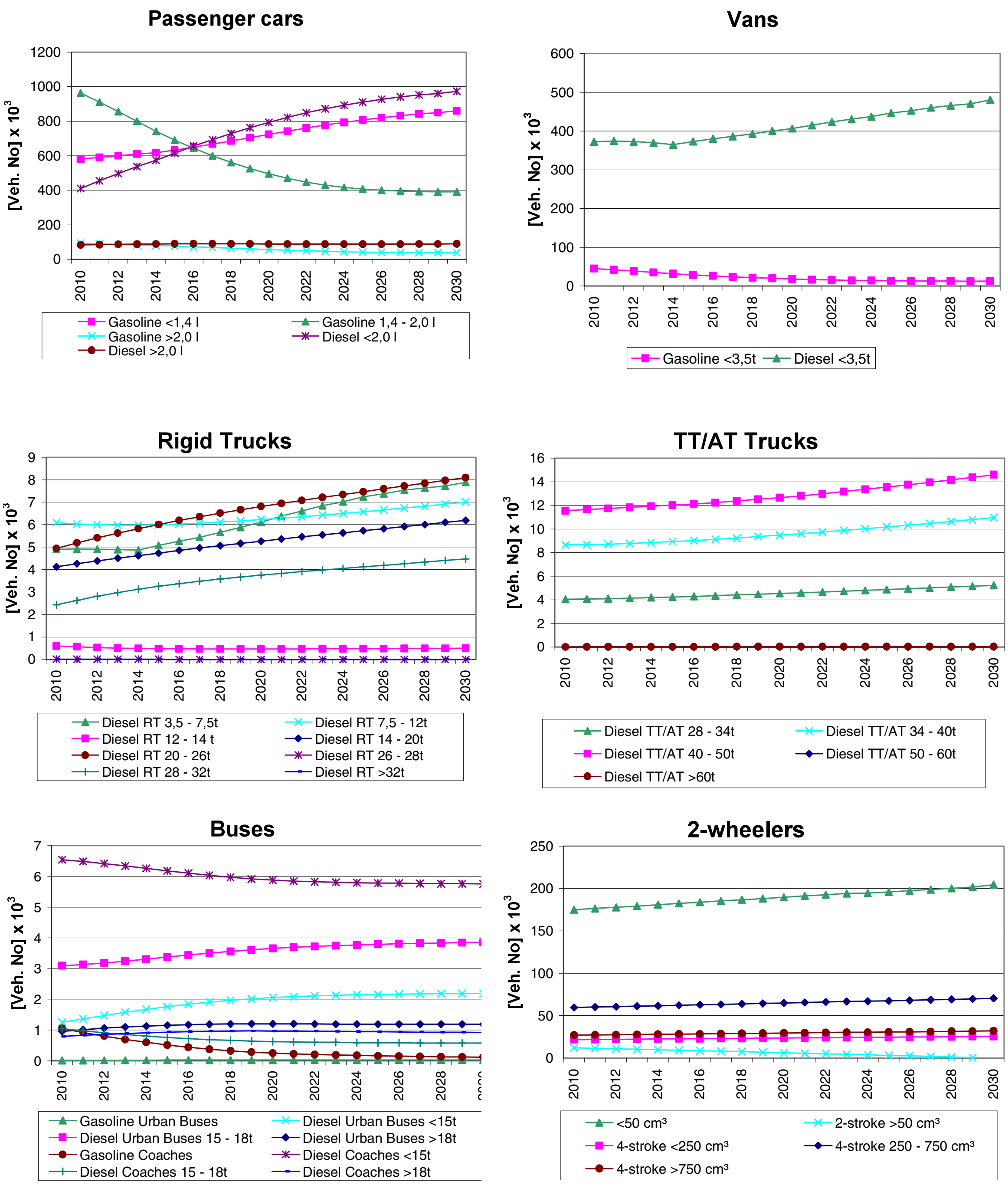

Figure 4.1 Number of vehicles in sub-classes from 2010-2030.

The vehicle numbers per sub-class are shown in Figure 6.1. The engine size differentiation is associated with some uncertainty.

The vehicle numbers are summed up in layers for each year (Figure 6.2) by using the correspondence between layers and first registration year:

$$N_{j,y} = \sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \qquad (1)$$

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

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

$$M_{j,y} = \frac{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \cdot M_{i,y}}{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y}} \qquad (2)$$

Vehicle numbers and weighted annual mileages per layer are shown in Annex 4.1 for 2010-2030. The trends in vehicle numbers per EU layer are also shown in Figure 4.2 for the 2010-2030 periods. The latter figure clearly shows how vehicles complying with the gradually stricter EU emission levels (EURO IV, V and VI) are introduced into the Danish motor fleet in the forecast period.

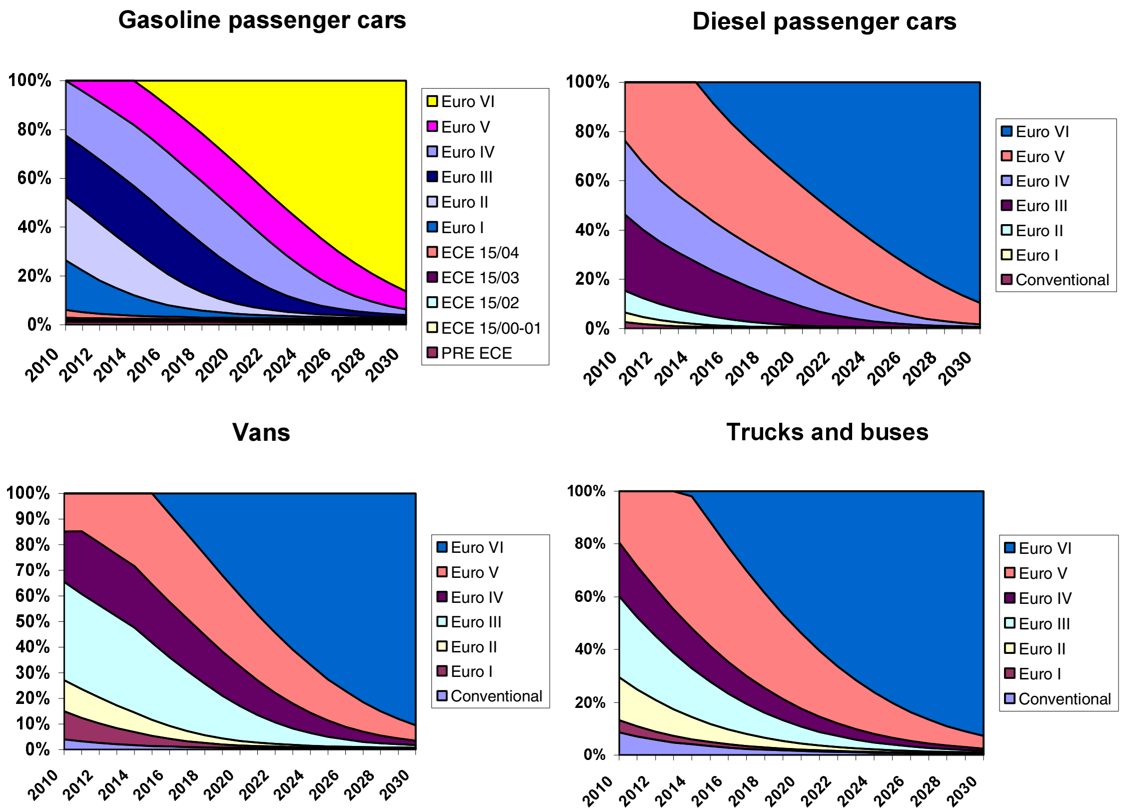

Figure 4.2 Layer distribution of vehicle numbers per vehicle type in 2010-2030.

4.1.2 Fuel and emission legislation

For Euro 1-4 passenger cars and light duty trucks, the chassis dynamometer test cycle used in the EU for emission approval is the NEDC (New European Driving Cycle), see Nørgaard and Hansen (2004). The test cycle is also used also for fuel consumption 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[4] (average speed: 19 km pr h). The second part of the test is the run-through of the EUDC (Extra Urban Driving Cycle) test driving segment, simulating the fuel consumption under rural and highway driving conditions. The driving length of EUDC is 7 km at an average speed of 63 km pr h. More information regarding the fuel measurement procedure can be found in the EU-directive 80/1268/EØF.

For NOx, VOC (NMVOC + CH_4), CO and PM, the emissions from road transport vehicles have to comply with the different EU directives listed in Table 4.3. The emission directives distinguish between three vehicle classes according to vehicle reference mass[5]: Passenger cars and light duty trucks (<1305 kg), light duty trucks (1305-1760 kg) and light duty trucks (>1760 kg).The specific emission limits are shown in Nielsen et al. (2011).

In practice, the emissions from vehicles in traffic are different 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 reflect only to a small degree the large variety of emission influencing factors in the real traffic situation, 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 derive from numerous emission measurements, using a broad range of real world driving patterns and a sufficient number of test vehicles. It is similarly important to have separate fuel consumption 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 pr 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 the Euro norm and exhaust gas after-treatment system installed. A description of the test cycles is given by Nørgaard and Hansen, 2004). Measurement results in g pr kWh from emission approval tests cannot be directly used for inventory work. Instead, emission factors used for national estimates must be transformed into g pr km, and derived from a sufficient number of measurements which represent 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

[4] For Euro 3 and on, the emission approval test procedure was slightly changed. The 40 s engine warm up phase before start of the urban driving cycle was removed.
[5] Reference mass: net vehicle weight + mass of fuel and other liquids + 100 kg.

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.

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

Vehicle category	Emission layer	EU directive	First reg. date
Passenger cars (gasoline)	PRE ECE		0
	ECE 15/00-01	70/220 - 74/290	1972[a]
	ECE 15/02	77/102	1981[b]
	ECE 15/03	78/665	1982[c]
	ECE 15/04	83/351	1987[d]
	Euro I	91/441	1.10.1990[e]
	Euro II	94/12	1.1.1997
	Euro III	98/69	1.1.2001
	Euro IV	98/69	1.1.2006
	Euro V	715/2007	1.1.2011
	Euro VI	715/2007	1.9.2015
Passenger cars (diesel and LPG)		Conventional	0
	ECE 15/04	83/351	1987[d]
	Euro I	91/441	1.10.1990[e]
	Euro II	94/12	1.1.1997
	Euro III	98/69	1.1.2001
	Euro IV	98/69	1.1.2006
	Euro V	715/2007	1.1.2011
	Euro VI	715/2007	1.9.2015
Light duty trucks (gasoline and diesel)		Conventional	0
	ECE 15/00-01	70/220 - 74/290	1972[a]
	ECE 15/02	77/102	1981[b]
	ECE 15/03	78/665	1982[c]
	ECE 15/04	83/351	1987[d]
	Euro I	93/59	1.10.1994
	Euro II	96/69	1.10.1998
	Euro III	98/69	1.1.2002
	Euro IV	98/69	1.1.2007
	Euro V	715/2007	1.1.2012
	Euro VI	715/2007	1.9.2016
Heavy duty vehicles	Euro 0	88/77	1.10.1990
	Euro I	91/542	1.10.1993
	Euro II	91/542	1.10.1996
	Euro III	1999/96	1.10.2001
	Euro IV	1999/96	1.10.2006
	Euro V	1999/96	1.10.2009
	Euro VI	595/2009	1.10.2014
Mopeds		Conventional	0
	Euro I	97/24	2000
	Euro II	2002/51	2004
Motor cycles		Conventional	0
	Euro I	97/24	2000
	Euro II	2002/51	2004
	Euro III	2002/51	2007

a,b,c,d: Expert judgement suggest that Danish vehicles enter into the traffic before EU directive first registration dates. The effective inventory starting years are a: 1970; b: 1979; c: 1981; d: 1986.

e: The directive came into force in Denmark in 1991 (EU starting year: 1993).

4.1.3 Fuel consumption and emission factors

Trip speed dependent base factors for fuel consumption and emissions are taken from the COPERT IV model, using trip speeds as shown in Table 4.2. The factors can be seen in Nielsen et al. (2011). The scientific basis for COPERT IV is fuel consumption figures and emission information from various European measurement programmes, transformed into trip speed dependent fuel consumption and emission factors for all vehicle categories and layers. Real measurement data lies behind the emission factors for passenger cars (Euro 4 and prior), vans (Euro 1 and prior), trucks and buses (Euro V and prior), and for mopeds and motorcycles (all technologies).

The emission factors for later engine technologies are produced by using reduction factors (see Winther, 2008b). The latter factors are determined by assessing the EU emission limits and the relevant emission approval test conditions for each vehicle type and Euro class.

In order to account for the trend towards more fuel efficient vehicles being sold in Denmark in the later years, fuel consumption factors for Euro 5 and Euro 6 passenger cars are estimated in the following way.

An aggregated CO_2 emission factor (g/km) for new registered passenger cars in the years 2009 and 2010 have been calculated from 1) type approval fuel economy values incorporated in the DTU Transport fleet and mileage statistics and 2) fuel specific CO_2 emission factors. The aggregated CO_2 emission factor for 2010 is used in combination with the overall EU target of 130 g CO_2/km in 2015 and 95 g CO_2/km in 2020 in order to calculate an interpolated time series of type approval related CO_2 emission factors for the years 2011-2014 and 2016-2019 (year specific CO_2 emission factors).

By assuming that the fuel type/engine size specific COPERT IV fuel consumption factors for Euro 4 cars relate to cars from 2009, Euro 5 and 6 COPERT corresponding factors for each fuel type/engine size combination are calculated for each year in the forecast period by multiplying the Euro 4 factor with the ratio between the year specific aggregated CO_2 emission factor and the aggregated CO_2 emission factor for 2009.

4.1.4 Fuel consumption and emission calculations

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

The calculation procedure for hot engines is to combine basis fuel consumption and emission factors, number of vehicles and annual mileage numbers (Annex 4.1) and mileage road type shares (from Table 4.2). For additional description of the hot and cold start calculations and fuel balance approach, please refer to Winther (2008b).

Fuel consumption and emission results per layer and vehicle type, respectively, are shown in Annex 4.2 from 2010-2030.

4.2 Other mobile sources

Other mobile sources are divided into several sub-sectors: sea transport, fishery, air traffic, railways, military, and working machinery and equipment in the sectors agriculture, forestry, industry and residential. The emission calculations are made using the detailed method as described in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2009) for air traffic, off-road working machinery and equipment, and ferries, while for the remaining sectors the simple method 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 2001-2009, 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 of total take-off numbers for other Danish airports is provided by CAA-DK. Fuel statistics for jet fuel consumption and aviation gasoline are obtained from the Danish energy projections (DEA, 2010).

Prior to emission calculations for historical years, the aircraft types are grouped into a smaller number of representative aircrafts for which fuel consumption 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 engine). Secondly, information on the aircraft Maximum Take-Off Mass (MTOM) and number of engines are used to append a representative aircraft to the aircraft type in question. A more thorough explanation is given in Winther (2001a, b).

No forecast of air traffic movements is available as input to the emission projection calculations. Instead, the official Danish national fuel consumption projections from the DEA (2011) are used as activity data in the projection period.

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 4.4 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, lawn-mowers, chainsaws, cultivators, shrub clearers, hedge cutters, trimmers, other

Please refer to the report by Winther et al. (2006) for detailed information of the number of different types of machines, their load factors, engine sizes and annual working hours.

National sea transport

An internal model is used to estimate the fuel consumption figures for national sea transport based on fleet activity estimates for regional ferries, local ferries, sailing activities between Denmark and Greenland/Faroe Islands, and other national sea transport (Winther, 2008a; Nielsen et al., 2011).

Further, the statistical fuel sales and energy projections from DEA for the sectors "National sea transport" and "Greenland/Faroe Islands maritime" are used as an input for the fuel balance made in the subsequent emission calculations.

Table 4.5 lists the most important domestic ferry routes in Denmark in the period 1990-2009. For these ferry routes and the years 1990-2005, the following detailed traffic and technical data have been gathered by Winther (2008a): Ferry name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip).

For 2006-2009, the above mentioned traffic and technical data for specific ferries have been provided by Kristensen (2010) in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus), by Hjortberg (2010) for Bornholmstrafikken (Køge-Rønne) and by Simonsen (2010) for Langelandstrafikken A/S (Tårs-Spodsbjerg). For Esbjerg-Torshavn and Hanstholm-Torshavn traffic and technical data have been provided by Dávastovu (2010) for Smyril Line.

Table 4.5 Ferry routes comprised in the Danish inventory.

Ferry service	Service period
Esbjerg-Torshavn	1990-1995, 2009
Halsskov-Knudshoved	1990-1999
Hanstholm-Torshavn	1991-1992, 1999-2009
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, international sea transport and fishery consists of fuel consumption information from DEA (2011). For international sea transport, the basis is expected fuel sold in Danish ports for vessels with a foreign destination, as prescribed by the IPCC guidelines. For all other mobile sectors, fuel consumption figures are given in Annex 4.3 for the years 2010-2030 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 pr 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 consumption) 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 4.6 Overview of EU emission directives relevant for diesel fuelled non road machinery.

Stage/Engine size [kW]	CO	VOC	NO_X	VOC+NO_X	PM [g pr kWh]	Diesel machinery EU directive	Implement. date Transient	Implement. date Constant	Tractors EU Directive	Tractors Implement. Date (dd/mm/yy)
Stage I										
37<=P<75	6.5	1.3	9.2	-	0.85	97/68	1/4 1999	-	2000/25	01.07.2001
Stage II										
130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	01.07.2002
75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		01.07.2003
37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		01.01.2004
18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		01.01.2002
Stage IIIA										
130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	01.01.2006
75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		01.01.2007
37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		01.01.2008
19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		01.01.2007
Stage IIIB										
130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	01.01.2011
75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		01.01.2012
56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		01.01.2012
37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		01.01.2013
Stage IV										
130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014		2005/13	01.01.2014
56<=P<130	5	0.19	0.4	-	0.025		1/10 2014			01.10.2014

Table 4.7 Overview of the EU emission directive 2002/88 for gasoline fuelled non road machinery.

	Category	Engine size [ccm]	CO [g pr kWh]	HC [g pr kWh]	NO_X [g pr kWh]	HC+NO_X [g pr kWh]	Implement. date
	Stage I						
Hand held	SH1	S<20	805	295	5.36	-	01.02.2005
	SH2	20=<S<50	805	241	5.36	-	01.02.2005
	SH3	50=<S	603	161	5.36	-	01.02.2005
Not hand held	SN3	100=<S<225	519	-	-	16.1	01.02.2005
	SN4	225=<S	519	-	-	13.4	01.02.2005
	Stage II						
Hand held	SH1	S<20	805	-	-	50	01.02.2008
	SH2	20=<S<50	805	-	-	50	01.02.2008
	SH3	50=<S	603	-	-	72	01.02.2009
Not hand held	SN1	S<66	610	-	-	50	01.02.2005
	SN2	66=<S<100	610	-	-	40	01.02.2005
	SN3	100=<S<225	610	-	-	16.1	01.02.2008
	SN4	225=<S	610	-	-	12.1	01.02.2007

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 4.8 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 4.9 Overview of the EU emission directive 2004/26 for railway locomotives and motor cars.

	Engine size [kW]		CO [g pr kWh]	HC [g pr kWh]	NO_X [g pr kWh]	HC+NO_X [g pr kWh]	PM [g pr kWh]	Impl. date
Locomotives	Stage IIIA							
	130<=P<560	RL A	3.5	-	-	4	0.2	01.01.2007
	560<P	RH A	3.5	0.5	6	-	0.2	01.01.2009
	2000<=P and piston displacement >= 5 l/cyl.	RH A	3.5	0.4	7.4	-	0.2	01.01.2009
	Stage IIIB	RB	3.5	-	-	4	0.025	01.01.2012
Motor cars	Stage IIIA							
	130<P	RC A	3.5	-	-	4	0.2	01.01.2006
	Stage IIIB							
	130<P	RC B	3.5	0.19	2	-	0.025	01.01.2012

For non-road machinery, the limit value of 50 ppm sulphur in diesel from 2005, given by EU directive 2003/17/EC, is lowered to 10 ppm from 2011.

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 underwent 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.

The NO_x emission limits for ship engines in relation to their rated engine speed (n) given in RPM (Revolutions Pr Minute) are the following:

- 17 g pr kWh, $n < 130$ RPM
- 45 x n-0.2 g pr kWh, $130 \leq n < 2000$ RPM
- 9.8 g pr kWh, $n \geq 2000$ RPM

Further, the Marine Environment Protection Committee (MEPC) of IMO has agreed amendments to MARPOL Annex VI in October 2008 in order to strengthen the emission standards for NO_x and the sulphur contents of heavy fuel oil used by ship engines.

For NO_x emission regulations, a three tiered approach is considered, which comprises the following:

- Tier I: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2000 and prior to 1 January 2011
- Tier II: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2011
- Tier III[6]: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2016

As for the existing NO_x emission limits, the new Tier I-III NO_x legislation values rely on the rated engine speeds. The emission limit equations are shown in Table 4.10.

Table 4.10 Tier I-III NOx emission limits for ship engines (amendments to MARPOL Annex VI).

	NO_x limit	RPM (n)
Tier I	17 g pr kWh	$n < 130$
	$45 \cdot n^{-0.2}$ g pr kWh	$130 \leq n < 2000$
	9,8 g pr kWh	$n \geq 2000$
Tier II	14.4 g pr kWh	$n < 130$
	$44 \cdot n^{-0.23}$ g pr kWh	$130 \leq n < 2000$
	7.7 g pr kWh	$n \geq 2000$
Tier III	3.4 g pr kWh	$n < 130$
	$9 \cdot n^{-0.2}$ g pr kWh	$130 \leq n < 2000$
	2 g pr kWh	$n \geq 2000$

The Tier I emission limits are identical with the existing emission limits from MARPOL Annex VI.

Also agreed by IMO in October 2008, the NO_x Tier I limits are to be applied for existing engines with a power output higher than 5000 kW and a displacement pr cylinder at or above 90 litres, installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000.

[6] For ships operating in a designated Emission Control Area. Outside a designated Emission Control Area, Tier II limits apply.

In relation to the sulphur content in heavy fuel and marine gas oil used by ship engines, Table 4.11 shows the current legislation in force, and the amendment of MARPOL Annex VI agreed by IMO in October 2008.

Table 4.11 Current legislation in relation to marine fuel quality.

Legislation		Heavy fuel oil		Gas oil	
		S- %	Impl. date (dd/mm/yy)	S- %	Impl. date (dd/mm/yy)
EU-directive 93/12		None		0.2[1]	01.10.1994
EU-directive 1999/32		None		0.2	01.01.2000
EU-directive 2005/33[2]	SECA - Baltic sea	1.5	11.08.2006	0.1	01.01.2008
	SECA - North sea	1.5	11.08.2007	0.1	01.01.2008
	Outside SECA's	None		0.1	01.01.2008
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		
MARPOL Annex VI amendments	SECA's	1	01.03.2010		
	SECA's	0.1	01.01.2015		
	Outside SECA's	3.5	01.01.2012		
	Outside SECA's	0.5	01.01.2020[3]		

[1] Sulphur content limit for fuel sold inside EU.

[2] From 1.1.2010 fuel with a sulphur content higher than 0.1 % must not be used in EU ports for ships at berth exceeding two hours.

[3] Subject to a feasibility review to be completed no later than 2018. If the conclusion of such a review becomes negative the effective date would default 1 January 2025.

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).

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 (EMEP/EEA, 2009).

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 Delvig (2010), 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 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, CO and TSP emission factors are derived from various European measurement programmes; see IFEU (2004) and Winther et al. (2006). 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 (EMEP/EEA, 2009).

For national sea transport and fisheries, the NO_x emission factors predominantly come from the engine manufacturer MAN Diesel, as a function of engine production year. The CO, VOC and TSP emission factors come from the Danish TEMA2000 emission model (Ministry of Transport, 2000), whereas the PM_{10} and $PM_{2.5}$ size fractions are obtained from MAN Diesel.

Specifically for the ferries used by Mols Linjen new NO_x, VO and CO emission factors are provided by Kristensen (2008), originating from measurement results by Hansen & Jensen (2004), Wismann (1999) and PHP (1996).

For ship engines VOC/CH_4 splits are taken from EMEP/EEA (2009).

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 2008a).

Non-road working machinery and recreational craft

Fuel consumption and emissions are calculated as the product of the number of engines, annual working hours, average rated engine size, load factors, and fuel consumption/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 (2008a).

National sea transport

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

The difference between the DEA statistical fuel sales and the sum of estimated fuel consumption in local and regional ferries and remaining national sea transport, 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 Nielsen et al. (2011) 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 consumption from the DEA.

For all other mobile sectors, emission results are given in Annex 4.3 for the years 2010-2030 in both CollectER and NFR formats.

4.3 Fuel consumption and emission results

An overview of the fuel consumption and emission results for all mobile sources in Denmark is given in Table 4.12.

Table 4.12 Summary table of fuel consumption and emissions for mobile sources in Denmark.

Component	Category	NFR code	2010	2015	2020	2025	2030
Energy	Industry	(1A2f)	14,8	14,8	14,5	14,5	14,4
	Civil Aviation	(1A3a)	2,1	2,3	2,6	2,7	2,5
	Road	(1A3b)	163,1	172,4	174,6	182,6	195,1
	Railways	(1A3c)	3,1	3,1	3,1	3,1	3,1
	Navigation	(1A3d)	8,0	7,9	7,9	7,9	7,7
	Commercial/Institutional	(1A4a)	2,4	2,3	2,3	2,3	2,3
	Residential	(1A4b)	0,9	0,8	0,8	0,8	0,8
	Ag./for./fish.	(1A4c)	25,1	25,9	26,4	27,0	27,4
	Military	(1A5)	2,2	2,2	2,2	2,2	2,2
	Navigation int.	(1A3d)	19,7	19,7	19,7	19,7	19,7
	Civil Aviation int.	(1A3a)	33,4	38,4	43,9	45,4	42,5
SO_2	Industry	(1A2f)	32	6	6	6	6
	Civil Aviation	(1A3a)	47	52	60	62	58
	Road	(1A3b)	75	74	75	79	84
	Railways	(1A3c)	1	1	1	1	1
	Navigation	(1A3d)	1369	360	360	360	352
	Commercial/Institutional	(1A4a)	1	1	1	1	1
	Residential	(1A4b)	0	0	0	0	0
	Ag./for./fish.	(1A4c)	392	361	362	362	370
	Military	(1A5)	3	3	3	3	3
	Navigation int.	(1A3d)	5130	941	941	941	941
	Civil Aviation int.	(1A3a)	767	883	1008	1044	978
NO_x	Industry	(1A2f)	8874	7068	5410	4543	4426
	Civil Aviation	(1A3a)	642	712	814	843	789
	Road	(1A3b)	42624	31290	17318	12339	11076
	Railways	(1A3c)	2483	1881	1280	1280	1280
	Navigation	(1A3d)	9564	9500	8769	8005	6056
	Commercial/Institutional	(1A4a)	217	219	219	219	219
	Residential	(1A4b)	87	92	93	93	93
	Ag./for./fish.	(1A4c)	20312	16612	10937	6784	4630
	Military	(1A5)	664	537	417	371	355
	Navigation int.	(1A3d)	36150	36295	31782	26522	21048
	Civil Aviation int.	(1A3a)	8398	9666	11041	11434	10707

Continued							
NH_3	Industry	(1A2f)	3	3	3	3	3
	Civil Aviation	(1A3a)	0	0	0	0	0
	Road	(1A3b)	1463	1017	834	912	1028
	Railways	(1A3c)	1	1	1	1	1
	Navigation	(1A3d)	0	0	0	0	0
	Commercial/Institutional	(1A4a)	0	0	0	0	0
	Residential	(1A4b)	0	0	0	0	0
	Ag./for./fish.	(1A4c)	4	4	4	4	4
	Military	(1A5)	1	1	1	1	1
	Navigation int.	(1A3d)	0	0	0	0	0
	Civil Aviation int.	(1A3a)	0	0	0	0	0
NMVOC	Industry	(1A2f)	1204	993	840	802	782
	Civil Aviation	(1A3a)	35	39	45	46	43
	Road	(1A3b)	13564	10831	9893	9828	9720
	Railways	(1A3c)	159	84	9	9	9
	Navigation	(1A3d)	937	745	739	741	727
	Commercial/Institutional	(1A4a)	4423	3598	3598	3598	3598
	Residential	(1A4b)	2032	1801	1716	1716	1716
	Ag./for./fish.	(1A4c)	2345	1932	1780	1719	1660
	Military	(1A5)	53	47	46	46	46
	Navigation int.	(1A3d)	1174	1213	1245	1266	1273
	Civil Aviation int.	(1A3a)	461	530	606	627	587
TSP	Industry	(1A2f)	713	532	350	303	284
	Civil Aviation	(1A3a)	2	3	3	3	3
	Road	(1A3b)	1405	933	564	424	398
	Road non exhaust	(1A3b)	2438	2677	2892	3266	3638
	Railways	(1A3c)	77	39	1	1	1
	Navigation	(1A3d)	305	237	231	231	227
	Commercial/Institutional	(1A4a)	67	67	67	67	67
	Residential	(1A4b)	14	15	15	15	15
	Ag./for./fish.	(1A4c)	935	619	404	327	279
	Military	(1A5)	15	9	6	4	4
	Navigation int.	(1A3d)	638	433	433	433	433
	Civil Aviation int.	(1A3a)	39	45	51	53	49
PM_{10}	Industry	(1A2f)	713	532	350	303	284
	Civil Aviation	(1A3a)	2	3	3	3	3
	Road	(1A3b)	1405	933	564	424	398
	Road non exhaust	(1A3b)	1573	1724	1861	2099	2335
	Railways	(1A3c)	77	39	1	1	1
	Navigation	(1A3d)	303	236	229	229	225
	Commercial/Institutional	(1A4a)	67	67	67	67	67
	Residential	(1A4b)	14	15	15	15	15
	Ag./for./fish.	(1A4c)	934	617	402	326	277
	Military	(1A5)	15	9	6	4	4
	Navigation int.	(1A3d)	631	429	429	429	429
	Civil Aviation int.	(1A3a)	39	45	51	53	49
$PM_{2.5}$	Industry	(1A2f)	713	532	350	303	284
	Civil Aviation	(1A3a)	2	3	3	3	3
	Road	(1A3b)	1405	933	564	424	398
	Road non exhaust	(1A3b)	853	936	1011	1141	1271
	Railways	(1A3c)	77	39	1	1	1
	Navigation	(1A3d)	302	235	228	228	225
	Commercial/Institutional	(1A4a)	67	67	67	67	67
	Residential	(1A4b)	14	15	15	15	15

Continued

Ag./for./fish.	(1A4c)	933	617	402	325	276
Military	(1A5)	15	9	6	4	4
Navigation int.	(1A3d)	628	427	427	427	427
Civil Aviation int.	(1A3a)	39	45	51	53	49

4.3.1 Road transport

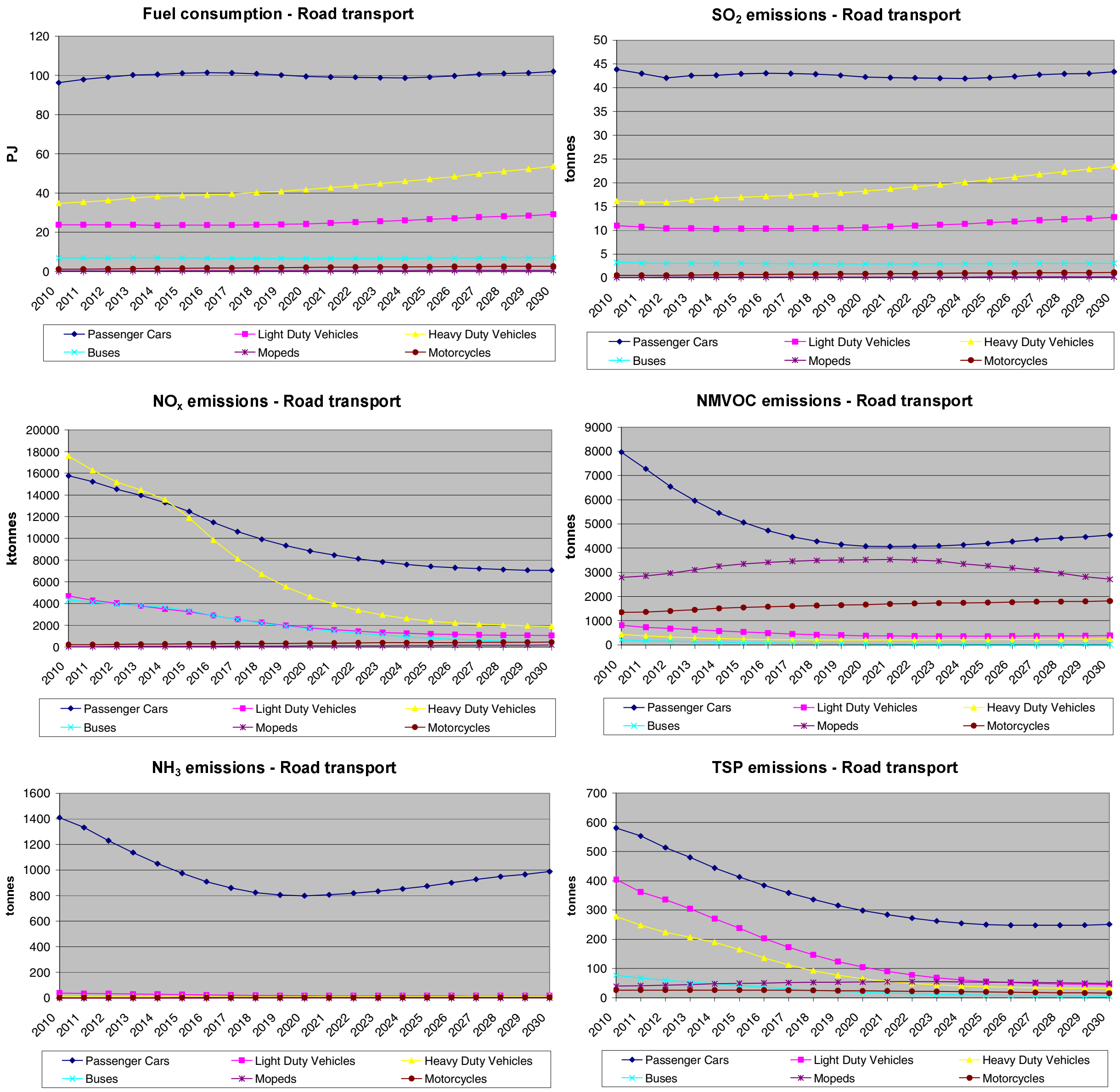

Figure 4.3 Fuel consumption, NO_X, SO_2, NMVOC, NH_3 and TSP ($PM_{2.5}$) emissions from 2010-2030 for road traffic.

Total fuel consumption for road traffic is projected to increase by 20 % from 2010 to 2030. Passenger cars will have the largest fuel consumption share, followed by heavy duty vehicles, light duty vehicles, buses and two-wheelers in decreasing order. 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 consumption.

The majority of the NMVOC and NH_3 emission from road transport comes from gasoline passenger cars (Figure 4.3). The NMVOC emission is projected to decrease around 50 % from 2010 to 2020 for passenger cars is explained by the introduction of gradually more efficient catalytic converters for gasoline cars. From 2020 onwards the emissions increase proportionally with the total mileage for these vehicles. The same explanation goes for the 43 % reduction of NH_3 emissions for passenger cars calculated from 2010 to 2020, and the emission increase from 2020 onwards.

The NO_X emission for road transport declines by 74 % from 2010 to 2030, and for all vehicle categories significant emission reductions are expected due to the gradual strengthening of the EU emission standards over the course of the forecast period. The introduction of the Euro VI emission standard for heavy duty trucks becomes very significant from 2015+, and the emissions from this vehicle category are projected to drop significantly throughout the remaining forecast period.

In terms of TSP, the total emission is expected to decline by 72 % from 2010 to 2030, and emission reductions are calculated for all vehicle types except for mopeds. 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

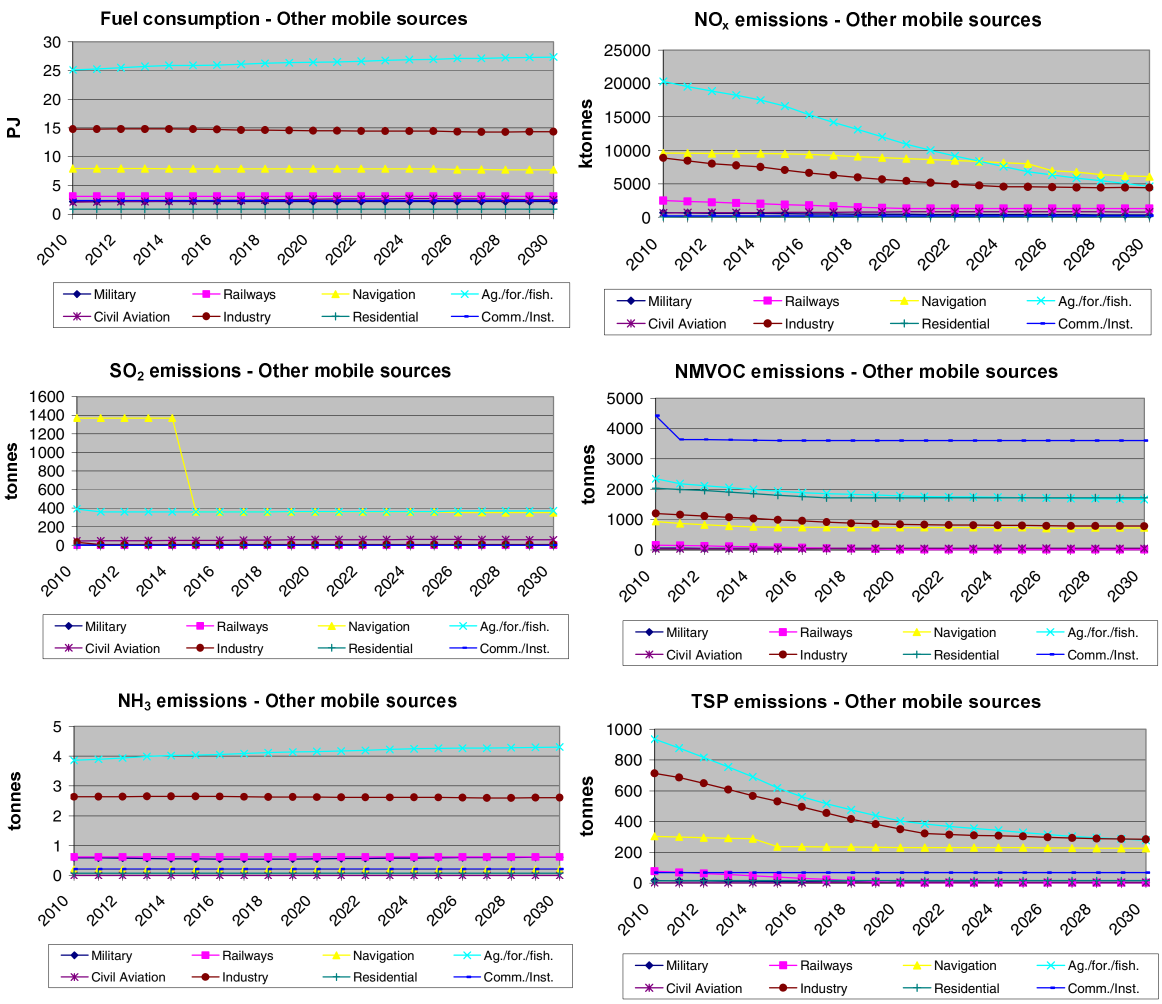

Figure 4.4 Fuel consumption, NO_X, SO_2, NMVOC, NH_3 and TSP emissions from 2010-2030 for other mobile sources.

The development in fuel consumption is forecasted by the DEA (2011). Agriculture/forestry/fisheries (1A4c) is by far the largest fuel consumption source followed by Industry (1A2f) and Navigation (1A3d). Rather small fuel consumption totals are noted for Railways (1A3c), Domestic aviation (1A3a), Military (1A5), Residential (1A4b) and Commercial/Institutional (1A4a).

For air traffic, the DEA energy projections assume a similar growth rate for domestic and international flights corresponding to a fuel consumption increase of 27 % from 2010 to 2030. The marginal fuel consumption 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 reduction of the sulphur content in heavy fuel oil used in the Baltic and North Sea SO_x emission control areas (SECAs) will have a visible emission impact from 2015. 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 (commercial/institutional, 1A4a). The same gasoline equipment types give considerable contributions for residential (1A4b). For railways (1A3c), domestic air traffic and military only small emission contributions are noted. The projected NMVOC emission reductions for commercial/institutional (1A4a), residential (1A4b) and navigation (1A3d) are due to the introduction of the cleaner gasoline stage II emission technology (commercial/-institutional, 1A4a; 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 will cause the NMVOC emission to decrease during the forecast period.

For TSP, agriculture/forestry/fisheries (1A4c) is the largest emission sources followed by industry (1A2f) and navigation (1A3d). The emissions from agriculture/forestry/fisheries (1A4c) are projected to decrease more rapidly than the emissions from industry and navigation, 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 for heavy fuel oil in 2015 bring visible TSP emission reductions in this year.

For NO_X, this shift in relative emission importance between agriculture/forestry/fisheries (1A4c) and navigation (1A3d) is projected to take place from 2024, since for navigation (1A3d) no strengthening in emission standards is in place during the forecast period. For agriculture/forestry/fisheries (1A4c) as well as for industry (1A2f) and railways (1A3c), substantial emission improvements are expected due to the penetration of cleaner engine technologies, in compliance with future emission standards.

4.4 Model structure for Danish transport models

More detailed emission models for transport comprising road transport, air traffic, non road machinery and sea transport have been developed by DCE. The emission models are organised in databases. They comprise input data tables for fleet and operational data, and fuel sale figures; and output fuel consumption and emission results are obtained through linked database queries.

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5 Agriculture

The projection of air pollutants from the agricultural sector includes emission of ammonia (NH_3), particulate matter (PM) given as TSP, PM_{10} and $PM_{2.5}$, non-methane volatile organic compounds (NMVOC) and other compounds related to field burning of agricultural residues as sulphur dioxide (SO_2) and nitrogen oxide (NO_X). Table 5.1 shows the agricultural contribution of emissions to the national total in 2009. The main part of the NH_3 emission (96 %) is related to the agricultural sector, while the agricultural contribution of TSP and PM_{10} are 29 % and 19 %, respectively. The agricultural part of the total emissions of $PM_{2.5}$, NMVOC, SO_X and NO_X is low (<1 % - 5 %).

Table 5.1 Emission 2009, reported to UNECE in January 2011.

	NH_3	TSP	PM_{10}	$PM_{2.5}$	NMVOC	SO_X	NO_X
National total, Gg	77	39	31	24	95	15	132
Agricultural total, Gg	74	11	6	1	2	<1	<1
Agricultural part, %	96	29	19	5	2	<1	<1

Assessment of projected emissions of air pollutants from the agricultural sector is regularly updated in line with new scientific knowledge. Therefore, some deviations are apparent in comparison with the projection scenarios published in previous reports. Present projection of NH_3 emissions replaces the latest basic projection published in NERI Technical Report No. 655 (Illerup et al., 2008).

The expectations to the future conditions for the agricultural production includes establishment of NH_3 reducing technologies. Increasing demands to reduce unintended environmental effects of the livestock production has lead to more legislation in connection with approvals and establishment of new animal houses (LBK No. 1486 of 04/12/2009, BEK No. 294 of 31/03/2009 and BEK No. 1695 of 19/12/2006). Another important initiative is the Agreement on Green Growth (2009 and 2010). Some of the objectives formulated in the agreement are included in the projection as establishment of non-cultivated area along streams and decrease of N-loss to the aquatic environment. Among other issues which are included in the projection, can be mentioned; expected change in livestock production, change in N-excretion, improved production efficiency for dairy cattle and sows, and expected change in housing system.

5.1 Projection of agricultural emission 2010-2030

This projection covers the latest official Danish reporting and includes emission until 2009. Thus, the projection comprises an assessment of the emissions from the agricultural sector from 2010 to 2030 – the emissions during 2020-2030 are, however for several of the variables, retained at the same level.

The emissions from the agricultural sector particularly depend on the livestock production and the size of the agricultural area. From 2009 to 2030 the total agricultural area is expected to decrease by 210 000 hectare, which corresponds to 8 % reduction. The livestock production is mainly dominated by two livestock categories – cattle and pigs. The total cattle production depends on production of dairy cattle and the milk quota, while the total pig production are affected by the production of sows and the production efficiency.

The projection assumes a decrease in the number of dairy cattle from 2009 to 2013 as a consequence of maintained milk quota and improvement of the average milk yield. From 2013 to 2030 the number of dairy cattle will be relatively constant, which would increase the total milk production as a consequence of increasing milk yield. Despite the economic crises, the production of pigs is expected to continue. However, production of fattening pigs and sows are assumed to be fixed nearly at the same level as in 2009, while the production of weaners is assumed to increase. The trend of increasing export of living pigs, dominated by weaners, is expected to continue and is assumed to reach a level in 2020 at 12 million produced weaners.

Based on these assumptions the result of the projection is shown in Table 5.2.

The emission of NO_X, SO_2 and NMVOC expects to be reduced from 2009 to 2030 by 2-7 % caused by a fall in the agricultural area.

Table 5.2 Historical agricultural emission of air pollutants 1990 – 2009 and expected development 2010-2030.

Gg	NFR category	1990	2000	2005	2009	2010	2015	2020	2025	2030
NH_3	4B - Animal husbandry and manure management	88.12	73.06	67.90	61.53	61.57	54.68	49.67	48.44	47.10
	4D - Crop production and agricultural soils									
	Synthetic fertiliser	8.68	5.07	4.27	4.72	4.73	4.27	4.12	3.92	3.71
	N-excretion on pasture range and paddock	2.92	2.92	2.21	2.00	1.93	1.86	1.86	1.87	1.88
	4F - Field burning of agricultural wastes	0.08	0.11	0.13	0.12	0.12	0.12	0.12	0.12	0.12
	4G - Agricultural other									
	Sewage sludge used as fertiliser	0.07	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Growing crops	5.92	5.21	5.34	5.41	5.24	5.06	4.99	4.91	4.83
	NH_3 treated straw	10.19	2.47	0.26	0	0	0	0	0	0
	Agricultural total	115.98	88.92	80.15	73.83	73.65	66.05	60.82	59.31	57.69
	Agricultural total included in NEC (National Emission Ceiling)	99.87	81.24	74.56	68.42	68.41	60.99	55.83	54.40	52.86
TSP	4B - Animal husbandry and manure management	11.22	12.50	12.83	11.25	10.74	10.78	10.89	11.07	11.25
	4F - Field burning of agricultural wastes	0.19	0.27	0.31	0.29	0.29	0.29	0.29	0.29	0.29
	Agricultural total	11.40	12.77	13.14	11.55	11.03	11.07	11.17	11.36	11.54
PM_{10}	4B - Animal husbandry and manure management	5.52	6.32	6.38	5.68	5.35	5.37	5.42	5.50	5.59
	4F - Field burning of agricultural wastes	0.19	0.27	0.31	0.29	0.29	0.29	0.29	0.29	0.29
	Agricultural total	5.71	6.59	6.69	5.97	5.64	5.66	5.71	5.79	5.87
$PM_{2.5}$	4B - Animal husbandry and manure management	1.41	1.41	1.34	1.22	1.14	1.13	1.15	1.16	1.17
	4F - Field burning of agricultural wastes	0.18	0.26	0.29	0.28	0.27	0.27	0.27	0.27	0.27
	Agricultural total	1.59	1.67	1.63	1.50	1.41	1.41	1.42	1.43	1.44
NMVOC	4F - Field burning of agricultural wastes	0.20	0.30	0.33	0.32	0.31	0.31	0.31	0.31	0.31
	4G - Agricultural other									
	Growing crops	1.90	1.68	1.77	1.88	1.87	1.81	1.79	1.76	1.73
	Agricultural total	2.10	1.98	2.10	2.20	2.19	2.13	2.10	2.07	2.04
	Agricultural total included in NEC (National Emission Ceiling)	0.20	0.30	0.33	0.32	0.31	0.31	0.31	0.31	0.31
NO_x	4F - Field burning of agricultural wastes	0.08	0.11	0.13	0.12	0.12	0.12	0.12	0.12	0.12
SO_2	4F - Field burning of agricultural wastes	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01

5.1.1 NH_3 emission

The projection shows an expected decrease of NH_3 emission from 73.83 Gg in 2009 to 60.82 Gg in 2020 and further reduction is expected to 57.69 Gg NH_3 in 2030. This corresponds to a 22 % reduction from 2009-2030. The main reduction takes place from 2009 to 2020 (18 %).

Regarding the National Emission Ceiling Directive, the NH_3 emission from growing crops is not taken into account. Thus, the estimated agricultural contribution of NH_3 emission is 68.41 Gg in 2010 and 55.83 Gg in 2020.

The emission of NH_3 from 1990 to 2009 is reduced by 36%. This decrease is a result of an active national environmental policy with focus on reduction of nitrogen loss to the aquatic environment, which also has lead to decrease of the NH_3 emission. The main part of the decreased NH_3 is related to a reduction in emission from manure management – and especially a reduction, which took place in connection with storage of manure and manure applied on soil (Figure 5.1).

In the projection the agricultural NH_3 emission is estimated to be reduced by 22 % from 2009 to 2030. Figure 5.2 shows the projected NH_3 emission from livestock production, which contributes 90 % of the total emission reduction (data see Appendix 5.A.1). The future decrease is expected to occur in emission from animal housing as a consequence of implementation of NH_3 reducing technology. Another reason for the decrease is reduction of emissions from manure applied to soil as a result of legislation, which demands the farmers to inject slurry applied on grass fields or fields without vegetation.

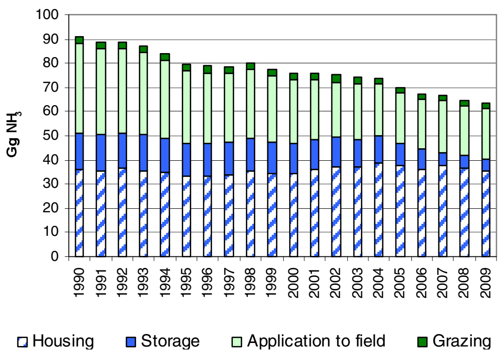

Figure 5.1 NH_3 emissions from manure management, 1990 to 2009.

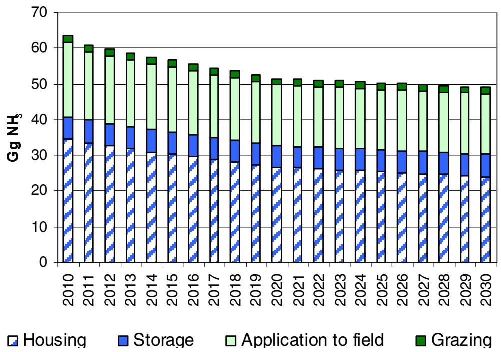

Figure 5.2 Projected NH_3 emissions from manure management, 2010 to 2030.

The projected NH_3 emission from the livestock production 2010 - 2030 distributed on the main livestock categories are represented in Figure 5.3 (data see Appendix 5.A.2). The total emission from the livestock production is reduced by 14.55 Gg NH_3, the main part owing to reduction from the pig production. This can mainly be explained by a combination of a high emission reduction rate from NH_3 reducing technology and decreasing N-excretion.

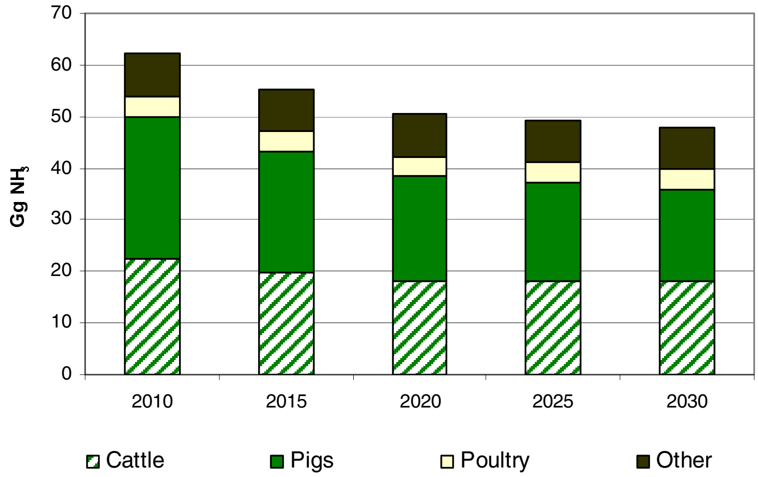

Figure 5.3 NH_3 emissions from manure management, 2010 to 2030.

5.1.2 PM emission

The PM emission in 2009 from manure management is estimated at 11.26 Gg TSP reported in the latest official Danish emission inventory in January 2011. Unfortunately, this calculation has been affected by an error in the database, where all agricultural emissions are estimated. This has to be corrected in the next emission inventory and will result in reduced PM emission of approximately 5 %, which means about 10.84 Gg in 2009. The same trend concerns the emissions of PM_{10} and $PM_{2.5}$. The consequence of this correction means that the PM emission estimated in the projection is expected to increase from 10.84 Gg TSP in 2009 to 11.25 Gg TSP in 2030, corresponding to 4 %. This rise is a result of increasing pig production. The PM emission from cattle will be nearly unaltered from 2009 to 2030. The fall in number of cattle result in increasing PM emission from 2009 to 2013. However, this will be compensated by an increased emission from 2013 to 2020 as a consequence of change in housing systems against slurry based systems, which has a higher emission factor compared to housing systems with solid manure.

Table 5.3 Emission of TSP 2009 and estimated emission 2010 – 2030.

TSP, Gg	2009 reported	2009 corrected	2010	2015	2020	2025	2030
Total	11.25	10.84	10.74	10.79	10.89	11.07	11.25
Cattle	1.36	1.21	1.21	1.18	1.20	1.20	1.20
Pigs	8.76	8.51	8.58	8.66	8.74	8.92	9.10
Other	1.14	1.11	0.95	0.95	0.95	0.95	0.95

5.2 Assumptions

The calculation of the agricultural emission is based on an Integrated Database model for Agricultural emissions (IDA). The model covers all aspects of the agricultural inputs and estimates both greenhouse gases and air pollutants.

The calculation of air pollutant emissions are in accordance with the methodologies described in the EMEP/EEA Guidebook (EMEP/EEA, 2009). National values and methodology are used when available.

Concerning the national total emission, the agricultural contribution of NH_3 and PM is particularly important. Figure 5.4 represents the different NH_3

emission sources in 2009 and 87 % of the emission is related to the livestock production (incl. grazing animal). The remaining part derives from use of synthetic fertiliser and growing crops. Figure 5.5 shows the NH_3 emission distributed on the main livestock categories in 2009 where emissions from pigs and cattle contribute 43 % and 36 %, respectively.

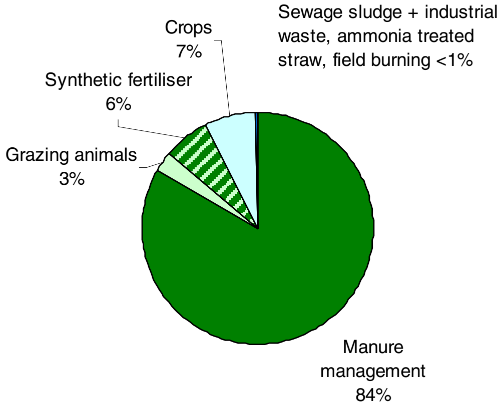

Figure 5.4 Emission of NH_3 in 2009 divided between sources.

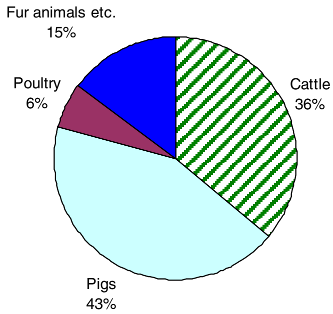

Figure 5.5 Emission of NH_3 in 2009 from manure management divided between animal categories.

Figure 5.6 shows the PM emission (TSP and PM_{10}) from manure management in 2009 distributed on the main livestock categories. The major part comes from the pig production.

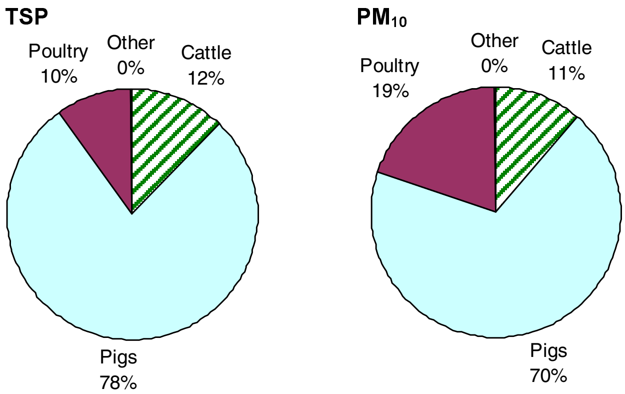

Figure 5.6 Emission of TSP and PM 10 in 2009 from manure management divided between animal categories.

It has to be mentioned that the present Danish PM emission inventory only includes emission from manure management. The EMEP/EEA Guidebook (EMEP/EEA, 2009) furthermore prescribes emissions from crop production and agricultural soils, which primarily cover emission from use of tractors and other machinery for field operations. The projection does not include the PM emissions from crop production or agricultural soils.

The emission inventory of air pollutants mainly depended on the livestock production and especially the production of cattle and pigs. Therefore, assumptions focus on changes related to the cattle and pig production. The remaining livestock categories have a minor effect of the total emission, why the populations in 2010 – 2030 are kept at a level equivalent to production conditions in 2009. The assumptions are described in Section 5.3.

Other important variables included in the projection, e.g. changes in the agricultural area, use of synthetic fertiliser and assumptions related to the field burning of agricultural waste, are described in Section 5.4.

5.3 The livestock production

This section gives a short overview of the assumptions for the production of cattle and pigs. These assumptions are discussed with the Knowledge Centre for Agriculture.

The following variables have significant effects on the total emission: number of produced animal, changes in N-excretion, changes in housing system and implementation of NH_3 reducing technologies.

5.3.1 Cattle

The total cattle production mainly depends on the production of dairy cattle and thus decided by the average milk yield and the total milk production. The milk production is fixed by the EU milk quota scheme until 2013. After 2013 the EU milk quota system will be replaced by free competition on the world market. It is uncertain how Danish milk production will adjust to the competition, but due to the highly intensive production form it is expected that the number of dairy cattle could be maintained.

Therefore, a total milk production is assumed to stay at the same level until 2013 which means a fall in number of dairy cattle due to an increase in the milk yield. From 2013 to 2030 the number of dairy cattle is kept constant, while an assumption of increased efficiency will give rise to an increased milk production.

Dairy cattle

In the projection continuing increase in production efficiency is expected in the form of improved milk yield per cow. From 2009 to 2020 an increase of milk yield of 150 kg milk per cow per year is assumed, which is based on an assessment provided by the Knowledge Centre for Agriculture (Aaes, 2010). From 2020 to 2030, the increasing trend is expected to ease off and is assumed to be 80 kg milk per cow per year. The increase in the efficiency gives an average milk yield of approximately 10 900 kg milk per cow per year in 2020 and 11 700 kg milk per cow per year in 2030.

Table 5.4 Number of dairy cattle and milk yield - figures used in the projection to 2030.

	2009	2015	2020	2025	2030
Dairy cattle, 1000 unit	563	525	525	525	525
Milk yield, kg milk per cow per year	9 100	10 100	10 900	11 300	11 700

N-excretion – dairy cattle

The N-excretion is closely related to the milk yield level. According to the default values, N-excretion in 2009 for dairy cattle (large breed) was 140.9 kg N per animal per year (Poulsen, 2010). An increase of the milk yield to 10 900 kg milk per cow in 2020 is assumed to result in an N-excretion of 144 kg N per animal per year (large breed) and 154 kg N per animal per year in 2030 based on an assessment provided by the Knowledge Centre for Agriculture (Aaes, 2010). The N-excretion for the years between 2009-2020 and 2020-2030 is estimated by interpolation.

It is assumed that the relationships between N ex Animal/N ex Housing and N ex Animal/N ex Storage are the same as in 2009. Table 5.5 shows the N-excretion figures used in the projection.

Table 5.5 N-excretion for dairy cows – figures used in the projection to 2030.

N-excretion dairy cattle	2009	2015	2020	2025	2030
	kg N per animal per year				
Large breed	140.6	142.4	143.6	148.9	154.2
Jersey	119.7	120.6	121.7	126.2	130.6

Non-dairy cattle

The production of non-dairy cattle is based on the number of dairy cattle. No significant change in the allocation of the subcategories of non-dairy cattle (heifers, bulls and suckling cattle), is expected until 2030. Thus, the changes in number of dairy cattle reflect the number of non-dairy cattle.

The historic normative data for N-excretion for all cattle subcategories shows few changes until 2005. From 2005 an increase in N-excretion for heifers, bulls and suckling cattle is observed. For the years 2007-2009 the N-excretion was constant. In the projection no significant changes in N-excretion is expected and therefore kept at the same level as in 2009.

Housing system - cattle

According to Statistics Denmark, the production of dairy cattle and heifer in 2009 is 563 000 dairy cows and 526 000 heifers. Around 80 % of the dairy cattle and 30 % of the heifers are estimated to be housed in housing systems with cubicles.

Changes in housing systems are assumed to lead towards phasing out both tethering and deep litter systems. All dairy cattle are expected to be housed in systems with cubicles in 2020, which means that all manure is handled as slurry. Same development is assumed for heifer, but extends over a longer period of time. All tethering housings are assumed to be replaced by housing system with cubicles in 2030, while around 15 % of the heifers are housed in deep litter systems.

5.3.2 Pigs

It is expected that the agricultural structural development towards larger farm units will contribute to additional growth in pig production. However, at the same time the development is strongly influenced by the present economic crises and stricter environmental regulations in e.g. Agreement of Green Growth (2009 and 2010), the Water Framework Directive and the Nitrate Directive. In the projection, the number of sows is assumed to remain at the same level as during the past four years, which corresponds to 1.1 million sows. However, the production of weaners and fattening pigs will increase as a consequence of production efficiency due to more produced weaners per sow.

Sows

During the period 1990-2009 a constant increase in the number of weaners per sow of 0.3 piglets per year in average was observed with no appreciable changes from year to year. In the projection this development rate is expected to continue until 2020. This is confirmed by the Knowledge Centre for Agriculture as a realistic estimate (Tybirk, 2011). A more conservative estimate of 0.1 piglets per sow per year is assumed for 2020-2030. This results in an average production of nearly 30 piglets per sow in 2030.

Weaners and fattening pigs

The number of sows and the production efficiency (number of produced weaners per sow) affects the production of weaners and fattening pigs. At the same time export data from Statistics Denmark shows a significant increase in export of weaners from 2004. This trend is expected to continue and thus the export is assumed to increase from 7 million weaners in 2009 to 12 million in 2020. This results in an increase in produced number of weaners from 28.5 million in 2010 to 31.8 in 2020 and 32.9 in 2030, which corresponds to an increase of 18 % from 2009 to 2030. As a consequence of the rising export of weaners, the production level of fattening pigs is assumed to be at the same level as in 2009.

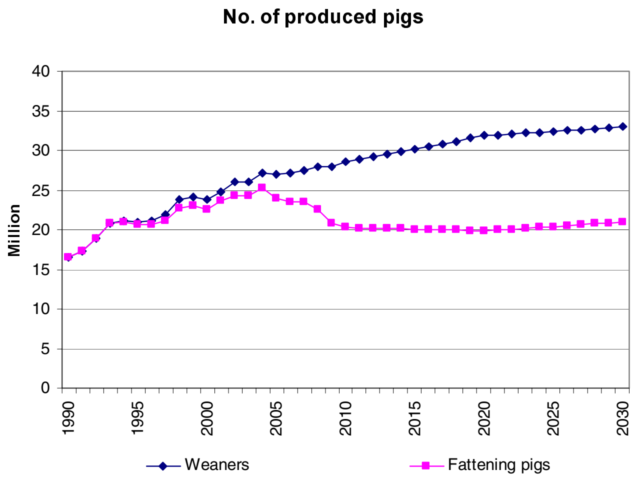

Figure 5.7 Number of produced weaners and fattening pigs.

Table 5.6 Number of produced sows, weaners and fattening pigs.

Pigs, million produced	2009	2015	2020	2025	2030
Sows	1.1	1.1	1.1	1.1	1.1
Weaners	27.9	30.2	31.8	32.4	32.9
Fattening pigs	20.9	20.0	19.8	20.4	20.9

Nearly 90 % of Danish pig meat is exported and the production is therefore closely related to the conditions at the export market. Thus, it could be interesting to compare the assumption in this projection with an estimate based on an economic model. In 2010 the Institute of Food and Resource Economics provided an estimate for the pig production in 2020 (Dubgaard et al., 2010) based on a model called "Agricultural Member State Modelling for the EU and Eastern European Countries" (AGMEMOD), which is based on world market prices of the most important agricultural products. The AGMEMOD predicts a pig production given in annual average population at 13.5 million in 2020 and this is consistent with the assumption in this projection, given that the number of produced pigs in the projection is converted to annual average population. However, the AGMEMOD is based on the 2007 situation and predict no significant changes in production from 2007-2020. But it has to be noted that the development in the years 2008 and 2009 shows a considerable decrease in the pig production (Statistics Denmark) as a result of the economic crises. AGMEMOD has not yet been tested with the latest population data and the question is how this will affect the development to 2020. It could indicate a potential scenario with a lower pig production.

Table 5.7 Number of pigs given as annual average production.

	2007	2008	2009	2020
AGMEMOD[1]	13.7	13.4	13.6	13.5
NERI, BF2011	13.7	12.7[2]	12.4[2]	13.5

[1] Dubgaard et al., 2010. Figure 2.2.3.

[2] Statistics Denmark.

N-excretion – pigs

Due to improvements of feed efficiency a decrease in nitrogen excretion is expected. The assumptions applied in the projection are based on results from research provided by the Faculty of Agricultural Science (DEPA, 2006).

According to the Ammonia report (DEPA, 2006) the N-excretion for sows in 2020 is expected to be 25.16 kg N per sow per year, which corresponds to 3 % reduction compared to 2009. For fattening pigs, N-excretion is expected to fall from 2.94 to 2.65 kg N per pig produced per year, which corresponds to a reduction of 10 %. For weaners an N-excretion at the same level as in 2009 is assumed.

In Table 5.8, the figures for N-excretion used in the projection are given.

Table 5.8 N-excretion for pigs – figures used in the projection to 2030.

N-excretion for pigs	2009	2015	2020	2025	2030
	kg N per pig per year				
Sows	25.97	25.53	25.16	25.16	25.16
Weaners	0.51	0.51	0.51	0.51	0.51
Fattening pigs	2.94	2.78	2.65	2.65	2.65

Housing system - pigs

In 2009, more than 50 % of the fattening pigs were housed in systems with fully slatted floor. In the projection is it assumed that these systems are phased out for fattening pigs in 2020. Also systems with solid floor and with deep layer of bedding are assumed to be phased out, and all fattening pigs are expected to be housed in systems with partially slatted or drained floor in 2020. For sows a phasing out of systems with fully slatted floor is expected as well, but over a longer period; all phased out in 2030. But for sows it is assumed that systems with deep layer of bedding will continue at almost the same level as in 2009.

5.3.3 Technology

In Denmark most of the environmental requirements due to the agricultural production have been focused on reducing nitrogen loss to the aquatic environment, protection of nitrogen exposed areas and reduction of the NH_3 emission. National and international decisions and agreements force the agricultural sector to further reduction.

For air pollutants the most important decisions, which can be considered as driving forces to implementation of further environmental requirements are; the national Agreement of Green Growth formulated in 2009 and followed up in 2010, the NEC Directive (Directive 2001/81/EC) and Danish Law on environmental approval of animal holdings (LBK No. 1486 of 04/12/2009 and BEK No. 294 of 31/03/2009).

Reducing technology is expected to take place in animal housing in future years. In the projection it is chosen to include the ammonia reducing effect of implementation of air cleaning and slurry acidification systems to adjust the pH value of the slurry. According to different technology suppliers these technologies seem to be the two most used systems. Furthermore, these technologies are described and the reduction effect is quantified in Best Available Techniques (BAT):

- BAT 1: Sulphuric acid treatment of slurry in housings for fattening pigs
- BAT 2: Sulphuric acid treatment of cattle slurry
- BAT 3: Air cleaning with acid

The main objective for both technologies is to reduce the emission of NH_3 along with a reduction in odour for the air cleaning.

In the projection, it has been decided to include the effects of emission reducing technologies for dairy cattle, heifers > ½ year, sows, fattening pigs and broilers, these being most important for total livestock production.

However, it has to be mentioned that other technologies can be brought into use in future years. In time with improved technology knowledge, other kind of technological initiatives could be relevant – e.g. technology with greater reduction potentials or technology, which could be implemented with lower economic or practical efforts.

Acidification of slurry

Acidification of slurry for pig slurry in housing systems with partially slatted floors is predicted to be able to reduce NH_3 evaporation in housings by 65-70 % (BAT 1). Acidification of slurry equipment for cattle slurry in housing systems with cubicles is predicted to be able to reduce NH_3 evaporation in housings by 50 % (BAT 2). In the projection, an average reduction factor of 60 % is used. Acidification of slurry will cause a greater proportion of the nitrogen in slurry to be retained in ammonium-form, which is far less volatile than NH_3. This means that NH_3 evaporation is also reduced for storage and for application of animal manure. Acidification of slurry is implemented in the projection for dairy cattle, heifers > ½ year, sows and fattening pigs.

Cleaning of air

Air cleaning in pig housings is, depending on the selected air cleaning system and capacity of the ventilation system, predicted to reduce the NH_3 evaporation by up to 90 % (90 % when assuming all air in the housing is cleaned) (BAT 3). In the projection an average reduction factor of 70 % is applied.

In housings for poultry air cleaning technologies are not yet implemented, but is under development and therefore this technology is included in the projection. The same reducing factor as for pigs is applied.

Estimation of technology

In Agreement of Green Growth a requirement of 30 % reduction of Nex Animal in 2020 is established, which is specified in Law on environmental approval of animal holdings (LBK No. 1486 of 04/12/2009 + BEK No. 294 of

31/03/2009). Part of the reduction is assumed to be achieved by improvements of feed efficiency and change in the distribution of housing types. For dairy cattle it is assumed that Nex housing is reduced by around 5 % by feed efficiency and distribution of housing types, and for fattening pigs the corresponding reduction is assumed to be 3 %. To achieve a total reduction of 30 % it is assumed that the remaining 25 % and 27 %, respectively, is reduced by implementation of NH_3 reducing technologies.

For cattle production one technology is included in the projection; acidification of slurry. This technology has an average reduction factor of 60 % and following it is estimated that this technology has been implemented for around 40 % of the dairy cattle in 2020. For the pig production two technologies are included; acidification of slurry and air cleaning. The average reduction factors for these technologies are 60 % and 70 %, respectively and the total average reduction factor for pigs is therefore 65 %. Based on this it is estimated that for fattening pigs around 40 % have implemented this technology in 2020.

Table 5.9 Predictions regarding establishment of NH_3 reducing technology in housings.

	2020, Share of production with reducing technology	2030, Share of production with reducing technology
Dairy cattle (60 % reduction)	40 %	70 %
Heifers > ½ year (60 % reduction)	60 %	70 %
Sows (65 % reduction)	50 %	60 %
Fattening pigs (65 % reduction)	40 %	80 %
Broilers (70 % reduction)	20 %	20 %

5.4 Other variables

5.4.1 Agricultural area

Developments from 1985 to 2009 show a total decrease in agricultural land area of 210 000 ha, which correspond to 8 800 ha each year. This is a result of urban and infrastructure development, but also due to removal of marginal land according to the EUs set-a-side scheme from 1992 and other legislations such as the Action Plan on the Aquatic Environment, Nitrate Directive and the Habitat Directive. In future years, this trend for rural areas, infrastructure and protection of vulnerable habitats is expected to continue. In the projection the agricultural land area is assumed to decrease by 130 000 ha from 2009-2020 and further by 80 000 ha from 2020-2030, which corresponds to a total decrease in the cultivated area of 8 % from 2009 to 2030.

From 2009 to 2020 a removal of around 7 300 ha per year due to rural development and infrastructure is estimated. A further decrease in the cultivated area is expected as a result of the Agreement on Green Growth presented in 2009 and followed up in the form of a second version Green Growth 2.0 in April 2010. This agreement includes among other objectives a removal of 50 000 ha near streams with the purpose to reduce the nitrogen loss to the aquatic environment. This removal is expected to be implemented in 2013 and 2014.

Assumptions for 2009-2020:

Decrease in agricultural land area of 130 000 ha:

- Decrease of around 7 300 ha per year = 80 000 ha
- Agreement on Green Growth = 50 000 ha

Assumption for 2020-2030:

- Decrease in agricultural land area of 80 000

In the projection no significant changes in the distribution of different crop types is expected. Changes in climatic conditions can affect the choice of crop type, which properly means implementation of new species in future production. However, global supply and demand are important factors too, which complicates the prediction. The most important variable concerning the total air pollutant emission is whether the areas are cultivated or not, while the crop type is less important.

Table 5.10 Agricultural land area in 2009 and in the projection.

	2009	2015	2020	2025	2030
Agricultural land area, 1 000 ha	2 624	2 530	2 494	2 454	2 414

5.4.2 Changes in practice of manure applied on soil

In the projection, some change in handling practice of manure applied to soil is expected. These assumptions are based on legislation BEK No. 1695 of 19/12/2006 and BEK No. 114 of 11/02/2011. From 2011 all slurry applied on grass fields or bare soil has to be injected. Alternatively an application technique with acid treated slurry can be used.

A still increasing part of the slurry is expected to be injected directly in the soil. From 2009 the part of injected slurry from cattle production is estimated to 63 % and is assumed to increase to 86 % in 2011. The same trend is assumed for pig slurry, from 28 % in 2009 to 45 % in 2011. Another expected change is acid treated slurry during the application. It is assumed that 20 % of the applied cattle slurry is acid treated in 2020.

5.4.3 Use of synthetic fertilisers

Consumption of synthetic fertilisers depends on the amount of nitrogen in animal manure, requirements for N-utilisation and the area under agricultural cultivation. In the projection, it is assumed that there is no significant change in the distribution of different crop types compared to the conditions in 2009. The nitrogen requirement in crops is estimated to 130 kg N per ha on average. It is assumed that an area of 50 000 ha has no need for fertilisation.

Use of nitrogen in synthetic fertilisers is predicted to decrease by 21 %. The two main reasons for this decrease, is a decrease in the agricultural area and implementation of NH_3-reducing technologies, which reduce the NH_3 emission from the housings and thereby increase the content of N in the animal manure (N ex storage).

Table 5.11 Expected development in consumption of synthetic fertilisers.

	2009	2015	2020	2025	2030
			Gg N		
N in animal manure (N ex storage)	209	203	204	209	213
N which is included in the farmers' fertiliser accounts	144	140	142	145	149
N in synthetic fertilisers	200	182	176	167	159

5.4.4 Field burning of agricultural residue

The field burning of agricultural residues has been prohibited since 1990 (BEK No. 1317 of 20/11/2006 and BEK No. 545 of 12/07/1991) and is only allowed on fields with repeated production of grass seeds and in cases of wet or broken bales of straw.

It is assumed that 15 % of the total amount of straw from grass seed production is expected to be burned, which corresponds to the assumption used in the historical emission inventory. Until 2030 no significant changes in area of grass seed fields are expected, and the emission for all years 2010 to 2030 is based on an average for 2005 – 2009.

The amount of straw burned from wet or broken bales of straw is estimated to be 0.1 % of the total amount of straw in the historical years. The same assumption is applied in the projection. No significant changes is expected for the distribution of crop types and therefore the amount of straw burned from wet or broken bales fluctuate with the area of agricultural land.

5.5 Sensitivity test for NH_3 emission

What is the effect on the NH_3 emission in 2030 if we change the assumptions for some of the selected variables? In the following section the consequences of changes in assumption for some variables are tested and the result is listed in Table 5.12.

It has to be pointed out that the effect of the different measures cannot simply be added since there are some overlaps in the reduction potentials. The calculation of the emission is based on a series of different correlations between the variables. As an example can be mentioned; the agricultural area influences the use of synthetic fertiliser; establishment of NH_3 reducing technology reduces the NH_3 emission in housing but at the same time increases the nitrogen in animal manure in storage and applied on soil.

Table 5.12 gives eight examples of changes in assumptions for the pig production, the technology and other variables as the cattle production and the agricultural area.

Especially the pig production is highly unpredictable caused by a close relation to the conditions on the export market. That is why it could be particularly interesting to test the effect of alternative scenarios of future development in the pig production.

5.5.1 Pig production

1. Pig production reduced by 10 % in 2020: What is the effect of a 10 % lower pig production in 2020 compared to the assumptions given in the basis projection (BP2011).

2. Constant export of weaners: In BP2011 an increase in the export of weaners is expected. The effect on the NH_3 emissions if the production of pigs is the same as projected in BP2011, but the export is not increasing (same level as in 2009) is tested.

3. Nex 15 % reduction for fattening pigs in 2020: In BP2011 a decrease in Nex for fattening pigs of around 10 % is expected in 2020 compared to 2009. The effect on the NH_3 emission if the Nex can be decreased by 15 % is tested.

4. Nex 15 % reduction for weaners in 2020: In BP2011 Nex for weaners kept at the same level as in 2009. The effect on the NH_3 emission if the Nex can be decreased by 15 % is tested.

5.5.2 Technology

5. Without technology: This includes the effect of the emissions with no implementation of NH_3 reducing technology in animal housings.

6. 100 % technology in 2020: The effect of implementation of NH_3 reducing technology in all housings for dairy cattle and fattening pigs in 2020/2030.

5.5.3 Other

7. Cattle production reduced 10 % in 2020: The effect of 10 % lower cattle production in 2020 compared to the assumptions given in the BP2011.

8. Agricultural area: BP2011 includes a decrease in the agricultural area of 210 000 hectare. What is the effect if the agricultural area only decrease with 100 000 hectare?

Table 5.12 Effect on the NH_3 emission by changing in different variable.

NH_3, Gg	2015	2020	2030	Difference from 2030-emission calculated in BP2011
Basis projection (BP2011)	66.05	60.82	57.69	
Pig production				
1. Pig production 10 % reduction in 2020	63.32	56.64	55.46	-2.24
2. Unchanged export of weaners	68.58	65.01	59.10	+1.41
3. Nex 15 % reduction for fattening pigs in 2020	65.69	60.20	57.25	-0.44
4. Nex 15 % reduction for weaners in 2020	65.76	60.27	57.13	-0.56
Technology				
5. Without technology	68.81	65.93	67.20	+9.50
6. 100 % technology in 2020/30, dairy cattle and fattening pigs	62.77	55.00	55.42	-2.28
Other				
7. Cattle production 10 % reduction in 2020	65.45	59.06	56.12	-1.57
8. Agricultural area (100 000 hectare 2009-2030)	66.24	61.05	58.01	+0.32

A reduction of the pig production by 10 % is estimated to a further decline in 2030-emission of 2.24 Gg NH_3. This production level is equal to the situation in the middle of the nineties.

The basic projection includes an assumption of increasing export of weaners, which obviously depends on the conditions on the export market. If the export of weaners until 2030 is kept at the 2009 level, the consequence is an increase in the Danish production of fattening pigs, which is expected to increase the 2030 emission by 1.41 Gg NH_3.

In BP2011 the Nex for fattening pigs is expected to decrease with around 10 % in 2020 (2.65 kg N per head per year) compared to 2009, while the Nex for weaners is expected to be nearly unaltered (0.51 kg N per head per year). It is possible that research results or improved feed efficiency could result in a further decrease of the Nex. The consequence of a 15 % decrease in Nex for fattening pigs and weaners in 2020, will affect the total emission in 2030 with a further decline of 0.44 and 0.56 Gg NH_3, respectively.

The sensitivity test shows that with no implementation of NH_3 reducing technology in animal housing an increase of the 2030-emission with 9.50 Gg compared to the basis projection (BP2011) is expected. This corresponds to an increase of 16 %. If the implementation rate for emission reducing technology is enhanced to 100 % in 2020 for all production of dairy cattle and fattening pigs, the 2030-emission is excepted to be reduced with additionally 2.28 Gg NH_3.

A change in the agricultural area does not affect the total 2030 emission significantly. If the agricultural area decreases by 100 000 ha instead of 280 000 ha as assumed in the BP2011, the emission in 2030 expects to increase to 0.32 Gg NH_3.

Changes in the production of cattle seem to affect the total emission less than the pig production. A 10 % reduction in cattle production is estimated to result in a further decline in 2030-emission of 1.57 Gg NH_3.

The sensitivity test shows that changes in the selected variables result in a variation of NH_3 emission between -5.26 Gg to +9.50 Gg, which is equal to a variation of -9 % to +16 %, respectively. The test indicates that especially changes in the assumptions for the pig production and the NH_3 reducing technology are very important variables, and thus affects the total emission significantly.

5.6 Summary

The present projection covering the ammonia (NH_3) emission replaces the latest basic projection published in NERI Technical Report No. 655 (Illerup et al., 2008).

Particularly agricultural emission of NH_3 and particulate matter (PM) are important contributors to the national total emission. The main part of the NH_3 emission (96 %) is related to agricultural activities in 2009. The agricultural contribution of TSP and PM_{10} are 29 % and 19 %, respectively. The agricultural part of the remaining air pollutants compounds ($PM_{2.5}$, NMVOC, SO_X and NO_X) account for less than 5 %.

The projection includes a series of initiatives, which are expected to take place in the future. Increasing demands to reduce unintended environmental effects as a consequence of an intensive livestock production have lead to more legislation. This is assumed, among other things, to be met by increasing implementation of NH_3 reducing technology, which in the projection is included as air cleaning in housings and slurry acidification systems to adjust the pH value of the slurry. A continuous effort to improve the nitrogen utilization in manure is also taken into account by decreasing N-excretion from pigs and expected changes in application of manure applied on soil. Other important variables included are changes in production of cattle and pigs, chance in housing types, decrease in use of synthetic fertiliser and a decrease in the agricultural area.

The emission of NH_3 is the most important agricultural contribution to the national total emission. There is no doubt that the agricultural NH_3 emission will be reduced over time, but it is difficult to predict the exact reduction rate and the limit for how much the emission can be reduced. This depends on the general structural developments, and developments within environmental regulation, especially for larger farm units. EU agricultural policy also plays an important role and of course the conditions for export and import of agricultural products.

Based on the provided assumptions, the projection shows that the NH_3 emission is expected to decrease from 73.83 Gg NH_3 in 2009 to 60.82 Gg NH_3 in 2020 and further decrease to 57.69 Gg NH_3 in 2030, which corresponds to a decrease of 22 % from 2009 to 2030. The decreased emission is mainly a result of a decline in emission from the animal housing and in particular from the pig housing, which will be a result of implementation of NH_3 reducing technology.

The PM emission covers emission from the livestock production. Changes over time are caused by changes in number of produced animals and changes in the housing system. The projection shows an increase of PM emission from 2009 to 2030, which corresponds to 4 %, given in TSP, due to an increasing pig production.

Based on the given assumptions, the projection shows a small decrease in emission of SO_2, NO_X and NMVOC from 2009 to 2030, corresponding to 2 % to 7 %, which is caused by the decrease of the agricultural area.

The sensitivity test shows that changes in the selected variables result in a variation of NH_3 emission of -9 % to +16 % in 2030. Especially changes in the assumptions for the pig production and the NH_3 reducing technology are very important variables.

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6 Solvent and Other Product Use

This category includes NMVOC emissions from solvents and other product use in industrial processes and households that are related to the source categories Paint application (NFR sector 3A), Degreasing and dry cleaning (NFR sector 3B), Chemical products, manufacture and processing (NFR sector 3C) and Other (NFR sector 3D). Additionally emissions from the use of fireworks are included as other product use.

Solvents are chemical compounds that are used on a global scale in industrial processes and as constituents in final products to dissolve e.g. paint, cosmetics, adhesives, ink, rubber, plastic, pesticides, aerosols or are used for cleaning purposes, i.e. degreasing. NMVOCs are the main components in solvents - and solvent use in industries and households is typically the dominant source of anthropogenic NMVOC emissions. In industrial processes where solvents are produced or used NMVOC emissions to air and as liquid can be recaptured and either used or destroyed. Solvent containing products are used indoor and outdoor and the majority of solvent sooner or later evaporate. A small fraction of the solvent ends up in waste or as emissions to water and may finally also contribute to air pollution by evaporation from these compartments. Emission inventories for solvents are based on model estimates, as direct and continuous emissions are only measured from a limited number of pollutants and sources.

The methodology for the Danish NMVOC emission inventory for solvent use is done for the period 1995 – 2009 based on the detailed approach described in EMEP/CORINAIR (2004) and emissions are calculated for industrial sectors, households in the NFR categories mentioned above, as well as for individual chemicals and/or chemical groups. Further details on the inventory methodology can be seen in Nielsen et al. (2011b).

6.1 Emission projections

Production, use, marketing and labelling of VOC containing products in Denmark are regulated by two Statutory Orders; BEK nr 350 af 29/05/2002 "Bekendtgørelse om begrænsning af emissionen af flygtige organiske forbindelser fra anvendelse af organiske opløsningsmidler i visse aktiviteter og anlæg" aka the VOC-emission directive, and its amendments BEK no. 817 of 25/08/2009, BEK no. 281 of 25/03/2010, BEK no. 282 of 25/03/2010 and BEK no. 283 of 25/03/2010. These are based on Directive 2004/42/CE, aka the VOC-product directive. Further regulation follows BEK no. 1049 af 27/10/2005 "Bekendtgørelse om markedsføring og mærkning af flygtige organiske forbindelser i visse malinger og lakker samt produkter til autoreparationslakering" and its amendments BEK no. 1073 of 27/10/2009 and BEK no. 84 of 02/02/2011. The VOC Directives are incorporated into the new EU Directive on Industrial Emissions.

The directives supplement each other, as the VOC-directive regulates paints and lacquers used for buildings and fixed parts in buildings with VOC consumption above a certain limit value, and BEK 1049 regulates the VOC consumption below the limit value. Not all activities covered by the CRF3 are regulated by the two directives, e.g. only the small amount used in surface treatment of plastic products is covered in the plastic industry.

The 2009 NMVOC emissions from CRF 3 and its SNAP sub-categories are shown in Table 6.1. Sub-categories 060412 Other use: Other, 060408 Other use: Domestic solvent use and 060314 Chemical products, manufacturing and processing: Other, comprise 49%, 15% and 14%, respectively, of the total NFR 3 NMVOC emissions. These sub-categories constitute highly diverse and diffuse activities and product uses, each comprising a number of chemicals.

Table 6.1 2009 NMVOC emission in Gg from NFR 3 Solvents and other product use and its sub-categories.

SNAP	Category description	NMVOC emission 2009 (Gg)	Fraction of total 2009 emission
060101	Manufacture of Automobiles	0.0414	0.0015
060102	Car Repairing	0.277	0.010
060103	Constructions and Buildings	0.622	0.023
060104	Domestic Use	0.397	0.015
060105	Coil Coating	0.0185	0.00068
060106	Boat Building	0.541	0.020
060107	Wood	0.0785	0.0029
060108	Other Industrial Paint Applications	1.26	0.046
060109	Other Non-Industrial Paint Application	0.0834	0.0030
	Paint Application (sum of above SNAP sub-categories)	3.32	0.12
060201	Metal Degreasing	0	0
060202	Dry Cleaning	1.31E-05	4.8E-07
060203	Electronic Components Manufacturing	0	0
060204	Other Industrial Dry Cleaning	0	0
	Degreasing and Dry Cleaning (sum of above SNAP sub-categories)	1.31E-05	4.8E-07
060301	Polyester Processing	0	0
060302	Polyvinylchlorid Processing	5.28E-08	1.9E-09
060303	Polyurethan Foam Processing	0.188	0.0069
060304	Polystyrene Foam Processing	0.894	0.033
060305	Rubber Processing	0	0
060306	Pharmaceuticals Products Manufacturing	0	0
060307	Paints Manufacturing	0.000264	9.7E-06
060308	Inks Manufacturing	0.000212	7.8E-06
060309	Glues Manufacturing	0	0
060310	Asphalt Blowing	0	0
060311	Adhesive, Magnetic Tapes, Film & Photographs Manufacturing	3E-06	1.1E-07
060312	Textile Finishing	0	0
060313	Leather Tanning	0	0
060314	Other	3.82	0.14
	Chemical Products Manufacturing & Processing (sum of above SNAP sub-categories)	4.90	0.18
060401	Glass Wool Enduction	4.89E-06	1.8E-07
060402	Mineral Wool Enduction	0.000521	1.9E-05
060403	Printing Industry	0.00911	0.00033
060404	Fat, Edible and Non-Edible Oil Extraction	0	0
060405	Application of Glues and Adhesives	1.54	0.056
060406	Preservation of Wood	0	0
060407	Underseal Treatment and Conservation of Vehicles	0	0
060408	Domestic Solvent Use (Other Than Paint Application)	4.11	0.15
060409	Vehicles Dewaxing	0	0
060411	Domestic Use of Pharmaceutical Products	0	0
060412	Other (Preservation of Seeds a.o)	13.5	0.49
	Other use (sum of above SNAP sub-categories)	19.1	0.70
	Total	27.4	1.0

The processes and activities that are covered by BEK 350 and the associated fraction of the total 2009 NMVOC emissions are shown in Table 6.2. They cover 9.1% of the total NMVOC emissions in NFR 3.

NMVOC emission threshold values that these categories must comply with refer to single installations and as the solvent consumption for any category is only known as a total it is not known how big a fraction of the solvent use exceeds the threshold values. A worst-case assumption could be that the entire solvent consumption in a category must comply with the emission limit. However this is not a realistic scenario as the emission values, for the solvent fraction that exceeds the thresholds in BEK 350, are considerably lower than the emission factors that are used in the inventory. Furthermore BEK 350 only covers industrial installations, and adhesive coating, which constitutes the largest fraction of the emissions covered by BEK 350, also includes diffuse use.

The predominant emissions in the inventory thus represent diffuse uses, which cannot be attributed to an industrial sector or trade organisation and it is not feasible to perform projections according to the above directives. The emission projection of all categories will be based on extrapolation of historic 1995-2009 emissions.

Table 6.2 Processes and activities (categories) that are covered by BEK 350, associated SNAP subcategories, NMVOC emissions in 2009 and fraction of 2009 emissions from BEK 350 category.

Categories in BEK 350	Corresponding SNAP categories	NMVOC emission 2009 (Gg)	Fraction of total 2009 emission
Adhesive coating	060405	1.54	0.056 (also includes diffuse use)
Coating activity and vehicle refinishing	060101, 060102, 060106, 060107	0.94	0.034
Coil coating and winding wire coating	060105	0.0185	0.00068
Dry cleaning	060202	0.000013	0.00000048
Footwear manufacture	Nd	Nd	Nd
Manufacturing of coating preparations, varnishes, inks and adhesives	060307, 060308, 060309, 060311	0.00048	0.000018
Manufacture of pharmaceutical products	060306	0	0
Printing	060403	0.0091	0.00033
Rubber conversion	060305	0	0
Surface cleaning	Nd	Nd	Nd
Vegetable oil and animal fat extraction and vegetable oil refining activities	060404	0	0
Wood impregnation	060406	0	0
Wood and plastic lamination	Nd	Nd	Nd
Total covered by BEK 350		2.5	0.091

nd: Not defined in SNAP and may be a fraction of different SNAP categories.

0: Some of the emissions that are reported as zero, e.g. rubber conversion, may have a NMVOC use and emissions. The categories in Statistics Denmark (2011) and SPIN (2011) that include rubber may cover more materials than rubber and the use therefore falls under a different SNAP category, e.g. softeners in plastic and rubber products enters SNAP 060302 Polyvinylchloride processing.

Table 6.3 shows the extrapolation of the historic NMVOC emissions from 1995 to 2009 for the four NFR 3 categories; NFR 3A Paint application, NFR 3B Degreasing and dry cleaning, NFR 3C Chemical products, manufacture and processing and NFR 3D Other. An exponential fit gives the best approximation with R^2 values of 0.85, 0.75, 0.72 and 0.93 respectively. All projected NFR 3 categories show a decrease in NMVOC emissions, however, a decrease in use and emissions is only realistic to a certain point in time, either because the use becomes zero or because a minimum of solvent use has been reached. There is stagnation in the latest three years of the historic emissions; i.e. the four NFR categories show approximately constant emissions during the latest three years (2007 to 2009). The most realistic projection is assumed to represent the mean of the exponential fit and constant estimates.

Table 6.3 Projected NMVOC emissions from NFR 3 Solvent and Other Product Use. NMVOC projections are mean values of exponential fit of historic 1995 to 2009 emissions, and constant mean historic 2007 to 2009 emissions.

NMVOC emissions Year	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3A Paint Application	Gg	3.40	3.29	3.20	3.11	3.02	2.94	2.86	2.79	2.73	2.67
3B Degreasing and Dry Cleaning	Gg	1.4E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.1E-05	1.1E-05	1.1E-05	1.0E-05	1.0E-05
3C Chemical Products, Manufacturing and Processing	Gg	5.24	5.15	5.06	4.98	4.91	4.83	4.76	4.69	4.62	4.56
3D5 Other Use	Gg	17.5	17.1	16.8	16.5	16.2	16.0	15.7	15.4	15.9	14.9
Total NMVOC	Gg	26.1	25.6	25.1	24.6	24.2	23.7	23.3	22.9	22.5	22.2
NMVOC emissions Year	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
3A Paint Application	Gg	2.61	2.55	2.50	2.45	2.41	2.37	2.33	2.29	2.25	2.22
3B Degreasing and Dry Cleaning	Gg	1.0E-05	9.8E-06	9.7E-06	9.5E-06	9.4E-06	9.3E-06	9.2E-06	9.1E-06	9.0E-06	8.9E-06
3C Chemical Products, Manufacturing and Processing	Gg	4.49	4.43	4.37	4.32	4.26	4.21	4.16	4.11	4.07	4.02
3D5 Other Use	Gg	14.7	14.5	14.3	14.1	13.9	13.7	13.5	13.3	13.2	13.0
Total NMVOC	Gg	21.8	21.5	21.2	20.9	20.6	20.3	20.0	19.7	19.5	19.3
NMVOC emissions Year	Unit	2030									
3A Paint Application	Gg	2.19									
3B Degreasing and Dry Cleaning	Gg	8.8E-06									
3C Chemical Products, Manufacturing and Processing	Gg	3.98									
3D5 Other Use	Gg	12.9									
Total NMVOC	Gg	19.0									

In the previous emission projection (Nielsen et al., 2010) four industrial sectors were elaborated in more detail: Auto paint and repair, Plastic industry, Graphic industry and Lacquer and paint industry. Their emissions are not directly derivable from the above tables, but an estimate is that they represent 1%, 4%, <1% and <1% of the 2009 emissions. Their considerable decrease compared to the previous assessment is caused by an alteration and improvement in the source allocation calculation. The plastic industry covers three main activities; production of expanded polystyrene products (EPS), production of fibreglass-reinforced polyester products (composite) and production of polyurethane products (PUR). Production of plastic materials does not take place in Denmark, only manufacturing and processing of plastic containing products are relevant. Emission reducing measures have already been implemented; i.e. 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. Polystyrene products are manufactured from imported polystyrene pellets, which contain 6% pentane. To comply with limit values in Luftvejledningen (EPA, 2001) and NEC directive there has been focus on reducing the pentane emissions during the EPS manufacturing and processing phase. However, due to technical barriers these initiatives will not be implemented. Other pentane reducing initiatives are reducing the pentane content in the polystyrene pellets from 6 % to 5.3 % or 3.5-4 %. This will probably be introduced in the near future. For composite and PUR there are ongoing initiatives on reducing the use of styrene, mainly due to exposure in the work place. However, it is not possible to quantify their effect on styrene emissions.

The Auto paint and repair sector follows the emission limit values in the VOC-product directive. No new emission reducing initiatives are planned in the near future or have been implemented since 2007, where a general shift to water soluble and high solid products was made.

In the lacquer and paint industry most companies are hoping for increased production and sales but they are strongly dependent on the demand from other industries and from consumer use. Product use constitutes the predominant emissions from lacquers and paints so the industrial and consumer demand is the primary driver for NMVOC emissions from the lacquer and paint sector. Companies are continuously working on developing better products, which i.a. implies limiting and substituting the use of NMVOCs, however, always accounting for the technical quality of the product. In sectors where the products traditionally have been solvent based, the trend goes towards increased use of water soluble products, more low-VOC products and high solid products. Furthermore, the development depends on emerging rules and regulations on products and their chemical content.

In conclusion Table 3 shows the projected NMVOC emissions for 2010 to 2030 for the UNFCCC source categories Paint application (NFR sector 3A), Degreasing and dry cleaning (NFR sector 3B), Chemical products, manufacture and processing (NFR sector 3C) and Other (NFR sector 3D). The projections show a 31 % decrease in total NMVOC emissions from 2009 (Table 1) to 2030. CFR 3A, 3C and 3D show a 34 %, 19 % and 32 % decrease, respectively. NFR 3B emissions are negligible.

The use of fireworks is difficult to project because this activity is very easily influenced and therefore has no clear development (Nielsen et al., 2011a).

Compounds that emit from combustion of fireworks are SO_2 and particles. It is assumed that the emission of these pollutants can be counted as constant on the 2009 level for the years 2010-2030.

The following table shows the activity, emission factors and national emission from the use of fireworks (Nielsen et al., 2011b).

Table 6.4 Emission projection for fireworks.

Compound	Activity, Gg	Emission factor, Mg pr Gg	Emission, Mg
SO_2	5.38	1.94	10.4
TSP		39.66	213.4
PM_{10}		19.83	106.7
$PM_{2.5}$		13.88	74.7

6.2 References

BEK nr. 350 af 29/05/2002 Bekendtgørelse om begrænsning af emissionen af flygtige organiske forbindelser fra anvendelse af organiske opløsningsmidler i visse aktiviteter og anlæg, aka the VOC directive.

BEK nr.. 1049 af 27/10/2005 Bekendtgørelse om markedsføring og mærkning af flygtige organiske forbindelser i visse malinger og lakker samt produkter til autoreparationslakering.

Directive no 350 on Limitation of Emissions of Volatile Organic Compounds from use of Organic Solvents in Certain Activities, aka VOC directive.

Directive no 1049 on Marketing and Labelling of Volatile Organic Compounds in Certain Paints and Lacquers and Products for Auto Repair Lacquering, aka Directive 1049.

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7 Industrial processes

7.1 Sources

A range of sources are covered in the projection of process emissions to 2030 (see Table 7.1). The emissions from industrial processes mixed with emissions from energy consumption are included in the chapter on stationary combustion.

Table 7.1 Sources/processes included in the projection of process emissions.

NFR code		Sources/processes	SNAP code
2A	Mineral products	2A5+6 Asphalt products	
		- Roof covering with asphalt products	04 06 10
		- Road surfacing with asphalt	04 06 11
2B	Chemical industry	2B5a Other chemical industry	
		- Pesticide production	04 05 25
2C	Metal production	2C5	
		- Lead production	03 03 07
		- Zinc production	03 03 08
2D	Other	2D2 Food and drink	
		- Bread	04 06 05
		- Beer	04 06 07
		- Spirits	04 06 08
		- Meat curing	04 06 27
		- Margarine and solid cooking fat	04 06 98
		- Coffee roasting	04 06 99
2G	Other production	2G	
		- Treatment of slaughterhouse waste	04 06 17

The processes included in the chapter on stationary combustion are e.g. cement production, glass and glass wool production, and stone wool production.

The projection of emissions from industrial processes is based on the national emissions inventory (Nielsen et al., 2011).

7.2 Projections

The projections are generally based on energy projections related to specific sectors (Danish Energy Agency, 2011); the applied extrapolation factors are presented in Table 7.2. The methodologies used within the different sectors - especially the estimate on 2010 activity - are described below.

Table 7.2 Extrapolation factors for estimation of CO_2 emissions from industrial processes (based on energy projections by (Danish Energy Agency (2011)).

	QJONF Food and beverage	QJONK Chemical industry	QJOST Iron and steel industry	QJONX Production, average
2010[1]	1	1	1	1
2011	0.98	0.97	1.00	0.99
2012	0.97	0.96	1.00	0.99
2013	0.96	0.94	0.99	1.00
2014	0.95	0.93	0.99	1.00
2015	0.95	0.92	0.99	1.01
2016	0.95	0.89	0.99	1.01
2017	0.94	0.87	0.99	1.01
2018	0.94	0.84	0.99	1.01
2019	0.94	0.81	1.00	1.01
2020	0.94	0.78	1.00	1.01
2021	0.95	0.74	1.00	1.00
2022	0.95	0.71	1.00	1.00
2023	0.95	0.68	1.00	0.99
2024	0.96	0.65	1.00	1.00
2025	0.96	0.62	1.00	1.00
2026	0.97	0.60	1.01	1.01
2027	0.98	0.58	1.01	1.01
2028	0.98	0.55	1.01	1.02
2029	0.99	0.52	1.01	1.02
2030	1.00	0.50	1.01	1.03

1) Emission in 2010 is based on sector specific assumptions.

Roof covering with asphalt products and road surfacing with asphalt are assumed to be at the same level in 2010 as in 2009. As extrapolation factors energy consumption for production, average has been used; see Table 7.2. The projected emissions are presented in Table 7.3.

Table 7.3 Projected emissions of NMVOC from roof covering with asphalt and road surfacing with asphalt (Gg NMVOC).

Process	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Roof covering with asphalt	0.0050	0.0049	0.0049	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Road surfacing with asphalt	0.54	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Total	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.55
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Roof covering with asphalt	0.0050	0.0050	0.0049	0.0049	0.0049	0.0050	0.0050	0.0050	0.0051	0.0051
Road surfacing with asphalt	0.54	0.54	0.53	0.53	0.54	0.54	0.54	0.54	0.55	0.55
Total	0.55	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55
Continued	2030									
Roof covering with asphalt	0.0051									
Road surfacing with asphalt	0.55									
Total	0.56									

The production within chemical industry is assumed to be at the same level in 2010 as in 2009. As extrapolation factor energy consumption for chemical industry has been used; see Table 7.2. The projected emissions are presented in Table 7.4.

Table 4.4 Projected emissions from chemical industry.

Pollutants	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gg NO_x	0.018	0.018	0.017	0.017	0.017	0.016	0.016	0.016	0.015	0.015
Gg NMVOC	0.018	0.018	0.017	0.017	0.017	0.017	0.016	0.016	0.015	0.015
Gg SO_2	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.017	0.017	0.016
Gg NH_3	0.17	0.16	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.13
Gg $PM_{2.5}$	0.010	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.008	0.008
Gg PM_{10}	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.011	0.011	0.010
Gg TSP	0.016	0.016	0.015	0.015	0.015	0.015	0.014	0.014	0.013	0.013
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Gg NO_x	0.014	0.013	0.013	0.012	0.012	0.011	0.011	0.010	0.010	0.009
Gg NMVOC	0.014	0.013	0.013	0.012	0.012	0.011	0.011	0.010	0.010	0.009
Gg SO_2	0.016	0.015	0.014	0.014	0.013	0.012	0.012	0.012	0.011	0.010
Gg NH_3	0.13	0.12	0.12	0.11	0.11	0.10	0.099	0.095	0.091	0.086
Gg $PM_{2.5}$	0.008	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.005
Gg PM_{10}	0.010	0.010	0.009	0.009	0.008	0.008	0.008	0.007	0.007	0.007
Gg TSP	0.012	0.012	0.011	0.011	0.010	0.010	0.010	0.009	0.009	0.008
Continued	2030									
Gg NO_x	0.009									
Gg NMVOC	0.009									
Gg SO_2	0.010									
Gg NH_3	0.083									
Gg $PM_{2.5}$	0.005									
Gg PM_{10}	0.007									
Gg TSP	0.008									

Zinc foundries and production of secondary lead are assumed to be at the same level in 2010 as in 2009. As extrapolation factors energy consumption in iron and steel industry has been used; see Table 7.2. The projected emissions are presented in Table 7.5.

Table 7.5 Projected emissions of $PM_{2.5}$, PM_{10} and TSP from metal industry.

Polluntants	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gg $PM_{2.5}$	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Gg PM_{10}	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
Gg TSP	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Gg $PM_{2.5}$	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Gg PM_{10}	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
Gg TSP	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
Continued	2030									
Gg $PM_{2.5}$	0.0015									
Gg PM_{10}	0.0024									
Gg TSP	0.0027									

The production of food and beverage are assumed to be at the same level in 2010 as in 2009. As extrapolation factor energy consumption in food and beverage industry has been used; see Table 7.2. The projected emissions are presented in Table 7.6.

Table 7.6 Projected emissions of NMVOC from production of food and beverage.

Pollutants	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gg NMVOC	8.56	8.39	8.32	8.23	8.17	8.12	8.09	8.08	8.07	8.07
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Gg NMVOC	8.07	8.09	8.11	8.15	8.19	8.24	8.29	8.35	8.41	8.48
Continued	2030									
Gg NMVOC	8.55									

The treatment of slaughterhouse waste is assumed to be at the same level in 2010 as in 2009. As extrapolation factors energy consumption for production, average has been used; see Table 7.2. The projected emissions are presented in Table 7.7.

Table 7.7 Projected emissions from other production (treatment of slaughterhouse waste).

Pollutants	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gg NMVOC	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Gg NH_3	0.093	0.093	0.092	0.092	0.092	0.093	0.093	0.093	0.093	0.093
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Gg NMVOC	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Gg NH_3	0.093	0.092	0.092	0.092	0.092	0.093	0.093	0.094	0.094	0.095
Continued	2030									
Gg NMVOC	0.012									
Gg NH_3	0.095									

7.3 References

Danish Energy Agency, 2011: Energy projections 2010-2030, 4 April 2011.

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8 Waste

This chapter covers the 2010-2030 projection of NEC gases and particle emissions from waste handling. This includes 6.C Waste Incineration and 6.D Waste Other.

8.1 Waste Incineration

The NFR source category *6.C Waste Incineration,* includes cremation of human bodies and cremation of animal carcasses.

Incineration of municipal, industrial, clinical and hazardous waste takes place with energy recovery, therefore the emissions are included in the relevant subsectors under NFR sector 1A. For documentation please refer to Chapter 2. Flaring off-shore and in refineries are included under NFR sector 1B2c, for documentation please refer to Chapter 3. No flaring in chemical industry occurs in Denmark.

Table 8.1a-c gives an overview of the projections of the national emissions from the NFR source category 6.C Waste Incineration.

Table 8.1a Projection of overall emission of NEC gases and particles from the incineration of human bodies and animal carcasses.

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
SO_2 emission from											
Human cremation	Mg	2.32	2.34	2.36	2.38	2.40	2.42	2.44	2.46	2.48	2.50
Animal cremation	Mg	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Total	Mg	3.42	3.44	3.46	3.48	3.51	3.53	3.55	3.57	3.59	3.61
NO_x emission from											
Human cremation	Mg	13.13	13.25	13.37	13.48	13.60	13.72	13.83	13.95	14.07	14.19
Animal cremation	Mg	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27
Total	Mg	19.40	19.52	19.63	19.75	19.87	19.98	20.10	20.22	20.34	20.46
NMVOC emission from											
Human cremation	Mg	0.55	0.56	0.56	0.57	0.57	0.58	0.58	0.59	0.59	0.60
Animal cremation	Mg	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
Total	Mg	3.19	3.20	3.20	3.21	3.21	3.22	3.22	3.23	3.23	3.24
NH_3 emission from											
Animal cremation	Mg	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
TSP emission from											
Human cremation	Mg	1.85	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Animal cremation	Mg	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
Total	Mg	4.73	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
PM_{10} emission from											
Human cremation	Mg	1.67	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Animal cremation	Mg	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
Total	Mg	3.69	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
$PM_{2.5}$ emission from											
Human cremation	Mg	1.67	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Animal cremation	Mg	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
Total	Mg	3.40	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75

Table 8.1b Projection of overall emission of NEC gases and particles from the incineration of human bodies and animal carcasses.

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
SO_2 emission from											
Human cremation	Mg	2.53	2.55	2.57	2.59	2.61	2.64	2.66	2.68	2.70	2.73
Animal cremation	Mg	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Total	Mg	3.63	3.65	3.68	3.70	3.72	3.74	3.77	3.79	3.81	3.83
NO_x emission from											
Human cremation	Mg	14.32	14.44	14.57	14.69	14.82	14.95	15.08	15.20	15.33	15.46
Animal cremation	Mg	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27
Total	Mg	20.58	20.71	20.83	20.96	21.09	21.22	21.34	21.47	21.60	21.72
NMVOC emission from											
Human cremation	Mg	0.60	0.61	0.61	0.62	0.62	0.63	0.64	0.64	0.65	0.65
Animal cremation	Mg	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
Total	Mg	3.24	3.25	3.25	3.26	3.27	3.27	3.28	3.28	3.29	3.29
NH_3 emission from											
Animal cremation	Mg	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
TSP emission from											
Human cremation	Mg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Animal cremation	Mg	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
Total	Mg	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
PM_{10} emission from											
Human cremation	Mg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Animal cremation	Mg	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
Total	Mg	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
$PM_{2.5}$ emission from											
Human cremation	Mg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Animal cremation	Mg	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
Total	Mg	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75

Table 8.1c Projection of overall emission of NEC gases and particles from the incineration of human bodies and animal carcasses.

	Unit	2030
SO_2 emission from		
Human cremation	Mg	2.75
Animal cremation	Mg	1.11
Total	Mg	3.85
NO_x emission from		
Human cremation	Mg	15.58
Animal cremation	Mg	6.27
Total	Mg	21.85
NMVOC emission from		
Human cremation	Mg	0.66
Animal cremation	Mg	2.64
Total	Mg	3.30
NH_3 emission from		
Animal cremation	Mg	2.51
TSP emission from		
Human cremation	Mg	0.02
Animal cremation	Mg	2.88
Total	Mg	2.90
PM_{10} emission from		
Human cremation	Mg	0.02
Animal cremation	Mg	2.02
Total	Mg	2.04
$PM_{2.5}$ emission from		
Human cremation	Mg	0.02
Animal cremation	Mg	1.73
Total	Mg	1.75

8.1.1 Human cremation

It is assumed that no drastic changes will take place with regards to human cremation that will influence the emissions.

The projection of NEC gas and particle emissions from human cremation is performed based on a projection of population done by Statistics Denmark and on known developments from the last two decades. The development in the total number of cremations and the cremation fraction in relation to the total number of deceased are shown in Figure 8.1 for 1990-2009.

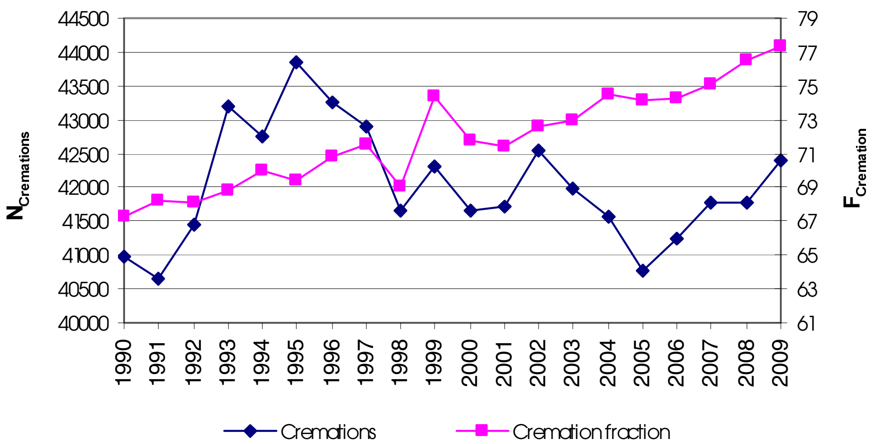

Figure 8.1 The development in the number of yearly cremations.

Based on this historical development, it is assumed that the increase of the cremation fraction will continue, and that the increase can be described by the linear regression based on 1990-2009 data. By comparing data for population with the yearly number of deceased for the years 1901-2009, the fraction of deaths is found to be 1 %.

Table 8.2…Data on population, number of deaths and number on cremations.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Population	5534738	5550947	5566621	5581819	5596683	5611417	5626237	5641206	5656494	5672179
Deaths	55347	55509	55666	55818	55967	56114	56262	56412	56565	56722
Cremation fraction	76.9 %	77.4 %	77.8 %	78.3 %	78.8 %	79.2 %	79.7 %	80.2 %	80.6 %	81.1 %
Cremations	42561	42945	43327	43707	44086	44465	44846	45229	45617	46009
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Population	5688268	5704816	5721762	5738933	5756276	5773533	5790604	5807341	5823561	5839127
Deaths	56883	57048	57218	57389	57563	57735	57906	58073	58236	58391
Cremation fraction	81.6 %	82.1 %	82.5 %	83.0 %	83.5 %	83.9 %	84.4 %	84.9 %	85.3 %	85.8%
Cremations	46406	46809	47216	47626	48040	48454	48869	49282	49693	50099
Continued	2030									
Population	5854021									
Deaths	58540									
Cremation fraction	86.3 %									
Cremations	50501									

The projection of emissions from human cremation shown in Table 8.1a-c is calculated by multiplying the estimated activity data from Table 8.2 with the emission factors. Nielsen et al. (2011) provides the emission factors for SO_2, NO_x, NMVOC and particles. From 1/2011 new demands for emission limits are enquiring the Danish crematoria to invest in flue gas cleaning equipment. The best suitable cleaning equipment for Danish crematoria is bag filters (Schleicher et al., 2008) and the emission factors for particles are therefore lowered by 99% for the years 2011-2030 according to standard bag filter efficiency (de Nevers, 2000).

Table 8.3 Emission factors for human cremation

	Unit	Value 2010	Value 2011-2030
SO_2	g pr body	54.4	54.4
NO_x	Kg pr body	0.31	0.31
NMVOC	g pr body	13.0	13.0
TSP	g pr body	43.5	0.44
PM_{10}	g pr body	39.2	0.39
$PM_{2.5}$	g pr body	39.2	0.39

8.1.2 Animal cremation

Historically, the development in the amount of cremated animal carcasses is difficult to explain. It is therefore also difficult to predict the future development. Figure 8.2 shows historical data from 1998-2009.

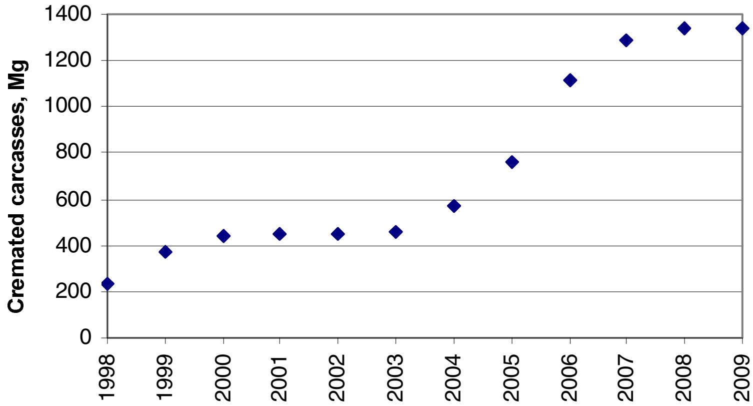

Figure 8.2 Cremated amount of carcasses, 1998-2009.

It is assumed that the 2010-2030 projection of activity data for animal cremation can be described by the constant average of the years 2007-2009.

Table 8.4 Amount of incinerated carcasses.

	2007	2008	2009	Average
Cremated carcasses, Mg	1284.2	1338.3	1338.9	1320.5

The projection of emissions from animal cremation shown in Table 8.1a-c are calculated by multiplying the estimated activity data from Table 8.4 with the emission factors known from the Nielsen et al. (2011).

Table 8.5 Emission factors for animal cremation.

	Unit	Value
SO_2	Kg pr Mg	0.84
NO_x	Kg pr Mg	4.75
NMVOC	Kg pr Mg	2.00
TSP	Kg pr Mg	2.18
PM_{10}	Kg pr Mg	1.53
$PM_{2.5}$	Kg pr Mg	1.31

8.2 Waste Other

This category is a catchall for the waste sector. Emissions in this category could stem from accidental fires, sludge spreading, compost production, biogas production and other combustion. Currently, the projections in this section cover accidental fires and compost production.

Table 8.6 provides an overview of the Danish gas emissions of SO_2, NO_x, NMVOC, NH_3 and particles from the NFR source category *6.D waste other*. All particles in this category are below the limit of $PM_{2.5}$, therefore only the emission of TSP is shown in Table 8.6 as it is equal to the emission of PM_{10} and $PM_{2.5}$.

Table 8.6 a Projection of overall emission of NEC gases and particles from accidental fires and compost production, 2010-2019.

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
SO_2 emission from											
Building fires	Mg	929.35	929.35	929.35	929.35	929.35	929.35	929.35	929.35	929.35	929.35
Vehicle fires	Mg	20.84	21.15	21.46	21.76	22.07	22.38	22.69	23.00	23.31	23.61
Total	Mg	950.19	950.49	950.80	951.11	951.42	951.73	952.04	952.35	952.65	952.96
NO_x emission from											
Building fires	Mg	62.44	62.44	62.44	62.44	62.44	62.44	62.44	62.44	62.44	62.44
Vehicle fires	Mg	8.34	8.46	8.58	8.71	8.83	8.95	9.08	9.20	9.32	9.45
Total	Mg	70.77	70.90	71.02	71.14	71.27	71.39	71.51	71.64	71.76	71.88
NMVOC emission from											
Building fires	Mg	312.18	312.18	312.18	312.18	312.18	312.18	312.18	312.18	312.18	312.18
Vehicle fires	Mg	35.43	35.95	36.47	37.00	37.52	38.05	38.57	39.10	39.62	40.15
Total	Mg	347.61	348.13	348.66	349.18	349.71	350.23	350.75	351.28	351.80	352.33
NH_3 emission from											
Compost production	Mg	570.64	583.08	595.52	607.95	620.39	632.83	645.27	657.70	670.14	682.58
TSP emission from											
Building fires	Mg	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Vehicle fires	Mg	8.54	8.67	8.79	8.92	9.05	9.17	9.30	9.43	9.55	9.68
Total	Mg	8.85	8.97	9.10	9.23	9.35	9.48	9.61	9.73	9.86	9.99

Table 8.6 b Projection of overall emission of NEC gases and particles from accidental fires and compost production, 2020 - 2029.

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
SO_2 emission from											
Building fires	Mg	929.35	929.35	929.35	929.35	929.35	929.35	929.35	929.35	929.35	929.35
Vehicle fires	Mg	23.92	24.23	24.54	24.85	25.16	25.47	25.77	26.08	26.39	26.70
Total	Mg	953.27	953.58	953.89	954.20	954.50	954.81	955.12	955.43	955.74	956.05
NO_x emission from											
Building fires	Mg	62.44	62.44	62.44	62.44	62.44	62.44	62.44	62.44	62.44	62.44
Vehicle fires	Mg	9.57	9.69	9.82	9.94	10.06	10.19	10.31	10.43	10.56	10.68
Total	Mg	72.01	72.13	72.25	72.38	72.50	72.62	72.75	72.87	72.99	73.12
NMVOC emission from											
Building fires	Mg	312.18	312.18	312.18	312.18	312.18	312.18	312.18	312.18	312.18	312.18
Vehicle fires	Mg	40.67	41.19	41.72	42.24	42.77	43.29	43.82	44.34	44.86	45.39
Total	Mg	352.85	353.38	353.90	354.43	354.95	355.47	356.00	356.52	357.05	357.57
NH_3 emission from											
Compost production	Mg	695.02	707.45	719.89	732.33	744.76	757.20	769.64	782.08	794.51	806.95
TSP emission from											
Building fires	Mg	0.31	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85	8.85
Vehicle fires	Mg	9.81	9.93	10.06	10.19	10.31	10.44	10.56	10.69	10.82	10.94
Total	Mg	10.11	18.78	18.91	19.03	19.16	19.29	19.41	19.54	19.67	19.79

Table 8.6 c Projection of overall emission of NEC gases and particles from accidental fires and compost production, 2030.

	Unit	2030
SO_2 emission from		
Building fires	Mg	929.35
Vehicle fires	Mg	27.01
Total	Mg	956.36
NO_x emission from		
Building fires	Mg	62.44
Vehicle fires	Mg	10.80
Total	Mg	73.24
NMVOC emission from		
Building fires	Mg	312.18
Vehicle fires	Mg	45.91
Total	Mg	358.10
NH_3 emission from		
Compost production	Mg	819.39
TSP emission from		
Building fires	Mg	0.31
Vehicle fires	Mg	11.07
Total	Mg	11.38

8.2.1 Sludge spreading

Sludge from waste water treatment plants is only spread out in the open with the purpose of fertilising crop fields. Any emissions that might derive from this activity are estimated in Chapter 5 (NFR Sector 4).

8.2.2 Biogas production

Emissions from biogas production are divided and reported in different sections according to use.

For the biogas production from organic waste with the purpose of energy production, see Chapter 2, Stationary Combustion.

Biogas production from manure is included in Chapter 5, Agriculture.

8.2.3 Other combustion

Other combustion sources include open burning of yard waste and wild fires.

In Denmark, the open burning of private yard waste is completely prohibited in urban zones. In rural zones, burning of garden waste is under different restrictions according to the respective municipality. These restrictions involve what can be burned but also the quantity, how, when and where. There is no registration of private waste burning and the activity data on this subject are very difficult to estimate. People are generally appealed to compost their yard waste or to dispose of it through one of the many waste disposal/recycling sites.

The occurrence of bonfires at midsummer night and in general are likewise not registered, therefore it has not been possible to obtain historical activity data or to predict the development of this activity.

Due to the cold and wet climate conditions in Denmark wild fires very seldom occurs. Controlled agricultural burnings are included in Chapter 5. The occasional wild fires are of such a small scale that this activity is assumed negligible, both historically and for the future.

8.2.4 Accidental building fires

Activity data for building fires are classified in three categories: large, medium and small. The emission factors comply for full scale building fires and the activity data is therefore recalculated as a full scale equivalent (FSE). Here it is assumed that a medium and a small scale fire makes up 50 % and 5 % of a FSE respectively, and that a large fire is a full scale fire.

Calculations of emissions for 1990-2009 are based on surrogate data and on detailed information for 2006-2009 given by the Danish Emergency Management Agency (DEMA). Because of the very limited amount of detailed historical information available, it has been difficult to predict the future development of this activity. Activity data for accidental building fires are therefore chosen as the average of 2006-2009 data.

Table 8.7 Number of accidental building fires 2006-2009.

		2006	2007	2008	2009	Average
Number of detached house fires	Large	1 018	988	1 153	1 222	1 095
	Medium	941	1 021	1 153	945	1 015
	Small	1 307	1 432	1 491	1 404	1 409
Number of undetached house fires	Large	186	239	206	173	201
	Medium	269	391	306	196	290
	Small	470	717	445	399	508
Number of apartment building fires	Large	141	152	145	169	152
	Medium	650	720	796	638	701
	Small	911	932	1 008	1 072	981
Number of industrial building fires	Large	240	268	244	282	259
	Medium	237	324	216	246	256
	Small	399	369	443	507	430

Full scale equivalents (FSE) can now be calculated from the assumption that a medium size fire has a damage rate of 50 % compared to a large (full scale) fire and that a small size fire leads to the emission of 5 % of a large fire. Table 8.8 shows the calculated FSEs based on the 2006-2009 average numbers of accidental building fires shown in Table 8.7.

Table 8.8 Projection of FSE fires 2010-2030.

FSE of detached house fires	1 673
FSE of undetached house fires	372
FSE of apartment building fires	551
FSE of industrial building fires	408
All building FSE fires	3 004

By assuming that building compositions and sizes will not significantly change over the next two decades, the emission factors known from Nielsen et al. (2011) are accepted for this projection.

Table 8.9 Emission factors for accidental building fires.

	Unit	Detached houses	Undetached houses	Apartment buildings	Industrial buildings
SO_2	Kg pr fire	258.54	213.58	123.65	802.92
NO_x	Kg pr fire	19.29	15.90	8.04	45.00
NMVOC	Kg pr fire	96.47	79.52	40.18	225.00
NH_3	-	NAV	NAV	NAV	NAV
TSP	g pr fire	143.82	61.62	43.78	27.23
PM_{10}	g pr fire	143.82	61.62	43.78	27.23
$PM_{2.5}$	g pr fire	143.82	61.62	43.78	27.23

Emissions from accidental building fires in 2010-2030 are shown in Table 8.6a-c.

8.2.5 Accidental vehicle fires

The Danish Emergency Management Agency (DEMA) provides data for the total number of accidental vehicle fires 2007-2009 divided into the categories; passenger cars, light duty vehicles, heavy duty vehicles, buses and motorcycles/mopeds.

DTU Transport (Jensen & Kveiborg, 2009) provides the national population of vehicles in these same categories for historical years as well as a projection of the 2010-2030 vehicle population. This projection is shown in Table 8.10.

Table 8.10 Projection of population of vehicles.

	Passenger cars	Buses	Light duty vehicles	Heavy duty vehicles	Motorcycles/ mopeds
2010	2128487	14741	417333	47700	295166
2011	2129561	14729	416090	48348	297039
2012	2125018	14718	411165	48970	298913
2013	2115873	14707	404649	49602	300786
2014	2102246	14697	396345	50236	302660
2015	2103980	14687	402051	51125	304533
2016	2110882	14677	406544	52000	306407
2017	2119165	14669	409997	52872	308280
2018	2128884	14661	414010	53786	310154
2019	2142536	14653	419815	54738	312027
2020	2156872	14647	424593	55699	313901
2021	2174592	14642	431632	56696	315774
2022	2194495	14638	438943	57694	317648
2023	2213392	14634	444980	58679	319521
2024	2231546	14631	450633	59632	320007
2025	2254278	14628	459518	60648	321811
2026	2274790	14626	465664	61584	323615
2027	2295836	14625	472885	62553	325419
2028	2314012	14624	478392	63474	327223
2029	2329027	14623	482695	64391	329027
2030	2352379	14622	493088	65404	332635

By comparing the number of burnt vehicles with the population of vehicles in each category for 2007-2009, the following fractions are calculated.

Table 8.11 Average fraction of vehicles that accidentally burned each year 2007-2009.

Category	Fraction, %
Passenger cars	0.09
Light duty vehicles	0.03
Heavy duty vehicles	0.32
Buses	0.43
Motorcycles/Mopeds	0.19

The number of accidental vehicle fires can now be calculated by using data from Table 8.10 and Table 8.11; results are shown in Table 8.12.

Table 8.12 Projection of number of accidental vehicle fires.

	Passenger cars	Buses	Light duty vehicles	Heavy duty vehicles	Motorcycles/ mopeds
2010	1836	64	138	153	546
2011	1837	64	137	155	550
2012	1833	64	136	157	553
2013	1825	64	133	159	557
2014	1813	63	131	161	560
2015	1815	63	133	163	563
2016	1821	63	134	166	567
2017	1828	63	135	169	570
2018	1836	63	136	172	574
2019	1848	63	138	175	577
2020	1861	63	140	178	581
2021	1876	63	142	181	584
2022	1893	63	145	184	588
2023	1909	63	147	188	591
2024	1925	63	149	191	592
2025	1945	63	151	194	595
2026	1962	63	154	197	599
2027	1980	63	156	200	602
2028	1996	63	158	203	605
2029	2009	63	159	206	609
2030	2029	63	163	209	615

It is assumed that no significant changes in the average vehicle weight will occur during the next two decades and that only 70 % of the mass involved in fires actually burns.

Table 8.13 Average vehicle weight in 2010.

	kg
Passenger cars	1144
Light duty vehicles	4498
Heavy duty vehicles	11883
Buses	11804
Motorcycles/Mopeds	104

The total burnt mass of vehicle have been calculated, results are shown in Table 8.14.

Table 8.14 Projection of activity data for accidental vehicle fires.

	Burnt mass of vehicles, Mg
2010	3738
2011	3754
2012	3763
2013	3766
2014	3765
2015	3796
2016	3828
2017	3861
2018	3896
2019	3937
2020	3977
2021	4023
2022	4071
2023	4117
2024	4161
2025	4213
2026	4258
2027	4306
2028	4349
2029	4389
2030	4443

By assuming that vehicle compositions will not significantly change over the next two decades, the emission factors known from Nielsen et al. (2011) are accepted for this projection.

Table 8.15 Emission factors for accidental vehicle fires.

	Unit	Value
SO_2	Kg pr Mg	5
NO_x	Kg pr Mg	2
NMVOC	Kg pr Mg	8.5
NH_3	-	NAV
TSP	Kg pr Mg	2.05
PM_{10}	Kg pr Mg	2.05
$PM_{2.5}$	Kg pr Mg	2.05

Calculated emissions are shown in Table 8.6a-c.

8.2.6 Compost production

In Denmark, composting of solid biological waste includes composting of:

- Garden and park waste (GPW)
- Organic waste from households and other sources
- Sludge
- Home composting of garden and vegetable food waste.

The future activity of each category has been projected individually.

Garden and park waste is for 1990-2009 determined based on the Danish waste statistics (Affaldsstatistik 2007 & 2008, and earlier years) and on the two statistical reports Petersen (2001) and Petersen & Hansen (2003). The projection of this waste category is made from the linear regression of the 1999-2008 activity data.

Activity data for both waste-categories; organic waste from households and other sources and sludge, are for the historical years 1990-2009 based on data from the Danish waste statistics. The projection of organic waste is done as an average of the activity data from 1995-2008 and sludge as an expert judgement.

Home composting of garden and vegetable food waste is for 1990-2009 determined based on data from Statistics Denmark and on Petersen & Kielland (2003). The 1990-2009 data is used in a linear regression to project home composting to 2010-2030.

Table 8.16 Projected activity data for compost production.

Gg	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Garden and park waste	816	835	853	872	891	909	928	946	965	983
Organic waste	49	49	49	49	49	49	49	49	49	49
Sludge	100	105	110	115	120	125	130	135	140	145
Home composting	23	23	23	23	23	23	23	24	24	24
Continued	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Garden and park waste	1002	1020	1039	1057	1076	1095	1113	1132	1150	1169
Organic waste	49	49	49	49	49	49	49	49	49	49
Sludge	150	155	160	165	170	175	180	185	190	195
Home composting	24	24	24	24	24	25	25	25	25	25
Continued	2030									
Garden and park waste	1187									
Organic waste	49									
Sludge	200									
Home composting	25									

By assuming that the process of compost production will not significantly change over the next two decades, the emission factors known from Nielsen et al. (2011) are accepted for this projection.

Table 8.17 Emission factors for compost production.

		Garden and Park waste	Organic waste	Sludge	Home composting
NH_3	Mg/Gg	0.66	0.314	0.022	0.630

Calculated emissions are shown in Table 8.6a-c.

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9 Conclusions

Emissions of SO_2, NO_x, NMVOC, NH_3 and $PM_{2.5}$ are listed in Table 9.1 for the historical year 2009 and the projection years 2020 and 2030. The emissions show more or less pronounced decreases in the projection period. The only exception is SO_2, which shows a slight increase in the projection period.

Table 9.1 Emissions in the historical year 2009 and the projection years 2020 and 2030 (ktonnes).

Pollutants	SO_2	NO_X	NMVOC*	NH_3*	$PM_{2.5}$
Emissions 2009	15	132	94	71	24
Projected emissions 2020	15	85	70	58	17
Projected emissions 2030	16	70	64	55	14

*: The NH_3 emissions are excluding emission from straw treatment and crops and the NMVOC emission are excluding emission from crops, according to the decisions in the NEC Directive.

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.

9.1 SO_2 emission

The SO_2 emission is shown in Figure 9.1. The total emission shows a decrease from 1990 to 2009, mainly because of decreasing coal consumption in the energy industry sector. From 2010 to 2030 a slight increase in the SO_2 emission is predicted caused by increasing fuel consumption in the industrial sector and other stationary sectors. The historic SO_2 emission decreased significantly due to installation of desulphurisation plant and shifting to fuels with lower sulphur content. The resulting decline in the total SO_2 emission from 1990 to 2005 was 89 %.

In 2020 the energy industry sector is expected to account for 28 % 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.

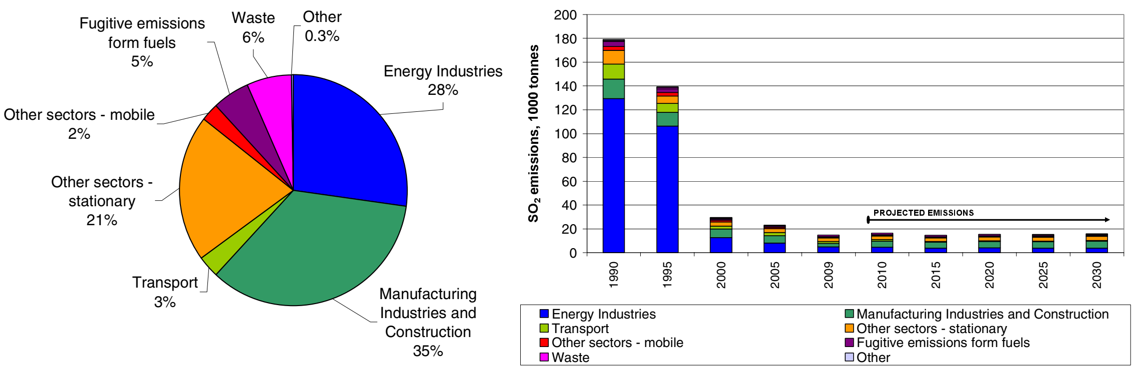

Figure 9.1 SO_2 emission. Distribution by main sectors (2020) and time-series including selected historical and projection years.

As shown in Figure 9.1 the main source category for SO_2 emission in 2020 is manufacturing industries but also other stationary combustion in residential or agricultural plants are contributing significantly to the SO_2 emission. This means that a larger share of emissions come from sources without continuous measurements. This in turn means that the uncertainty of the estimate increases. To lower this uncertainty it is important to improve emission factors including determining abatement used in manufacturing plants presently not included as point sources in the Danish inventory.

9.2 NO_x emission

From Figure 9.2 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 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 34 % of the total NO_X emission in 2020.

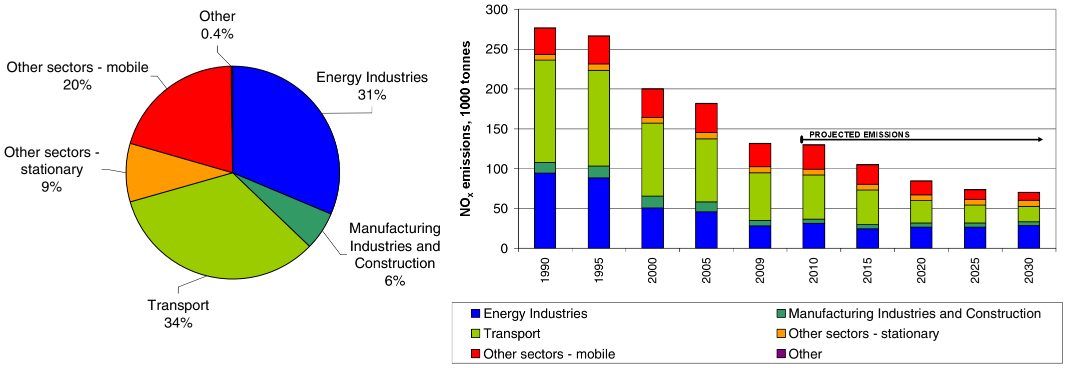

Figure 9.2 NO_X emissions. Distribution by main sectors (2020) and time-series including selected historical and projection years.

The NO_x emission mainly comes from transport, which is heavily regulated by EU directives and from large point sources where continuous measurement data are available. The uncertainties regarding the emission factors are therefore quite low. However, it must be noted that emission factors from biomass combustion currently are based on very few measurements and are more uncertain. Emissions from agricultural soils are not included at the moment.

9.3 NMVOC emissions

Figure 9.3 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 was due to the introduction of catalyst cars as well as reduced emissions from use of solvents and other product use.

In 2020 solvent and other product use is projected to account for 32 % of the total NMVOC emission. Other stationary sectors and transport are the second and third largest sources of the NMVOC emission. For other stationary sectors it is primarily wood combustion in the residential sector that contributes heavily to the emission. From 2010 to 2030 the emissions are expected to decrease further for the transport sector due to implementation of still stricter EU norms.

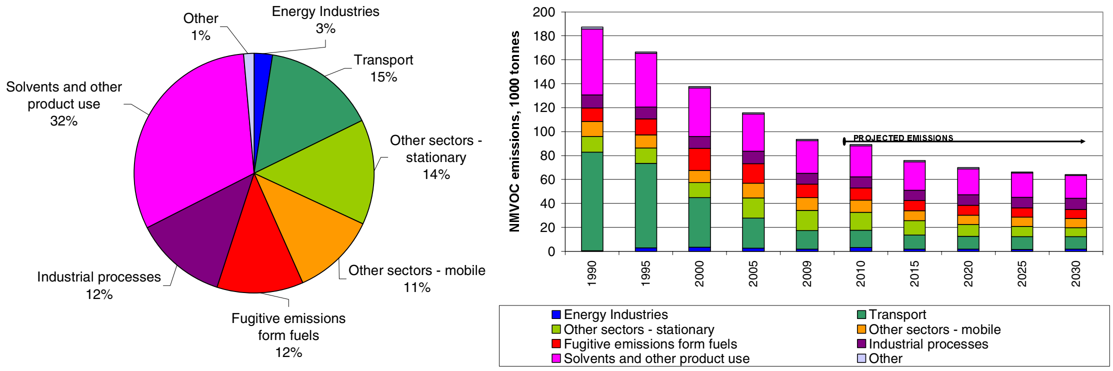

Figure 9.3 NMVOC emissions. Distribution by main sectors (2020) and time-series including selected historical and projection years.

Emissions from transport and mobile machinery have historically been a large source, however, due to EU regulation the most uncertain sectors are solvent use, industrial processes and residential plants (wood combustion). Work is ongoing to improve the estimate for industrial processes, which mainly consist of emission from the production of food and drink. Especially for sugar production improved emission factors are under development that is expected to result in lower emissions. For residential plants the biggest challenge is to have a correct distribution of wood burning technologies. For solvent use it should be considered to compare the top-down estimates used in the inventory and the projections with bottom-up data reported by companies under different EU directives.

Some sources are not currently estimated, e.g. emissions from waste disposal on land and wastewater handling.

9.4 NH_3 emission

The NH_3 emission is shown in Figure 9.4 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 was mainly due to 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 2020 the agricultural sector is projected to account for 97 % of the total NH_3 emission. Transport contributes with roughly 1 % of the emission while the remaining 2 % comes from mobile sources in other sectors and industrial processes.

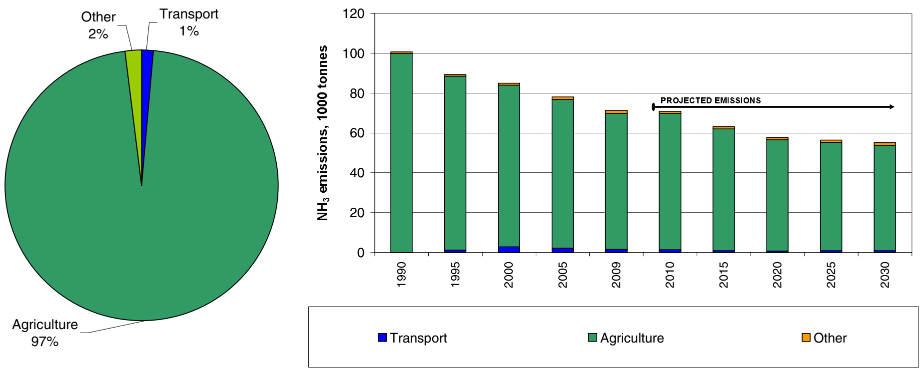

Figure 9.4 NH_3 emissions. Distribution by main sectors (2020) and time-series including selected historical and projection years.

The main uncertainties for the NH_3 emission are the development in the number of livestock and the phasing in of new abatement technology in the animal housing systems.

9.5 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 9.5, 9.6 and 9.7. 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.

9.5.1 TSP

The largest TSP emission sources are the residential sector and the agricultural sector. In 2020 other stationary sectors, in which residential wood combustion is expected to be the main sector, and is projected to account for 41 % of the total TSP emission, followed by the agricultural sector with 36 % of the total TSP emission.

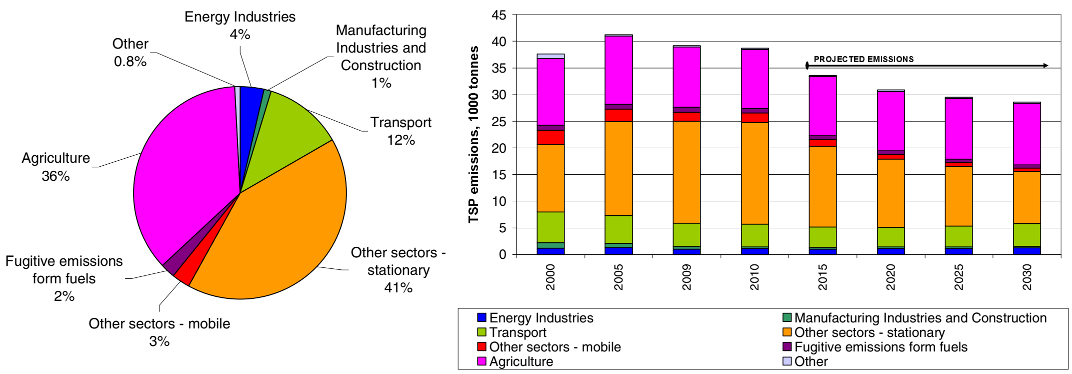

Figure 9.5 TSP emissions. Distribution by main sectors (2020) and time-series including selected historical and projection years.

9.5.2 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 was caused by the decreasing emission from the transport sector and other mobile sectors.

In 2020 other stationary sectors account for 53 % of the total PM_{10} emission. Agriculture and transport are the second and third largest sources for the PM_{10} emission, projected to account for 25 % and 12 %, respectively.

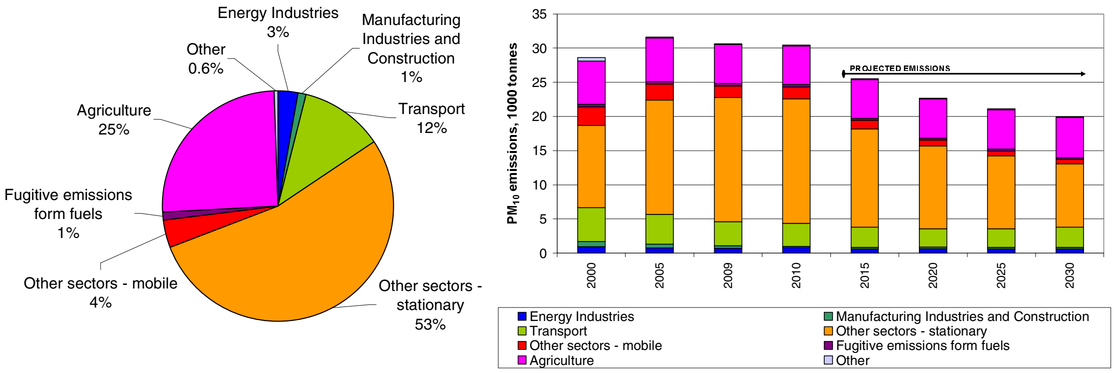

Figure 9.6 PM_{10} emissions. Distribution by main sectors (2020) and time-series including selected historical and projection years.

9.5.3 $PM_{2.5}$

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 stationary and mobile sectors. The decrease from 2000 to 2005 was caused by decreasing emissions, mainly from the transport sector.

In 2020 other stationary sectors are expected to account for 71 % of the total $PM_{2.5}$ emission. Transport and agriculture are the second and third largest sources for the $PM_{2.5}$ emission, projected to account for 11 % and 8 %, respectively.

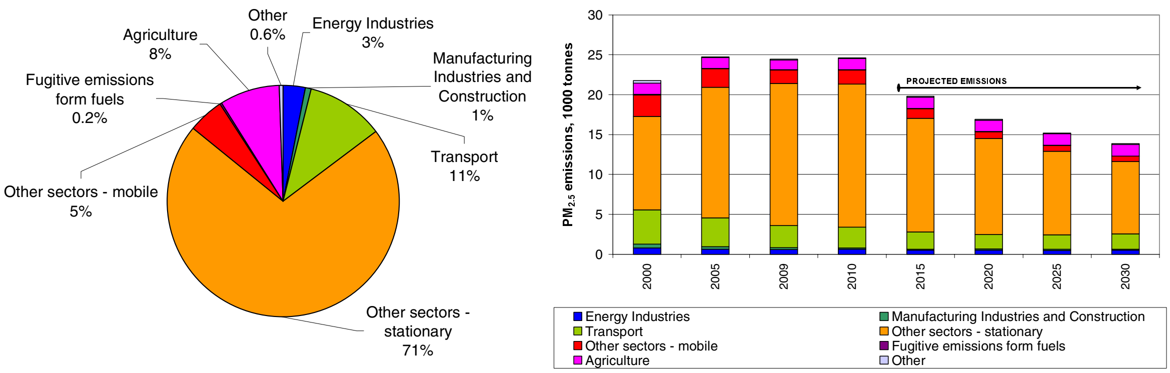

Figure 9.7 $PM_{2.5}$ emissions. Distribution by main sectors (2020) and time-series including selected historical and projection years.

For PM and especially $PM_{2.5}$ the dominating source is wood combustion in residential plants. This emission is highly dependent on the technology distribution and the estimate therefore highly depends on the accuracy of this distribution. Furthermore, it has to be noted that the Danish emission inventory and therefore also the projections omits several sources of particulate matter identified by the EMEP/EEA Guidebook. This means that emissions at the moment can be considered as underestimated

Table 7.2 to 7.8 list the emissions for 1990, 2000, 2005, 2009 and the projected emissions for 2010, 2015, 2020, 2025 and 2030.

Annual emissions are available for the years until 2009, while the presented emissions for 2010 are projections. In consequence the 2010 emissions are preliminary and are therefore not decisive as to whether Denmark fulfils its obligations with regard to the NEC Directive.

Table 7.2 NO_X emissions in tonnes.

SNAP	Sector	NFR	1990	2000	2005	2009	2010	2015	2020	2025	2030
0101	Public power	1A1a	90 483	42 715	37 604	19.796	21 425	14 132	15 703	14 985	15 959
0102	District heating plants	1A1a	IE	IE	IE	IE	1 861	2 561	2 310	2 295	2 067
0103	Petroleum refining plants	1A1b	1 616	1 393	1 284	1.610	1 414	1 414	1 414	1 414	1 414
0105	Coal mining, oil / gas extraction, pipeline	1A1c	2 295	6 285	6 982	6.686	6 398	6 325	7 173	7 890	8 860
0201	Commercial and institutional plants (t)	1A4a	1 188	1 304	1 104	812	682	646	634	697	839
0202	Residential plants	1A4b	4 939	4 723	5 815	6.192	6 197	5 673	5 544	5 420	5 252
0203	Plants in agriculture, forestry and aquaculture	1A4c	1 144	1 399	1 141	702	772	920	1 287	1 350	1 613
03	Combustion in manufacturing industry	1A2	13 277	14 922	12 324	6.764	5 359	5 361	4 934	4 938	5 083
04	Production processes	2A-G	36	34	30	18	18	16	14	11	9
07	Road	1A3b	109 035	78 585	65 533	46.637	42 624	31 290	17 318	12 339	11 076
0801	Military	1A5	495	544	1 308	704	664	537	417	371	355
0802	Railways	1A3c	4 913	3 727	3 724	2.603	2 483	1 881	1 280	1 280	1 280
0803	Navigation	1A3d	13 649	8 087	8 634	9.534	9 564	9 500	8 769	8 005	6 056
0805	Civil Aviation	1A3a	1 095	1 334	1 205	1.143	642	712	814	843	789
0806-0807	Ag./for./fish.	1A4c	21 066	22 807	24 018	20.802	20 312	16 612	10 937	6 784	4 630
0808	Industry	1A2f	11 081	12 096	10 664	7.137	8 874	7 068	5 410	4 543	4 426
0809	Residential	1A4b	34	50	72	84	87	92	93	93	93
0811	Commercial and institutional	1A4a	70	104	177	220	217	219	219	219	219
090206	Flaring in gas and oil extraction	1B2c	173	320	256	128	169	95	90	90	90
0909	Waste incineration	6C	13	15	16	19	19	20	21	21	22
0910	Other waste	6D	60	65	62	71	71	71	72	73	73
10	Agriculture	4A-G	77	91	114	127	127	120	119	119	119
Total			276 740	200 600	182 068	131.790	129 980	105 267	84 571	73 779	70 324
0804	Navigation int.	1A3d	60 639	94 441	56 540	35.658	36 150	36 295	31 782	26 522	21 048
0805	Civil Aviation int.	1A3a	7 043	8 835	10 405	9.363	8 398	9 666	11 041	11 434	10 707

Table 7.3 SO_2 emissions in tonnes.

SNAP	Sector	NFR	1990	2000	2005	2009	2010	2015	2020	2025	2030
0101	Public power	1A1a	126 052	12 020	7 783	4 589	3 436	2 326	2 660	2 306	2 456
0102	District heating plants	1A1a	IE	IE	IE	IE	1 117	1 435	1 452	1 399	1 158
0103	Petroleum refining plants	1A1b	3 411	598	267	341	57	57	57	57	57
0105	Coal mining, oil/gas extraction, pipeline	1A1c	3	8	8	8	8	8	9	10	11
0201	Commercial and institutional plants (t)	1A4a	1 874	356	283	130	62	59	57	84	144
0202	Residential plants	1A4b	6 415	1 522	1 653	1 636	1 576	1 434	1 412	1 390	1 340
0203	Plants in agriculture, forestry and aquaculture	1A4c	3 192	1 619	1 551	1 219	1 410	1 459	1 659	1 774	1 944
03	Combustion in manufacturing industry	1A2	16 296	7 421	6 230	2 847	4 983	5 037	5 268	5 450	5 962
04	Production processes	2A-G	636	421	402	20	20	18	16	12	10
05	Fugitive emissions from fuels	1B2a	3 335	981	255	375	375	375	375	375	375
06	Solvent and other product use	3A-D	2	9	7	10	10	10	10	10	10
07	Road	1A3b	5 767	352	77	76	75	74	75	79	84
0801	Military	1A5	48	27	57	25	3	3	3	3	3
0802	Railways	1A3c	376	7	1	1	1	1	1	1	1
0803	Navigation	1A3d	6 429	1 844	2 339	1 593	1 369	360	360	360	352
0805	Civil Aviation	1A3a	74	92	81	77	47	52	60	62	58
0806-0807	Ag./for./fish.	1A4c	2 303	1 021	852	392	392	361	362	362	370
0808	Industry	1A2f	952	253	28	24	32	6	6	6	6
0809	Residential	1A4b	1	1	0	0	0	0	0	0	0
0811	Commercial and institutional	1A4a	2	3	1	1	1	1	1	1	1
090206	Flaring in gas and oil extraction	1B2c	945	55	299	454	455	454	454	454	454
0909	Waste incineration	6C	10	11	14	16	16	15	15	15	15
0910	Other waste	6D	2	3	3	3	3	4	4	4	4
10	Agriculture	4A-G	824	836	806	952	950	952	953	955	956
Total			178 949	29 460	22 999	14 792	16 399	14 503	15 270	15 169	15 773
0804	Navigation int.	1A3d	41 317	55 367	34 283	7 383	5 130	941	941	941	941
0805	Civil Aviation int.	1A3a	558	708	784	711	767	883	1 008	1 044	978

Table 7.4 NMVOC emissions in tonnes.

SNAP	Sector	NFR	1990	2000	2005	2009	2010	2015	2020	2025	2030
0101	Public power	1A1a	424	3 541	2 595	1.938	2 880	1 602	1 581	1 356	1 550
0102	District heating plants	1A1a	IE	IE	IE	IE	103	132	124	130	122
0103	Petroleum refining plants	1A1b	58	2	2	1	22	22	22	22	22
0105	Coal mining, oil/gas extraction, pipeline	1A1c	13	36	40	38	36	35	40	44	50
0201	Commercial and institutional plants (t)	1A4a	125	305	266	275	258	235	226	228	240
0202	Residential plants	1A4b	12 098	11 521	15 745	16.245	14 031	11 172	8 934	7 570	6 298
0203	Plants in agriculture, forestry and aquaculture	1A4c	820	789	664	444	596	637	722	784	900
03	Combustion in manufacturing industry	1A2	1 131	545	439	295	315	311	312	310	322
04	Production processes	2A-G	10 774	9 834	10 477	9.133	9 133	8 690	8 639	8 805	9 133
0502	Extraction, 1st treatment and loading of liquid fuels	1B2a	11 164	18 258	16 159	11.001	10 170	8 454	8 159	7 505	7 508
0506	Gas distribution networks	1B2b	96	111	95	34	34	29	26	23	22
06	Solvent and other product use	3A-D	55 087	40 649	30 955	27.351	26 099	23 720	21 809	20 270	19 029
07	Road	1A3b	80 071	39 084	23 290	13.685	13 564	10 831	9 893	9 828	9 720
0801	Military	1A5	53	55	106	55	53	47	46	46	46
0802	Railways	1A3c	321	253	235	174	159	84	9	9	9
0803	Navigation	1A3d	1 686	1 731	1 423	1.013	937	745	739	741	727
0805	Civil Aviation	1A3a	274	260	258	332	35	39	45	46	43
0806-0807	Ag./for./fish.	1A4c	6 149	3 414	2 712	2.504	2 345	1 932	1 780	1 719	1 660
0808	Industry	1A2f	2 266	1 926	1 620	976	1 204	993	840	802	782
0809	Residential	1A4b	1 801	1 757	2 084	2.071	2 032	1 801	1 716	1 716	1 716
0811	Commercial and institutional	1A4a	2 303	2 845	5 775	5.159	4 423	3 598	3 598	3 598	3 598
090206	Flaring in gas and oil extraction	1B2c	45	78	67	62	67	61	61	61	61
0909	Waste incineration	6C	203	1 976	2 099	2.199	2 189	2 126	2 100	2 070	2 041
0910	Other waste	6D	1	1	1	2	2	3	3	3	3
10	Agriculture	4A-G	296	306	296	348	348	350	353	355	358
Total			187 257	139 276	117 402	95.335	91 034	77 652	71 776	68 043	65 960
	Navigation int.	1A3d	2 060	3 045	1 792	1.160	1 174	1 213	1 245	1 266	1 273
	Civil Aviation int.	1A3a	243	250	303	374	374	461	530	606	627
	Crops	4G	1 901	1 756	1 678	1.765	1 765	1 875	1 813	1 787	1 758

Table 7.5 NH_3 emissions in tonnes.

SNAP	Sector	NFR	1990	2000	2005	2009	2010	2015	2020	2025	2030
01	Combustion in energy and transformation industries	1A1	0	3	8	9	9	11	12	12	13
02	Non-industrial combustion	1A4	67	76	85	143	143	181	181	180	178
03	Combustion in manufacturing industries	1A2	489	497	335	324	1	1	1	1	1
04	Production processes	2A-G	37	48	211	258	258	244	221	196	178
07	Road	1A3b	69	2 767	2 298	1.612	1 463	1 017	834	912	1 028
0801	Military	1A5	0	0	1	1	1	1	1	1	1
0802	Railways	1A3c	1	1	1	1	1	1	1	1	1
0803	Navigation	1A3d	0	0	0	0	0	0	0	0	0
0805	Civil Aviation	1A3a	0	0	0	0	0	0	0	0	0
0806-0807	Ag./for./fish.	1A4c	3	3	3	4	4	4	4	4	4
0808	Industry	1A2f	2	2	2	2	3	3	3	3	3
0809	Residential	1A4b	0	0	0	0	0	0	0	0	0
0811	Commercial and institutional	1A4a	0	0	0	0	0	0	0	0	0
0909	Waste incineration	6C	0	1	1	3	3	3	3	3	3
0910	Other waste	6D	198	464	492	590	571	633	695	757	819
10	Animal manure	4A-G	99 797	87 198	81 161	74.508	74 508	68 411	60 986	55 828	54 399
Total			100 664	91 059	84 598	77.454	76 962	70 509	62 940	57 895	56 628
10	Crops		16 185	12 023	7 761	5.646	5 646	5 237	5 064	4 991	4 911

Table 7.6 TSP emissions in tonnes.

SNAP	Sector	NFR	2000	2005	2009	2010	2015	2020	2025	2030
0101	Public power	1A1a	1 021	1 168	903	808	623	747	767	890
0102	District heating plants	1A1a	IE	IE	IE	262	299	291	288	279
0103	Petroleum refining plants	1A1b	144	111	113	81	81	81	81	81
0105	Coal mining, oil/gas extraction, pipeline	1A1c	3	3	3	3	3	3	3	4
0201	Commercial and institutional plants (t)	1A4a	164	158	172	138	122	115	118	128
0202	Residential plants	1A4b	12 001	17 021	18.533	18 406	14 363	11 947	10 253	8 677
0203	Plants in agriculture, forestry and aquaculture	1A4c	465	413	389	585	645	730	810	915
03	Combustion in manufacturing industry	1A2	863	646	495	288	293	297	298	313
04	Production processes	2A-G	94	53	19	19	17	15	13	11
05	Fugitive emissions from solid fuels	1B1a	962	905	1.007	852	744	699	647	609
06	Solvent and other product use	3A-D	193	146	213	213	213	213	213	213
07	Road	1A3b	5 232	4 680	3.969	3 843	3 609	3 456	3 690	4 035
0801	Military	1A5	15	32	17	15	9	6	4	4
0802	Railways	1A3c	141	124	84	77	39	1	1	1
0803	Navigation	1A3d	383	425	327	305	237	231	231	227
0805	Civil Aviation	1A3a	6	5	5	2	3	3	3	3
0806-0807	Ag./for./fish.	1A4c	1 507	1 213	992	935	619	404	327	279
0808	Industry	1A2f	1 135	1 002	587	713	532	350	303	284
0809	Residential	1A4b	11	13	14	14	15	15	15	15
0811	Commercial and institutional	1A4a	30	65	67	67	67	67	67	67
090206	Flaring in gas and oil extraction	1B2c	11	8	4	5	3	3	3	3
0909	Waste incineration	6C	3	3	5	5	3	3	3	3
0910	Other waste	6D	8	8	9	9	9	10	11	11
10	Agriculture	4A-G	12 770	13 135	11.255	11 028	11 072	11 174	11 356	11 539
Total			37 160	41 339	39.179	38 672	33 618	30 860	29 505	28 591
0804	Navigation int.	1A3d	8 791	5 761	820	638	433	433	433	433
0805	Civil Aviation int.	1A3a	36	40	36	39	45	51	53	49

Table 7.7 PM_{10} emissions in tonnes.

SNAP	Sector	NFR	2000	2005	2009	2010	2015	2020	2025	2030
0101	Public power	1A1a	814	656	608	517	323	367	312	338
0102	District heating plants	1A1a	IE	IE	IE	186	215	210	205	197
0103	Petroleum refining plants	1A1b	131	104	106	80	80	80	80	80
0105	Coal mining, oil/gas extraction, pipeline	1A1c	2	2	2	2	2	2	2	2
0201	Commercial and institutional plants (t)	1A4a	158	151	170	136	120	113	116	126
0202	Residential plants	1A4b	11 421	16 217	17.629	17 525	13 682	11 386	9 776	8 278
0203	Plants in agriculture, forestry and aquaculture	1A4c	428	380	361	546	602	679	755	854
03	Combustion in manufacturing industry	1A2	712	478	357	218	221	225	225	236
04	Production processes	2A-G	85	45	15	15	14	12	11	9
05	Fugitive emissions from solid fuels	1B1a	385	362	403	341	298	279	259	244
06	Solvent and other product use	3A-D	96	73	107	107	107	107	107	107
07	Road	1A3b	4 436	3 814	3.101	2 978	2 657	2 424	2 523	2 733
0801	Military	1A5	15	32	17	15	9	6	4	4
0802	Railways	1A3c	141	124	84	77	39	1	1	1
0803	Navigation	1A3d	381	422	324	303	236	229	229	225
0805	Civil Aviation	1A3a	6	5	5	2	3	3	3	3
0806-0807	Ag./for./fish.	1A4c	1 505	1 211	990	934	617	402	326	277
0808	Industry	1A2f	1 135	1 002	587	713	532	350	303	284
0809	Residential	1A4b	11	13	14	14	15	15	15	15
0811	Commercial and institutional	1A4a	30	65	67	67	67	67	67	67
090206	Flaring in gas and oil extraction	1B2c	11	8	4	5	3	3	3	3
0909	Waste incineration	6C	2	3	4	4	2	2	2	2
0910	Other waste	6D	8	8	9	9	9	10	11	11
10	Agriculture	4A-G	6 593	6 626	5.682	5 643	5 662	5 708	5 791	5 873
Total			28 504	31 801	30.645	30 436	25 515	22 682	21 126	19 970
0804	Navigation int.	1A3d	8 703	5 703	812	631	429	429	429	429
0805	Civil Aviation int.	1A3a	36	40	36	39	45	51	53	49

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

SNAP	Sector	NFR	2000	2005	2009	2010	2015	2020	2025	2030
0101	Public power	1A1a	683	528	496	413	254	286	238	255
0102	District heating plants	1A1a	IE	IE	IE	149	174	170	165	158
0103	Petroleum refining plants	1A1b	124	101	103	80	80	80	80	80
0105	Coal mining, oil/gas extraction, pipeline	1A1c	1	1	1	1	1	1	2	2
0201	Commercial and institutional plants (t)	1A4a	147	141	161	128	112	106	109	120
0202	Residential plants	1A4b	11 167	15 866	17.296	17 271	13 542	11 280	9 675	8 181
0203	Plants in agriculture, forestry and aquaculture	1A4c	396	351	335	511	563	636	707	801
03	Combustion in manufacturing industry	1A2	449	301	231	137	139	141	141	148
04	Production processes	2A-G	50	27	11	11	11	9	8	7
05	Fugitive emissions from solid fuels	1B1a	38	36	40	34	30	28	26	24
06	Solvent and other product use	3A-D	67	51	75	75	75	75	75	75
07	Road	1A3b	3 771	3 089	2.378	2 257	1 869	1 575	1 565	1 669
0801	Military	1A5	15	32	17	15	9	6	4	4
0802	Railways	1A3c	141	124	84	77	39	1	1	1
0803	Navigation	1A3d	379	421	323	302	235	228	228	225
0805	Civil Aviation	1A3a	6	5	5	2	3	3	3	3
0806-0807	Ag./for./fish.	1A4c	1 504	1 210	989	933	617	402	325	276
0808	Industry	1A2f	1 135	1 002	587	713	532	350	303	284
0809	Residential	1A4b	11	13	14	14	15	15	15	15
0811	Commercial and institutional	1A4a	30	65	67	67	67	67	67	67
090206	Flaring in gas and oil extraction	1B2c	11	8	4	5	3	3	3	3
0909	Waste incineration	6C	2	3	3	3	2	2	2	2
0910	Other waste	6D	8	8	9	9	9	10	11	11
10	Agriculture	4A-G	1 675	1 626	1.219	1 411	1 406	1 418	1 431	1 445
Total			21 810	25 010	24.451	24 619	19 785	16 892	15 184	13 853
0804	Navigation int.	1A3d	8 659	5 675	808	628	427	427	427	427
0805	Civil Aviation int.	1A3a	36	40	36	39	45	51	53	49

PROJECTION OF SO_2, NO_X, NH_3 AND PARTICLE EMISSIONS 2010-2030

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 Agency. The emission factors refer either to international guidelines or 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.

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