ANNUAL DANISH INFORMATIVE INVENTORY REPORT TO UNECE

Emission inventories from the base year of the protocols to year 2015

Scientific Report from DCE – Danish Centre for Environment and Energy No. 222 2017

AARHUS UNIVERSITY
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Data sheet

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Abstract: This report is a documentation report on the emission inventories for Denmark as reported to the UNECE Secretariat under the Convention on Long Range Transboundary Air Pollution due by 15 February 2017. The report contains information on Denmark's emission inventories regarding emissions of (1) SO_X for the years 1980-2015, (2) NO_X, CO, NMVOC and NH_3 for the years 1985-2015, (3) Particulate matter: TSP, PM_{10}, $PM_{2.5}$ for the years 2000-2015, (4) Heavy Metals: Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn for the years 1990-2015, (5) Polyaromatic hydrocarbons (PAH): Benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene, PCDD/F and HCB for the years 1990-2015. Further, the report contains information on background data for emissions inventory

Keywords: Emission Inventory; Emissions; Projections; UNECE; EMEP; LRTAP; NO_X; CO; NMVOC; SO_X; NH_3; TSP; PM_{10}; $PM_{2.5}$; Pb; Cd; Hg; As; Cr; Cu; Ni; Se; Zn; Polyaromatic hydrocarbons; Dioxin; Benzo(a)pyrene, Benzo(b)fluoranthene

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Summary

I Background information on emission inventories

Annual report

This report is Denmark's Annual Informative Inventory Report (IIR) due March 15, 2017 to the UNECE-Convention on Long-Range Transboundary Air Pollution (LRTAP) and Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants. The report contains information on Denmark's inventories for all years from the base years of the protocols to 2015.

The air pollutants reported are SO_2, NO_X, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, dioxins/furans, HCB, PCBs and PAHs,.

The annual emission inventory for Denmark is reported in the Nomenclature for Reporting (NFR) 2014 format.

The issues addressed in this report are: trends in emissions, description of each NFR category, uncertainty estimates, recalculations, planned improvements and procedures for quality assurance and control. The structure of the report follows to the extent possible the proposed outline.

Information contained in this report is available to the public on the Danish Centre for Environment and Energy (DCE), Aarhus University's homepage:

http://envs.au.dk/videnudveksling/luft/emissioner/emissioninventory/

This report and the NFR tables are available on the Eionet central data repository:

http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_EMEP_UNECE

Responsible institute

DCE-Danish Centre for Environment and Energy, Aarhus University, is on behalf of the Danish Ministry of Environment and Food responsible for the annual preparation and submission of the Annual Informative Inventory Report and the inventories in the NFR format to the UNECE-LRTAP Convention and the European Commission. DCE participates in meetings under the UNECE Task Force on Emission Inventories and Projections and the related expert panels, where parties to the convention prepare the guidelines and methodologies on inventories.

II Trends in emissions

Acidifying gases

In 1990, the relative contribution in acid equivalents was almost equal for the three gases SO_2, NO_x and NH_3. In 2015, the most important acidification factor in Denmark is 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.

Sulphur dioxide (SO_2)

The main part of the sulphur dioxide (SO_2) emission originates from combustion of fossil fuels, i.e. mainly coal and oil, in public power and district heating plants. Since 1990, the total emission has decreased by 94 %. The large reduction is mainly due to installation of desulphurisation plant and use of fuels with lower content of sulphur in public power and district heating plants. Despite the large reduction of the SO_2 emissions, these plants make up 24 % of the total emission. Also emissions from industrial combustion plants, non-industrial combustion plants and other mobile sources are important. National sea traffic (navigation and fishing) contributes with about 5 % of the total SO_2 emission in 2015. This is due to the use of residual oil with higher sulphur content. This share decreased substantially from 2014 to 2015 due to new legislative requirements on sulphur content.

Nitrogen oxide (NO_x)

The largest sources of emissions of nitrogen oxides (NO_x) are road transport followed by other mobile sources 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 2015, 42 % 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 energy industries have decreased by 83 % from 1990 to 2015. In the same period, the total emission decreased by 62 %. The reduction is due to the increasing use of catalyst cars and installation of low-NO_x burners and denitrifying units in power plants and district heating plants.

Ammonia (NH_3)

Almost all atmospheric emissions of ammonia (NH_3) result from agricultural activities. Only a minor fraction originates from stationary combustion (2.0 %), road transport (1.5 %), industrial processes (0.7 %) and waste (1.0 %). The share for road transport was increasing during the 1990's and early 2000's due to increasing use of catalyst cars. In more recent years the share has been decreasing due to more advanced catalysts being implemented.

The major part of the emission from agriculture stems from livestock manure (49 %) and the largest losses of ammonia occur during the handling of the manure in animal housing systems. The second largest agricultural source is agricultural soils contributing 45 % in 2015; this is mainly emissions from application of mineral fertiliser, application of animal manure and emissions from crowing crops. The total ammonia emission has decreased by 42 % since 1985.

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 demands for improved utilisation of nitrogen in livestock manure, a ban against field 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 reduced considerably.

Other air pollutants

Non-methane volatile organic compounds (NMVOC)

The emissions of Non-Methane Volatile Organic Compounds (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 contribute approximately 26 % of the NMVOC emissions from combustion processes. NMVOC from road transportation vehicles have been decreasing since 1990, due to the introduction of catalyst cars. The evaporative emissions mainly originate from the agricultural sector, use of solvents, and the extraction, handling and storage of oil and natural gas. The total anthropogenic emissions have decreased by 46 % since 1990, largely due to the increased use of catalyst cars and reduced emissions from use of solvents.

Particulate Matter (PM)

The particulate matter (PM) emission inventory is reported for the years 1990 onwards. 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 source is residential plants (67 %), road transport (9 %) and other mobile sources (7 %). Emissions from residential plants have increased by 114 % from 1990 to 2007, followed by a decrease of 36 % from 2007 to 2015. The increase was caused by increasing wood consumption while the decrease has been caused by a slightly lower wood consumption combined with legislative demands on new wood stoves and boilers. For the road transport sector, exhaust emissions account for the about half (48 %) of the emissions while the other half comes from tyre and brake wear and road abrasion. For other mobile sources, the most important sources are off-road vehicles and machinery in the industrial sector and in the agricultural/forestry sector (28 % and 35 %, respectively). The $PM_{2.5}$ emission decreased by 19 % from 1990 to 2015 as the increasing wood consumption in the residential sector has been counterbalanced by decreasing emissions for the remaining sectors, the most important being the transport sector.

The largest TSP emission sources are agriculture and non-industrial combustion (70 % and 18 % of total TSP emission in 2015, respectively). Residential plants is the largest source in the non-industrial combustion sector, making up 16 % of the national total TSP emission in 2015.The TSP emissions from transport are also important and include both exhaust emissions and the non-exhaust emissions from brake and tyre wear and road abrasion. The non-exhaust emissions account for 76 % of the TSP emission from road transport in 2015.

Black carbon (BC)

The black carbon (BC) emission inventory is reported for the years 1990 onwards. The main sources are residential plants and road transport contributing 50 % and 19 % in 2015, respectively. From 1990 to 2015 the total BC emission decreased by 46 %. The trend for non-industrial combustion is mainly controlled by the trend for the wood consumption in the residential sector.

BC emissions from the transport sector decreased by 66 % from 1990 to 2015, mainly due to implementing of new EURO norms and improved technology. An important factor is the use of particle filters for heavy duty vehicles and passenger cars, which reduce the BC emission effectively.

BC emissions from fugitive emissions from fuels, which is mainly due to storage of coal, decreased by 73 % from 1990 to 2015, in line with the decrease of the coal consumption in electricity and heat production.

Heavy metals

In general, the most important sources of heavy metal emissions are combustion of fossil fuels and waste. The heavy metal emissions have decreased substantially in recent years, except for Cu. The reductions span from 13 % to 91 % for Zn and Pb, respectively. The reason for the reduced emissions is mainly increased use of gas cleaning devices at power and district heating plants (including waste incineration plants). The large reduction in the Pb emission is due to a gradual shift towards unleaded gasoline, the latter being essential for catalyst cars. The major source of Cu is automobile tyre and break wear (47 % in 2015) and the 35 % increase from 1990 to 2015 owe to increasing mileage.

III Recalculations and Improvements

In general, considerable work is being carried out to improve the inventories. Investigations and research carried out in Denmark and abroad produce new results and findings which are given consideration and, to the extent which is possible, are included as the basis for emission estimates and as data in the inventory databases. Furthermore, the updates of the EMEP/EEA Guidebook, and the work of the Task Force on Emission Inventories and its expert panels are followed closely in order to be able to incorporate the best scientific information as the basis for the inventories.

The implementation of new results in inventories is made in a way so that improvements, as far as possible, better reflect Danish conditions and circumstances. This is in accordance with good practice. Furthermore, efforts are made to involve as many experts as possible in the reasoning, justification and feasibility of implementation of improvements.

In improving the inventories, care is taken to consider implementation of improvements for the whole time series of inventories to make it consistent. Such efforts lead to recalculation of previously submitted inventories. This submission includes recalculated inventories for the whole time series. A description of the recalculations is provided in Chapter 9 and more detail can be found in the sectoral chapters of this report. For sector specific planned improvements please also refer to the relevant sectoral chapters.

Sammenfatning

I Baggrund for emissionsopgørelser

Årlig rapport

Denne rapport er Danmarks årlige rapport om emissionsopgørelser rapporteret d. 15. marts 2017 til UNECE-konventionen om langtransporteret grænseoverskridende luftforurening (LRTAP) og Direktiv (EU) 2016/2284 om nedbringelse af nationale emissioner af visse luftforurenende stoffer. Rapporten indeholder oplysninger om Danmarks opgørelser for alle år fra basisårene for protokollerne til 2015.

Luftforureningskomponenterne der rapporteres er SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2,5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, dioxiner/furaner, HCB, PCBs og PAH.

Den årlige emissionsopgørelse for Danmark rapporteres i NFR 2014-formatet.

Emnerne behandlet i rapporten er: Udvikling i emissioner, beskrivelse af hver NFR-kategori, usikkerheder, genberegninger, planlagte forbedringer og procedure for kvalitetssikring og -kontrol. Strukturen i rapporten følger, så vidt muligt, den foreslåede disposition.

Informationer fra denne rapport er tilgængelige for offentligheden på Aarhus Universitets hjemmeside:

http://envs.au.dk/videnudveksling/luft/emissioner/emissioninventory/

Den fulde rapport samt NFR-skemaer er tilgængelige på Eionets hjemmeside:

http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_EMEP_UNECE

Ansvarlig institution

DCE – Nationalt Center for Miljø og Energi, Aarhus Universitet, er på vegne af Miljø- og Fødevareministeriet ansvarlig for udarbejdelse af den årlige danske emissionsrapport og opgørelserne i NFR. DCE deltager i møder under UNECEs arbejdsgruppe for emissionsopgørelser og –fremskrivninger samt ekspertpaneler, hvor parter i konventionen udarbejder retningslinjer og metoder for emissionsopgørelserne.

II Udviklingen i emissioner

Forsurende gasser

I 1990 var det relative bidrag af syreækvivalenter næsten ens for de tre gasarter. I 2015 var ammoniak den vigtigste forsurende faktor i Danmark og de relative bidrag for SO_2, NO_x og NH_3 var på henholdsvis 6 %, 36 % og 58 %.

Med hensyn til langtransporteret luftforurening er det dog stadig SO_2 og NO_x, der er de vigtigste forureningskomponenter.

Svovldioxid (SO_2)

Hovedparten af SO_2-emissionerne stammer fra forbrænding af fossile brændsler, dvs. primært kul og olie, på kraftværker, kraftvarmeværker og fjernvarmeværker. Siden 1990 er den totale udledning reduceret med 94 %. Den store reduktion er primært opnået gennem installation af afsvovlingsanlæg på kraftværker og fjernvarmeværker og brug af brændsler med lavere svovlindhold. Trods den store reduktion er disse værker kilde til 24 % af den samlede udledning. Også emissioner fra industrielle forbrændingsanlæg, ikke-industrielle forbrændingsanlæg, andre mobile kilder samt teglværker og produktion af ekspanderede lerprodukter er væsentlige bidragsydere til emissionen. National søfart (sejlads og fiskeri) bidrager med 5 % af den totale SO_2-emission. Dette skyldes brug af fuelolie med et højt svovlindhold. Denne andel er faldet væsentlig fra 2014 til 2015 pga. nye grænseværdier for svovlindholdet i brændslet.

Kvælstofilte (NO_x)

Den største kilde til emissioner af NO_x er transportsektoren efterfulgt af andre mobile kilder og forbrænding i energisektoren (hovedsageligt kraftværker og fjernvarmeværker). Transportsektoren er den sektor, der bidrager mest til udledningen af NO_x, og i 2015 stammede 42 % af de danske NO_x-emissioner fra vejtransport, national søfart, jernbaner og civil luftfart. Også emissioner fra nationalt fiskeri og off-road-køretøjer (entreprenør-, landbrugsmaskiner, m.m.) bidrager betydeligt til NO_x-emissionen. For ikke-industrielle forbrændingsanlæg er de primære kilder forbrænding af gasolie, naturgas og træ i husholdninger. Emissionerne fra kraftværker og fjernvarmeværker er faldet med 83 % fra 1990 til 2015. I samme periode er den totale emission faldet med 62 %. Reduktionen skyldes øget brug af katalysatorer i biler og installation af lav-NO_x-brændere og de-NO_x-anlæg på kraftværker og fjernvarmeværker.

Ammoniak (NH_3)

Hovedparten af emissioner af NH_3 stammer fra aktiviteter i landbruget. Kun en mindre del skyldes stationær forbrænding (2.0 %), vejtransport (1.5 %), industrielle processer (0.7 %) og affald (1.0 %). Andelen fra transporten var stigende gennem 1990'erne og i starten af 2000'erne pga. den øgede brug af biler med katalysator. I de senere år er andelen igen faldet på grund af implementeringen af mere effektive katalysatorer.

Hovedparten af emissionen fra landbruget stammer fra husdyrgødning (49 %), og de største tab af ammoniak optræder under håndtering af gødningen i stalden. Den næststørste kilde indenfor landbrug er landbrugsjorde som bidrager med 45 % i 2015. Emissionen stammer hovedsageligt fra anvendelse af handelsgødning, udbringning af husdyrgødning samt emissioner fra voksende afgrøder.

Den totale ammoniakemission er faldet 42 % fra 1985-2014. Dette skyldes implementeringen af vandmiljøplaner og ammoniakhandlingsplanen som introducerede en række tiltag for at mindske kvælstoftabet i landbruget. Tiltagene har inkluderet krav om forbedret udnyttelse af kvælstof i husdyrgødning, et forbud mod udbringning af husdyrgødning om vinteren, forbud mod bredspredning af gødning, regler for plantning af efterafgrøder, regulering af antallet af tilladte dyr per hektar og et loft for gødningsanvendelsen for afgrøder. På trods af en stigning i produktionen af svin og fjerkræ, så er emissionen faldet betydeligt.

Anden luftforurening

Flygtige organiske forbindelser (NMVOC)

Emissionen af flygtige organiske forbindelser ekskl. metan (NMVOC) stammer fra mange forskellige kilder og kan opdeles i to hovedgrupper: Ufuldstændig forbrænding og fordampning. Hovedkilderne til NMVOC-emissioner fra ufuldstændige forbrændingsprocesser er brændeovne, vejtrafik og andre mobile kilder, som national sejlads og ikke vejgående maskiner. Køretøjer til vejtransport er fortsat den største bidragsyder, selvom emissionerne er faldet siden introduktionen af biler med katalysator i 1990. Emissionerne fra fordampning stammer hovedsageligt fra landbrug, anvendelse af opløsningsmidler og udvinding, lagring og transport af olie og gas. De totale menneskeskabte emissioner er faldet med 46 % siden 1990, primært som følge af øget brug af biler med katalysator og reducerede emissioner fra anvendelse af opløsningsmidler.

Partikler (PM)

Emissionsopgørelsen for partikler (Particulate Matter, forkortet PM) er blevet rapporteret for år 1990 og fremefter. Opgørelsen inkluderer den totale emission af partikler: Total Suspended Particles (TSP), emissionen af partikler mindre end 10 µm (PM_{10}) og emissionen af partikler mindre end 2,5 µm ($PM_{2,5}$).

De største kilder til $PM_{2,5}$-emission er husholdninger (67 %), vejtrafik (9 %) og andre mobile kilder (7 %). Emissionen fra husholdninger steg med 114 % fra 1990 til 2007 efterfulgt af et fald på 36 % fra 2007 til 2015. For andre mobile kilder er offroad-køretøjer i industrien samt landbrugs- og skovbrugsmaskiner de vigtigste kilder (hhv. 28 % og 35 %). I transportsektoren tegner udstødningsemissioner sig for omkring halvdelen (48 %), mens resten udgøres af partikler fra slid på dæk, bremser og vej. $PM_{2.5}$-emissionen er faldet med 19 % fra 1990 til 2014, da det stigende træforbrug og dermed emissioner fra husholdninger modsvares fald i emissionen fra de øvrige sektorer især transportsektoren.

De største kilder til TSP-emission er landbrugssektoren og husholdningerne med henholdsvis 70 % og 18 %. TSP-emissionen fra transport er også vigtig og inkluderer både udstødningsemissioner og ikke-udstødningsrelaterede emissioner fra slid af bremser, dæk og vej. De ikke-udstødningsrelaterede emissioner udgør 76 % af TSP-emissionen fra transport.

Sod (BC)

Emissionsopgørelsen for sod (Black Carbon – BC) er rapporteret fra år 1990 og fremefter. De vigtigste kilder er husholdninger og vejtransport, der bidrager med henholdsvis 50 % og 19 % i 2015. Fra 1990 til 2014 er den samlede BC-emission faldet med 46 %. Udviklingen indenfor ikke-industriel forbrænding er domineret af udviklingen i træforbruget i husholdninger.

BC-emissionen fra transportsektoren er faldet med 66 % fra 1990 til 2015, hvilket skyldes implementeringen af nye EURO-normer og forbedret teknologi. En vigtig faktor er anvendelsen af partikelfiltre for lastbiler og personbiler, som effektivt begrænser udledningen af partikler og også BC.

BC-emissioner fra udvinding/lagring /transport af kul, olie og gas kommer hovedsageligt fra lagring af kul. Emissionen er faldet med 73 % fra 1990 til 2015 på grund af det faldende kulforbrug til produktion af el og varme.

Tungmetaller

Generelt er de vigtigste kilder til emissioner af tungmetaller forbrænding af fossile brændsler og affald. Emissionerne af tungmetaller er med undtagelse af kobber, faldet betydeligt de seneste år. Reduktionerne spænder fra 13 % til 91 % for henholdsvis Zn og Pb. Årsagen til de reducerede emissioner er hovedsageligt den øgede brug af røggasrensning på kraftværker og fjernvarmeværker (inklusive affaldsforbrændingsanlæg). Den store reduktion i emissionen af Pb skyldes et løbende skift til fordel for blyfri benzin, som er nødvendigt for biler med katalysator. Den største kilde til emission af kobber er slid af køretøjers dæk og bremser (47 % i 2015). Emissionen herfra er steget 35 % fra 1990 til 2015 pga. en stigning i antal kørte kilometer.

III Genberegninger og forbedringer

Generelt pågår der et betydeligt arbejde med at forbedre emissionsopgørelserne. Nye undersøgelser og forskning fra Danmark og udlandet inkluderes så vidt muligt som basis for emissionsestimaterne. Desuden følges arbejdet med opdateringer af EMEP/EEA Guidebook for emissionsopgørelser nøje, med henblik på at indarbejde de bedste videnskabelige informationer som basis for opgørelserne.

Opgørelserne opdateres løbende med ny viden, således at opgørelserne bedst mulig afspejler danske forhold. Ved forbedringer lægges vægt på at opdateringer omfatter hele tidsserier, for at sikre konsistente data. Disse tiltag medfører genberegning af tidligere indberettede opgørelser. Denne aflevering indeholder genberegninger for hele tidsserien. Begrundelserne for genberegningerne er inkluderet i kapitel 9 samt i de enkelte sektorkapitler i denne rapport. For planlagte sektorspecifikke forbedringer henvises der til sektorkapitlerne.

1 Introduction

1.1 Background information on emission inventories

DCE (Danish Centre for Environment and Energy), Aarhus University is contracted by the Ministry of the Environment and Food and the Ministry of Energy, Utilities and Climate to complete emission inventories for Denmark. Department of Environmental Science, Aarhus University is responsible for calculation and reporting of the Danish national emission inventory to the EU (Monitoring Mechanism Regulation & Directive on reduction of national emissions of certain atmospheric pollutants) and the UNFCCC (United Nations Framework Convention on Climate Change) and UNECE CLRTAP (Convention on Long Range Transboundary Air Pollution) conventions.

1.1.1 Annual report

According to the guidelines for reporting emission data under the Convention on Long-Range Transboundary Air Pollution (ECE/EB.AIR/125) prepared by the Task Force on Emission Inventories and Projections and approved by the Executive Body, countries that are parties to the UNECE-Convention on Long-Range Transboundary Air Pollution should annually submit an informative inventory report to the Secretariat. The current reporting Guidelines (ECE/EB.AIR/125) were accepted at the meeting of the Executive Body in December 2013. Due to a lack of resources, it has not been possible to incorporate all the new elements of the reporting guidelines in this submission nor has the previous reporting guidelines (ECE/EB.AIR/75) been fully implemented.

The directive on reduction of national emissions of certain atmospheric pollutants (Directive 2016/2284/EU – the revised NEC directive) entered into force on 31 December 2016. This report is the official submission of the Informative Inventory report in accordance with Article 8.

This report is Denmark's Annual Informative Inventory Report due March 15, 2017. The report contains information on Denmark's inventories for all years from the base years of the protocols to 2015.

The annual emission inventory for Denmark is reported in the Nomenclature for Reporting (NFR) 2014 format.

The issues addressed in this report are: trends in emissions, description of each NFR category, uncertainty estimates, recalculations, planned improvements and procedures for quality assurance and control. The outline in annex V of the reporting guidelines is followed as far as possible.

This report and NFR tables are available to the public on the Danish emission inventory webpage:
http://envs.au.dk/videnudveksling/luft/emissioner/emissioninventory/

and on the Eionet central data repository:
http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_EMEP_UNECE

1.2 A description of the institutional arrangement for inventory preparation

DCE (Danish Centre for Environment and Energy, Aarhus University, is responsible for the annual preparation and submission to the UNECE-LRTAP Convention of the Informative Inventory Report, and the inventories in the NFR format in accordance with the guidelines. DCE participates in meetings under the UNECE Task Force on Emission Inventories and Projections and the related expert panels where parties to the convention prepare the guidelines and methodologies on inventories. DCE is also responsible for estimating and reporting emissions under Directive 2016/2284/EU.

The work concerning the annual emission inventory is carried out in cooperation with other Danish ministries, research institutes, organisations and companies:

Danish Energy Agency (DEA), Ministry of Energy, Utilities and Climate:
Annual energy statistics in a format suitable for the emission inventory work and fuel-use data for the large combustion plants.

Danish Environmental Protection Agency (DEPA), Ministry of Environment and Food:
Company reporting to e.g. the PRTR. Database on waste.

Statistics Denmark, Ministry of Social Affairs and the Interior:
Statistical yearbook, production statistics for manufacturing industries, agricultural statistics and import/export/production figures.

DCA (Danish Centre for Food and Agriculture), Aarhus University:
Data on use of mineral fertiliser, feeding stuff consumption and nitrogen turnover in animals.

The Road Directorate, Ministry of Transport and Building:
Number of vehicles grouped in categories corresponding to the EU classification, mileage (urban, rural, highway), trip speed (urban, rural, highway).

Civil Aviation Agency of Denmark, Ministry of Transport and Building:
City-pair flight data (aircraft type and origin and destination airports) for all flights leaving major Danish airports.

Danish Railways, Ministry of Transport and Building:
Fuel-related emission factors for diesel locomotives.

Danish companies:
Audited environmental reports and direct information gathered from producers and agency enterprises.

Formerly, the provision of data was on a voluntary basis, but now formal agreements are in place with the most important data suppliers, e.g. the Danish Energy Agency and DCA.

1.3 Brief description of the process of inventory preparation - Data collection and processing, data storage and archiving

The background data (activity data and emission factors) for estimation of the Danish emission inventories is collected and stored in central databases located at DCE. The databases are in Access format and handled with software developed by the European Environmental Agency (EEA) and DCE. As input to the databases, various sub-models are used to estimate and aggregate the background data in order to fit the format and level in the central databases. The methodologies and data sources used for the different sectors are described in Chapter 1.4 and Chapters 3 to 6. As part of the QA/QC plan (Chapter 1.5), the data structure for data processing support the pathway from collection of raw data to data compilation, modelling and final reporting.

For each submission, databases and additional tools and submodels are archived together with the resulting NFR reporting format. This material is placed on central institutional servers, which are subject to routine back-up services. Material, which has been backed up is archived safely. A further documentation and archiving system is the official journal for DCE, for which obligations apply to DCE, as a governmental institute. In this journal system, correspondence, both in-going and out-going, is registered, which in this case involves the registration of submissions and communication on inventories with the UNECE-LRTAP Secretariat, the European Commission, review teams, etc.

Figure 1.1 shows a schematic overview of the process of inventory preparation. The figure illustrates the process of inventory preparation from the first step of collecting external data to the last step, where the reporting schemes are generated for the UNFCCC and EU (in the CRF format (Common Reporting Format)) and to the United Nations Economic Commission for Europe/Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (UNECE/EMEP) (in the NFR format (Nomenclature For Reporting)). For data handling, the software tool is CollectER II and for reporting the software tool is developed by DCE. Data files and programme files used in the inventory preparation process are listed in Table 1.1.

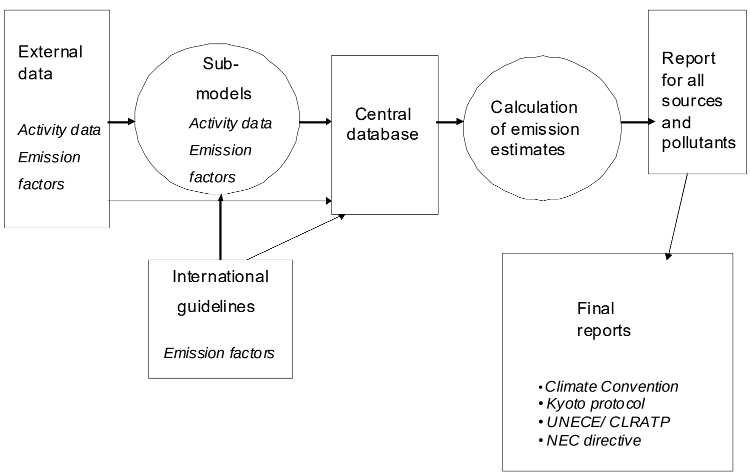

Figure 1.1 Schematic diagram of the process of inventory preparation.

Table 1.1 List of current data structure; data files and programme files in use.

QA/QC Level	Name	Application type	Path	Type	Input sources
4 store	CFR Submissions (UNFCCC and EU) NFR Submissions (UNECE and EU)	External report	U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_4a_Storage\	MS Excel, xml	CRF Reporter
3 process	CRF Reporter	Management tool	Working path: local machine Archive path: U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_3b_Processes	(exe + mdb)	manual input and Importer2CRF
3 process	Importer2CRF	Help tool	U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_3b_Processes	MS Access	CRF Reporter, CollectEr2CRFand excel files
3 process	CollectER2CRF	Help tool	U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_3b_Processes	MS Access	NERIRep
2 process 3 store	NERIRep	Help tool	Working path: U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_3a_Storage	MS Access	CollectER databases; dk1972.mdb..dkxxxx.mdb
2 process	CollectER	Management tool	Working path: local machine Archive path: U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_2b_Processes	(exe +mdb)	manual input
2 store	dk1980.mdb.dkxxxx.mdb	Datastore	U:\ST_ENVS-LUFT-EMI\Inventory\AllYears\8_AllSectors\Level_2a_Storage	MS Access	CollectER

1.4 Brief description of methodologies and data sources used

Denmark's air emission inventories are based on the EMEP/EEA Guidebook, the CORINAIR methodology as well as the 2006 IPCC Guidelines (IPCC, 2006). CORINAIR (COoRdination of INformation on AIR emissions) is a European air emission inventory programme for national sector-wise emission estimations, harmonised with the IPCC guidelines. In 2016 the latest edition of the EMEP/EEA Guidebook (EEA, 2016) was adopted for use by the EMEP Executive Body, the changes in the 2016 edition have only been reflected to a limited extent in this submission and the changes will be implemented depending on the availability of resources. In 2009 the EMEP/CORINAIR Guidebook changed name to the EMEP/EEA Guidebook (EEA, 2009). In this change the Guidebook switched nomenclature from SNAP to NFR.

The Danish inventory is prepared at the more detailed SNAP level rather than at the NFR level that is only suitable for reporting. To ensure estimates are as timely, consistent, transparent, accurate and comparable as possible, the inventory programme has developed calculation methodologies for most subsectors and software for storage and further data processing.

A thorough description of the CORINAIR inventory programme used for Danish emission estimations is given in Illerup et al. (2000). The CORINAIR calculation principle is to calculate the emissions as activities multiplied by emission factors. Activities are numbers referring to a specific process generating emissions, while an emission factor is the mass of emissions per unit activity. Information on activities to carry out the CORINAIR inventory is largely based on official statistics. The most consistent emission factors have been used, either as national values or default factors proposed by international guidelines.

A list of all subsectors at the most detailed level is given in Illerup et al. (2000) together with a translation between CORINAIR and IPCC codes for sector classifications.

1.4.1 The specific methodologies regarding stationary combustion

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

The Danish emission inventory for stationary combustion plants is based on the former CORINAIR system. The emission inventory for stationary combustion is based on activity rates from the Danish energy statistics. General emission factors for various fuels, plants and sectors have been determined. Some large plants, such as power plants, are registered individually as large point sources and plant-specific emission data are used.

The fuel consumption rates are based on the official Danish energy statistics prepared by the Danish Energy Agency (DEA). DCE aggregates fuel consumption rates to SNAP categories. The fuel consumption of the NFR category 1A2 Manufacturing industries and construction is disaggregated to subsectors according to the DEA data prepared and reported to Eurostat.

For each of the fuel and SNAP categories (sector and e.g. type of plant), a set of general emission factors has been determined. Some emission factors refer to the EMEP/EEA Guidebook 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.

A number of large plants, e.g. power plants, municipal waste incineration plants and large industrial plants are registered individually as large point sources. This enables use of plant-specific emission factors that refer to emission measurements stated in annual environmental reports. Emission factors of SO_2, NO_X, HM and PM are often plant specific.

Please refer to Chapter 3.2 and Annex 3A for further information on emission inventories for stationary combustion plants.

1.4.2 Specific methodologies regarding transport

The emissions from transport referring to SNAP category 07 (Road transport) and the sub-categories in 08 (Other mobile sources) are made up in the NFR categories; 1A3b (Road transport), 1A2f (Industry-other), 1A3a (Civil aviation), 1A3c (Railways), 1A3d (Navigation), 1A4c (Agriculture/forestry/-fisheries), 1A4a (Commercial/institutional), 1A4b (Residential) and 1A5 (Other).

An internal DCE model with a structure similar to the European COPERT IV emission model (EEA, 2016) is used to calculate the Danish annual emissions for road traffic. The emissions are calculated for operationally hot engines, during cold start and fuel evaporation. The model also includes the emission effect of catalyst wear. Input data for vehicle stock and mileage is obtained from DTU Transport and Statistics Denmark, and is grouped according to average fuel consumption and emission behaviour. For each group, the emissions are estimated by combining vehicle type and annual mileage figures with hot emission factors, cold:hot ratios and evaporation factors.

For air traffic, from 2001 onwards estimates are made on a city-pair level, using flight data provided by the Danish Civil Aviation Agency (CAA-DK) for flights between Danish airports and flights between Denmark and Greenland/Faroe Islands, and LTO and distance-related emission factors from the CORINAIR guidelines (Tier 2 approach). For previous years, the background data consists of LTO/aircraft type statistics from Copenhagen Airport and total LTO numbers from CAA-DK. With appropriate assumptions, consistent time series of emissions are produced back to 1990 and include the findings from a Danish city-pair emission inventory in 1998.

Off-road working machines and equipment are grouped in the following sectors: inland waterways (pleasure craft), agriculture, forestry, industry, and household and gardening. The sources for stock and operational data are various branch organisations and key experts. In general, the emissions are calculated by combining information on the number of different machine types and their respective load factors, engine sizes, annual working hours and emission factors.

The inventory for navigation consists of regional ferries, local ferries and other national sea transport (sea transport between Danish ports and between Denmark and Greenland/Faroe Islands). For regional ferries, the fuel consumption and emissions are calculated as a product of number of round trips per ferry route (Statistics Denmark), sailing time per round trip, share of round trips per ferry, engine size, engine load factor and fuel consumption/emission factor. The estimates take into account the changes in emission factors and ferry specific data during the inventory period.

For the remaining navigation categories, the emissions are calculated simply as a product of total fuel consumption and average emission factors. For each inventory year, this emission factor average comprises the emission factors for all present engine production years, according to engine life times.

Please refer to Chapter 3.3 and Annex 3B for further information on emissions from transport.

1.4.3 The specific methodologies regarding fugitive emissions

Fugitive emissions from oil (1.B.2.a)

Fugitive emissions from oil are estimated according to the methodology described in the Emission Inventory Guidebook (EEA, 2016). The sources include offshore extraction of oil and gas, onshore oil tanks, onshore and offshore loading of ships, and gasoline distribution. Activity data are given in the Danish Energy Statistics by the Danish Energy Agency. The emission factors are based on the figures given in the guidebook except in the case of onshore oil tanks and gasoline distribution where national values are included.

The VOC emissions from petroleum refinery processes cover non-combustion emissions from feed stock handling/storage, petroleum products processing, and product storage/handling. SO_2 is also emitted from non-combustion processes and includes emissions from product processing and sulphur-recovery plants. The emission calculations are based on information from the Danish refineries.

Fugitive emissions from natural gas (1.B.2.b)

Inventories of NMVOC emission from transmission and distribution of natural gas and town gas are based on annual environmental reports from the Danish gas transmission company and annual reports for the gas distribution companies. The annual gas composition is based on from the national transmission company.

Fugitive emissions from flaring (1.B.2.c)

Emissions from flaring offshore, in gas treatment and storage plants, and in refineries are included in the inventory. Emissions calculations are based on annual reports from the Danish Energy Agency and environmental reports from gas storage and treatment plants and the refineries. Calorific values are based on the reports for the EU ETS for offshore flaring, on annual gas quality data from Energinet.dk, and on additional data from the refineries. Emission factors are based on national studies and the EMEP/EEA Guidebook (EEA, 2016).

Please refer to Chapter 3.4 for further information on fugitive emissions from fuels.

1.4.4 Specific methodologies regarding industrial processes and product use

Energy consumption associated with industrial processes and the emissions thereof is included in the inventory for stationary combustion plants. This is due to the overall use of energy balance statistics for the inventory.

Mineral industry

The sub-sector includes production of cement, lime, container glass/glass wool, mineral wool, other production (consumption of lime), and roofing and road paving with asphalt. The activity data as well as emission data are primarily based on information from Environmental Reports (In Danish: "Grønne regnskaber") prepared by companies according to obligations under Danish law. Also, data on production and import/export from Statistics Denmark are used. The published information is supplemented with information obtained directly from companies or by use of standard emission factors. The distribution of TSP between PM_{10} and $PM_{2.5}$ is based on European average data.

Chemical industry

The sub-sector includes production of nitric and sulphuric acid (ceased in 1997 and 2004, respectively), catalysts, fertilisers and pesticides. The activity data as well as emission data are based on information from the companies as accounted for and published in the Environmental Reports combined with information obtained by contact to the companies. The distribution of TSP between PM_{10} and $PM_{2.5}$ is based on European average data.

Metal industry

The sub-sector includes electro steelwork, production of steel sheets and bars (electro steelwork until 2005 and thereafter, only rolling mills), cast iron, aluminium (ceased in 2008), lead and lead products and various other metal products. The activity data as well as emission data for the steelworks are based on information from the companies as accounted for and published in the Environmental Reports, combined with information obtained through contact with the companies. The activity data for the other processes are based on information from Statistics Denmark combined with Danish average emission factors and standard emission factors. The particle size distribution of TSP (PM_{10} and $PM_{2.5}$) is based on European average data.

Other production

The sub-sector includes breweries, production of spirits and other activities within the food sector e.g. sugar production, meat curing and production of margarine and solid cooking fats. The activity data are obtained from Statistics Denmark and the emission factors are obtained from the EMEP/EEA Guidebook combined with emission factors (EF) derived from specific emission measurements at the companies.

Solvent and other product use

The approach for calculating the emissions of Non-Methane Volatile Organic Carbon (NMVOC) from industrial and household use in Denmark focuses on single chemicals rather than activities. This leads to a clearer picture of the influence from each specific chemical, which enables a more detailed differentiation on products and the influence of product use on emissions. The procedure is to quantify the use of the chemicals and estimate the fraction of the chemicals that is emitted as a consequence of use.

The detailed approach in EMEP/EEA Guidebook (2013) is used. Here all relevant consumption data on all relevant solvents must be inventoried or at least those together representing more than 90 % of the total NMVOC emission. Simple mass balances for calculating the use and emissions of chemicals are set up 1) use = production + import – export, 2) emission = use emission factor. Production, import and export figures are extracted from Statistics Denmark, from which a list of more than 400 single chemicals, a few groups and products is generated. For each of these, a "use" amount in tonnes per year (from 1990 to 2014) is calculated. For some chemicals and/or products, e.g. propellants used in aerosol cans and ethanol used in windscreen washing agents, use amounts are obtained from the industry as the information from Statistics Denmark does not comply with required specificity. It is found that approximately 40 different NMVOCs comprise over 95 % of the total use and it is these 40 chemicals that are investigated further. The "use" amounts are distributed across industrial activities according to the Nordic SPIN (Substances in Preparations in Nordic Countries) database, where information on industrial use categories is available in a NACE coding system. The chemicals are also related to specific products according to the Use Category (UCN) system. Emission factors are obtained from regulators, literature or the industry.

The same method is used for calculating emissions from the use of fireworks, tobacco, candles and charcoal for barbeques (BBQ). These activities lead to emissions of SO_2, NO_x, CO, NH_3, particles, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, dioxins/furans and PAHs.

Please refer to Chapter 4 and Annex 3C for further information on industrial processes and product use.

1.4.5 Specific methodologies regarding agriculture

The emission from agricultural activities covers NH_3, NO_x, NMVOC and particles from animal husbandry/manure management and agricultural soils. Furthermore, the inventory includes emissions from field burning of straw which covers NH_3, PM, NO_x, CO, NMVOC, SO_2, heavy metals, dioxin and PAH.

Emissions from agricultural activities are estimated according to the methodology described in the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2013). Activity data and national data regarding emission factors are collected, evaluated and discussed in cooperation with Statistics Denmark, DCA-Danish Centre for Food and Agriculture (Aarhus University), the Danish Agricultural Advisory Service, Danish Environmental Protection Agency and the Danish AgriFish Agency. It means that data are evaluated continuously according to the latest knowledge and information.

The Danish agricultural emissions are calculated and managed in a comprehensive model complex called IDA (Integrated Database model for Agricultural emissions), which is used to calculate both air pollutants compounds and greenhouse gas related emissions. The livestock production has a great influence on the Danish agricultural emissions. IDA works with approximately 40 different livestock categories, dependent on livestock category, weight class and age. Each of these subcategories is subdivided according to housing type and manure type, which results in about 200 different combinations of subcategories and housing type and the emissions are calculated from each of these combinations and aggregated to relevant main categories in the reporting format.

Most of the emissions from agricultural activities are directly related to livestock production. The remaining part comes from the use of synthetic fertiliser, growing crops, NH_3 treated straw, field burning of agricultural residues and sewage sludge applied to fields as fertiliser. The number of animals can be considered as the most important activity data in estimation of the agricultural emissions.

The number of animals is mainly based on data from Statistics Denmark. For data covering pigs, bulls and poultry, the number is based on slaughter data also collected from the Agricultural Statistics. The production of sheep, goats and horses typically takes place on small farms below five hectare, which are not included in the annual statistics and the production of these categories as well as for deer and ostriches are therefore based on the Central House-animal farm Register (CHR) managed by the Ministry of Food, Agriculture and Fisheries.

Data concerning nitrogen excretion, distribution of housing types until 2004 and handling of manure is based on data and information from DCA-Danish Centre for Food and Agriculture at Aarhus University and the Danish Agricultural Advisory Service. From 2005 annual statistics covering housing types are available from the Danish AgriFish Agency.

Data related to use of synthetic fertiliser, both the amount of fertiliser and the nitrogen content is based on statistics published by the Danish AgriFish Agency.

Please refer to Chapter 5 and Appendix 3D for further information on emission inventories for agriculture.

1.4.6 Specific methodologies regarding waste

The waste sector consists of the four main NFR categories 5A Solid waste disposal, 5B Biological treatment of solid waste, 5C Waste incineration, 5D Wastewater treatment and discharge and 5E Other waste.

Emissions from solid waste disposal and wastewater treatment and discharge are currently not estimated.

Composting includes four types of biological waste; garden and park waste, organic waste from households and other sources, sludge and home composting of garden and vegetable food waste. Individual emission factors are found for each waste category.

Waste incineration covers the cremation of human bodies and animal carcasses. Both are calculated as an activity multiplied by an emission factor.

The Other waste category includes accidental building- and vehicle fires

Emissions from building fires are calculated by multiplying the number of building fires with selected emission factors. Six types of buildings are separated with different emission factors; detached houses, undetached houses, apartment buildings, industrial buildings, additional buildings and containers.

Activity data for building fires are classified in four categories; full scale, large, medium and small. The emission factors comply for full scale building fires and the activity data are therefore recalculated as a full scale equivalent where it is assumed that a large, medium and small fire leads to 75 %, 30 % and 5 % of a full scale fire, respectively.

Emissions from vehicle fires are calculated by multiplying the total burnt vehicle mass with selected emission factors. 14 different vehicle types are included in the total mass of burned vehicle. Emission factors are not available for different vehicle types, why it is assumed that all the different vehicle types lead to similar emissions. As with accidental building fires, four different sizes are known in relation to damage; full scale (100 % burnout), large (75 %), medium (30 %) and small (5 %).

Please refer to Chapter 6 and Annex 3E for further information on emission inventories for agriculture.

1.5 Key categories

The determination of key categories has not been made due to insufficient resources being available at the moment.

1.6 Information on the Quality Control and Quality Assurance plan including verification and treatment of confidential issues where relevant

In the Danish National Inventory Report to UNFCCC (Nielsen et al., 2016) as well as in the QA/QC manual for the Danish Greenhouse gas inventory (Nielsen et al., 2012), the plan for Quality Control (QC) and Quality Assurance (QA) for greenhouse gas emission inventories prepared by the DCE is outlined. The plan is in accordance with the guidelines provided by the UNFCCC (IPCC, 2006). The ISO 9000 standards are also used as important input for the plan. The plan also, to a limited extent, includes air pollutants. Due to a lack of resources it has not been possible to extend the QA/QC system for the greenhouse gas inventory to also cover the air pollutants.

1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

The uncertainty estimates are based on the simple Tier 1 approach in the EMEP/CorinAir *Good Practice Guidance for LRTAP Emission Inventories* (Pulles & Aardenne, 2004).

The uncertainty estimates are based on emission data for the base year and year 2015, and on uncertainties for activity rates and emission factors for each of the main SNAP sectors. For all pollutants 1990 is used as the base year.

Uncertainty estimates include uncertainty of the total emission as well as uncertainty of the trend. The estimated uncertainties are shown in Table 1.2. The uncertainty estimates include all sectors.

Table 1.2 Danish uncertainty estimates, 2015.

Pollutant	Uncertainty Total emission [%]	Trend 1990-2015 [%]	Uncertainty Trend [%-age points]
SO_2	33	-94	1.9
NO_x	53	-62	9
NMVOC	100	-46	24
CO	48	-56	16
NH_3	21	-42	10
TSP	190	-15	18
PM_{10}	106	-9	34
$PM_{2.5}$	129	-8	50
BC	483	-34	203
Arsenic	160	-77	23
Cadmium	449	-40	230
Chromium	258	-73	63
Copper	924	35	81
Mercury	103	-91	11
Nickel	437	-83	48
Lead	488	-91	30
Selenium	373	-73	70
Zinc	460	-13	219
PCDD/F	296	-64	108
Benzo(b)fluoranthene	676	46	268
Benzo(k)fluoranthene	628	41	243
Benzo(a)pyrene	727	37	229
Indeno(1,2,3-c,d)pyrene	664	5	305
HCB	481	-91	42
PCBs	727	-62	94

1.8 General assessment of the completeness

Annex 4 provides a full and comprehensive explanation on the use of notation keys in the Danish inventory. The Danish emission inventory due 15 February 2017 includes all sources identified by the EMEP/EEA guidebook except the following.

1.8.1 Industrial processes

Categories reported as not estimated:

- Emissions from storage, handling and transport of mineral products
- Emissions from pulp and paper production

1.8.2 Agriculture

Categories reported as not estimated:

- Emissions from off-farm storage, handling and transport of agricultural products

1.8.3 Waste

Categories reported as not estimated:

- Emissions from solid waste disposal on land
- Emissions from wastewater handling
- Emissions from small scale waste burning

1.8.4 Categories reported as "included elsewhere"

The following table lists the categories reported as IE (included elsewhere) and provides information on where the associated emissions are reported, more detailed information is provided in Annex 4.

Table 1.3. List of categories reported as included elsewhere.

Category reported as IE	Category where emissions are included
2 A 1 Cement production	1 A 2 f Stationary combustion in manufacturing industries and construction: Non-metallic minerals
2 A 2 Lime production	1 A 2 f Stationary combustion in manufacturing industries and construction: Non-metallic minerals
2 A 3 Glass production	1 A 2 f Stationary combustion in manufacturing industries and construction: Non-metallic minerals

1.8.5 General description on the use of notation keys

The NFR as reported by Denmark makes use of five notation keys: NO (Not Occurring), NA (Not Applicable), NE (Not Estimated), IE (Included Elsewhere) and NR (Not Reported).

NO is used in instances where the activity does not occur in Denmark, e.g. adipic acid production, buffaloes, etc.

NA is used in instances where the activity occurs in Denmark but the emission of a certain pollutant is not believed to be relevant, e.g. heavy metals from dairy cattle.

NE is used in instances where the activity occurs in Denmark and emissions of a certain pollutant are thought to occur but the emission has not been estimated; see Chapter 1.8.3 and Annex 4.

IE is used where emissions of a certain pollutant or the whole source category are reported under another source category; see Chapter 1.8.4 and Annex 4.

NR is used for pollutants prior to the base year, e.g. HM emissions prior to the year 1990.

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2 Trends in Emissions

2.1 Acidifying gases

Acid deposition of sulphur and nitrogen compounds mainly derives from emissions of SO_2, NO_X and NH_3. The effects of acidification may appear in a number of ways, including defoliation and reduced vitality of trees, and declining fish stocks in acid-sensitive lakes and rivers.

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

Weighting the individual substances according to their acidification effect, total emissions in terms of acid equivalents can be calculated as:

$$A = \frac{m_{SO_2}}{M_{SO_2}} \cdot 2 + \frac{m_{NO_x}}{M_{NO_x}} + \frac{m_{NH_3}}{M_{NH_3}} = \frac{m_{SO_2}}{64} \cdot 2 + \frac{m_{NO_x}}{46} + \frac{m_{NH_3}}{17}$$

where A is the acidification index in Mmole

m_i is the emission of pollutant *i* in tonnes

M_i is the mole weight [tonne/Mmole] of pollutant *i*

The actual effect of the acidifying substances depends on a combination of two factors: the amount of acid deposition and the natural capacity of the terrestrial or aquatic ecosystem to counteract the acidification. In areas where the soil minerals easily weather or have a high lime content, acid deposition will be relatively easily neutralised.

Figure 2.1 shows the emission of Danish acidifying gases in terms of acid equivalents. In 1990, the relative contribution in acid equivalents was almost equal for the three gases. In 2015, the most important acidification factor in Denmark is 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.

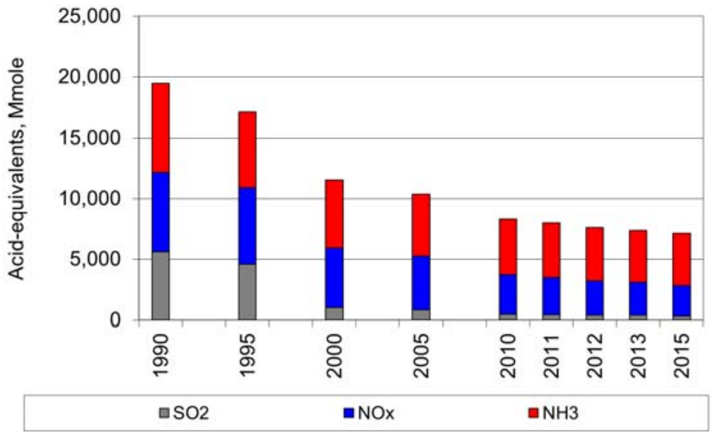


Figure 2.1 Emissions of NH_3, NO_X and SO_2 over time in acid equivalents.

2.2 Description and interpretation of emission trends by gas

2.2.1 Sulphur dioxide (SO_2)

The main part of the sulphur dioxide (SO_2) emission originates from combustion of fossil fuels, i.e. mainly coal and oil, in public power and district heating plants. Since 1990, the total emission has decreased by 94 %. The large reduction is mainly due to installation of desulphurisation plant and use of fuels with lower content of sulphur in public power and district heating plants. Despite the large reduction of the SO_2 emissions, these plants make up 24 % of the total emission. Also emissions from industrial combustion plants, non-industrial combustion plants and other mobile sources are important. National sea traffic (navigation and fishing) contributes with about 5 % of the total SO_2 emission in 2015. This is due to the use of residual oil with higher sulphur content. This share decreased substantially from 2014 to 2015 due to new legislative requirements on sulphur content.

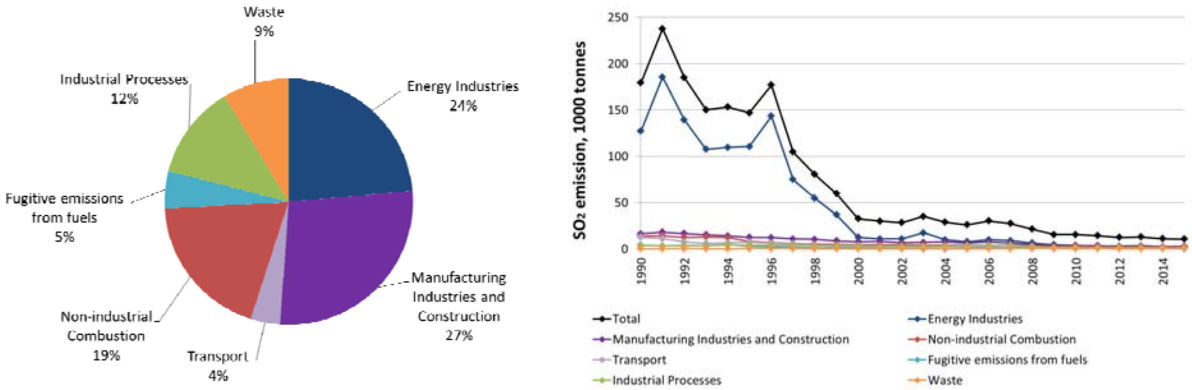


Figure 2.2 SO_2 emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.2.2 Nitrogen oxides (NO_x)

The largest sources of emissions of nitrogen oxides (NO_x) are road transport followed by other mobile sources 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 2015, 42 % 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 energy industries have decreased by 83 % from 1990 to 2015. In the same period, the total emission decreased by 62 %. The reduction is due to the increasing use of catalyst cars and installation of low-NO_x burners and denitrifying units in power plants and district heating plants.

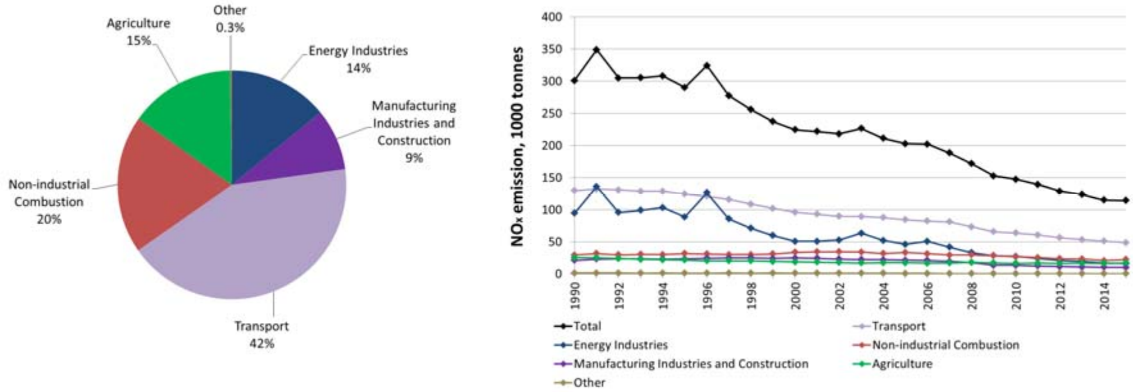


Figure 2.3 NO_X emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.2.3 Ammonia (NH_3)

Almost all atmospheric emissions of ammonia (NH_3) result from agricultural activities. Only a minor fraction originates from stationary combustion (2.0 %), road transport (1.5 %), industrial processes (0.7 %) and waste (1.0 %). The share for road transport was increasing during the 1990's and early 2000's due to increasing use of catalyst cars. In more recent years the share has been decreasing due to more advanced catalysts being implemented. The major part of the emission from agriculture stems from livestock manure (49 %) and the largest losses of ammonia occur during the handling of the manure in animal housing systems. The second largest agricultural source is agricultural soils contributing 45 % in 2015, this is mainly emissions from application of mineral fertiliser, application of animal manure and emissions from crowing crops. The total ammonia emission has decreased by 42 % since 1985. 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 demands for improved utilisation of nitrogen in livestock manure, a ban against field application of livestock manure in winter, prohibition of broadspreading 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 reduced considerably.

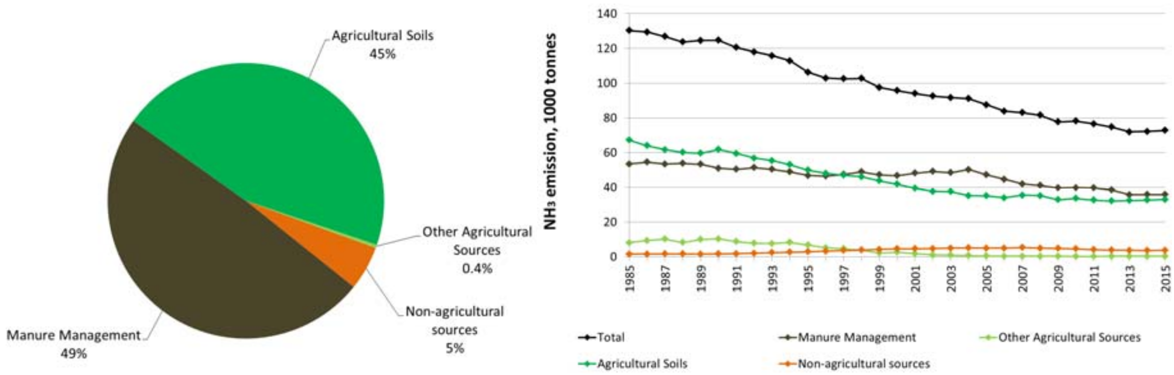


Figure 2.4 NH_3 emissions. Distribution on the main sectors (2015) and time series for 1985 to 2015.

2.3 Other air pollutants

2.3.1 Non-Methane Volatile Organic Compounds (NMVOC)

The emissions of Non-Methane Volatile Organic Compounds (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 contribute approximately 26 % of the NMVOC emissions from combustion processes. NMVOC from road transportation vehicles have been decreasing since 1990, due to the introduction of catalyst cars. The evaporative emissions mainly originate from the agricultural sector, use of solvents, and the extraction, handling and storage of oil and natural gas. The total anthropogenic emissions have decreased by 46 % since 1990, largely due to the increased use of catalyst cars and reduced emissions from use of solvents.

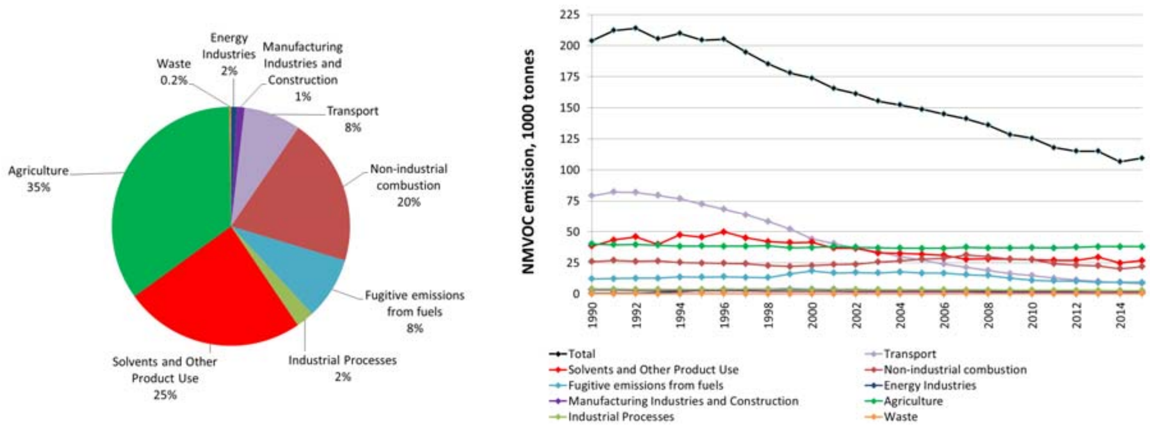


Figure 2.5 NMVOC emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.2 Carbon monoxide (CO)

Non-industrial combustion plants are the main source to the total CO emission. For the non-industrial sector, emissions from commercial/institutional sources have increased and emissions from agriculture/forestry/fishing sources have decreased from 1990 to 2015, while emissions from the residential sector have been fluctuating, but around the same level in 1990 and 2015. Transport is the second largest contributor to the total CO emission in 2015, showing a decrease of 84 % from 1990 to 2015. The major transport source is passenger cars, which made up 58 % in 1990, but has decreased to 18 % in 2015. The main driver is the increase of catalyst cars. In 1990 a law forbidding the burning of agricultural crop residues on fields was implemented, which caused a significant reduction in CO emission. The total CO emission decreased further by 56 % from 1990 to 2015, largely because of decreasing emissions from road transport.

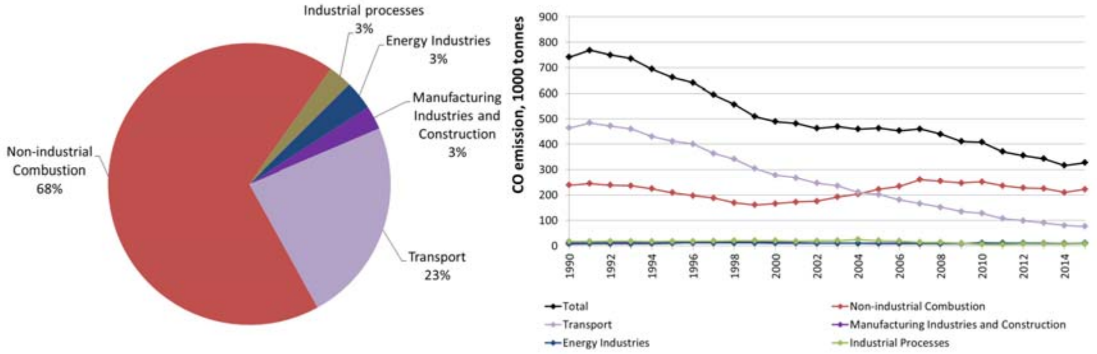


Figure 2.6 CO emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.3 Particulate matter (PM)

The particulate matter (PM) emission inventory is reported for the years 1990 onwards. 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 source is residential plants (67 %), road transport (9 %) and other mobile sources (7 %). Emissions from residential plants have increased by 114 % from 1990 to 2007, followed by a decrease of 36 % from 2007 to 2015. The increase was caused by increasing wood consumption while the decrease has been caused by a slightly lower wood consumption combined with legislative demands on new wood stoves and boilers. For the road transport sector, exhaust emissions account for the about half (48 %) of the emissions while the other half comes from tyre and brake wear and road abrasion. For other mobile sources, the most important sources are off-road vehicles and machinery in the industrial sector and in the agricultural/forestry sector (28 % and 35 %, respectively). The $PM_{2.5}$ emission decreased by 19 % from 1990 to 2015 as the increasing wood consumption in the residential sector has been counterbalanced by decreasing emissions for the remaining sectors, the most important being the transport sector.

The largest TSP emission sources are agriculture and non-industrial combustion (70 % and 18 % of total TSP emission in 2015, respectively). Residential plants is the largest source in the non-industrial combustion sector, making up 16 % of the national total TSP emission in 2015.The TSP emissions from transport are also important and include both exhaust emissions and the non-exhaust emissions from brake and tyre wear and road abrasion. The non-exhaust emissions account for 76 % of the TSP emission from road transport in 2015.

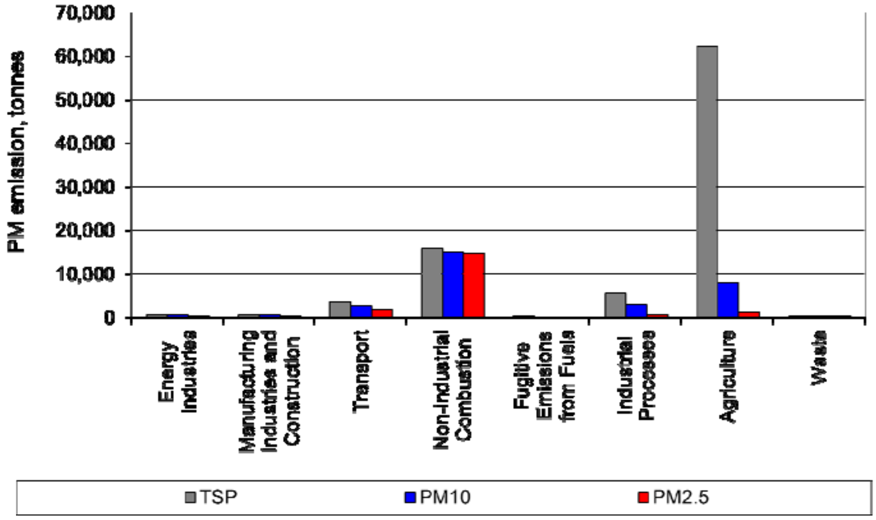


Figure 2.7 PM emissions per sector for 2015.

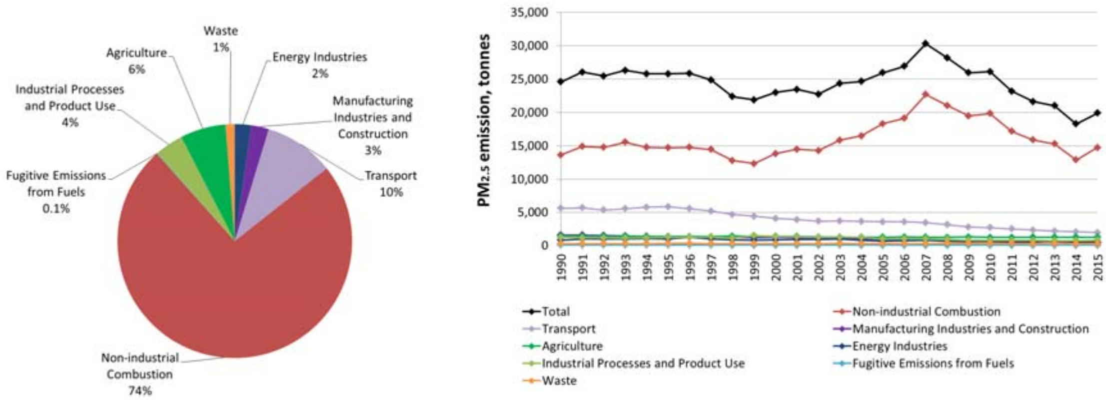


Figure 2.8 $PM_{2.5}$ emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.4 Black carbon (BC)

The black carbon (BC) emission inventory is reported for the years 1990 onwards. The main sources are residential plants and road transport contributing 50 % and 19 % in 2015, respectively. From 1990 to 2015 the total BC emission decreased by 46 %. The trend for non-industrial combustion is mainly controlled by the trend for the wood consumption in the residential sector. BC emissions from the transport sector decreased by 66 % from 1990 to 2015, mainly due to implementing of new EURO norms and improved technology. An important factor is the use of particle filters for heavy duty vehicles and passenger cars, which reduce the BC emission effectively. BC emissions from fugitive emissions from fuels, which is mainly due to storage of coal, decreased by 73 % from 1990 to 2015, in line with the decrease of the coal consumption in electricity and heat production.

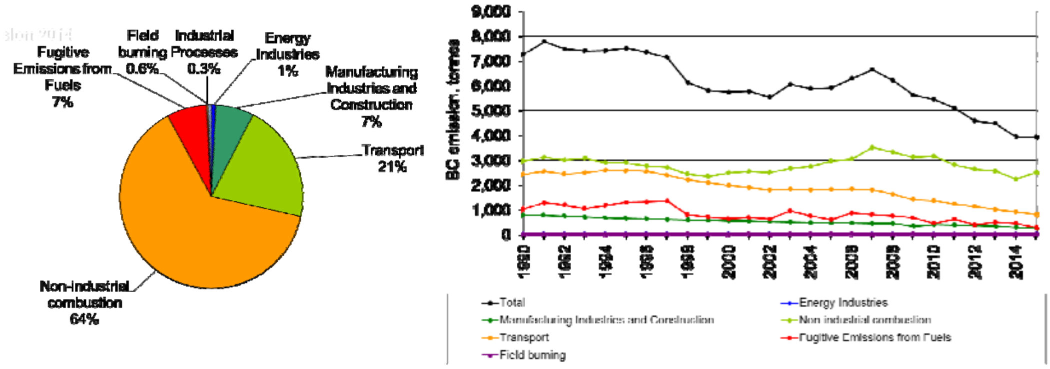


Figure 2.9 BC emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.5 Heavy metals

In general, the most important sources of heavy metal emissions are combustion of fossil fuels and waste. The heavy metal emissions have decreased substantially in recent years, except for Cu. The reductions span from 13 % to 91 % for Zn and Pb, respectively. The reason for the reduced emissions is mainly increased use of gas cleaning devices at power and district heating plants (including waste incineration plants). The large reduction in the Pb emission is due to a gradual shift towards unleaded gasoline, the latter being essential for catalyst cars. The major source of Cu is automobile tyre and break wear (47 % in 2015) and the 35 % increase from 1990 to 2015 owe to increasing mileage.

Table 2.1 Emissions of heavy metals.

Heavy metals, kilogramme	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
1990	1345	1095	5812	32 218	3172	21064	128 305	4865	68 879
2015	310	657	1587	43 462	297	3673	11 673	1309	60 005
Reduction, %	77	40	73	-35	91	83	91	73	13

According to the UNECE Heavy Metal Protocol, the priority metals are Pb, Cd and Hg and the objective is to reduce emissions of these heavy metals.

Cadmium (Cd)

The main sources of emissions of cadmium (Cd) to air are mainly combustion of wood, wood waste and municipal waste. Non-industrial combustion contributes 76 % in 2015, of which 98 % comes from residential plants. Emissions from residential plants have increased by 287 % from 1990 to 2015 due to increasing wood consumption. Emissions from energy industries, manufacturing industries and construction, and industrial processes have decreased by 86 % from 1990 to 2015. The decreasing emission from energy industries are related to the decreasing combustion of coal. In the transport sector emissions from passenger cars is the main source contributing with 59 % of the sectoral emission in 2015.

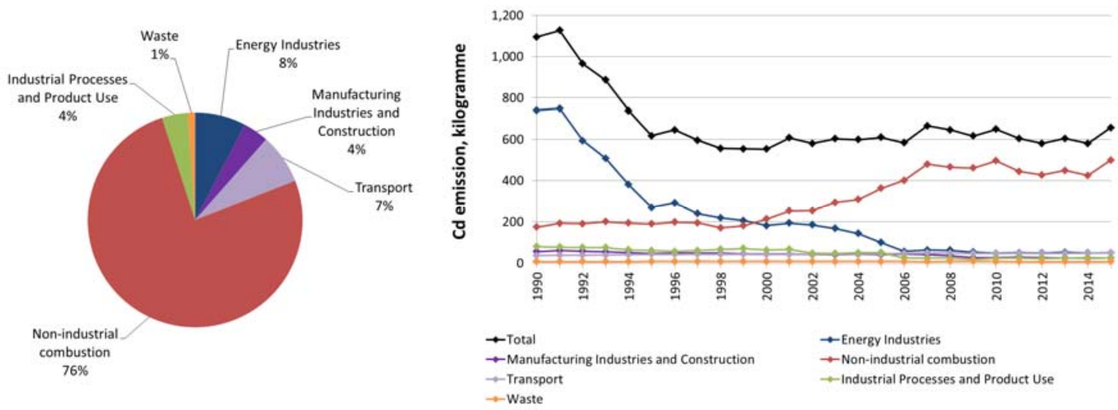


Figure 2.10 Cd emissions. Distribution by main sectors (2015) and time series for 1990 to 2015.

Mercury (Hg)

The largest sources of mercury (Hg) emissions to air are waste incineration and coal combustion in energy industries. Due to improved flue gas cleaning and decreasing coal combustion the emissions from Energy industries decreased by 76 % from 1990-2000. The trend has continued in the following years and the corresponding decrease from 1990-2015 is 94 %. Non-industrial combustion is dominated by wood combustion in residential plants while the main contributions to emissions from manufacturing industries and construction are food processing, beverages and tobacco, and non-metallic minerals. The variations in emissions from industrial processes owe to the closure in 2002 followed by re-opening and a second shut down in 2005 of the only Danish electro-steelwork.

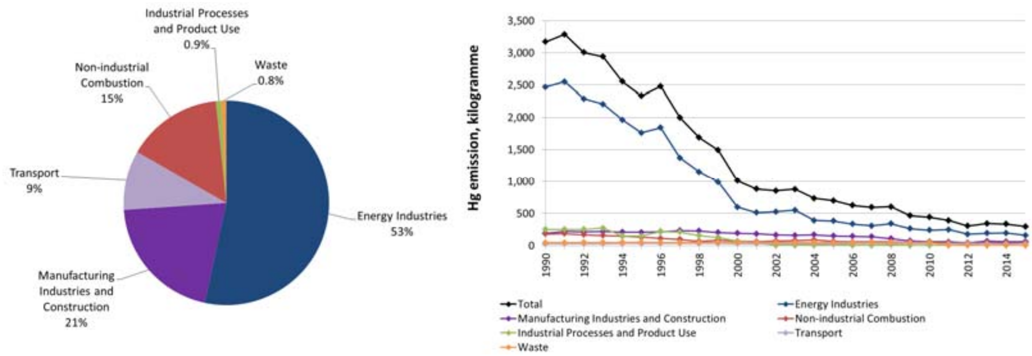


Figure 2.11 Hg emissions. Distribution by main sectors (2015) and time series for 1990 to 2015.

Lead (Pb)

The main lead (Pb) emission sources are transport, waste, non-industrial combustion and industrial processes. In earlier years combustion of leaded gasoline was the major contributor to Pb emissions to air but the shift toward use of unleaded gasoline for transport have decreased the Pb emission from transport by 94 % from 1990-2015. The trend in the Pb emission from non-industrial combustion from 1990 to 2015 is a decrease of 24 %. In the non-industrial combustion sector the dominant source is wood combustion in residential plants, which has been increasing from 1990 to 2015, but counterbalanced by decreasing emissions from stationary combustion in commercial/institutional and in agriculture/forestry/fishing. The decreasing emission from Energy industries (97 % from 1990 to 2015) is caused by the deceasing coal combustion and more efficient particle abatement.

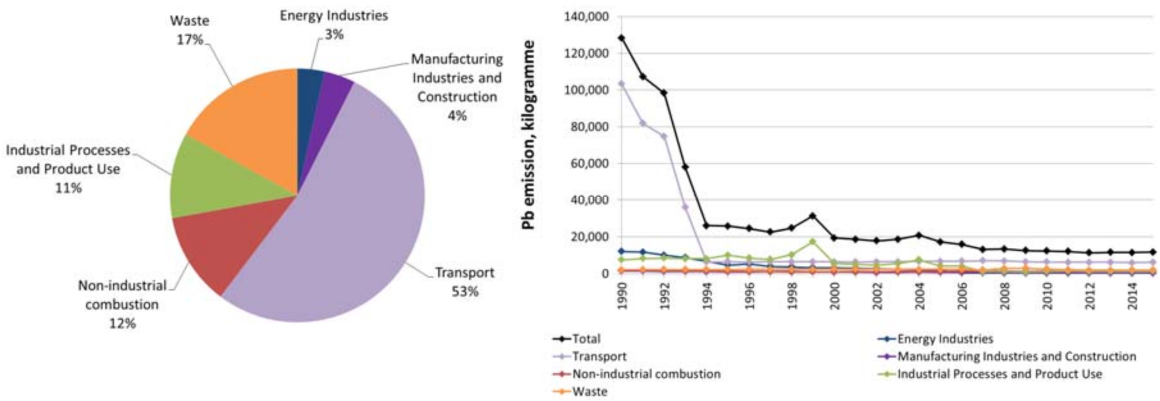


Figure 2.12 Pb emissions. Distribution by main sectors (2015) and time series for 1990 to 2015.

2.3.6 Polycyclic aromatic hydrocarbons (PAHs)

The present emission inventory for polycyclic aromatic hydrocarbons (PAH) includes four PAHs: benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene. The major part of the total PAH emission is benzo(b)fluoranthene and benzo(a)pyrene, which contribute by 35 % and 32 %, respectively in 2015.

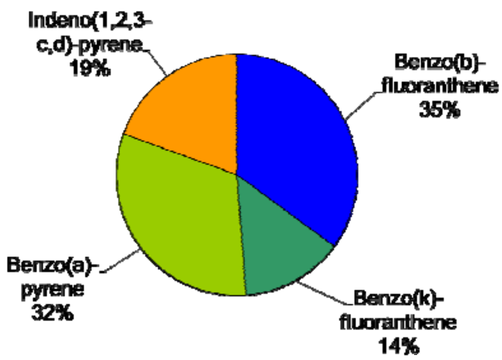


Figure 2.13 PAH emissions. Distribution according to reported PAHs in 2015.

The most important source of PAHs emissions is combustion of wood in the residential sector making up 69 % of the total emission in 2015. The increasing emission trend is due to increasing combustion of wood in the residential sector. The PAH emission from combustion in residential plants has increased by 51 % from 1990 to 2015.

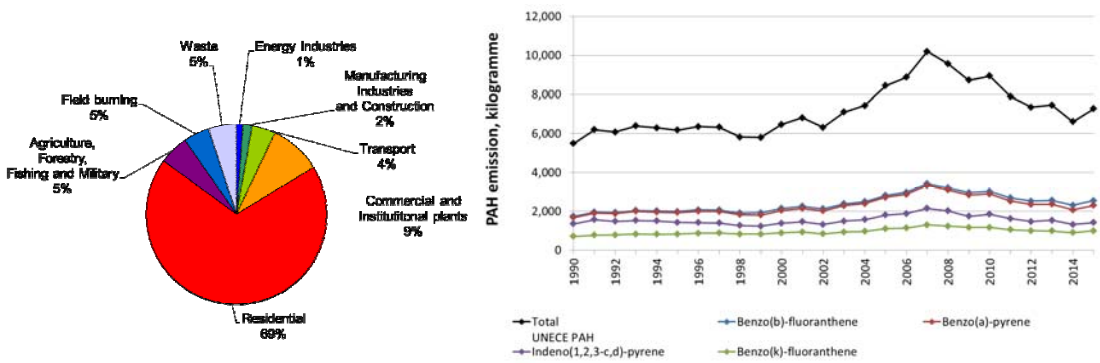


Figure 2.14 PAH emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.7 Dioxins and furans

The major part of the dioxin emission owes to wood combustion in the residential sector, mainly in wood stoves and ovens without flue gas cleaning.

Wood combustion in residential plants accounts for 54 % of the national dioxin emission in 2015. The contribution to the total dioxin emission from the waste sector (32 % in 2015) mainly owes to accidental fires, especially building fires. The emissions of dioxins from energy industries are dominated by emissions from combustion of biomass as wood, wood waste and to a less extend agricultural waste.

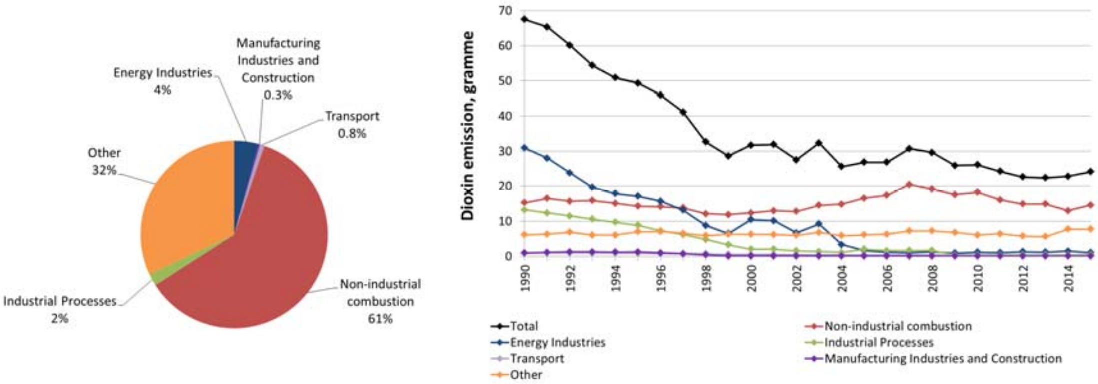


Figure 2.15 Emissions of dioxins and furans. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.8 Hexachlorobenzene (HCB)

Stationary combustion accounts for 42 % of the estimated national hexachlorobenzene (HCB) emission in 2015. This owes mainly to combustion of municipal solid waste in heating and power plants. Transport is an important source, too, making up 31 % of the total emission in 2015. Emissions from transport have increased by 66 % since 1990 due to increasing diesel consumption. The HCB emission from stationary plants has decreased 74 % since 1990 mainly due to improved flue gas cleaning in MSW incineration plants. The emission from agriculture was very high in the early 1990'ties due to the use of pesticides containing impurities of HCB. The HCB emission from agriculture decreased by 94 % from 1990 to 1994 and by 99 % from 1990 to 2015, causing the share of HCB emission from agriculture to drop from 67 % in 1990 to 6 % in 2015. The emission from industrial processes has decreased due to the closure of steel production and secondary aluminium production in Denmark.

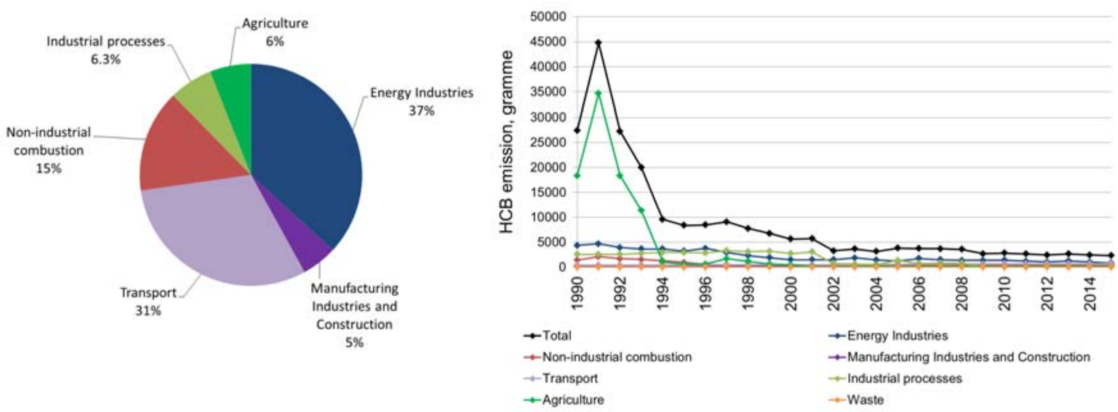


Figure 2.16 HCB emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

2.3.9 Polychlorinated biphenyls (PCBs)

Transport accounts for 68 % of the estimated national polychlorinated biphenyls (PCBs) emission in 2015. This owes mainly to combustion of diesel in road transport. The emission from transport has decreased by 69 % since 1990 due to the phase out of leaded gasoline, which has a high PCBs emission factor. This has led to diesel fuel use being the most important source of PCBs emissions from transport in later years. The emission from manufacturing industries and non-industrial combustion is dominated by diesel fuel used in non-road machinery.

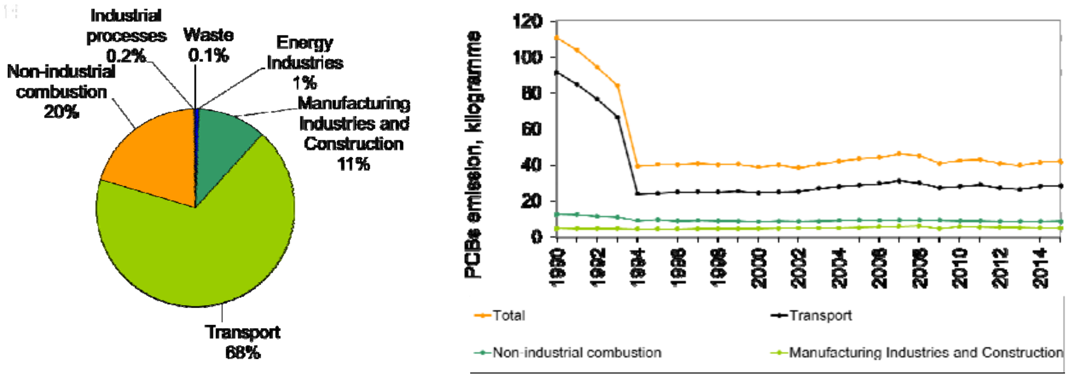


Figure 2.17 PCBs emissions. Distribution according to the main sectors (2015) and time series for 1990 to 2015.

3 Energy (NFR sector 1)

3.1 Overview of the sector

The energy sector is reported in three main chapters:

3.2 Stationary combustion (NFR sector 1A1, 1A2 and 1A4)
3.3 Transport and other mobile sources (NFR sector 1A2, 1A3, 1A4 and 1A5)
3.4 Fugitive emissions (NFR sector 1B)

Summary tables for the emissions from the energy sector are shown below.

Table 3.1.1 SO_2, NO_x, NMVOC, CO, PM and BC emissions from the energy sector, 2015.

	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	kt NO_2	kt	kt SO_2	kt	kt	kt	kt	kt	kt
1A1 Energy Industries	16.09	0.85	2.55	0.02	0.44	0.55	0.71	0.03	11.02
1A2 Manufacturing industries and Construction	10.01	1.17	2.98	0.04	0.49	0.55	0.63	0.27	8.81
1A3 Transport	48.65	8.47	0.41	1.07	1.92	2.66	3.63	0.82	76.60
1A4 Other Sectors	21.09	21.65	2.01	1.41	14.65	15.03	15.79	2.47	218.76
1A5 Other	1.30	0.30	0.06	0.00	0.09	0.09	0.09	0.03	2.93
1B1 Fugitive Emissions from fuels, Solid fuels	-	-	-	-	0.02	0.17	0.41	0.28	-
1B2 Fugitive Emissions from fuels, Oil and Natural gas	0.12	9.25	0.53	-	0.00	0.00	0.00	0.00	0.21
Energy, Total	97.26	41.69	8.56	2.54	17.60	19.05	21.25	3.90	318.32

Table 3.1.2 HM emissions from the energy sector, 2015.

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
	t	t	t	t	t	t	t	t	t
1A1 Energy Industries	0.40	0.05	0.16	0.12	0.17	0.18	0.47	0.56	0.46
1A2 Manufacturing industries and Construction	0.46	0.03	0.06	0.07	0.08	0.10	1.04	0.09	1.32
1A3 Transport	6.18	0.05	0.03	0.04	0.20	40.18	1.71	0.06	27.23
1A4 Other Sectors	1.33	0.50	0.04	0.03	0.90	0.30	0.13	0.07	20.68
1A5 Other	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
1B1 Fugitive Emissions from fuels, Solid fuels	-	-	-	-	-	-	-	-	-
1B2 Fugitive Emissions from fuels, Oil and Natural gas	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Energy, Total	8.43	0.62	0.29	0.26	1.36	40.77	3.35	0.78	49.76

Table 3.1.3 PAH, dioxin, HCB and PCB emissions from the energy sector, 2015.

	PCDD/ PCDF	Ben-zo(a)-pyrene	Ben-zo(b)-fluoran-thene	Ben-zo(k)-fluoran-thene	Indeno-(1,2,3-cd)-pyrene	HCB	PCB
	g I-Teq	t	t	t	t	kg	kg
1A1 Energy Industries	1.01	0.01	0.04	0.03	0.01	0.86	0.23
1A2 Manufacturing industries and Construction	0.06	0.02	0.08	0.01	0.01	0.12	4.64
1A3 Transport	0.19	0.06	0.09	0.08	0.07	0.71	28.28
1A4 Other Sectors	14.62	1.99	2.12	0.76	1.19	0.34	7.70
1A5 Other	0.00	0.00	0.00	0.00	0.00	0.01	0.67
1B1 Fugitive Emissions from fuels, Solid fuels	-	-	-	-	-	-	-
1B2 Fugitive Emissions from fuels, Oil and Natural gas	0.00	0.00	0.00	0.00	0.00	-	-
Energy, Total	15.89	2.09	2.33	0.88	1.27	2.03	41.51

3.2 Stationary combustion (NFR sector 1A1, 1A2 and 1A4)

This chapter includes stationary combustion plants in the NFR sectors 1A1, 1A2 and 1A4.

3.2.1 Source category description

Source category definition

In the Danish emission database, all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according to the CORINAIR system[1]. The emission inventories are prepared from a complete emission database based on the SNAP sectors. Aggregation to the NFR sector codes is based on a correspondence list between SNAP and NFR enclosed in Annex 3A-1. Stationary combustion is defined as combustion activities in the SNAP sectors 01-03, not including SNAP 0303.

Stationary combustion plants are included in the emission source subcategories:

- 1A1 Energy, Fuel consumption, Energy Industries
  - 1A1a Public electricity and heat production
  - 1A1b Petroleum refining
  - 1A1c Oil and gas extraction
- 1A2 Energy, Fuel consumption, Manufacturing Industries and Construction
  - 1A2a Iron and steel
  - 1A2b Non-ferrous metals
  - 1A2c Chemicals
  - 1A2d Pulp, Paper and Print
  - 1A2e Food processing, beverages and tobacco
  - 1A2f Non-metallic minerals
  - 1A2 g viii Other manufacturing industry
- 1A4 Energy, Fuel consumption, Other Sectors
  - 1A4a i Commercial/Institutional plants.
  - 1A4b i Residential plants.
  - 1A1c i Agriculture/Forestry.

The emission and fuel consumption data included in tables and figures in Chapter 3.2 only include emissions originating from stationary combustion plants of a given NFR sector.

Emission share from stationary combustion compared to national total

Table 3.2.1 gives an overview of the emission share from stationary combustion compared to national total. Main emission sources are discussed in Chapter 3.2.3. Key category analysis has not been performed.

[1] And some additional SNAP added for industrial combustion.

Table 3.2.1 Emission share from stationary combustion compared to national total, 2015.

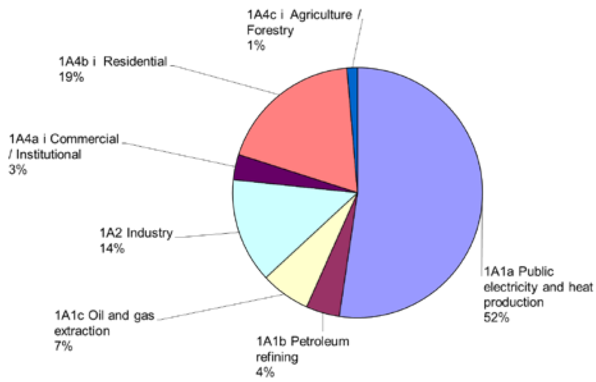
Pollutant	Emission share %
SO_2	66
NO_x	23
NMVOC	21
CO	36
NH_3	2.2
TSP	18
PM_{10}	50
$PM_{2.5}$	73
BC	55
As	69
Cd	86
Cr	71
Cu	1.3
Hg	85
Ni	44
Pb	18
Se	52
Zn	35
HCB	50
PCDD/F	65
Benzo(a)pyrene	88
Benzo(b)fluoranthene	87
Benzo(k)fluoranthene	79
Indeno(123cd)pyrene	84
PCB	0.92

3.2.2 Fuel consumption data

In 2015, the total fuel consumption for stationary combustion plants was 387 PJ of which 253 PJ was fossil fuels and 134 PJ was biomass.

Fuel consumption distributed according to the stationary combustion subcategories is shown in Figure 3.2.1 and Figure 3.2.2. The majority - 52 % - of all fuels is combusted in the source category, *Public electricity and heat production*. Other source categories with high fuel consumption are *Residential plants* and *Industry*.

Fuel consumption including biomass



Fuel consumption, fossil fuels

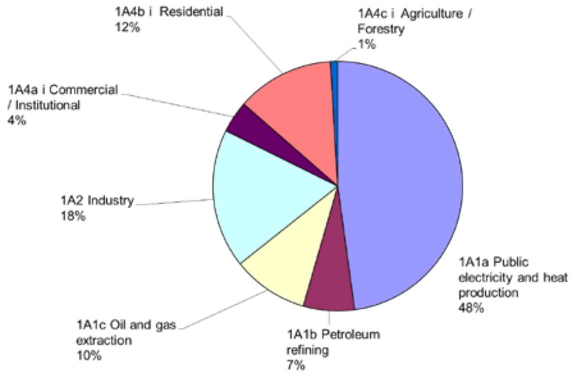


Figure 3.2.1 Fuel consumption of stationary combustion source categories, 2015. Based on DEA (2016a).

Natural gas, wood and coal are the most utilised fuels for stationary combustion plants. Coal is mainly used in power plants and natural gas is used in power plants and decentralised combined heating and power (CHP) plants, as well as in industry, residential plants and off-shore gas turbines (see Figure 3.2.2). Wood is mainly applied for public electricity and heat production and in residential plants.

Detailed fuel consumption rates are shown in Annex 3A-2.

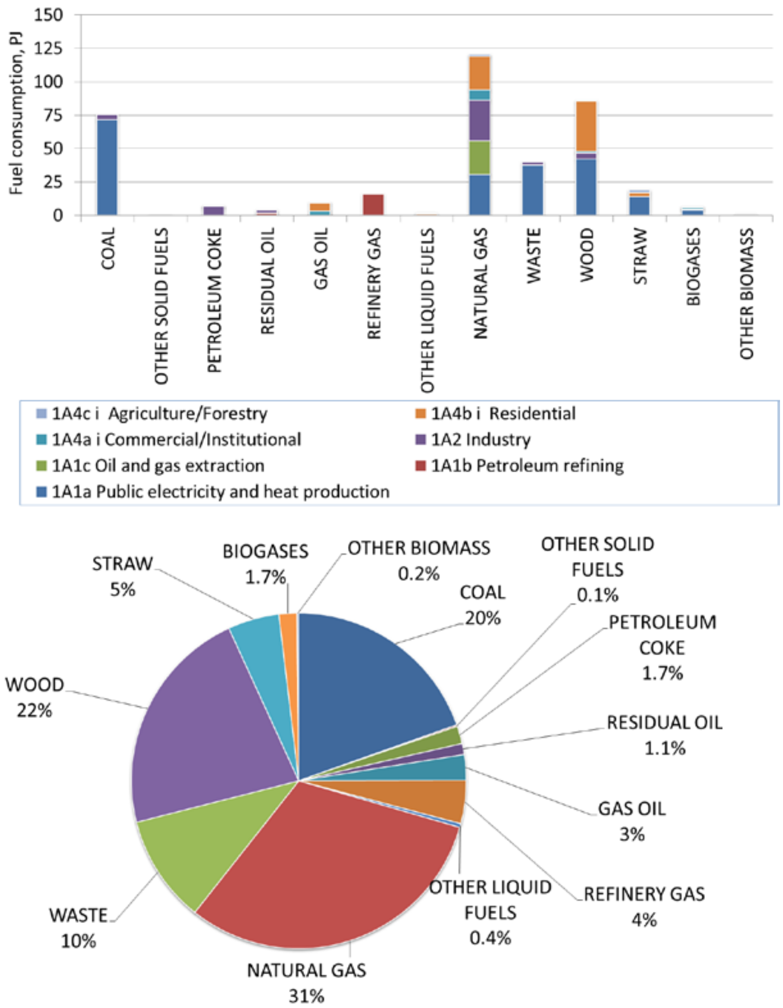


Figure 3.2.2 Fuel consumption of stationary combustion 2015, disaggregated to fuel type. Based on DEA (2016a).

Fuel consumption time series for stationary combustion plants are presented in Figure 3.2.3[2]. The fuel consumption for stationary combustion was 23 % lower in 2015 than in 1990, while the fossil fuel consumption was 45 % lower and the biomass fuel consumption 3.3 times the level in 1990.

The consumption of natural gas, waste and biomass has increased since 1990 whereas the consumption of coal has decreased.

[2] Time series 1980 onwards are included in Annex 3A-10.

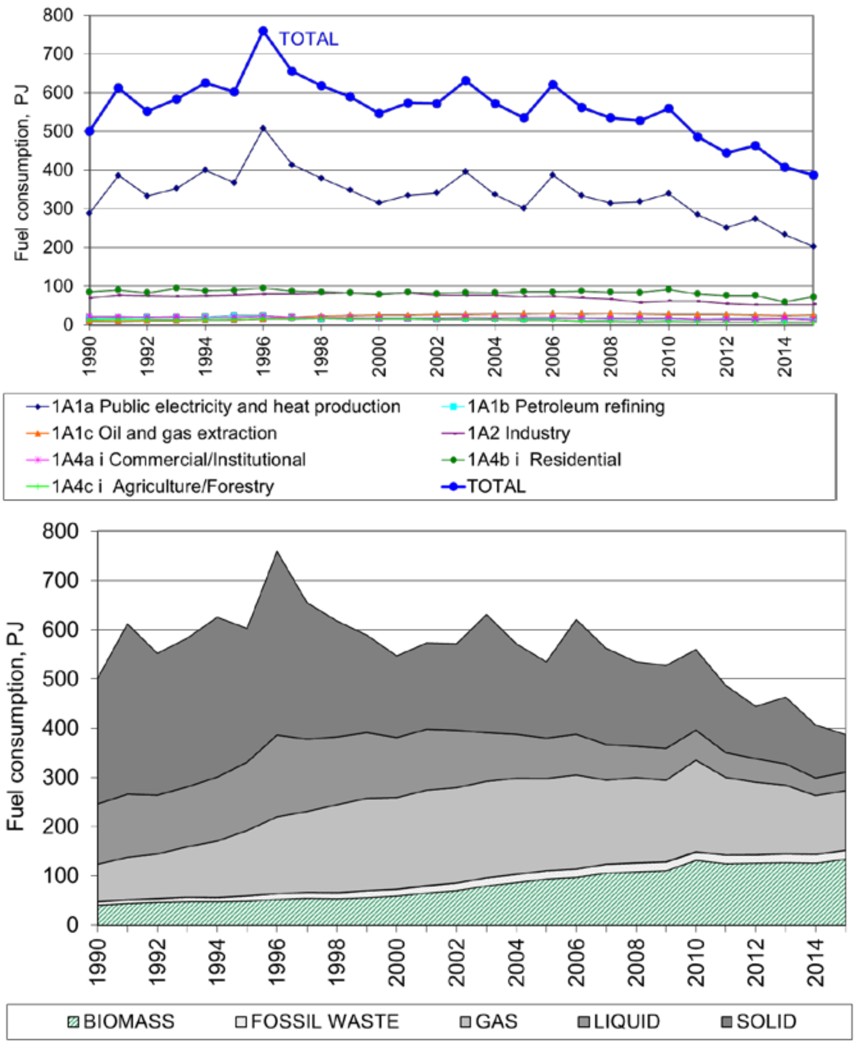


Figure 3.2.3 Fuel consumption time series, stationary combustion. Based on DEA (2016a).

The fluctuations in the time series for fuel consumption are mainly a result of electricity import/export, but also of outdoor temperature variations from year to year. This, in turn, leads to fluctuations in emission levels. The fluctuations in electricity trade, fuel consumption and NO_x emission are illustrated and compared in Figure 3.2.4. In 1990, the Danish electricity import was large causing relatively low fuel consumption, whereas the fuel consumption was high in 1996 and 2003 due to a large electricity export. In 2015, the net electricity import was 21 PJ, whereas there was a 10 PJ electricity import in 2014. The large electricity export that occurs some years is a result of low rainfall in Norway and Sweden causing insufficient hydropower production in both countries.

To be able to follow the national energy consumption as well as for statistical and reporting purposes, the Danish Energy Agency produces a correction of the actual fuel consumption without random variations in electricity imports/exports and in ambient temperature. This fuel consumption trend is also illustrated in Figure 3.2.4. The corrections are included here to explain the fluctuations in the time series for fuel rate and emissions.

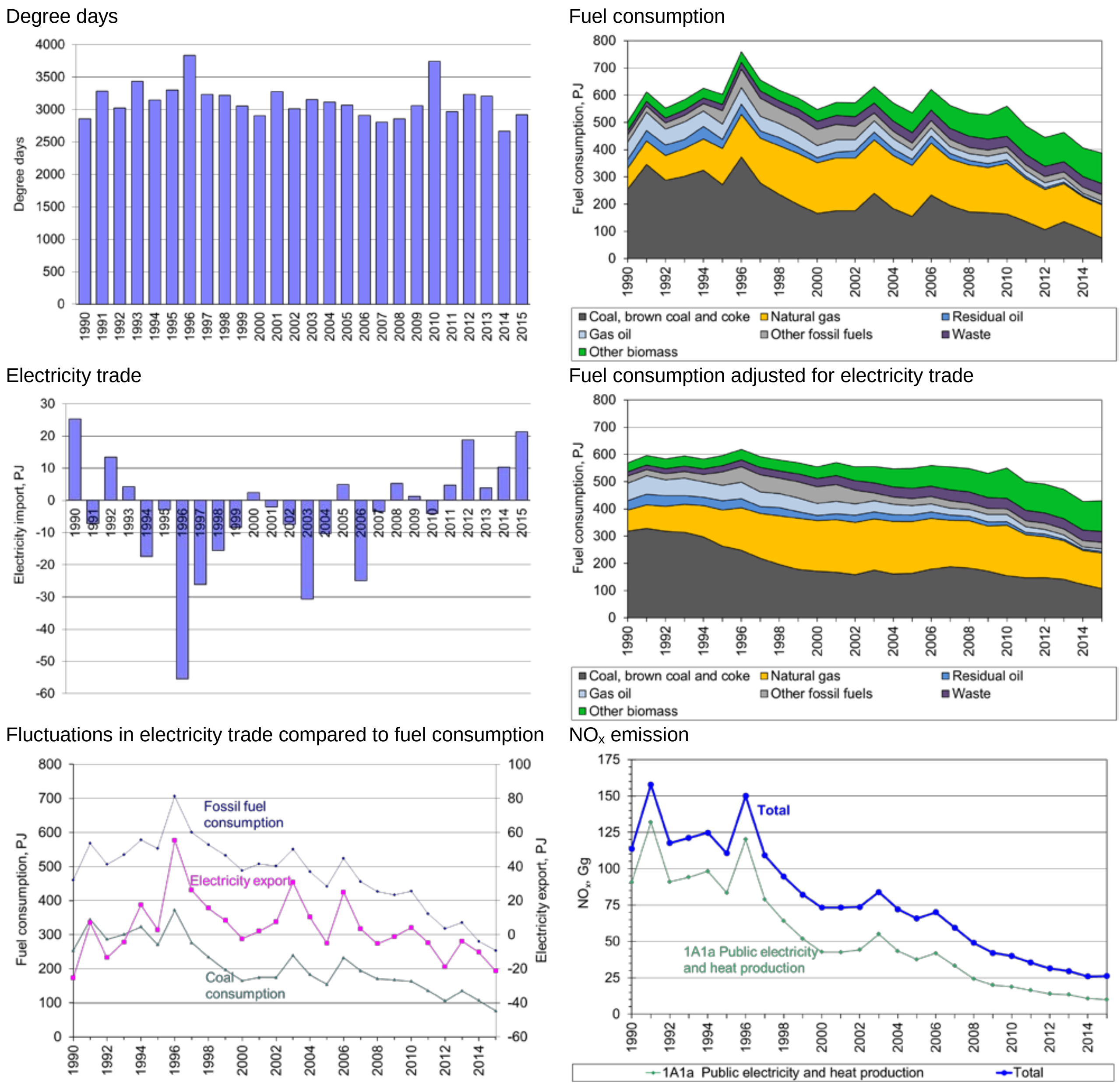


Figure 3.2.4 Comparison of time series fluctuations for electricity trade, fuel consumption and NO_x emission. Based on DEA (2016a).

Fuel consumption time series for the subcategories to stationary combustion are shown in Figure 3.2.5 – 3.2.7.

Fuel consumption for *Energy Industries* fluctuates due to electricity trade as discussed above. The fuel consumption in 2015 was 12 % lower than in 1990 and the fossil fuel consumption was 45 % lower. The fluctuation in electricity production is based on fossil fuel consumption in the subcategory *Public electricity and Heat Production*. The energy consumption in *Oil and gas extraction* is mainly natural gas used in gas turbines in the off-shore industry. The biomass fuel consumption in *Energy Industries* in 2015 added up to 82 PJ, which is 5.0 times the level in 1990 and almost the same as in 2014.

The fuel consumption in *Industry* was 24 % lower in 2015 than in 1990 (Figure 3.2.6). The fuel consumption in industrial plants decreased considerably as a result of the financial crisis. The biomass fuel consumption in *Industry* in 2015 added up to 7 PJ which is a 13 % increase since 1990.

The fuel consumption in *Other Sectors* decreased 24 % since 1990 (Figure 3.2.7) and increased 11 % since 2014. The biomass fuel consumption in *Other sectors* in 2015 added up to 46 PJ which is 2.5 times the consumption in 1990 and 15 % decrease since 2014. Wood consumption in residential plants in 2015 was 2.5 times the consumption in year 2000.

Time series for subcategories are shown in Chapter 3.2.4.

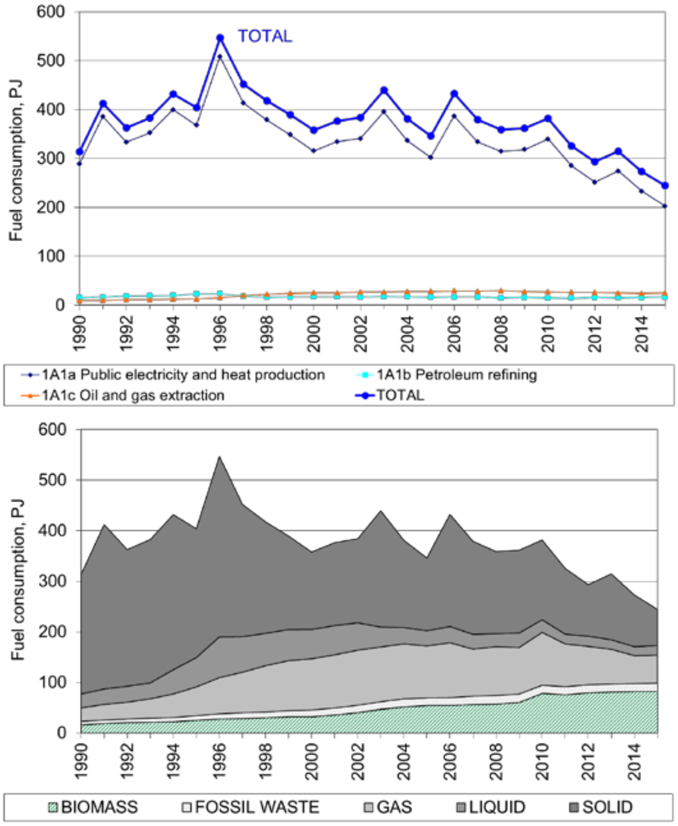


Figure 3.2.5 Fuel consumption time series for subcategories - 1A1 Energy Industries.

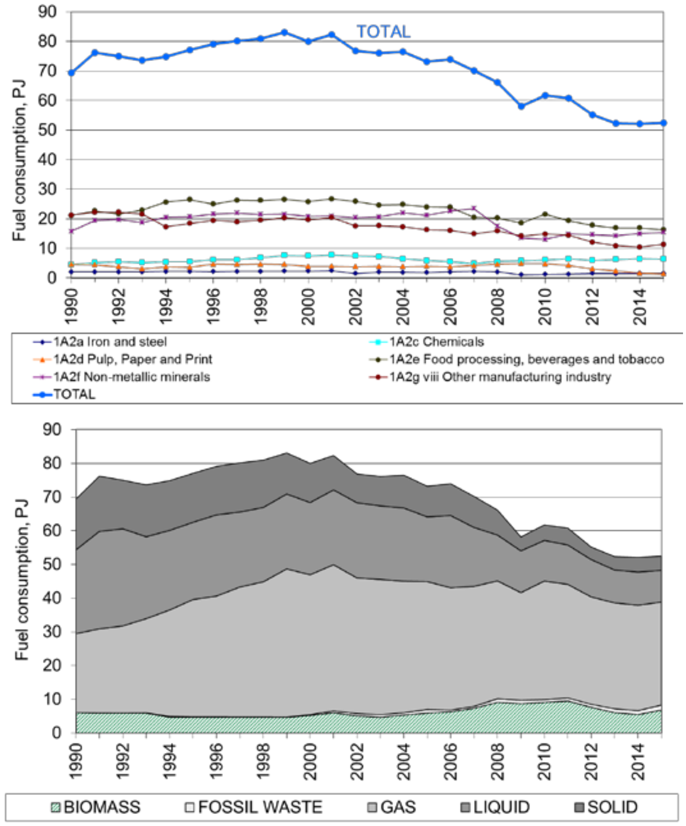


Figure 3.2.6 Fuel consumption time series for subcategories - 1A2 Industry.

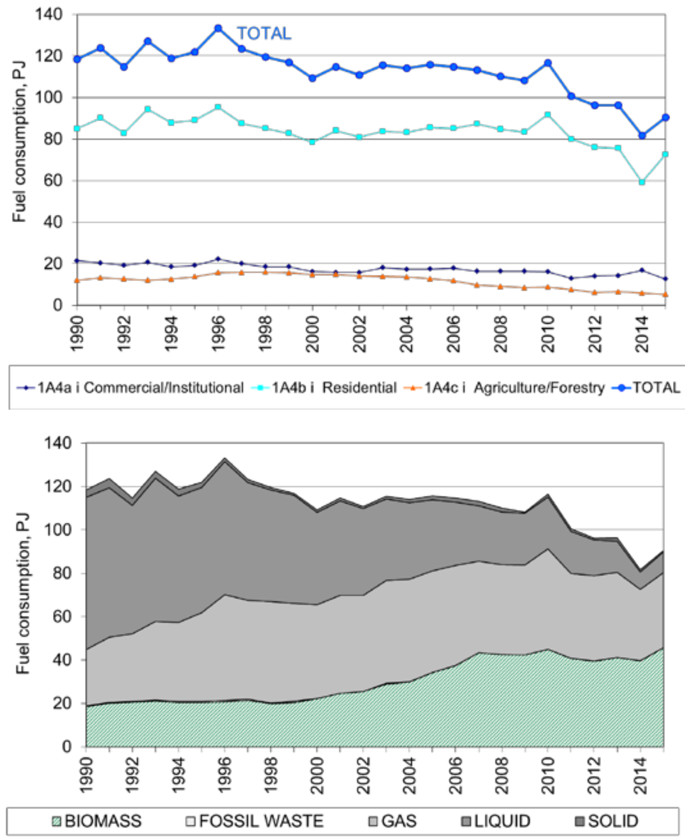


Figure 3.2.7 Fuel consumption time series for subcategories - 1A4 Other Sectors.

3.2.3 Emissions

SO_2

Stationary combustion is the most important emission source for SO_2 accounting for 66 % of the national emission. Table 3.2.2 presents the SO_2 emission inventory for the stationary combustion subcategories.

The largest emission sources are *Public electricity and heat production* and *Manufacturing industries and construction* accounting for 32 % and 42 % of the emission from stationary combustion.

For *Public electricity and heat production* the SO_2 emission share is however lower than the fuel consumption share for this source category, which is 52 %. This is a result of effective flue gas desulphurisation equipment installed in power plants combusting coal. In the Danish inventory, the source category *Public electricity and heat production* is further disaggregated. Figure 3.2.8 shows the SO_2 emission from *Public electricity and heat production* on a disaggregated level. District heating boilers < 50 MW and Power plants >300MW_{th} are the main emission sources, accounting for 45 % and 28 % of the emission.

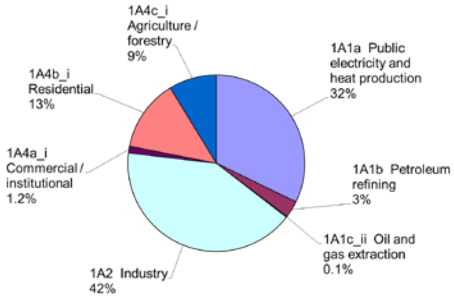
The SO_2 emission from industrial plants adds up to 42 % of the emission from stationary combustion, a remarkably high emission share compared with fuel consumption. The main emission sources in the industrial category are combustion of coal and emissions from the cement industry, mineral wool industry and sugar production plants. Until year 2000, the SO_2 emission from the industrial category only accounted for a small part of the emission from stationary combustion, but as a result of reduced emissions from power plants, the share has now increased.

The time series for SO_2 emission from stationary combustion is shown in Figure 3.2.9. The SO_2 emission from stationary combustion plants has decreased by 95 % since 1990. The large emission decrease is mainly a result of the reduced emission from *Public electricity and heat production*, made possible due to installation of desulphurisation plants and due to the use of fuels with lower sulphur content. Despite the considerable reduction in emission from public electricity and heat production plants, these still account for 32 % of the emission from stationary combustion, as mentioned above. The emission from other source categories also decreased considerably since 1990. Time series for subcategories are shown in Chapter 3.2.4.

The emission of SO_2 has decreased since 2005, but the emission level has steadied since 2009.

Table 3.2.2 SO_2 emission from stationary combustion plants, 2015[1)]

		SO_2, Mg
1A1a	Public electricity and heat production	2317
1A1b	Petroleum refining	225
1A1c	Oil and gas extraction	11
1A2	Industry	2979
1A4a	Commercial/Institutional	88
1A4b	Residential	947
1A4c	Agriculture/Forestry	627
Total		7194



1) Only emission from stationary combustion plants in the source categories is included.

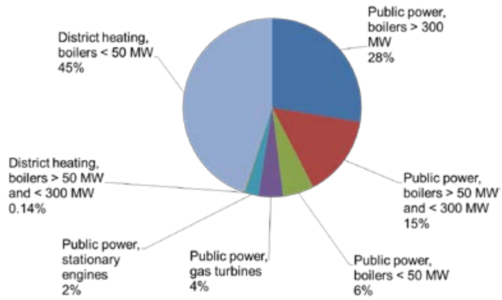


Figure 3.2.8 Disaggregated SO_2 emissions from 1A1a Public electricity and heat production.

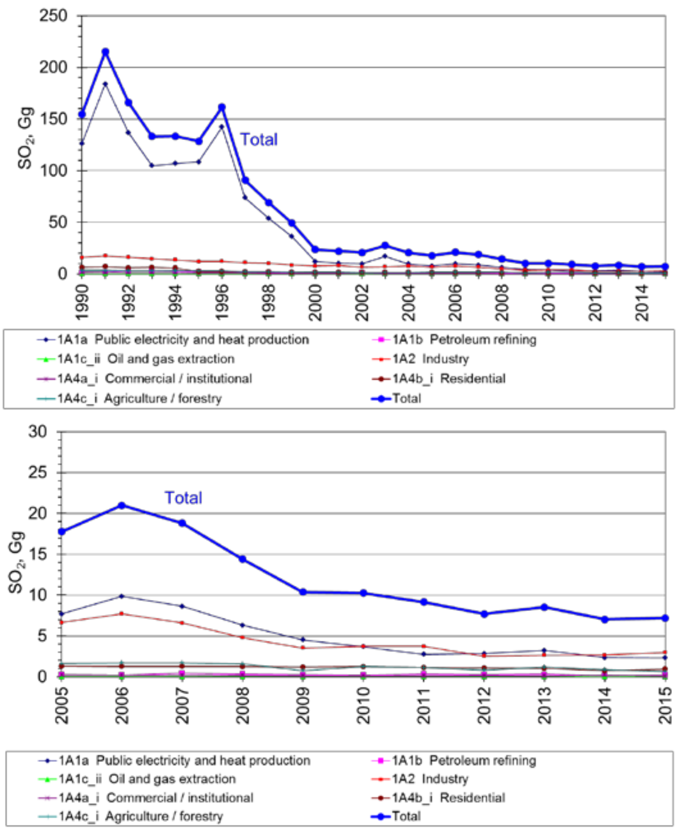


Figure 3.2.9 SO_2 emission time series for stationary combustion.

NO_x

Stationary combustion accounts for 23% of the national NO_x emission. Table 3.2.3 shows the NO_x emission inventory for stationary combustion subcategories.

Public electricity and heat production is the largest emission source accounting for 38 % of the emission from stationary combustion plants. The emission from public power boilers > 300 MW_{th} accounts for 21 % of the emission in this subcategory.

Industrial combustion plants are also an important emission source accounting for 18 % of the emission. The main industrial emission source is cement production, which accounts for 38 % of the emission.

Residential plants account for 16 % of the NO_x emission. The fuel origin of this emission is mainly wood accounting for 70 % of the residential plant emission.

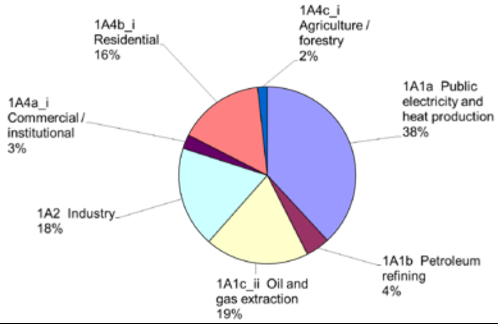
Oil and gas extraction, which is mainly off-shore gas turbines accounts for 19 % of the NO_x emission.

Time series for NO_x emission from stationary combustion are shown in Figure 3.2.10. NO_x emission from stationary combustion plants has decreased by 77 % since 1990. The reduced emission is largely a result of the reduced emission from public electricity and heat production due to installation of low NO_x burners, selective catalytic reduction (SCR) units and selective non-catalytic reduction (SNCR) units. The fluctuations in the time series follow the fluctuations in public electricity and heat production, which, in turn, result from electricity trade fluctuations.

The emission has also decreased considerably since 2005, see figure 3.2.10.

Table 3.2.3 NO_x emission from stationary combustion plants, 2015[1)].

	NO_x, Mg
1A1a Public electricity and heat production	9974
1A1b Petroleum refining	1153
1A1c Oil and gas extraction	4964
1A2 Industry	4824
1A4a Commercial/Institutional	672
1A4b Residential	4114
1A4c Agriculture/Forestry	461
Total	26163



1) Only emission from stationary combustion plants in the source categories is included.

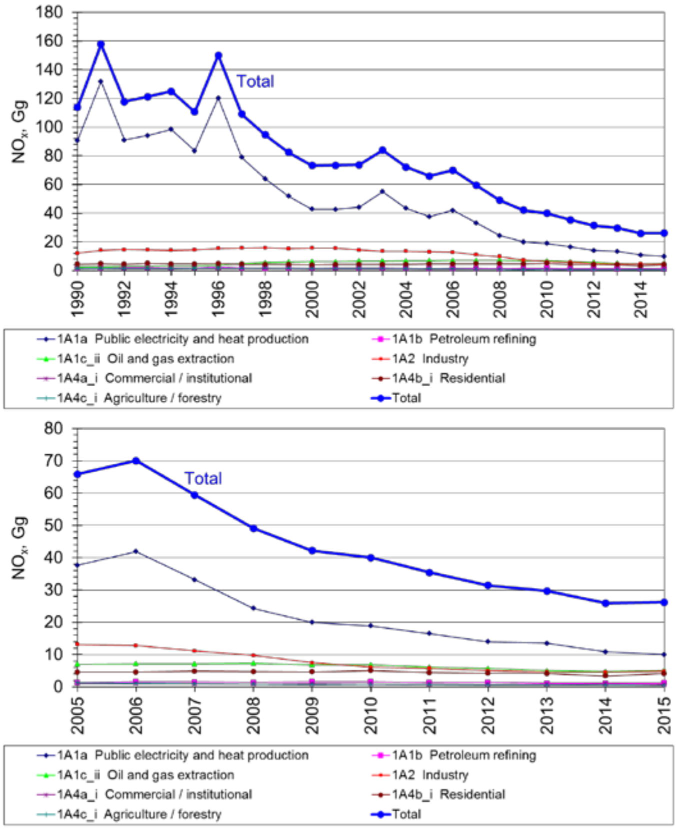


Figure 3.2.10 NO_x emission time series for stationary combustion.

NMVOC

Stationary combustion plants account for 21 % of the national NMVOC emission. Table 3.2.4 presents the NMVOC emission inventory for the stationary combustion subcategories.

Residential plants are the largest emission source accounting for 83 % of the emission from stationary combustion plants. For residential plants NMVOC is mainly emitted from wood and straw combustion, see Figure 3.2.11.

Public electricity and heat production is also a considerable emission source, accounting for 5 % of the emission. Lean-burn gas engines have a relatively high NMVOC emission factor and are the most important emission source in this subcategory (see Figure 3.2.11). The gas engines are either natural gas or biogas fuelled.

Agricultural plants accounted for 8 % of the emission in 2015. Combustion of straw was the main emission source in this category.

The time series for NMVOC emission from stationary combustion is shown in Figure 3.2.12. The emission has decreased by 3 % from 1990. The emission increased until 2007 and decreased between 2007 and 2014. The increased emission is mainly a result of the increasing wood consumption in residential plants and of the increased use of lean-burn gas engines in CHP plants. The decrease in 2007-2014 is a result of lower emission from residential wood combustion and the low number of operation hours for the lean burn gas engines. The increase from 2014 to 2015 is a result of increased consumption of wood in residential plants.

The emission from residential plants has increased 9 % since 1990.

The emission from straw combustion in farmhouse boilers has decreased (42 %) over this period due to both a decreasing emission factor and decrease in straw consumption in this source category. The emission from most other fuels has also decreased.

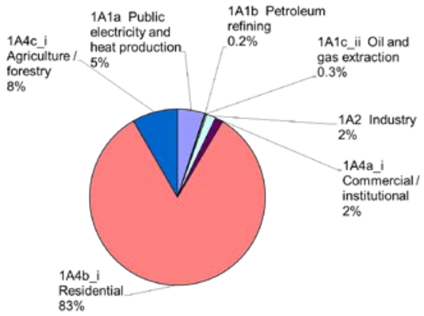
However, the NMVOC emission from residential wood combustion was 50 % higher in 2015 than in 1990 due to increased wood consumption. However, the emission factor has decreased since 1990 due to installation of modern stoves and boilers with improved combustion technology.

The use of wood in residential boilers and stoves was relatively low in 1998-99 resulting in a lower emission level.

The consumption of wood in residential plants increased until 2007. The improved technology that has been implemented in residential wood combustion have led to lower emission factors and thus decreasing NMVOC emission since 2007. The increased NMVOC emission from 2014 to 2015 reflects an increase of residential wood consumption.

Table 3.2.4 NMVOC emission from stationary combustion plants, 2015[1)].

	NMVOC, Mg
1A1a Public electricity and heat production	786
1A1b Petroleum refining	24
1A1c Oil and gas extraction	40
1A2 Industry	266
1A4a Commercial/Institutional	220
1A4b Residential	12921
1A4c Agriculture/Forestry	1297
Total	15555



1) Only emission from stationary combustion plants in the categories is included.

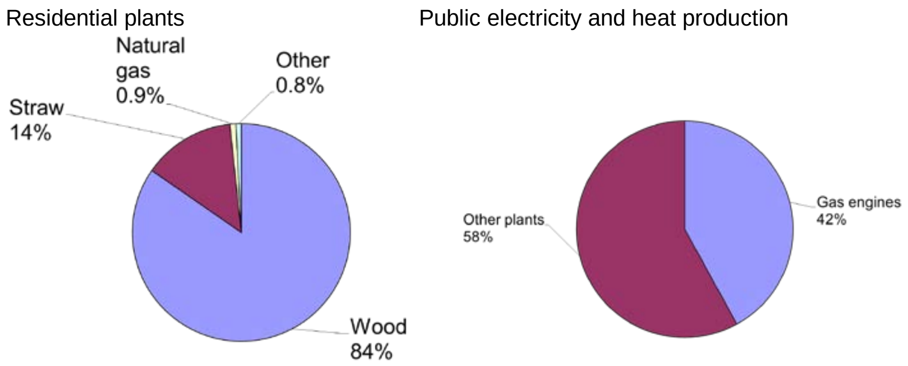


Figure 3.2.11 NMVOC emission from residential plants and from public electricity and heat production, 2015.

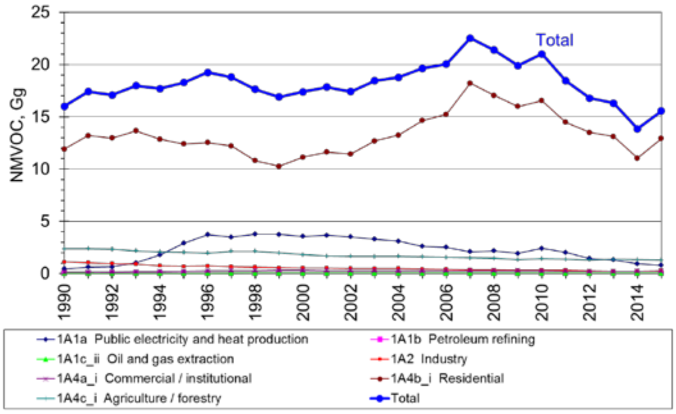


Figure 3.2.12 NMVOC emission time series for stationary combustion.

CO

Stationary combustion accounts for 36 % of the national CO emission. Table 3.2.5 presents the CO emission inventory for stationary combustion subcategories.

Residential plants are the largest emission source, accounting for 79 % of the emission. Wood combustion accounts for 86 % of the emission from residential plants, see Figure 3.2.13. This is in spite of the fact that the fuel consumption share is only 51 %. Combustion of straw is also a considerable emission source whereas the emission from other fuels used in residential plants is almost negligible.

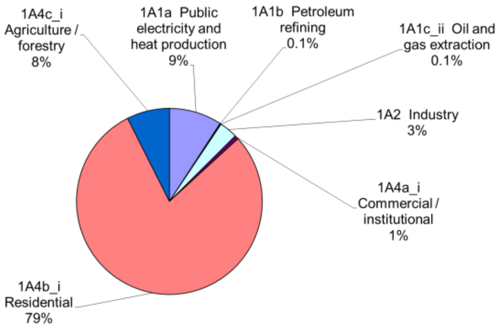
The time series for CO emission from stationary combustion is shown in Figure 3.2.14. The emission has decreased by 20 % from 1990. The time series for CO from stationary combustion plants follow the time series for CO emission from residential plants.

The increase of wood consumption in residential plants in 1999-2007 is reflected in the time series for CO emission. The consumption of wood in residential plants in 2015 was 4.2 times the 1990 level. The decreased emission in 2007-2015 is a result of implementation of improved residential wood combustion technologies and the fact that the rapid increase of wood consumption until 2007 have stopped. The increased CO emission in 2015 is a result of increased wood consumption in residential plants in 2015.

Both consumption and CO emission factor for have decreased for residential straw combustion plants since 1990.

Table 3.2.5 CO emission from stationary combustion plants, 2015[1].

	CO, Mg
1A1a Public electricity and heat production	10780
1A1b Petroleum refining	119
1A1c Oil and gas extraction	120
1A2 Industry	3705
1A4a Commercial/Institutional	796
1A4b Residential	93048
1A4c Agriculture/Forestry	8728
Total	117296



[1] Only emission from stationary combustion plants in the source categories is included.

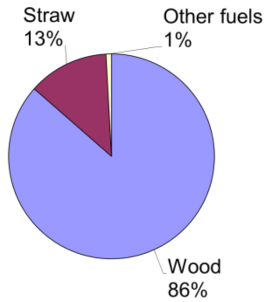


Figure 3.2.13 CO emission sources, residential plants, 2015.

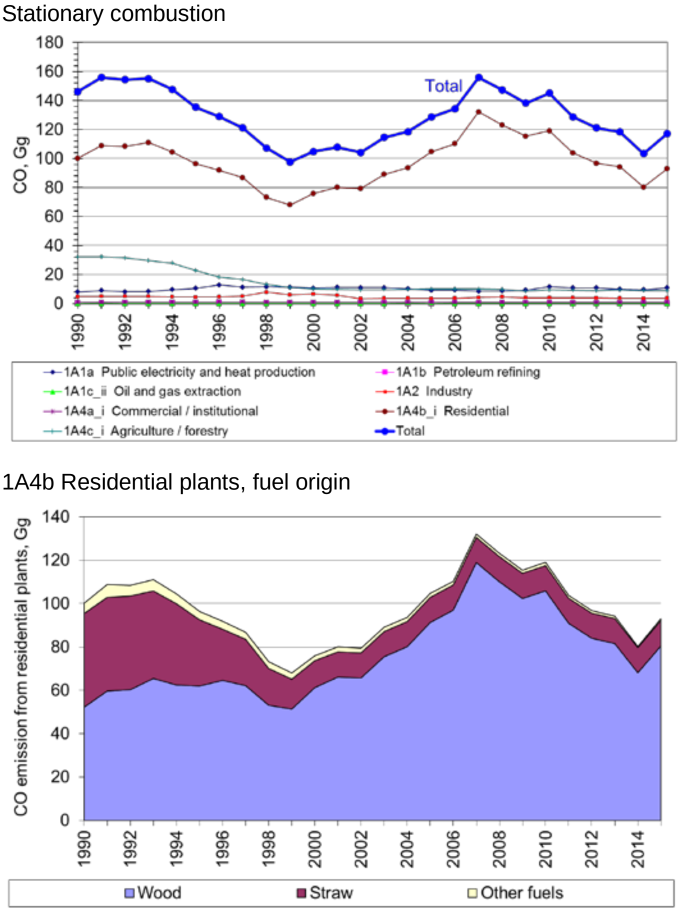


Figure 3.2.14 CO emission time series for stationary combustion.

NH_3

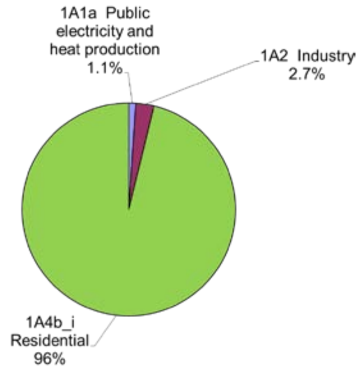
Stationary combustion plants accounted for only 2.2 % of the national NH_3 emission in 2015.

Table 3.2.6 shows the NH_3 emission inventory for the stationary combustion subcategories. Residential plants account for 96 % of the emission. Wood combustion accounts for 99 % of the emission from residential plants.

The time series for the NH_3 emission is presented in Figure 3.2.15. The NH_3 emission has increased to 2.3 times the 1990-level.

Table 3.2.6 NH_3 emission from stationary combustion plants, 2015[1].

		NH_3, Mg
1A1a	Public electricity and heat production	15
1A1b	Petroleum refining	-
1A1c	Oil and gas extraction	-
1A2	Industry	40
1A4a	Commercial/Institutional	-
1A4b	Residential	1407
1A4c	Agriculture/Forestry	-
Total		1463



1) Only the emission from stationary combustion plants in the source categories is included.

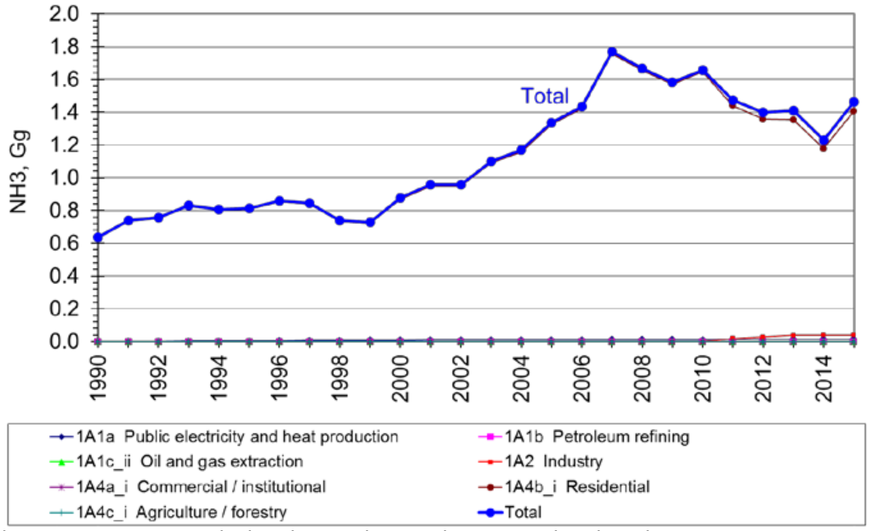


Figure 3.2.15 NH_3 emission time series, stationary combustion plants.

Particulate matter (PM)

TSP from stationary combustion accounts for 18 % of the national emission. The emission shares for PM_{10} and $PM_{2.5}$ are 50 % and 73 %, respectively.

Table 3.2.7 and Figure 3.2.16 show the PM emission inventory for the stationary combustion subcategories. Residential plants are the largest emission source accounting for 92 % of the $PM_{2.5}$ emission from stationary combustion plants. The primary sources of PM emissions are:

- Residential boilers, stoves and fireplaces combusting wood
- Farmhouse / residential boilers combusting straw
- Power plants primarily combusting coal
- Wood combusted in non-residential plants

The PM emission from wood combusted in residential plants is the predominant source. Thus, 87 % of the $PM_{2.5}$ emission from stationary combustion is emitted from residential wood combustion. This corresponds to 64 % of the national emission. A literature review (Nielsen et al., 2003) and a Nordic project (Sternhufvud et al., 2004) has demonstrated that the emission factor uncertainty for residential combustion of wood in stoves and boilers is notably high.

Figure 3.2.17 shows the fuel consumption and the $PM_{2.5}$ emission of residential plants. Wood combustion accounts for 95 % of the $PM_{2.5}$ emission from residential plants in spite of a wood consumption share of 51 %.

Emission inventories for PM are now reported for the years 1990-2015. The time series for PM emission from stationary combustion is shown in Figure 3.2.18. The emission of TSP, PM_{10} and $PM_{2.5}$ was 20 %, 21% and 24 % higher in 2015 than in 1990. The PM emissions increased until 2007 and decreased after 2007. However, the emission increased in 2015. The increase until 2007 was caused by the increased wood combustion in residential plants. However, the PM emission factors have decreased for this emission source category due to installation of modern stoves and boilers. The stabilisation of wood consumption in residential plants in 2007-2014 has resulted in a decrease of PM emission from stationary combustion in recent years. However, due to increased wood consumption in 2015 the emission was higher in 2015 than in 2014.

The time series for PM emission from stationary combustion plants follows the time series for PM emission from residential plants.

Table 3.2.7 PM emission from stationary combustion plants, 2015[1)].

		TSP, Mg	PM_{10}, Mg	$PM_{2.5}$, Mg
1A1a	Public electricity and heat production	595	439	340
1A1b	Petroleum refining	112	106	103
1A1c	Oil and gas extraction	2	2	1
1A2	Industry	258	187	119
1A4a	Commercial/Institutional	181	179	169
1A4b	Residential	14401	13676	13329
1A4c	Agriculture/Forestry	502	474	447
Total		16052	15062	14509

1) Only emission from stationary combustion plants in the source categories is included.

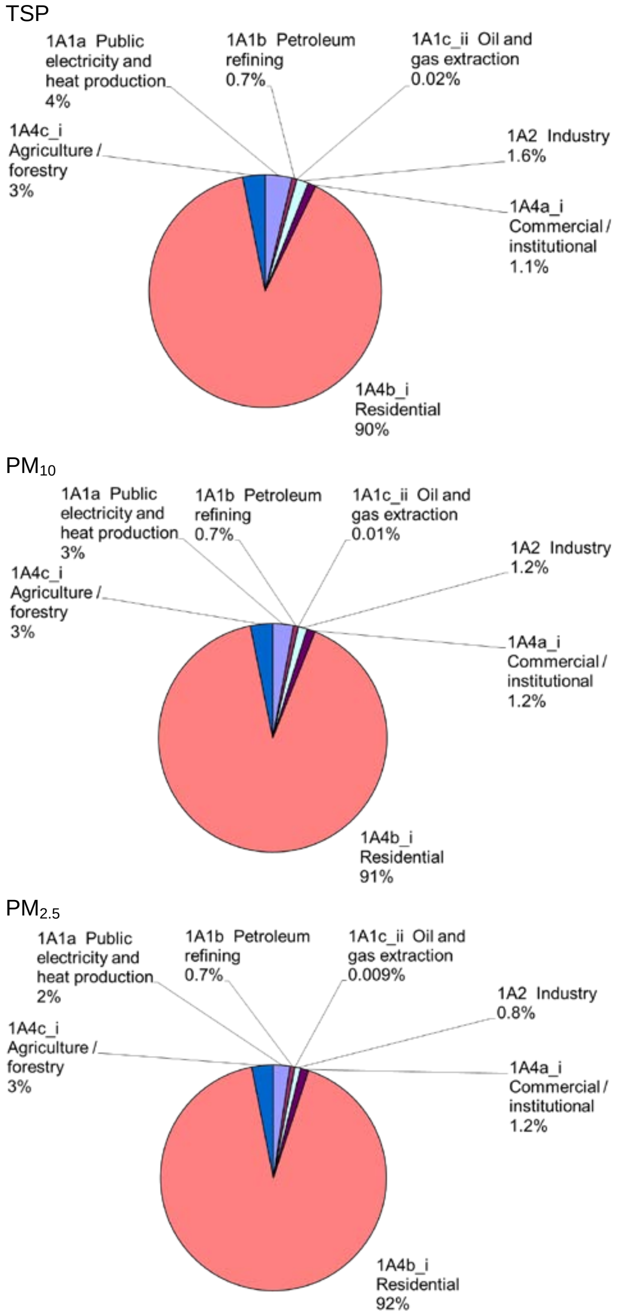


Figure 3.2.16 PM emission sources, stationary combustion plants, 2015.

Figure 3.2.17 Fuel consumption and $PM_{2.5}$ emission from residential plants.

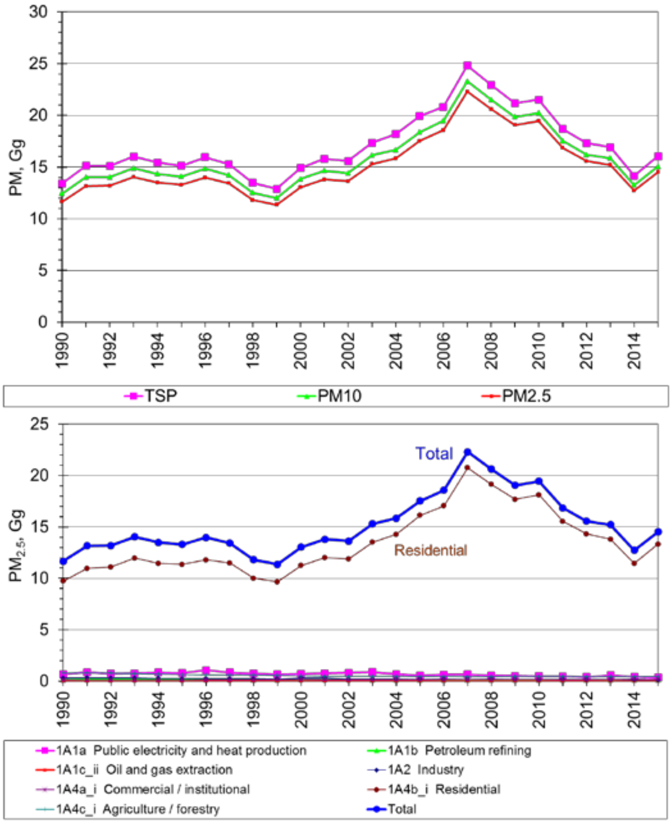


Figure 3.2.18 PM emission time series for stationary combustion.

Black carbon (BC)

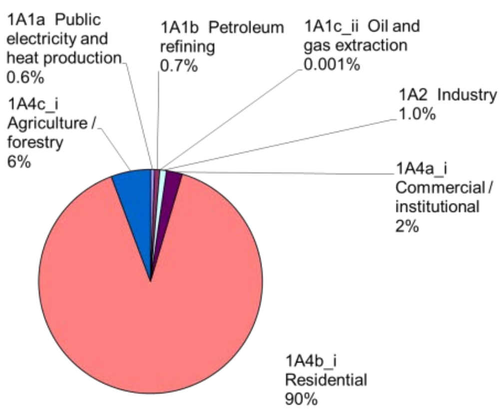
BC from stationary combustion accounts for 55 % of the national emission. Residential combustion is the main emission source accounting for 90 % of the emission from stationary combustion. Residential wood combustion is the main emission source accounting for 97 % of the emission from residential plants.

Table 3.2.8 shows the BC emission inventory for the stationary combustion subcategories.

BC emissions are reported for year 1990 onwards. Figure 3.2.19 shows time series for BC emission. The emission increased until 2007 and decreased in 2007-2014. The emission increased in 2015. The time series follows the time series for $PM_{2.5}$.

Table 3.2.8 BC emission from stationary combustion plants, 2015[1)].

		BC, Mg
1A1a	Public electricity and heat production	13
1A1b	Petroleum refining	16
1A1c	Oil and gas extraction	0
1A2	Industry	21
1A4a	Commercial/Institutional	50
1A4b	Residential	1955
1A4c	Agriculture/Forestry	124
Total		2179



1) Only emission from stationary combustion plants in the source categories is included.

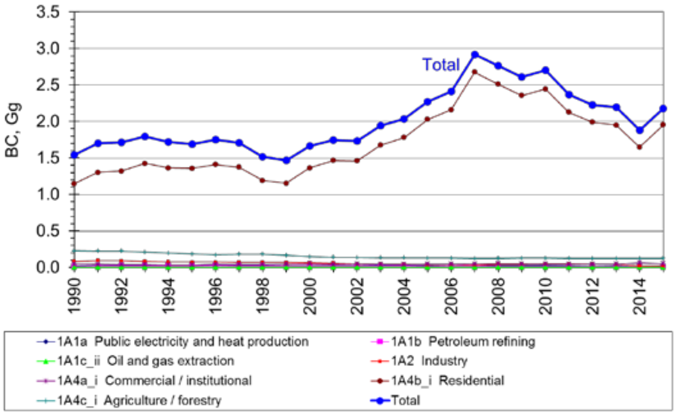


Figure 3.2.19 BC emission time series for stationary combustion.

Heavy metals

Stationary combustion plants are among the most important emission sources for heavy metals. The emission share for stationary combustion compared to national total is shown for each metal in Table 3.2.9.

Table 3.2.9 and Figure 3.2.20 present the heavy metal emission inventory for the stationary combustion subcategories. The source categories *Public electricity and heat production, Residential* and *Industry* are the main emission sources. The emission share for waste incineration plants has decreased considerably since the year 2000 due to installation of new improved flue gas cleaning technology that was initiated based on lower emission limit values in Danish legislation (DEPA, 2011).

Table 3.2.9 Heavy metal emission from stationary combustion plants, 2015[1)].

	As, kg	Cd, kg	Cr, kg	Cu, kg	Hg, kg	Ni, kg	Pb, kg	Se, kg	Zn, kg
1A1a Public electricity and heat production	88	27	144	135	133	219	330	451	368
1A1b Petroleum refining	32	23	24	47	23	248	69	111	88
1A1c Oil and gas extraction	3	0	0	0	2	0	0	0	0
1A2 Industry	70	23	78	100	60	1041	453	85	958
1A4a Commercial/Institutional	3	1	4	4	2	5	5	1	9
1A4b Residential	13	489	867	250	26	89	1125	20	19476
1A4c Agriculture/Forestry	5	4	15	29	6	18	162	17	385
Total	213	567	1133	564	252	1620	2144	686	21284
Emission share from stationary combustion	69%	86%	71%	1%	85%	44%	18%	52%	35%

1) Only emission from stationary combustion plants in the source categories is included.

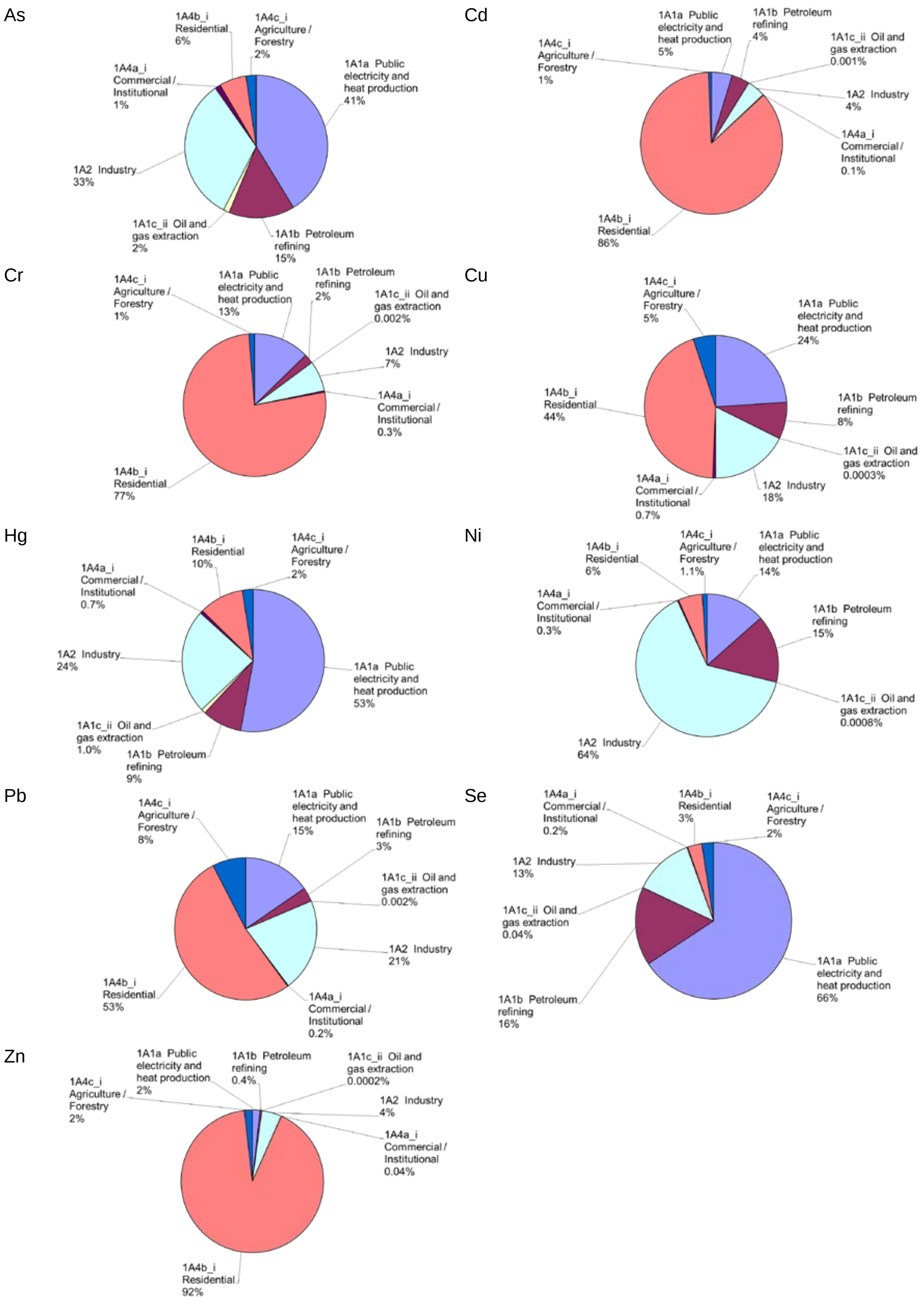


Figure 3.2.20 Heavy metal emission sources, stationary combustion plants, 2015.

The time series for heavy metal emissions are provided in Figure 3.2.21. Emissions of all heavy metals have decreased considerably (23 % - 91 %) since 1990, see Table 3.2.10. Emissions have decreased despite increased incineration of waste. This has been made possible due to installation and improved performance of gas cleaning devices in waste incineration plants and also in large power plants, the latter being a further important emission source.

Table 3.2.10 Decrease in heavy metal emission 1990-2015.

Pollutant	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Decrease since 1990, %	82	41	79	84	91	90	86	83	23

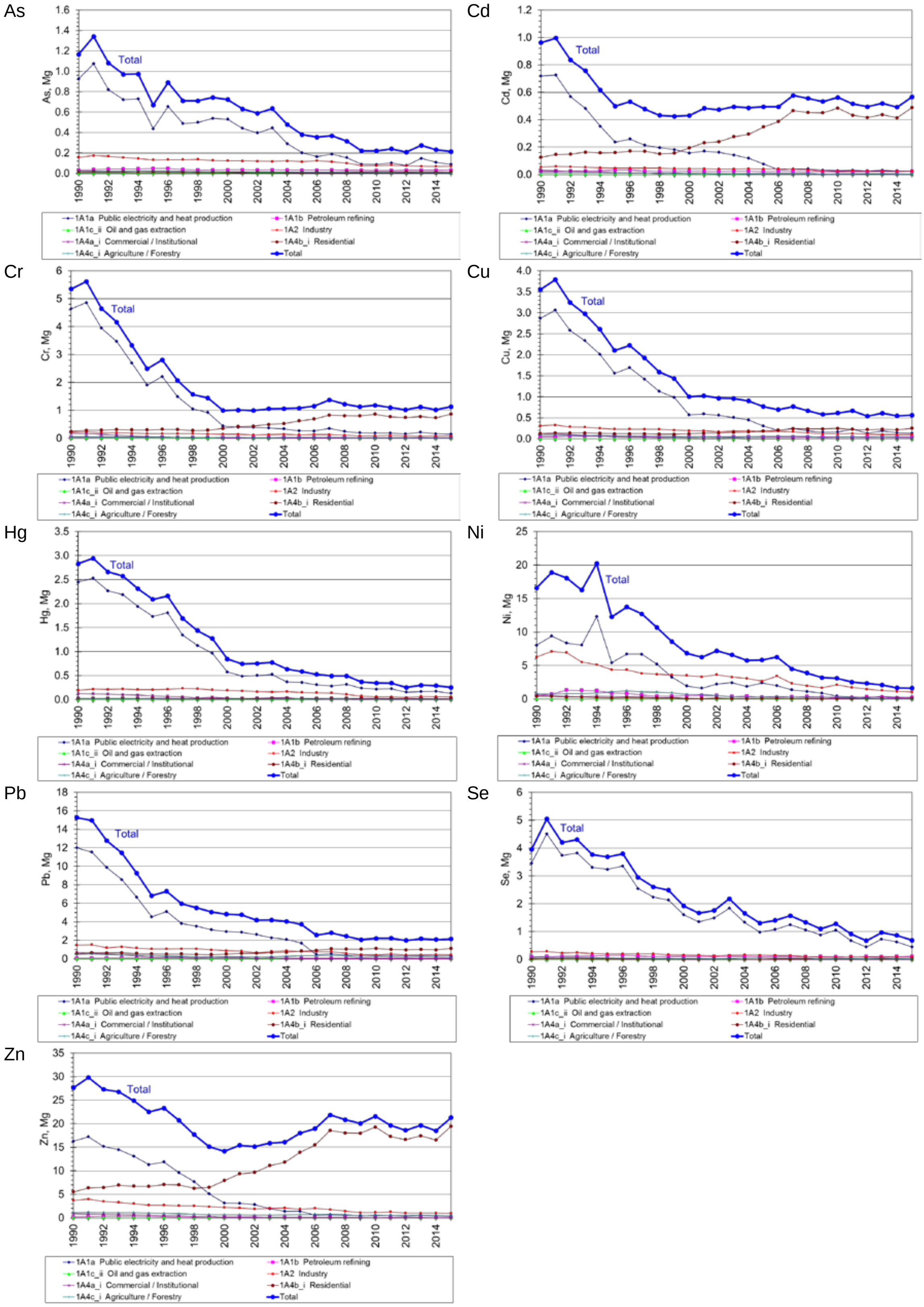


Figure 3.2.21 Heavy metal emission time series, stationary combustion plants.

Polycyclic aromatic hydrocarbons (PAH)

Stationary combustion plants accounted for more than 79 % of the PAH emission in 2015.

Table 3.2.11 and Figure 3.2.22 present the PAH emission inventories for the stationary combustion subcategories. Residential combustion is the largest emission source accounting for more than 78 % of the emission. Combustion of wood is the predominant source, accounting for more than 96 % of the PAH emission from residential plants, see Figure 3.2.23.

The time series for PAH emissions are presented in Figure 3.2.24. The increase of PAHs until 2007 is a result of the increased combustion of wood in residential plants. The time series for wood combustion in residential plants is also provided in Figure 3.2.24. The stabilisation of the consumption of wood in residential plants in 2007-2014 is reflected in the PAH emission time series. The decrease in these years is related to installation of new residential wood combustion units. The increase in 2015 reflects an increased wood consumption in residential plants.

Table 3.2.11 PAH emission from stationary combustion plants, 2015[1)].

	Benzo(a)-Pyrene, kg	Benzo(b)-fluoranthene, kg	Benzo(k)-fluoranthene, kg	Indeno(1,2,3-c,d)pyrene, kg
1A1a Public electricity and heat production	10	39	25	7
1A1b Petroleum refining	0	0	0	0
1A1c Oil and gas extraction	0	0	0	0
1A2 Industry	21	73	10	3
1A4a Commercial/Institutional	195	256	85	138
1A4b Residential	1697	1738	636	937
1A4c Agriculture/Forestry	96	109	30	106
Total	2019	2216	787	1192
Emission share from stationary combustion	88%	87%	79%	84%

1) Only emission from stationary combustion plants in the source categories is included.

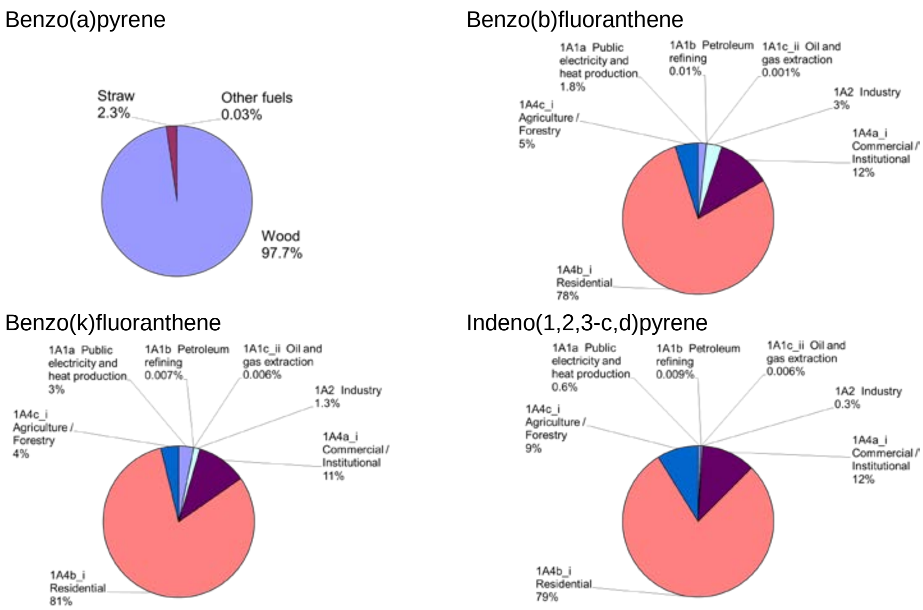


Figure 3.2.22 PAH emission sources, stationary combustion plants, 2015.

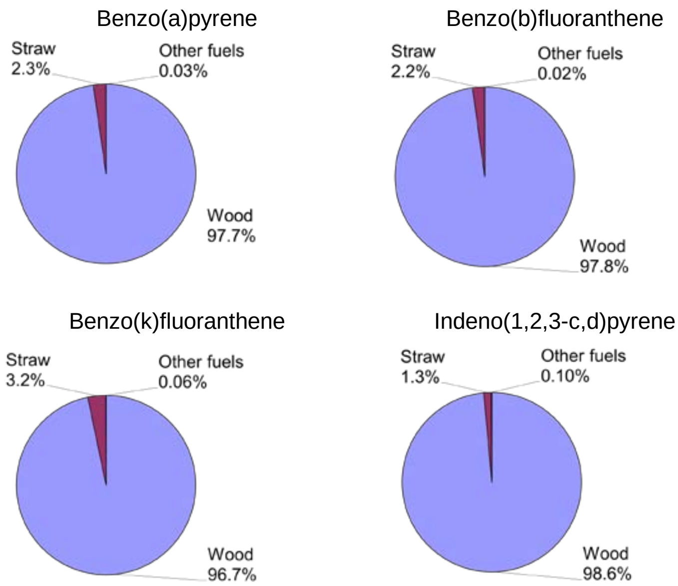


Figure 3.2.23 PAH emission from residential combustion plants (stationary), fuel origin.

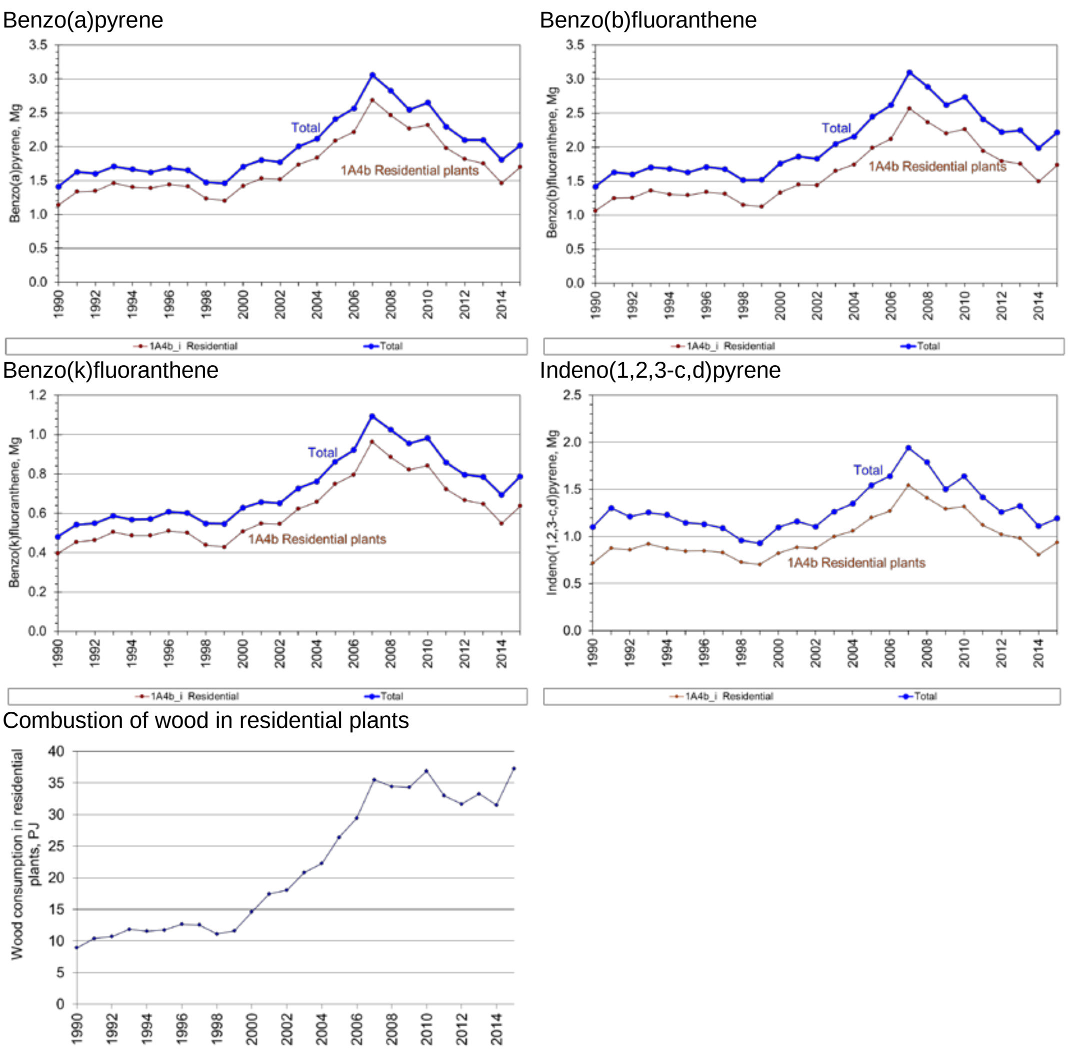


Figure 3.2.24 PAH emission time series, stationary combustion plants. Comparison with wood consumption in residential plants.

Polychlorinated dibenzodioxins and -furans (PCDD/F)

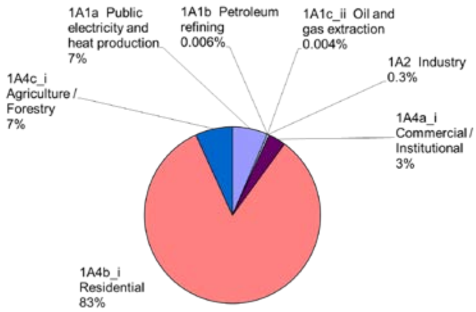
Stationary combustion plants accounted for 65 % of the national emission of polyclorinated dibenzodioxins and –furans (PCDD/F) in 2015.

Table 3.2.12 presents the PCDD/F emission inventories for the stationary combustion subcategories. In 2015, the emission from residential plants accounted for 83 % of the emission. Combustion of wood is the predominant source accounting for 88 % of the emission from residential plants (Figure 3.2.25).

The time series for PCDD/F emission is presented in Figure 3.2.26. The PCDD/F emission has decreased 67 % since 1990 mainly due to installation of dioxin filters in waste incineration plants. The emission from residential plants has increased due to increased wood consumption in this source category. However, the emission factor for residential wood combustion has decreased due to installation of modern stoves and boilers.

Table 3.2.12 PCDD/F emission from stationary combustion plants, 2015[1)].

	PCDD/F, g I-teq
1A1a Public electricity and heat production	1.01
1A1b Petroleum refining	0.00
1A1c Oil and gas extraction	0.00
1A2 Industry	0.05
1A4a Commercial/Institutional	0.50
1A4b Residential	12.94
1A4c Agriculture/Forestry	1.06
Total	15.57



1) Only emission from stationary combustion plants in the source categories is included.

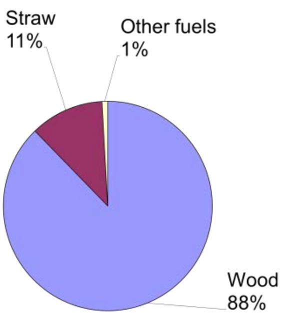


Figure 3.2.25 PCDD/F emission from residential plants, fuel origin.

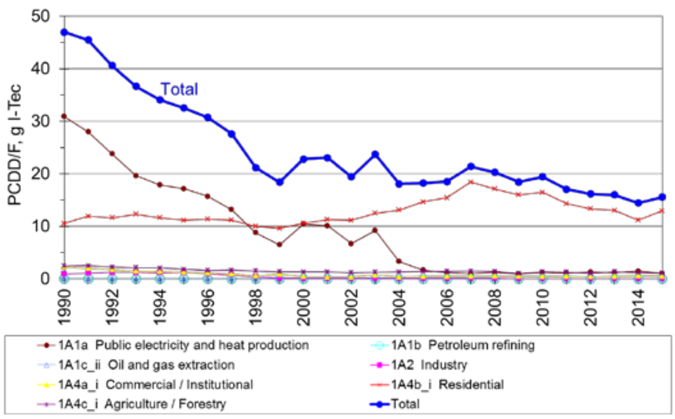


Figure 3.2.26 PCDD/F emission time series, stationary combustion plants.

Hexachlorobenzene (HCB)

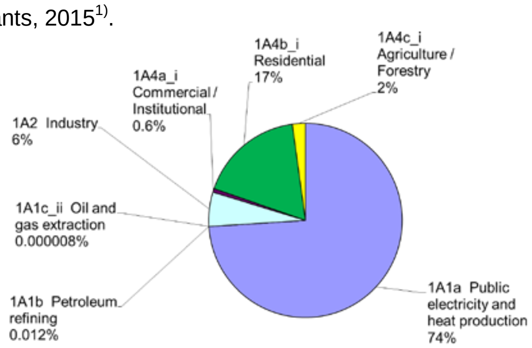
Stationary plants accounted for 50 % of the estimated national emission of hexachlorobenzene (HCB) in 2015.

Table 3.2.13 shows the HCB emission inventory for the stationary combustion subcategories. *Public electricity and heat production* account for 74 % of the emission. Residential plants account for 17 % of the emission.

The time series for HCB emission is presented in Figure 3.2.27. The HCB emission has decreased 80 % since 1990 mainly due to improved flue gas cleaning in waste incineration plants. The emission from residential plants has increased in recent years due to increased wood consumption in this source category.

Table 3.2.13 HCB emission from stationary combustion plants, 2015[1].

	HCB, kg
1A1a Public electricity and heat production	0.855
1A1b Petroleum refining	0.0001
1A1c Oil and gas extraction	0.00000009
1A2 Industry	0.066
1A4a Commercial/Institutional	0.007
1A4b Residential	0.203
1A4c Agriculture/Forestry	0.025
Total	1.156



1) Only the emission from stationary combustion plants in the source categories is included.

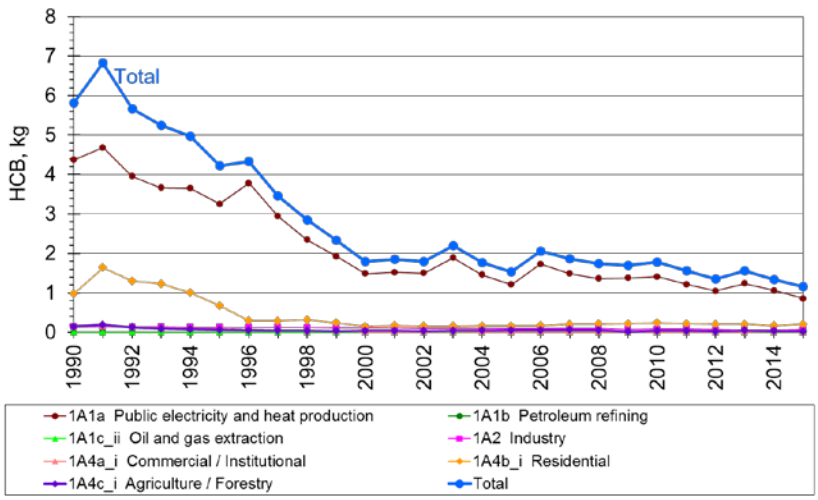


Figure 3.2.27 HCB emission time series, stationary combustion plants.

Polychlorinated biphenyls (PCB)

PCB can be emitted in any chemical process involving chloride and organic carbon or emitted due to incomplete combustion of PCB in fuel (waste incineration). In Denmark, waste with high levels of PCB is only incinerated in plants with permission to incinerate this waste fraction as it requires a high combustion temperature.

Different references for PCB emissions are not directly comparable because some PCB emission data are reported for individual PCB congeners, some as a sum of a specified list of PCB congeners and some PCB emission data are reported as toxic equivalence (teq) based on toxicity equivalence factors

(TEF) for 12 dioxin-like PCB congeners. The emission measurements reported by Thistlethwaite (2001a and 2001b) show that the emission of non-dioxin-like PCBs is high compared to the emission of dioxin-like PCBs.

Furthermore, teq values based on TEF are reported as WHO_{2005}-teq or WHO_{1998}-teq. This difference is however typically less than 50 %[3].

For stationary combustion the emission inventory is a sum of dioxin-like PCB (dl-PCB) emission, no teq values applied.

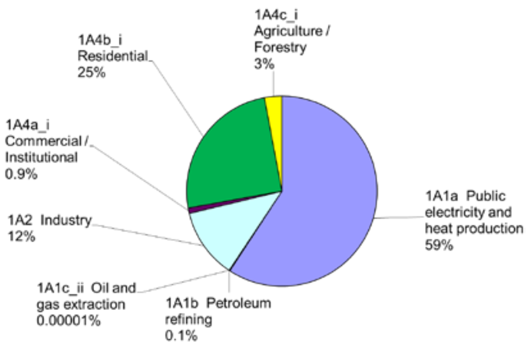
Stationary plants accounted for 0.9 % of the estimated national PCB emission in 2015.

Table 3.2.14 shows the dl-PCB emission inventory for the stationary combustion subcategories. *Public electricity and heat production* accounted for 59 % of the emission in 2015. Residential plants accounted for 25 % of the emission.

The time series for dl-PCB emission is presented in Figure 3.2.28. The dl-PCB emission has decreased 67 % since 1990. The decrease is mainly a result of the flue gas cleaning devices that have been installed in waste incineration plants for dioxin reduction.

Table 3.2.14 PCB emission from stationary combustion plants, 2015[1)].

	PCB, kg
1A1a Public electricity and heat production	0.228
1A1b Petroleum refining	0.001
1A1c Oil and gas extraction	0.000
1A2 Industry	0.046
1A4a Commercial/Institutional	0.004
1A4b Residential	0.096
1A4c Agriculture/Forestry	0.011
Total	0.385



1) Only the emission from stationary combustion plants in the source categories is included.

[3] Data have been compared for a few datasets in which each dioxin-like PCB congener was specified.

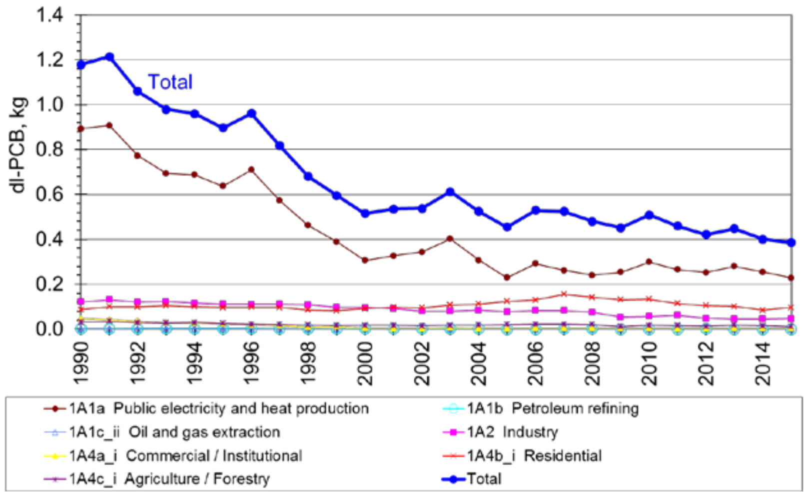


Figure 3.2.28 PCB emission time series, stationary combustion plants.

3.2.4 Trend for subsectors

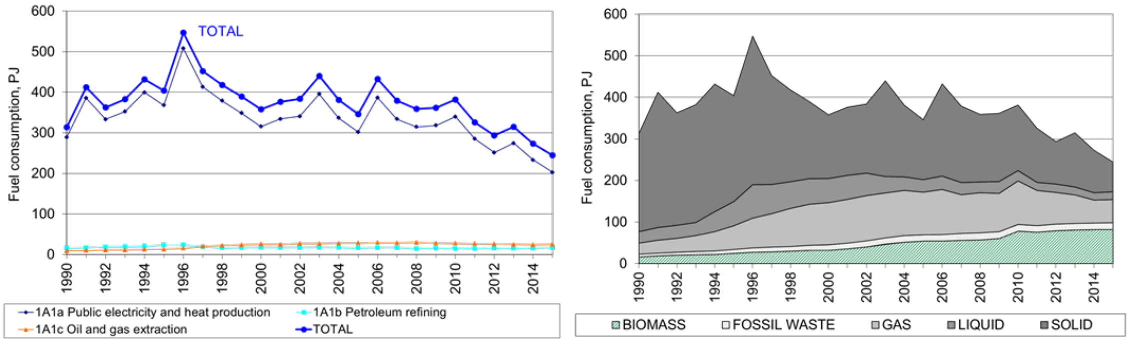
In addition to the data for stationary combustion, this chapter presents and discusses data for each of the subcategories in which stationary combustion is included. Time series are presented for fuel consumption and emissions.

1A1 Energy industries

The emission source category *1A1 Energy Industries* consists of the subcategories:

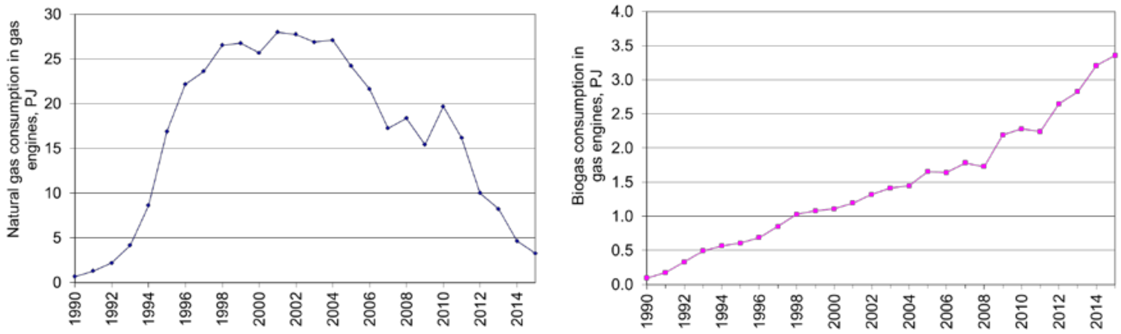
- 1A1a Public electricity and heat production
- 1A1b Petroleum refining
- 1A1c Oil and gas extraction

Figure 3.2.29 – 3.2.33 present time series for the *Energy Industries*. *Public electricity and heat production* is the largest subcategory accounting for the main part of all emissions. Time series are discussed below for each subcategory.



Natural gas fuelled engines

Biogas fuelled engines



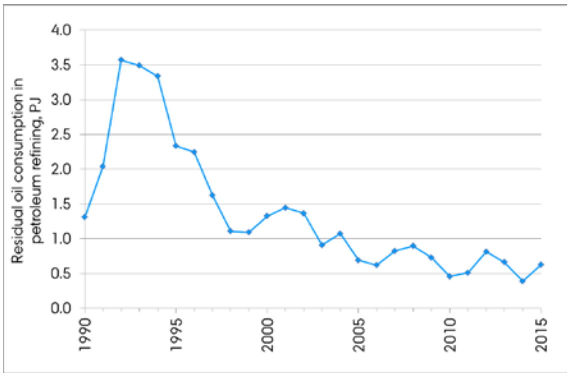


Figure 3.2.29 Time series for fuel consumption, 1A1 Energy industries.

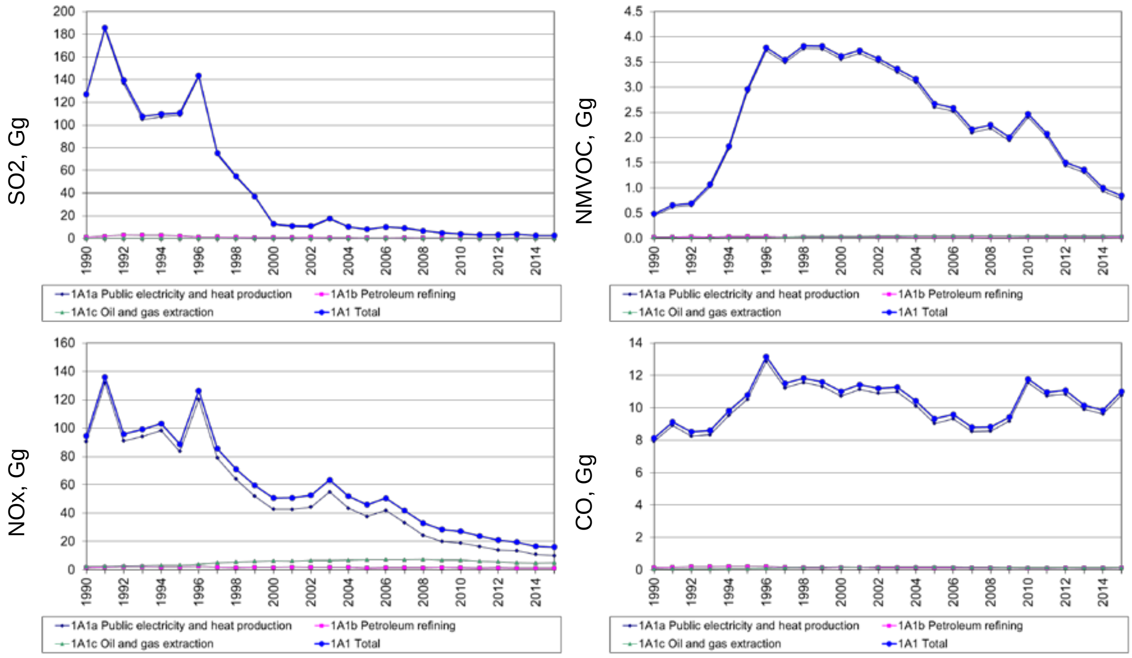


Figure 3.2.30 Time series for SO_2, NO_x, NMVOC and CO emission, 1A1 Energy industries.

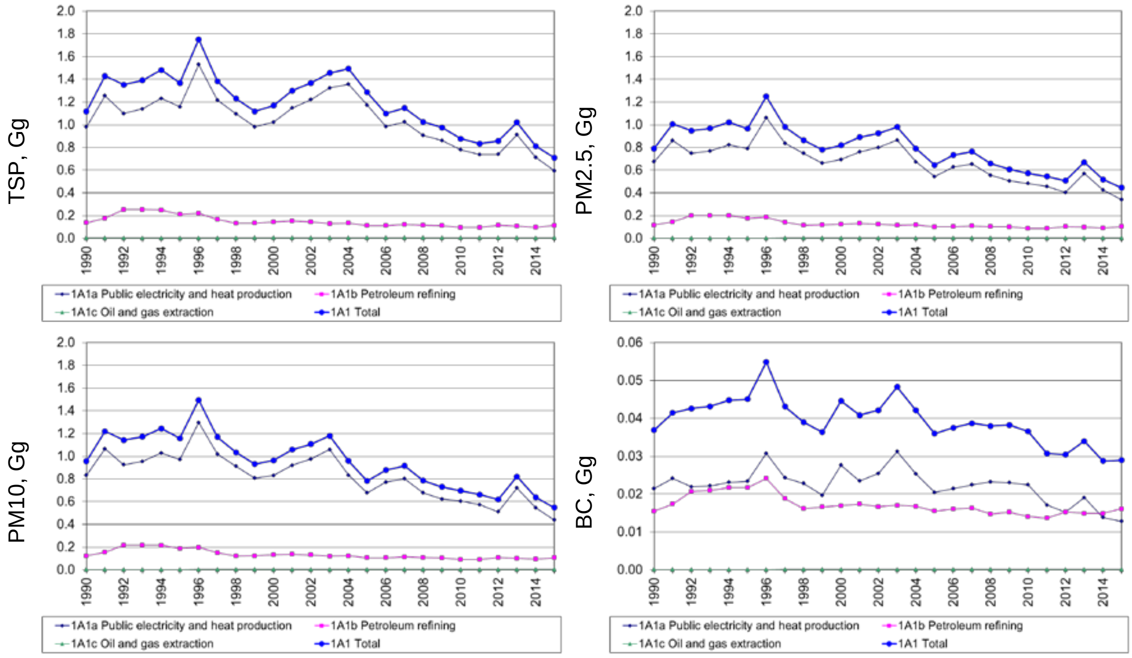


Figure 3.2.31 Time series for PM and BC emission, 1A1 Energy industries.

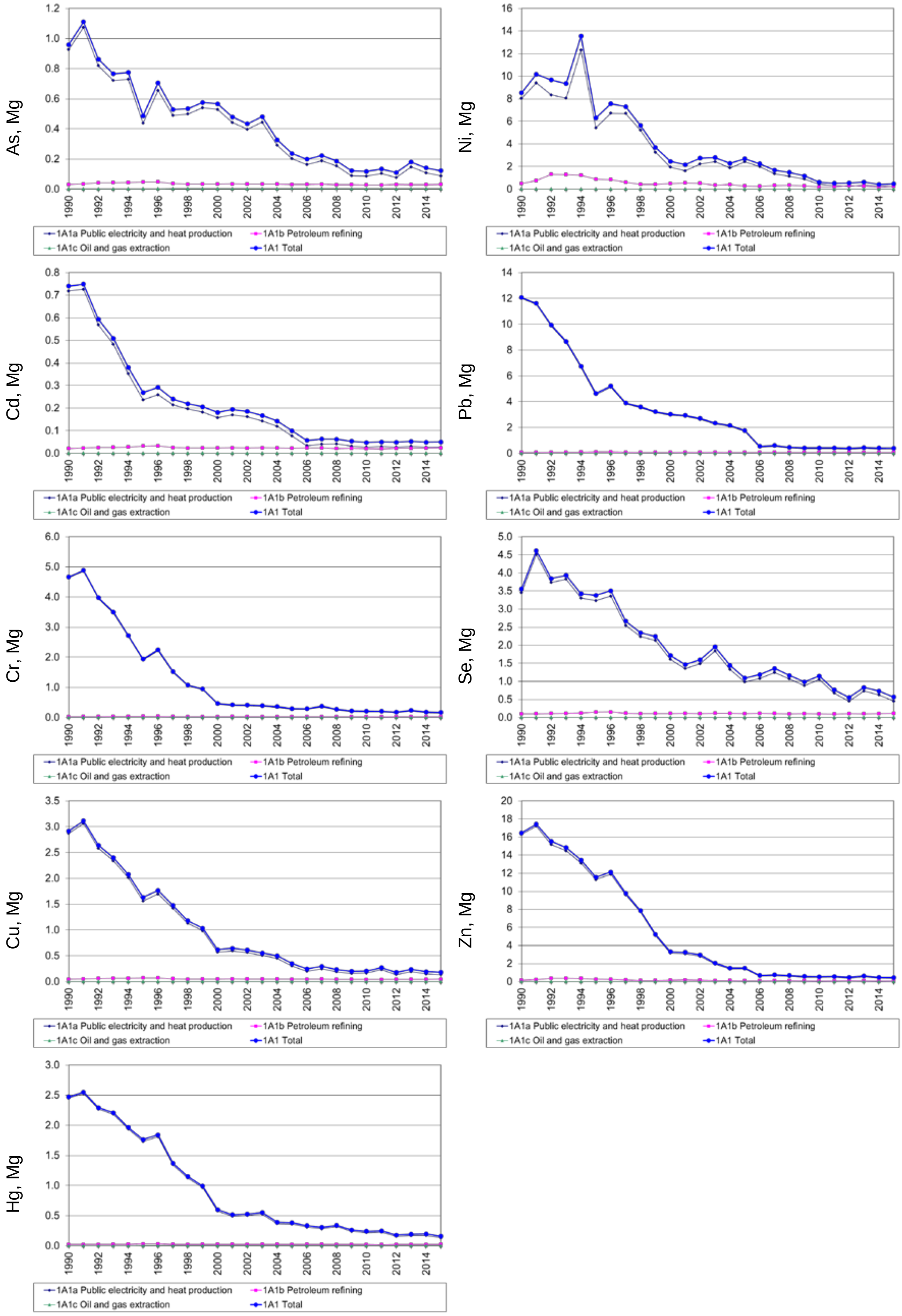


Figure 3.2.32 Time series for HM emission, 1A1 Energy industries.

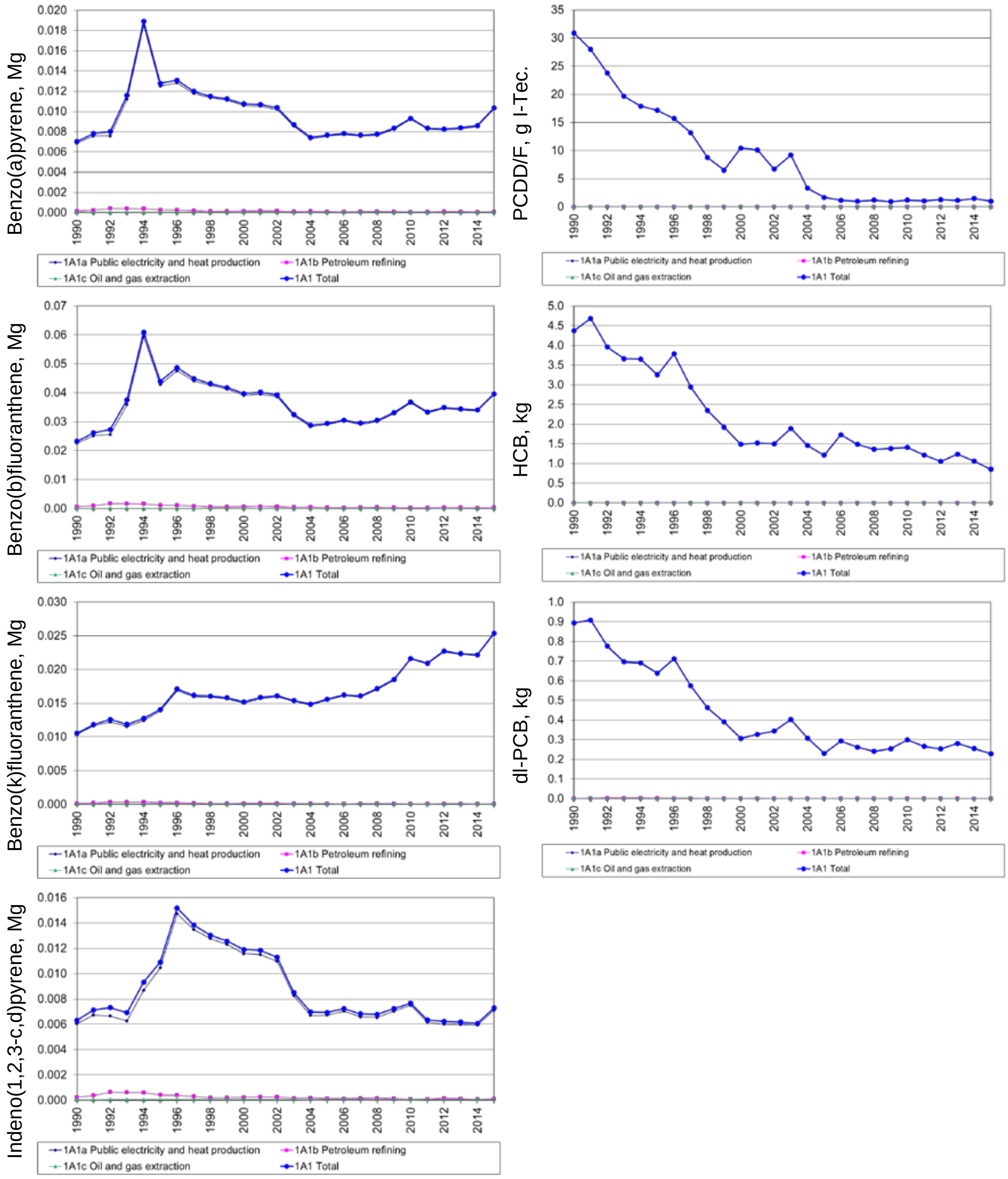


Figure 3.2.33 Time series for PAH, PCDD/F, HCB and dl-PCB emission, 1A1 Energy industries.

1A1a Public electricity and heat production

Public electricity and heat production is the largest source category regarding fuel consumption for stationary combustion. Figure 3.2.34 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO.

The fuel consumption in public electricity and heat production was 30 % lower in 2015 than in 1990. As discussed in Chapter 3.2.2 the fuel consumption fluctuates mainly as a consequence of electricity trade. Coal is the fuel that is affected the most by the fluctuating electricity trade. Coal is the main fuel in the source category even in years with electricity import. The coal consumption in 2015 was 70 % lower than in 1990. Natural gas is also an important fuel and the consumption of natural gas increased in 1990-2000 but has decreased since 2010. A considerable part of the natural gas is combusted in gas engines (Figure 3.2.29). The consumption of waste, wood and straw has increased.

The SO_2 emission has decreased 98 % from 1990 to 2015. This decrease is a result of both lower sulphur content in fuels and installation and improved performance of desulphurisation plants. The emission was 1 % lower in 2015 than in 2014.

The NO_x emission has decreased 89 % since 1990 due to installation of low NO_x burners, selective catalytic reduction (SCR) units and selective non-catalytic reduction (SNCR) units. The fluctuations in time series follow the fluctuations in fuel consumption and electricity trade. The NO_x emission was 8 % lower in 2015 than in 2014.

The emission of NMVOC was 74 % higher in 2015 than in 1990. The emission increased until 1996 and decreased after 2002. This is a result of the large number of gas engines that has been installed in Danish CHP plants. The decreasing emission in 2004-2015 is results of the time series for natural gas consumption in gas engines (Figure 3.2.29). In addition, the emission of NMVOC from engines decreased in 1995-2007 as a result of introduction of an emission limits for unburned hydrocarbon[4] (DEPA, 2005).

The CO emission was 36 % higher in 2015 than in 1990. The fluctuations follow the fluctuations of the fuel consumption. In addition, the emission from gas engines is considerable.

[4] Including methane.

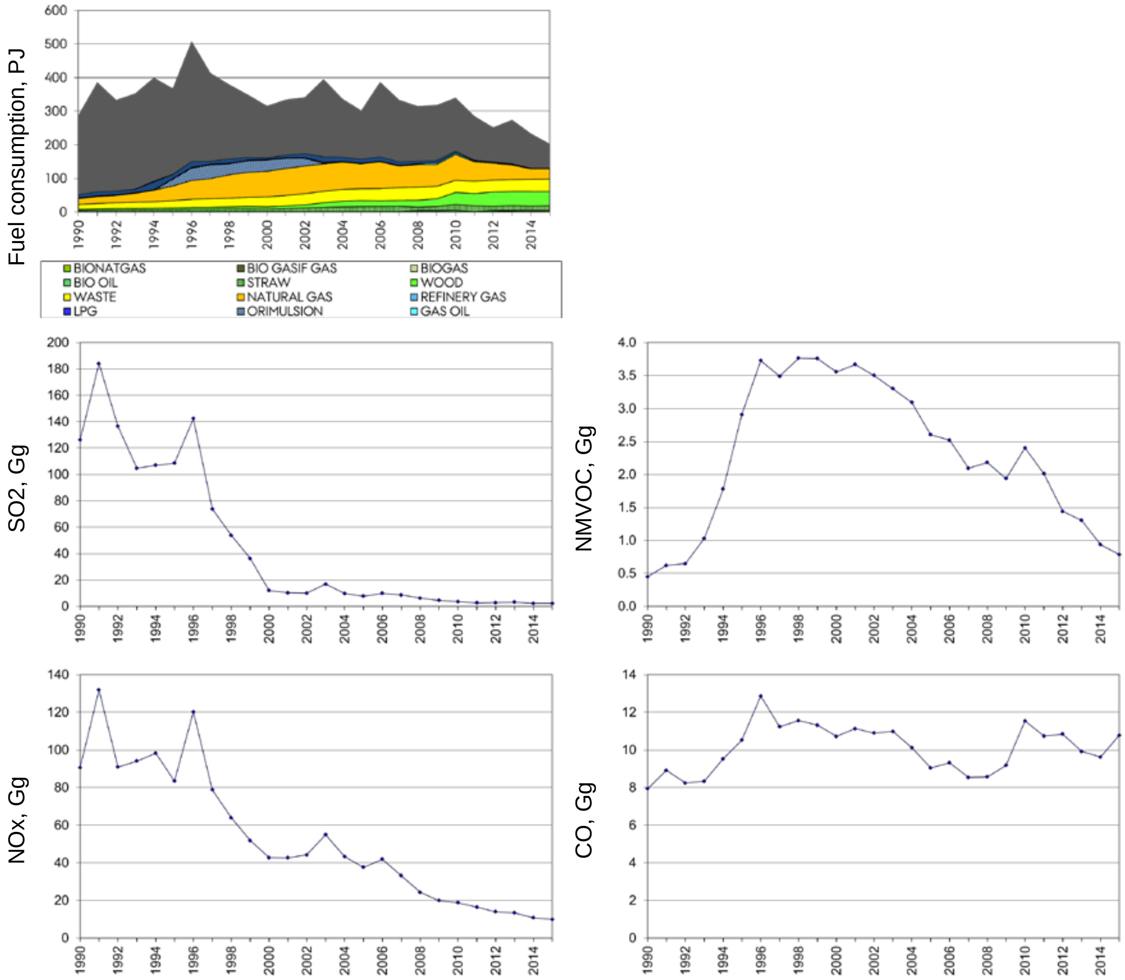


Figure 3.2.34 Time series for 1A1a Public electricity and heat production.

1A1b Petroleum refining

Petroleum refining is a small source category regarding both fuel consumption and emissions for stationary combustion. Presently two refineries are operating in Denmark. Figure 3.2.35 shows the time series for fuel consumption and emissions.

The significant decrease in both fuel consumption and emissions in 1996 is a result of the closure of a third refinery.

The fuel consumption has increased 10 % since 1990.

The emission of SO_2 has shown a pronounced decrease (79 %) since 1990, mainly because decreased consumption of residual oil (52 %) also shown in Figure 3.2.35. The increase in SO_2 emission in 1990-1992 also follows the residual oil consumption. The NO_x emission in 2015 was 21 % lower in 2015 than in 1990. Since 2005, data for both SO_2 and NO_x are plant specific data stated by the refineries.

The NMVOC emission time series follows the time series for fuel consumption.

A description of the Danish emission inventory for fugitive emissions from fuels is given in Plejdrup et al. (2015) and in Chapter 3.4.

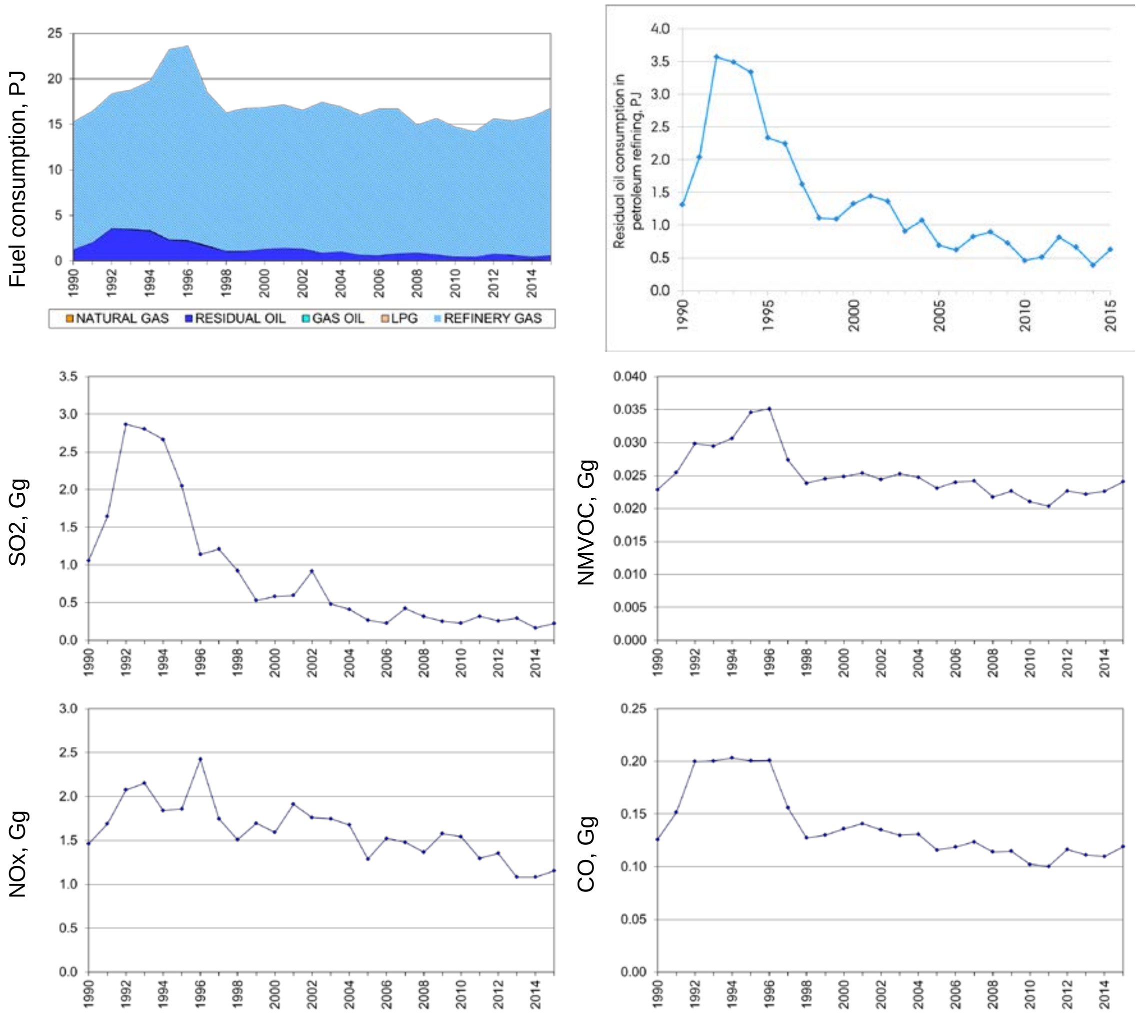


Figure 3.2.35 Time series for 1A1b Petroleum refining.

1A1c Oil and gas extraction

The source category *Oil and gas extraction* comprises natural gas consumption in the off-shore industry and in addition a small consumption in the Danish gas treatment plant[5]. Gas turbines are the main plant type. Figure 3.2.36 shows the time series for fuel consumption and emissions.

The fuel consumption in 2015 was 2.6 times the consumption in 1990. The fuel consumption has decreased since 2008, but increased between 2014 and 2015.

The emissions follow the increase of fuel consumption.

The decrease of CO emission in 2005 – 2007 is a result of a lower emission factor. This decrease of emission factor is valid for gas turbines in cogeneration plants, but might not be valid for off shore gas turbines. However, the same emission factors have been assumed for CO emission due to the lack of data from off shore gas turbines.

[5] Nybro.

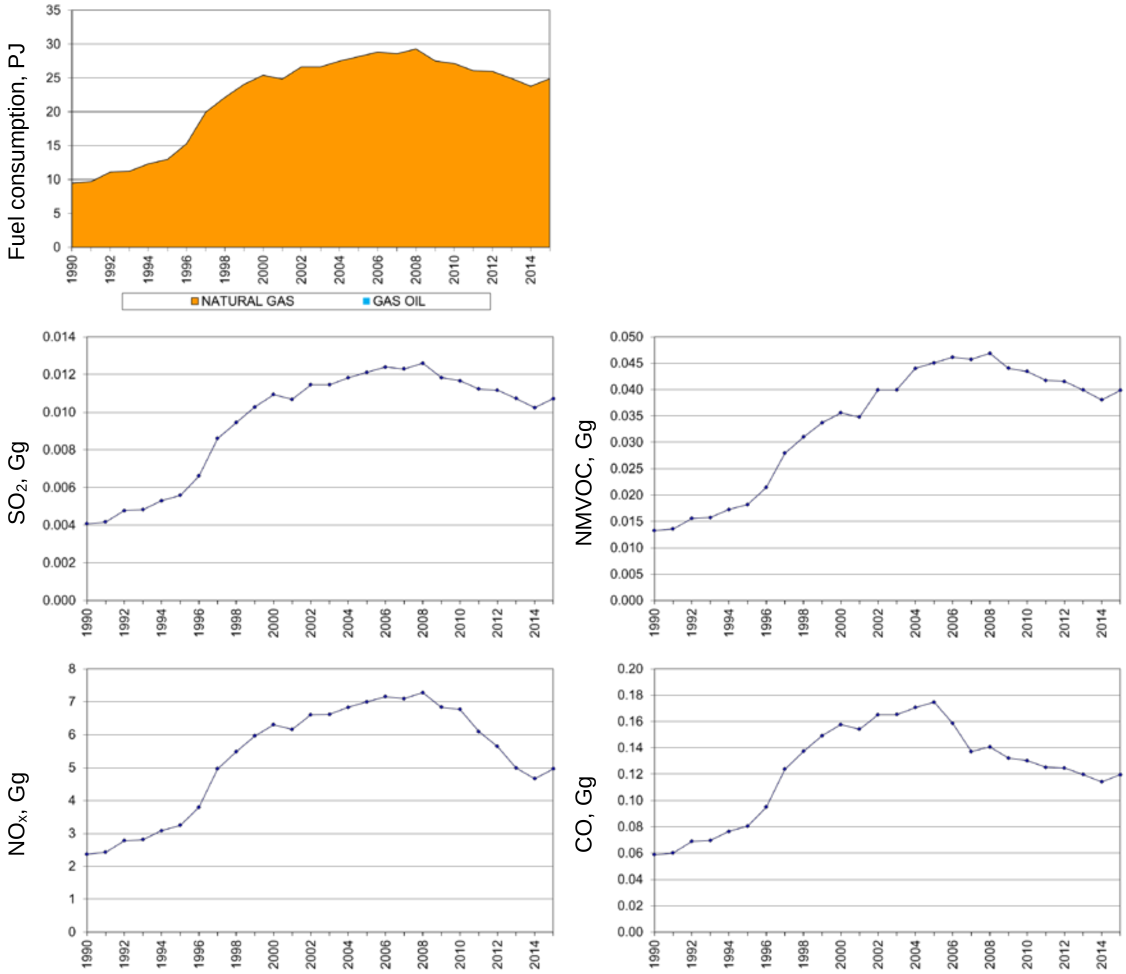


Figure 3.2.36 Time series for 1A1c Oil and gas extraction.

1A2 Industry

Manufacturing industries and construction (Industry) consists of both stationary and mobile sources. In this chapter, only stationary sources are included.

The emission source category *1A2 Industry* consists of the subcategories:

- 1A2a Iron and steel
- 1A2b Non-ferrous metals
- 1A2c Chemicals
- 1A2d Pulp, Paper and Print
- 1A2e Food processing, beverages and tobacco
- 1A2f Non-metallic minerals
- 1A2 g viii Other manufacturing industry

Figure 3.2.37 - 3.2.41 show the time series for fuel consumption and emissions. The subsectors *Non-metallic minerals*, *Other manufacturing industry* and *Food processing, beverages and tobacco* are the main subsectors for fuel consumption and emissions.

The total fuel consumption in industrial combustion was 24 % lower in 2015 than in 1990. The consumption of natural gas has increased since 1990 whereas the consumption of coal has decreased. The consumption of residual oil has decreased, but the consumption of petroleum coke increased.

The SO_2 emission has decreased 81 % since 1990. This is mainly a result of lower consumption of residual oil in the industrial sector (Figure 3.2.37). Further, the sulphur content of residual oil and several other fuels has decreased since 1990 due to legislation and tax laws.

The NO_x emission has decreased 60 % since 1990 due to the reduced emission from industrial boilers in general. Cement production is the main emission source accounting for more than 50 % of the industrial emission in 1990-2010[6]. After 2010 the NO_x emission from cement production was reduced considerably and in 2015, the NO_x emission from cement industry was 38 % of the total emission from manufacturing industries and construction (stationary combustion). The NO_x emission from cement production was reduced 72 % since 1990. The reduced emission is a result of installation of SCR on all production units at the cement production plant in 2004-2007[7] and improved performance of the SCR units in recent years. A NO_x tax was introduced in 2010 (DMT, 2008).

The NMVOC emission has decreased 76 % since 1990. The decrease is mainly a result of decreased emission factor for combustion of wood in industrial boilers. The emission from gas engines has however increased considerably after 1995 due to the increased fuel consumption that is a result of the installation of a large number of industrial CHP plants (Figure 3.2.37). The NMVOC emission factor for gas engines is much higher than for boilers regardless of the fuel.

The CO emission in 2015 was 21 % lower than in 1990. The main sources of emission are combustion of wood and cement production. The CO emission from mineral wool production is included in the industry sector (2A6).

The large decrease of Hg emission since 2009 is related to a large decrease of particulate matter emission and to a large decrease of coal consumption since 2009.

[6] More than 80 % of sector 1A2f i.

[7] To meet emission limit.

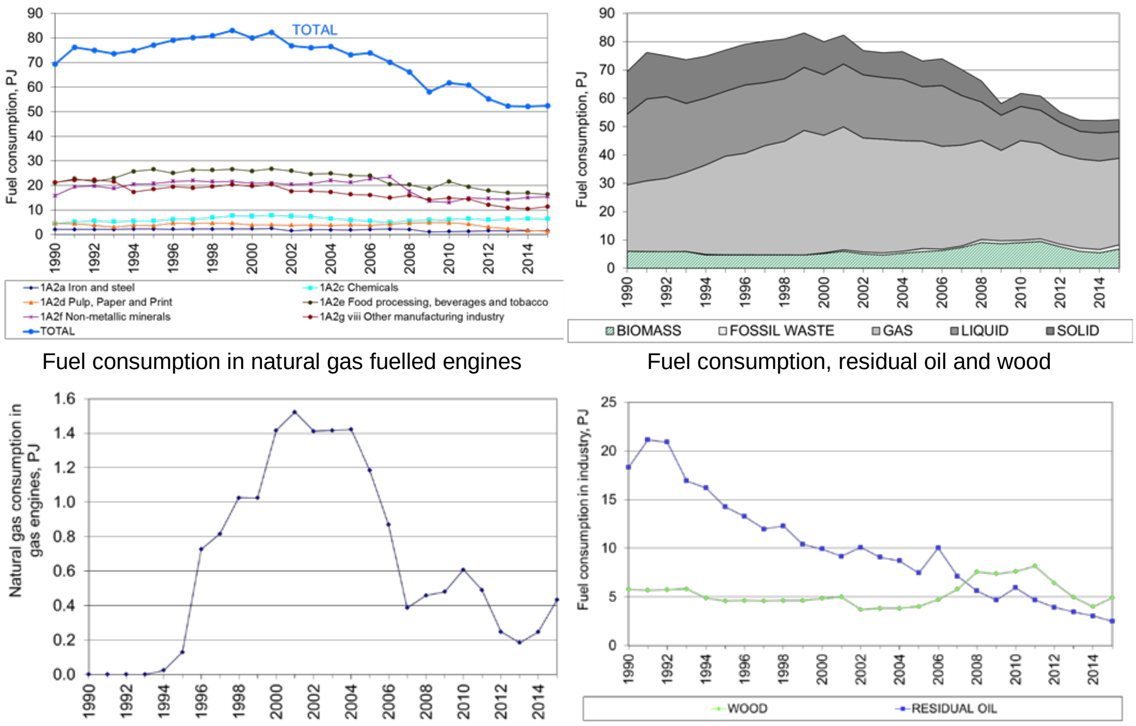


Figure 3.2.37 Time series for fuel consumption, 1A2 Industry.

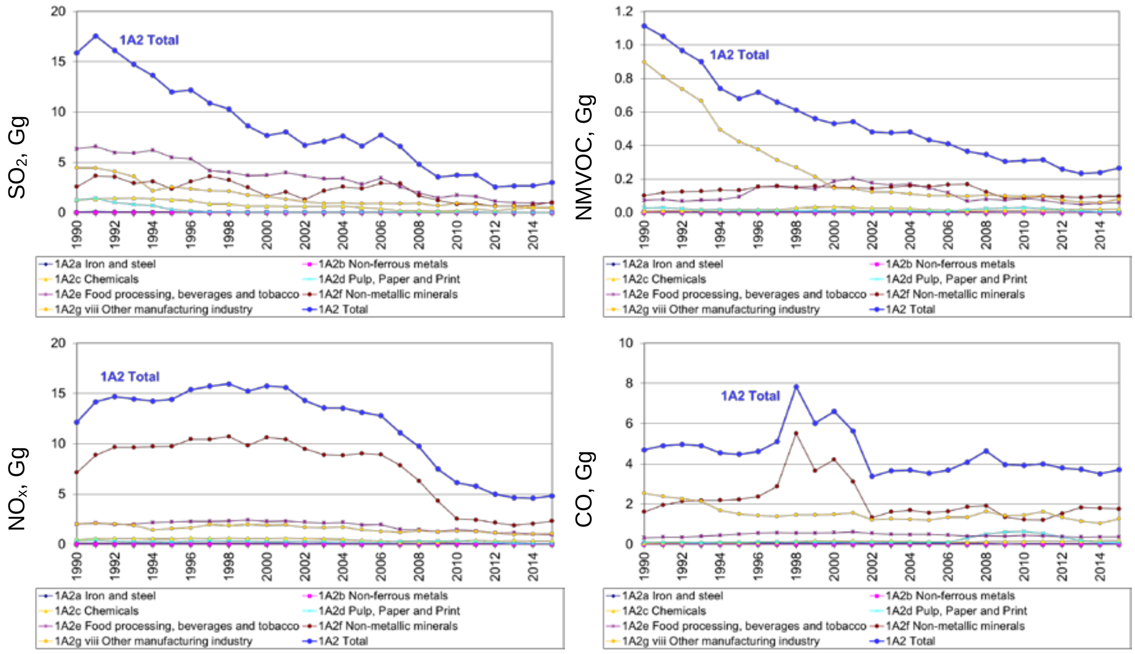


Figure 3.2.38 Time series for SO_2, NO_x, NMVOC and CO emission, 1A2 Industry.

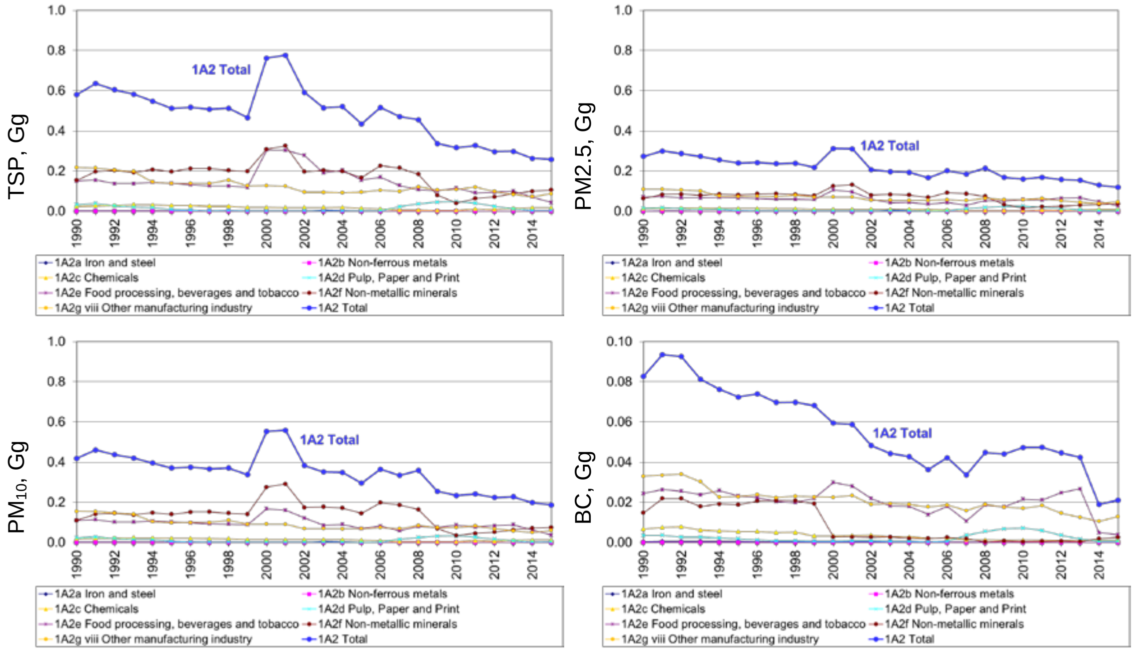


Figure 3.2.39 Time series for PM and BC emission, 1A2 Industry.

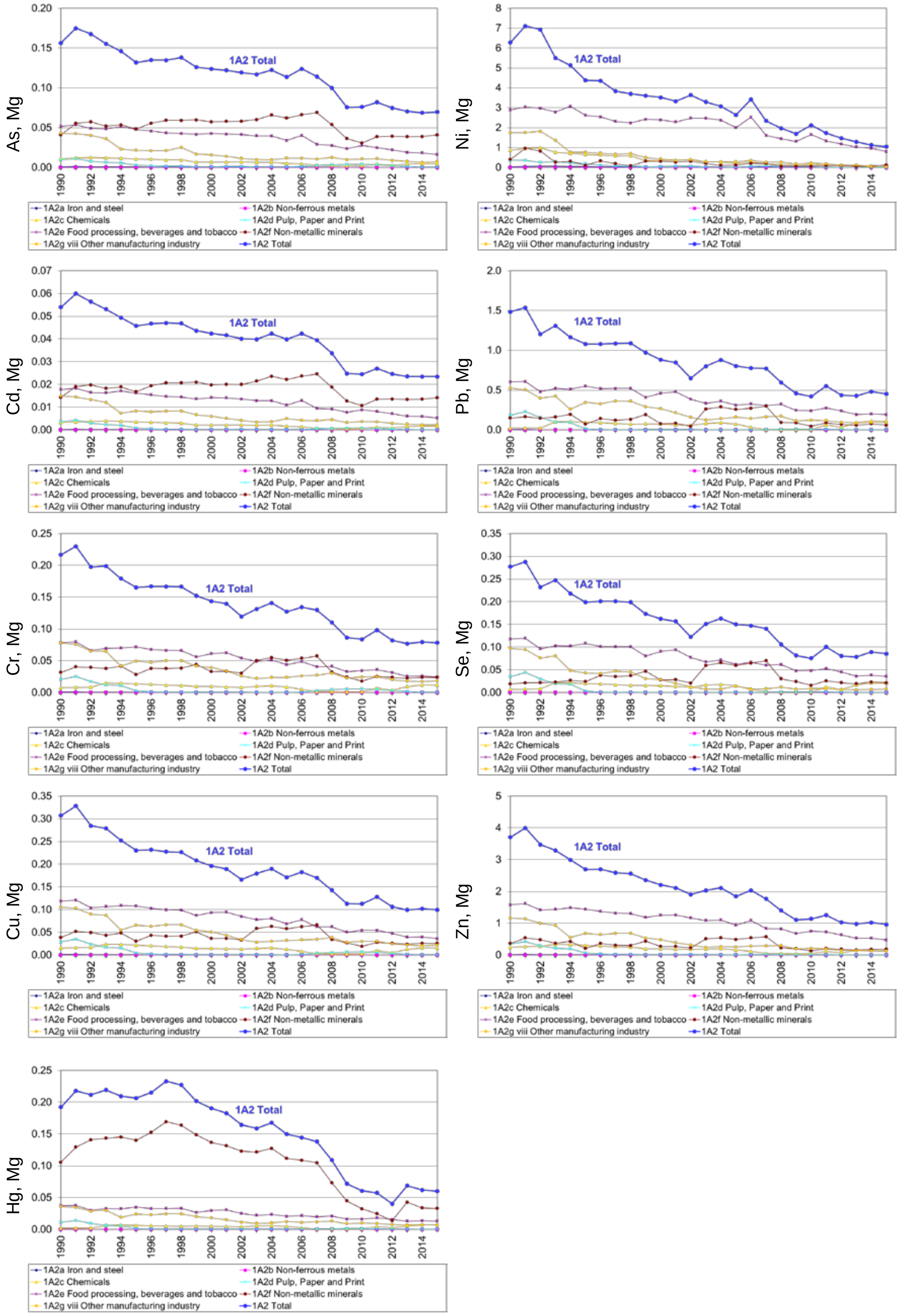


Figure 3.2.40 Time series for HM emission, 1A2 Industry.

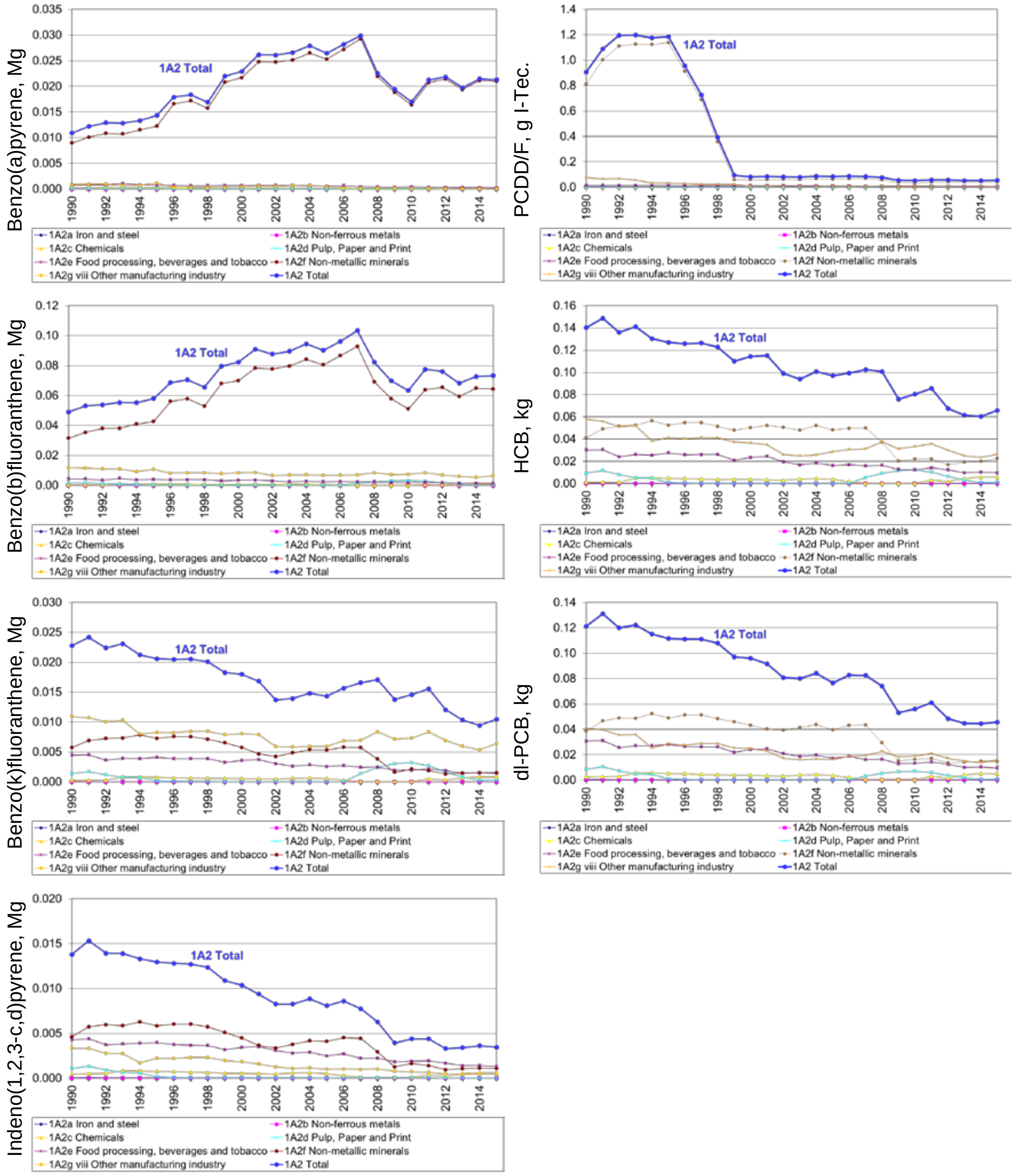


Figure 3.2.41 Time series for PAH, PCDD/F, HCB and dioxin-like PCB emission, 1A2 Industry.

1A2a Iron and steel

Iron and steel is a very small emission source category. Figure 3.2.42 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO.

Natural gas is the main fuel in the subsector.

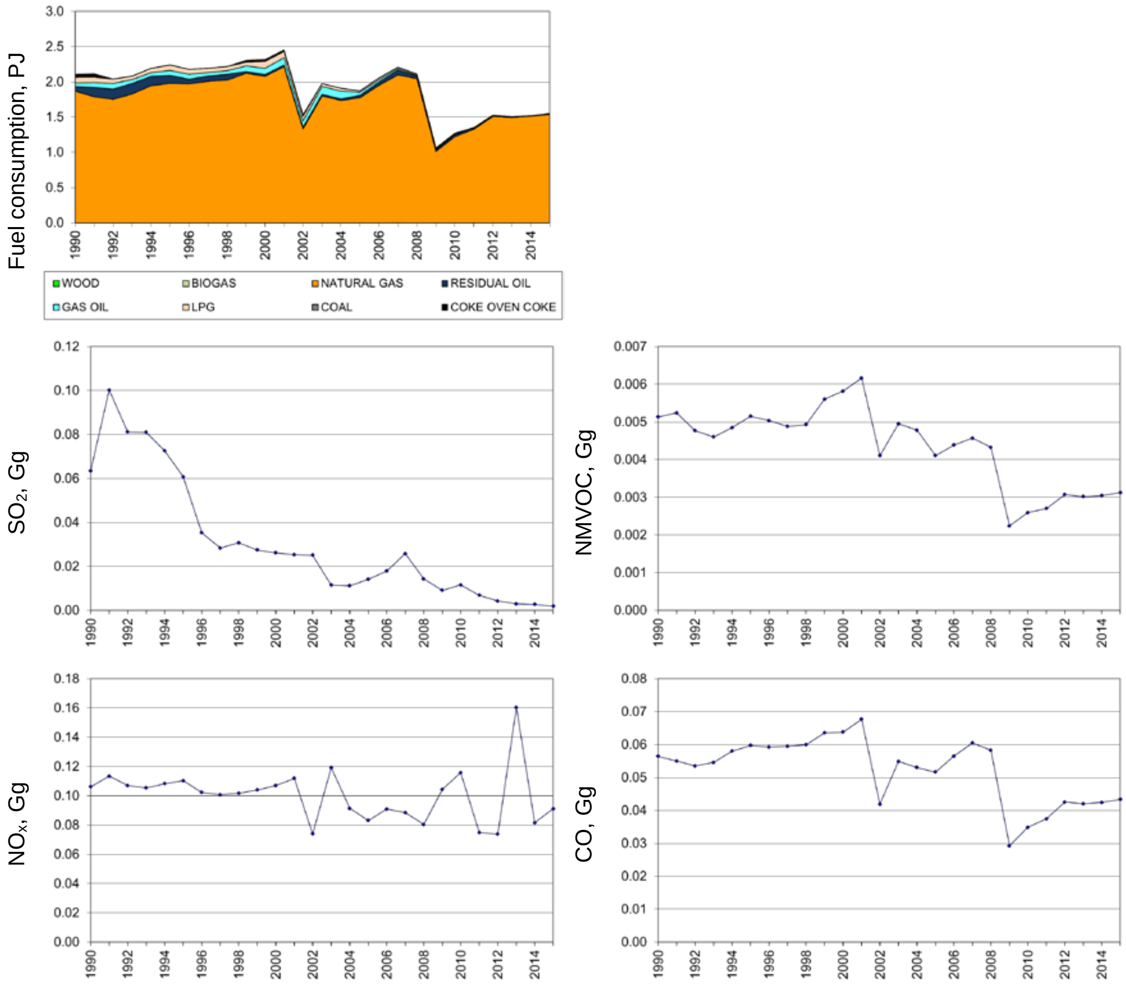


Figure 3.2.42 Time series for 1A2a Iron and steel.

1A2b Non-ferrous metals

The energy statistics have been recalculated and now no fuel consumption is reported for non-ferrous metals.

1A2c Chemicals

Chemicals is a minor emission source category. Figure 3.2.43 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO.

Natural gas is the main fuel in this subsector. The consumption of residual oil has decreased and the SO_2 emission follows this fuel consumption.

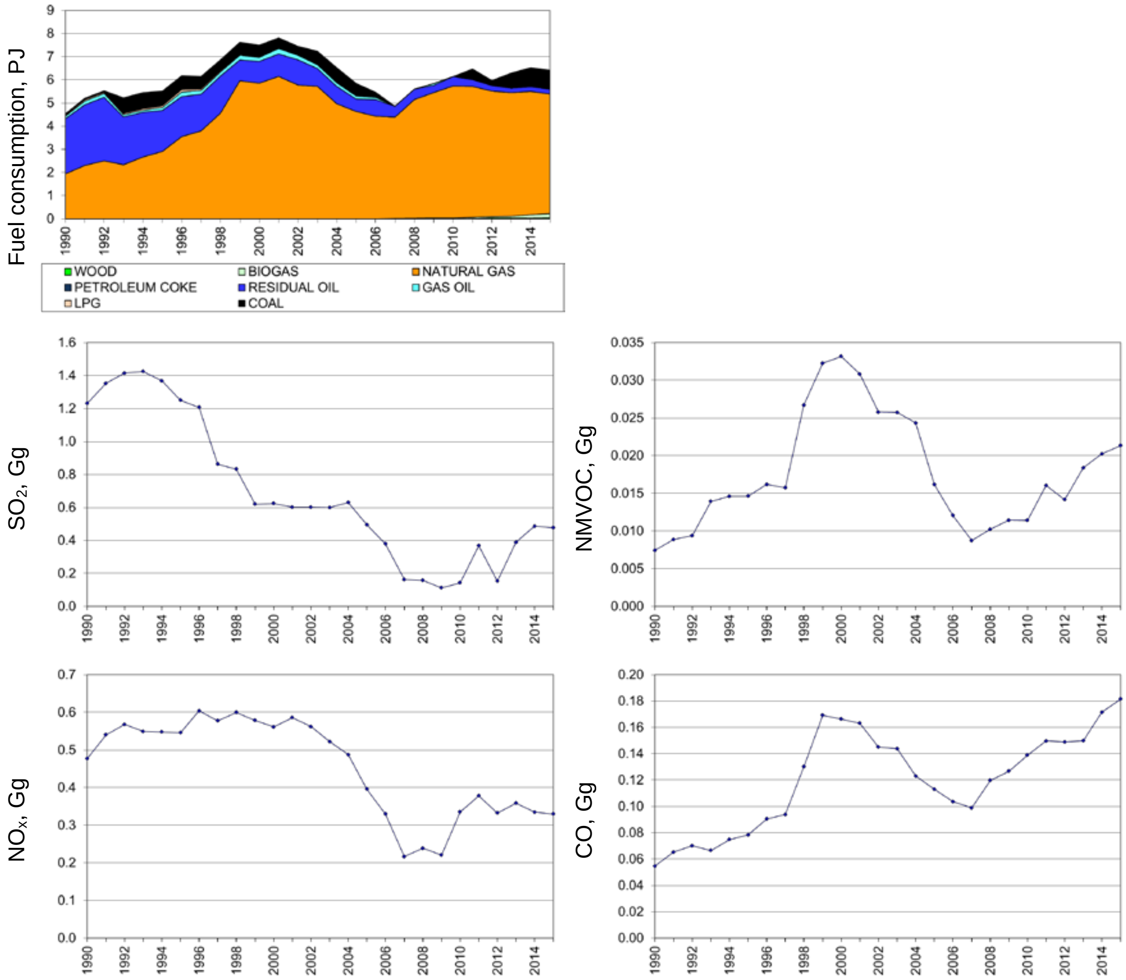


Figure 3.2.43 Time series for 1A2c Chemicals.

1A2d Pulp, paper and print

Pulp, paper and print is a minor emission source category. Figure 3.2.44 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO.

Natural gas - and in 2007-2012 also wood - are the main fuels in the subsector. The consumption of coal and residual oil has decreased and this is reflected in the SO_2 emission time series. The increased consumption of wood in 2007-2012 has resulted in a considerable increase and decrease in NMVOC and CO emission in 2007-2012.

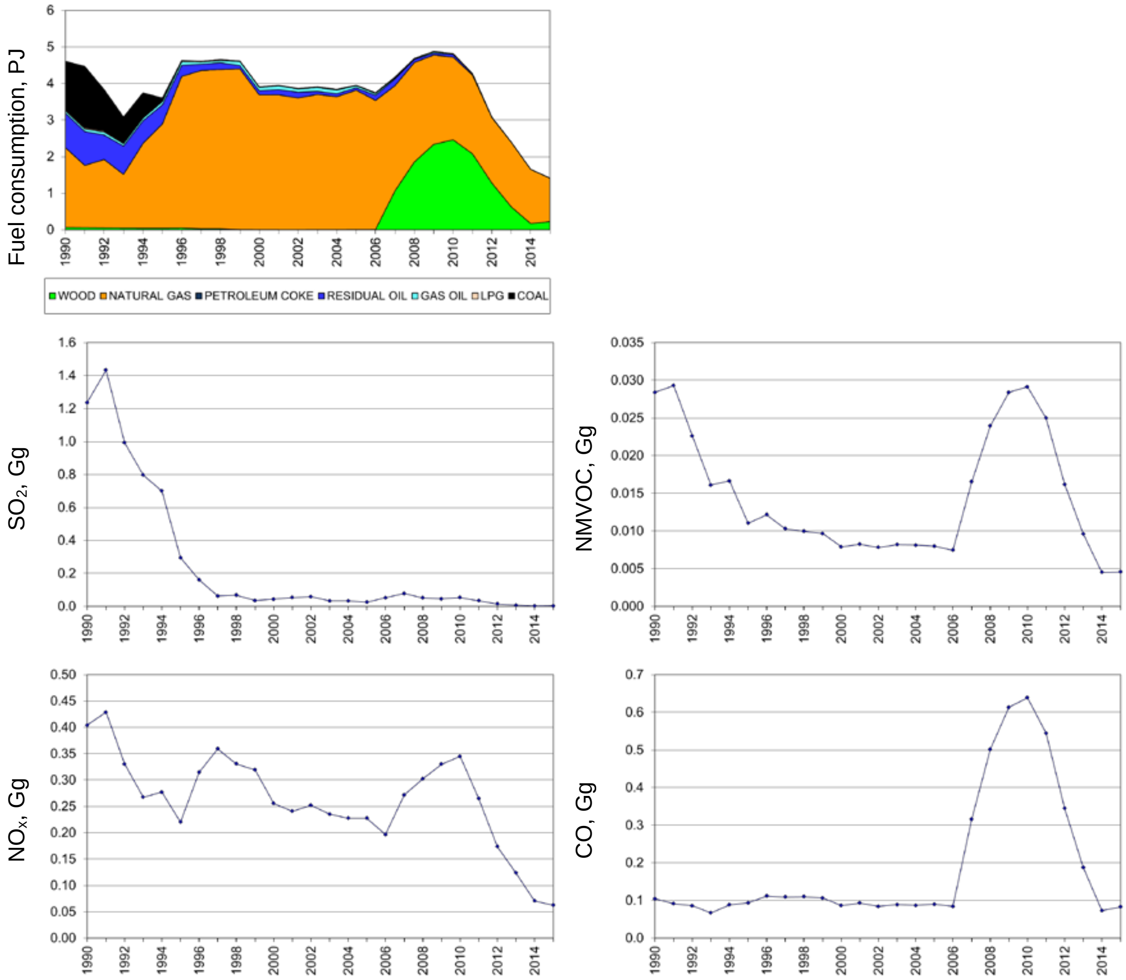


Figure 3.2.44 Time series for 1A2d Pulp, paper and print.

1A2e Food processing, beverages and tobacco

Food processing, beverages and tobacco is a considerable industrial subsector. Figure 3.2.45 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO.

Natural gas and residual oil are the main fuels in the subsector. The consumption of residual oil has decreased and this is reflected in the SO_2 emission time series. The consumption of natural gas has increased.

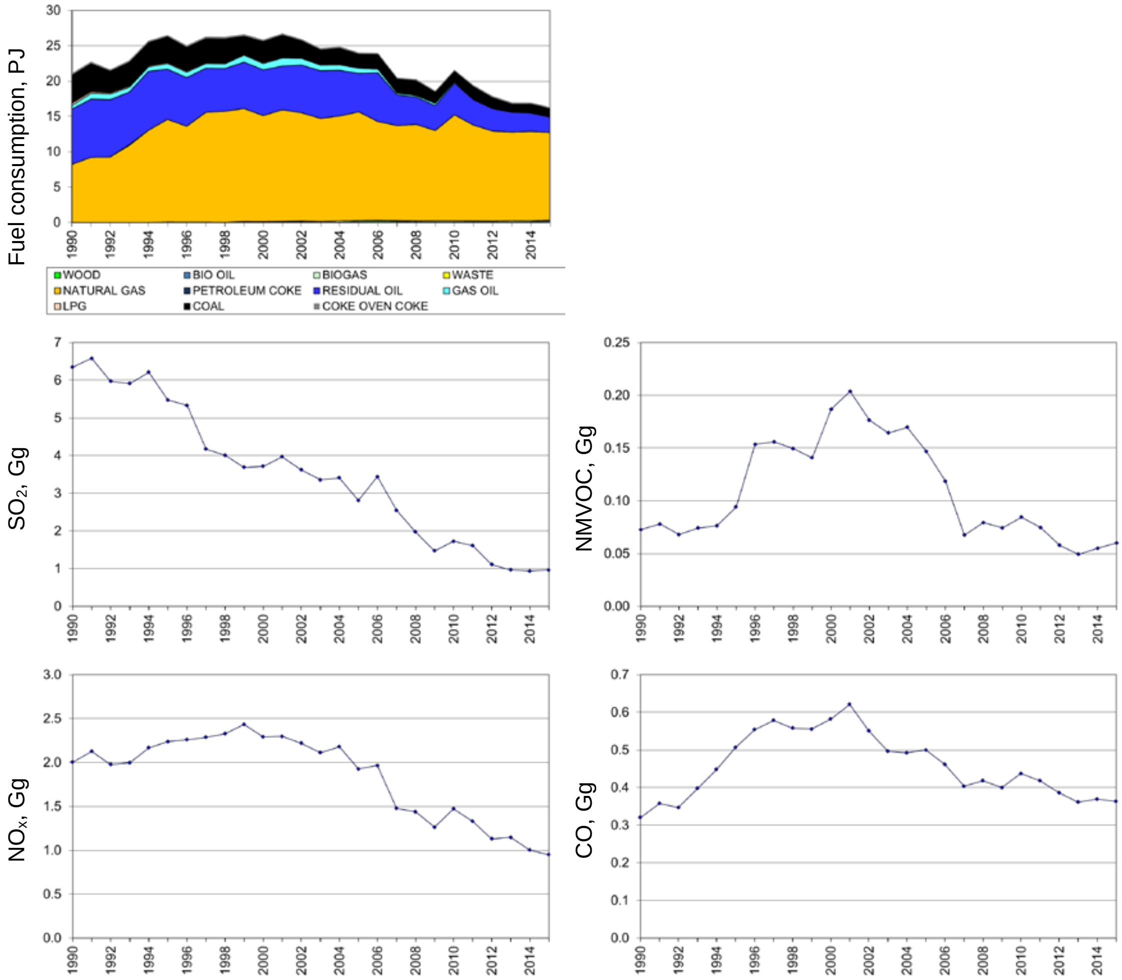


Figure 3.2.45 Time series for 1A2e Food processing, beverages and tobacco.

1A2f Non-metallic minerals

Non-metallic minerals is a considerable industrial subsector. Figure 3.2.46 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO. The subsector includes cement production that is a major industrial emission source in Denmark.

Petroleum coke, natural gas, industrial waste and coal are the main fuels in the subsector in recent years. The consumption of coal and residual oil has decreased.

The NO_x time series is discussed above on page 77.

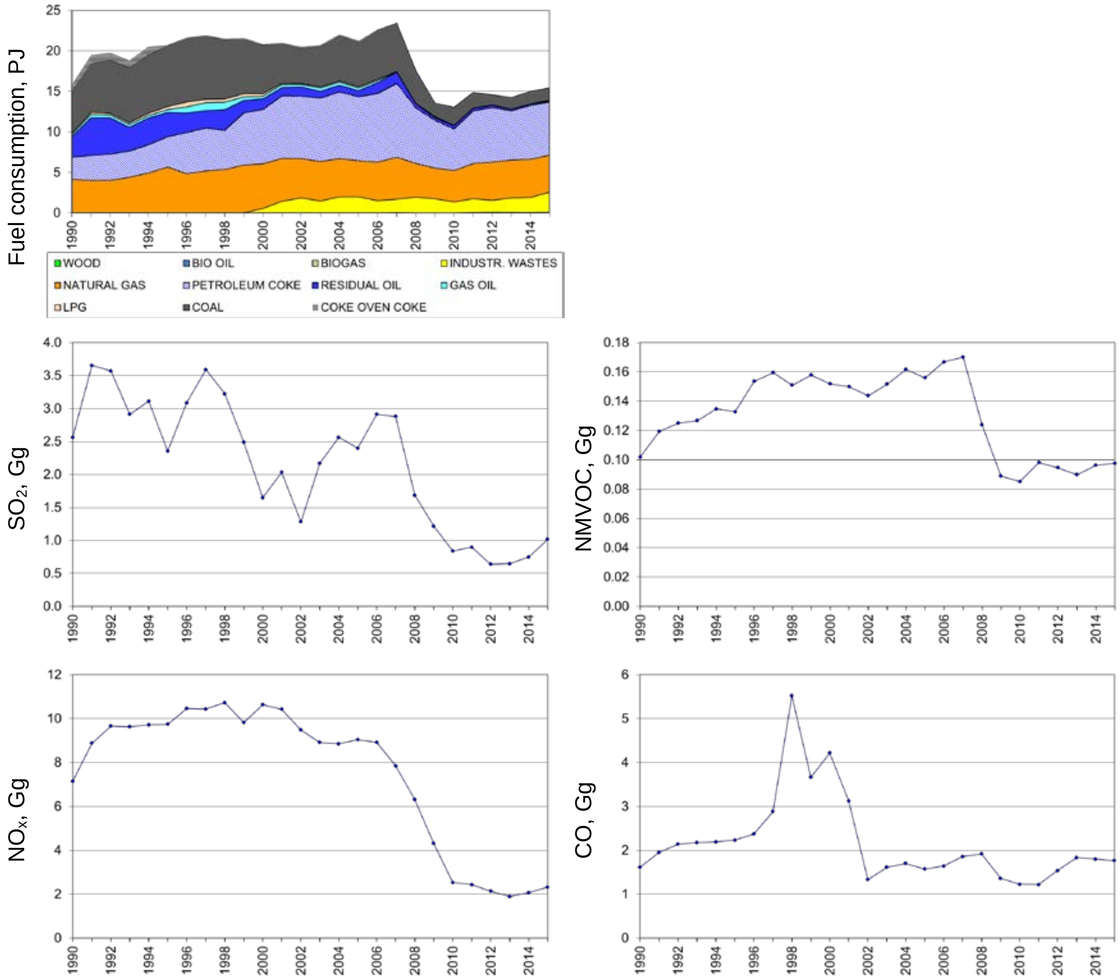


Figure 3.2.46 Time series for 1A2f Non-metallic minerals.

1A2g Other manufacturing industry

Other manufacturing industry is a considerable industrial subsector. Figure 3.2.47 shows the time series for fuel consumption and emissions of SO_2, NO_x, NMVOC and CO.

Natural gas and wood are the main fuels in the subsector in recent years. The consumption of coal and residual oil has decreased.

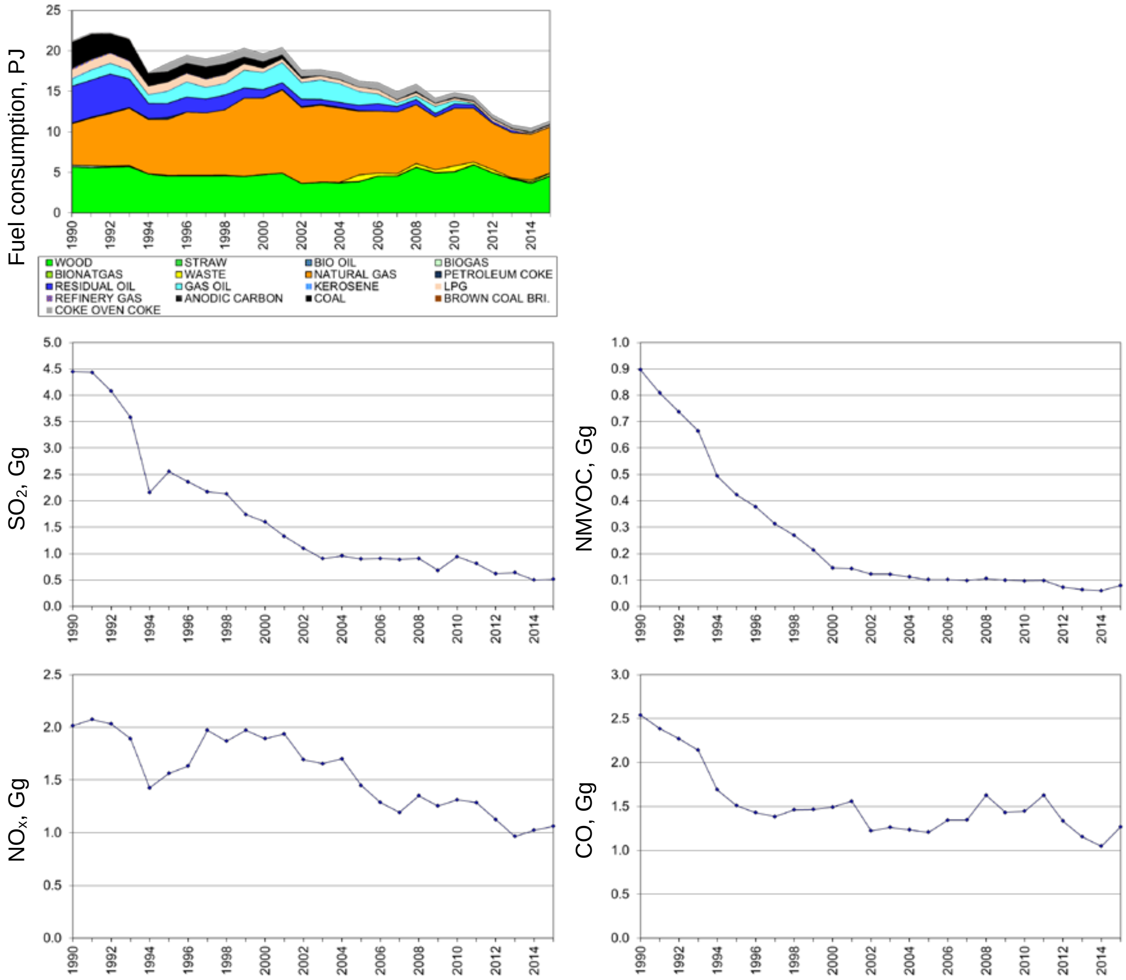


Figure 3.2.47 Time series for 1A2g Other manufacturing industry.

1A4 Other Sectors

The emission source category *1A4 Other Sectors* consists of the subcategories:

- 1A4a Commercial/Institutional plants.
- 1A4b Residential plants.
- 1A1c Agriculture/Forestry.

Figure 3.2.48 – 3.2.52 present time series for this emission source category. *Residential plants* is the largest subcategory accounting for the largest part of all emissions. Time series are discussed below for each subcategory.

The HCB emission time series follows the fuel consumption of coal in residential plants. The HCB emission factor for coal used in residential plants is high compared to other fuels.

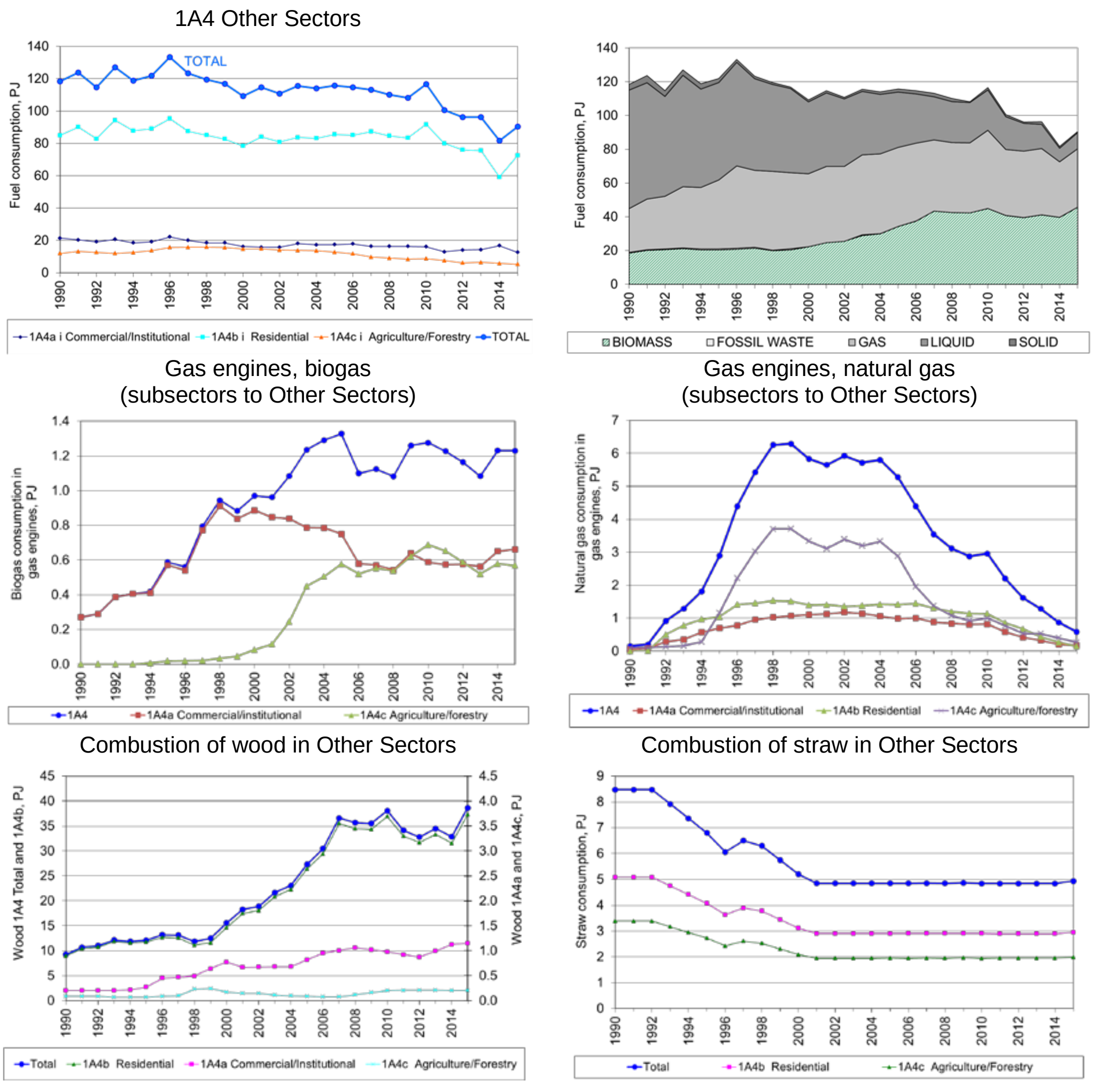


Figure 3.2.48 Time series for fuel consumption, 1A4 Other Sectors.

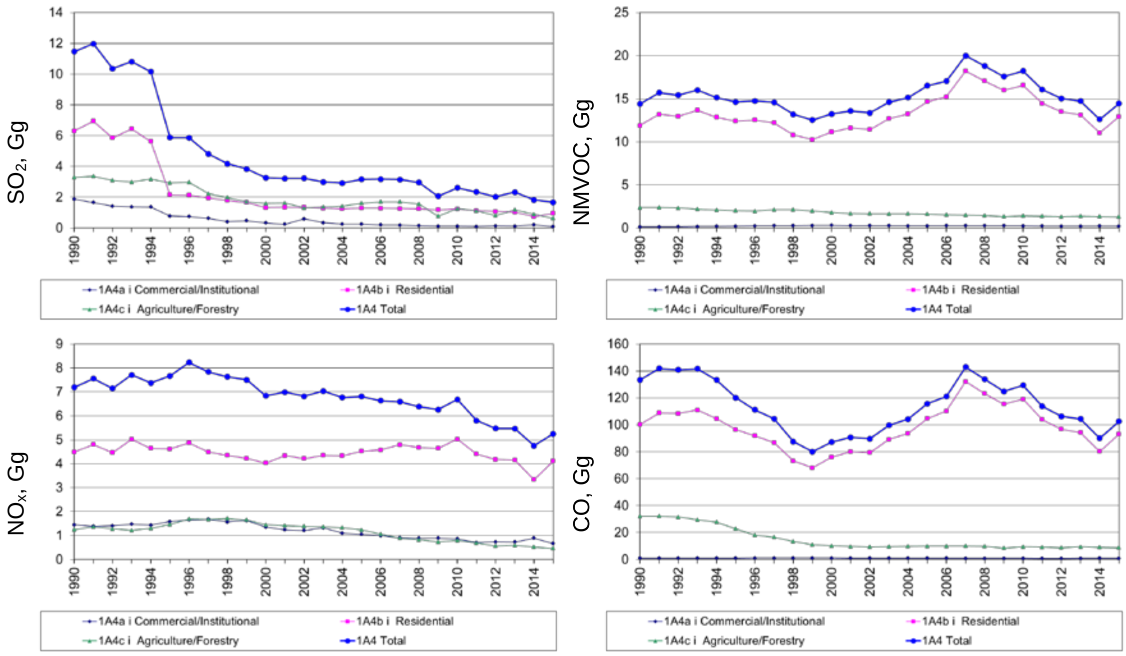


Figure 3.2.49 Time series for SO_2, NO_x, NMVOC and CO emission, 1A4 Other Sectors.

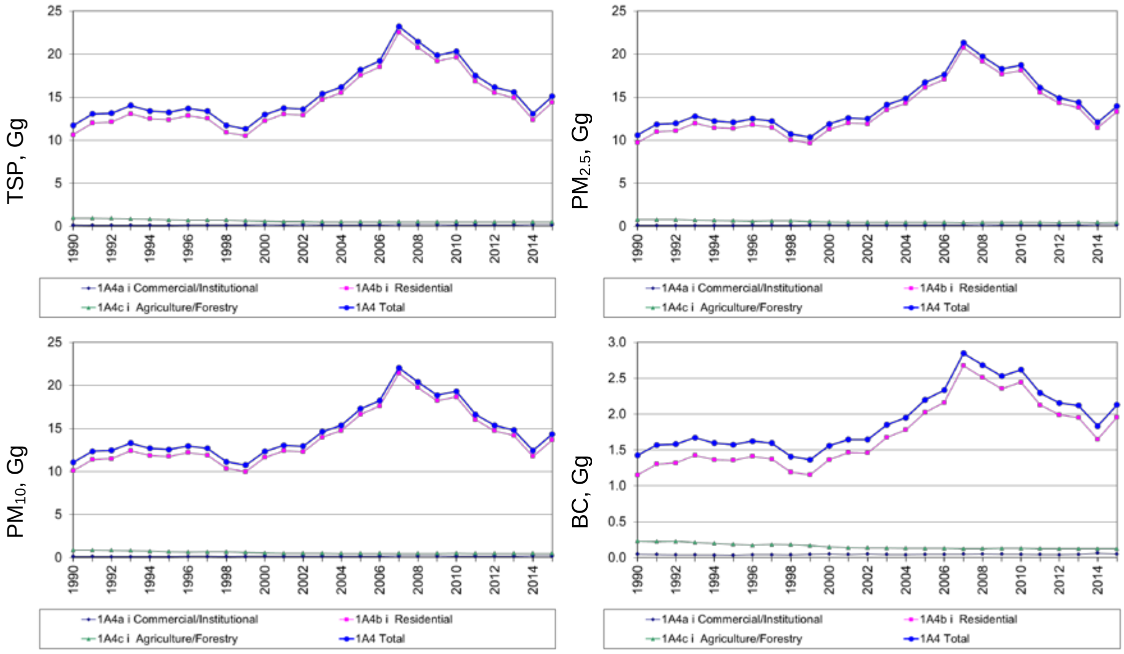


Figure 3.2.50 Time series for PM and BC emission, 1A4 Other Sectors.

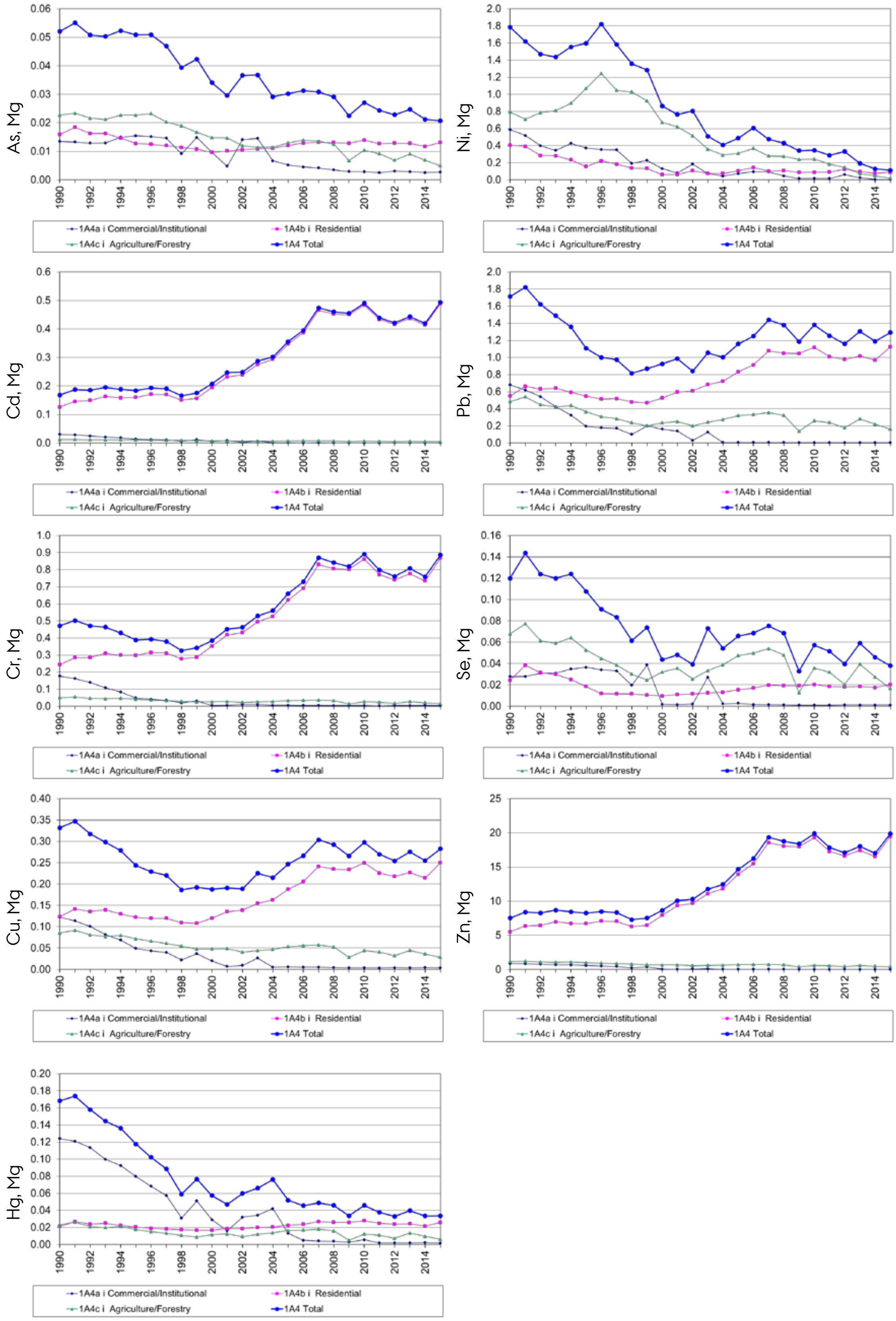


Figure 3.2.51 Time series for HM emission, 1A4 Other Sectors.

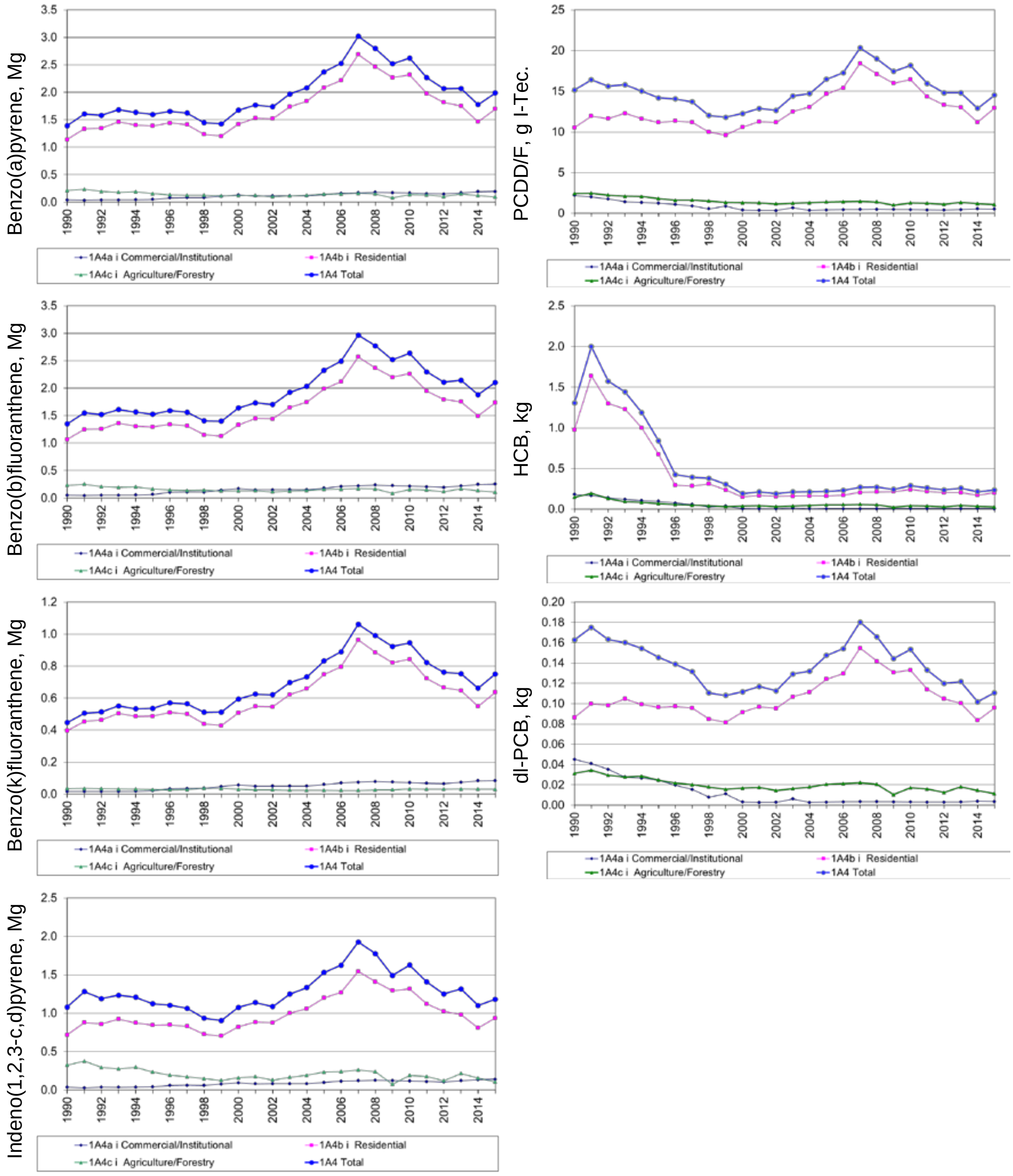


Figure 3.2.52 Time series for PAH, PCDD/F, HCB and dioxin-like PCB emission, 1A4 Other Sectors.

1A4a i Commercial and institutional plants

The emission source category *Commercial and institutional plants* consists of both stationary and mobile sources. In this chapter, only stationary sources are included (1A4a i).

The fuel consumption and the emissions from commercial and institutional plants are low compared to the other stationary combustion emission source categories. Figure 3.2.53 shows the time series for fuel consumption and emissions.

The fuel consumption in commercial/institutional plants has decreased 41 % since 1990 and there has been a change of fuel type. The fuel consumption consists mainly of gas oil and natural gas. The consumption of gas oil has decreased since 1990. The consumption of wood and biogas has increased.

The wood consumption in 2015 was 5.6 times the consumption in 1990 (see Figure 3.2.48).

The SO_2 emission has decreased 95 % since 1990. The decrease is a result of both the change of fuel from gas oil to natural gas and of the lower sulphur content in gas oil and in residual oil. The lower sulphur content (0.05 % for gas oil since 1995 and 0.7 % for residual oil since 1997) is a result of Danish tax laws (DEPA, 1998).

The NO_x emission was 54 % lower in 2015 than in 1990. The decrease is mainly a result of the lower fuel consumption but also the change from gas oil to natural gas has contributed to the decrease. The emission from wood combustion has increased.

The NMVOC emission in 2015 was 67 % higher than the 1990 emission level. The large increase is a result of the increased combustion of wood that is the main source of emission. The increase and decrease of natural gas consumption in gas engines (Figure 3.2.48) is also reflected in the time series for NMVOC emission.

The CO emission has decreased 17 % since 1990. The emission from wood has increased whereas the emission from gas oil has decreased. This is a result of the change of fuels used in the sector.

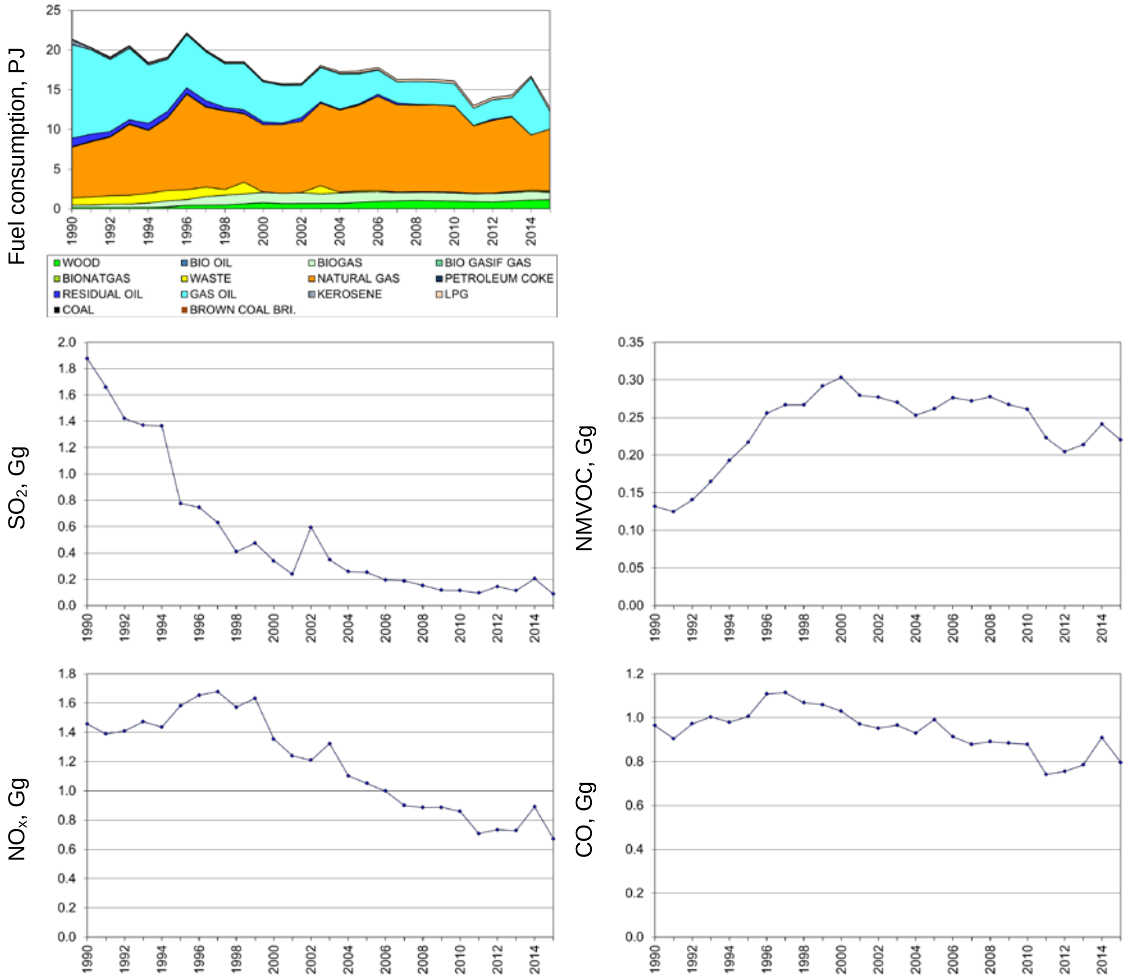


Figure 3.2.53 Time series for 1A4a Commercial /institutional.

1A4b i Residential plants

The emission source category *Residential plants* consists of both stationary and mobile sources. In this chapter, only stationary sources are included (1A4b i). Figure 3.2.54 shows the time series for fuel consumption and emissions.

For residential plants, the total fuel consumption was 15 % lower in 2015 than in 1990. The large decrease from 2010 to 2011 was caused by high temperature in the winter season of 2011. The low consumption of gas oil in 2014 seems to be related to an incorrect disaggregation of gas oil between sector 1A4a and 1A4b. This will be improved in the next inventory. The consumption of gas oil has decreased since 1990 whereas the consumption of wood has increased considerably (4.2 times the 1990 level). The consumption of natural gas has also increased since 1990.

The large decrease (85 %) of SO_2 emission from residential plants is mainly a result of a change of sulphur content in gas oil since 1995. The lower sulphur content (0.05 %) is a result of Danish tax laws (DEPA, 1998). In addition, the consumption of gas oil has decreased and the consumption of natural gas that results in very low SO_2 emissions has increased.

The NO_x emission has decreased by 8 % since 1990. As mentioned above the fuel consumption has also decreased. The emission factor for wood is higher than for natural gas and gas oil and both consumption and the emission factor for wood have increased. However, the NO_x emission factor for natural gas has decreased.

The emission of NMVOC has increased 9 % since 1990. The consumption of wood has increased but the emission factor for wood has decreased since 1990. The emission factors for wood and straw are higher than for liquid or gaseous fuels.

The CO emission has decreased 7 % since 1990. The use of wood that is the main source of emission has increased whereas the emission factor has decreased. The emission from combustion of straw has decreased since 1990.

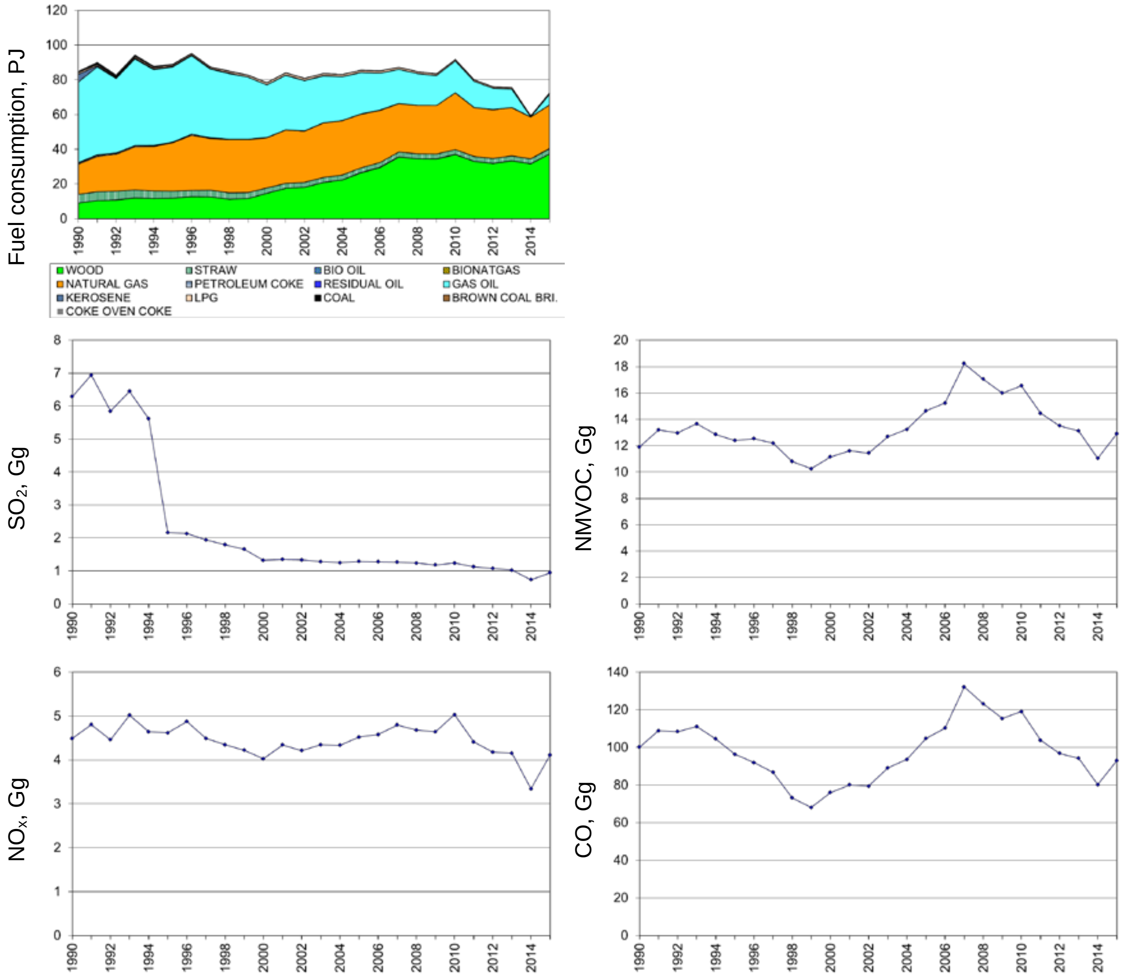


Figure 3.2.54 Time series for 1A4b Residential plants.

1A4c i Agriculture/forestry

The emission source category Agriculture/forestry consists of both stationary and mobile sources. In this chapter, only stationary sources are included (1A4c i). Figure 3.2.55 shows the time series for fuel consumption and emissions.

For plants in agriculture/forestry, the fuel consumption has decreased 46 % since 1990.

The type of fuel that has been applied has changed since 1990. In the years 1994-2006, the consumption of natural gas was high, but in recent years, the consumption decreased again. A large part of the natural gas consumption has been applied in gas engines (Figure 3.2.48). Most CHP plants in agriculture/forestry based on gas engines came in operation in 1995-1999. The decrease in later years is a result of the liberalisation of the electricity market.

The consumption of coal, residual oil and straw has decreased since 1990. The consumption of biogas has increased.

The SO_2 emission was 81 % lower in 2015 than in 1990. The emission decreased mainly in the years 1996-2002.

The emission of NO_x was 63 % lower in 2015 than in 1990.

The emission of NMVOC has decreased 45 % since 1990.

The CO emission has decreased 73 % since 1990. The major emission source is combustion of straw. In addition to the decrease of straw consumption, the emission factor for straw has also decreased since 1990.

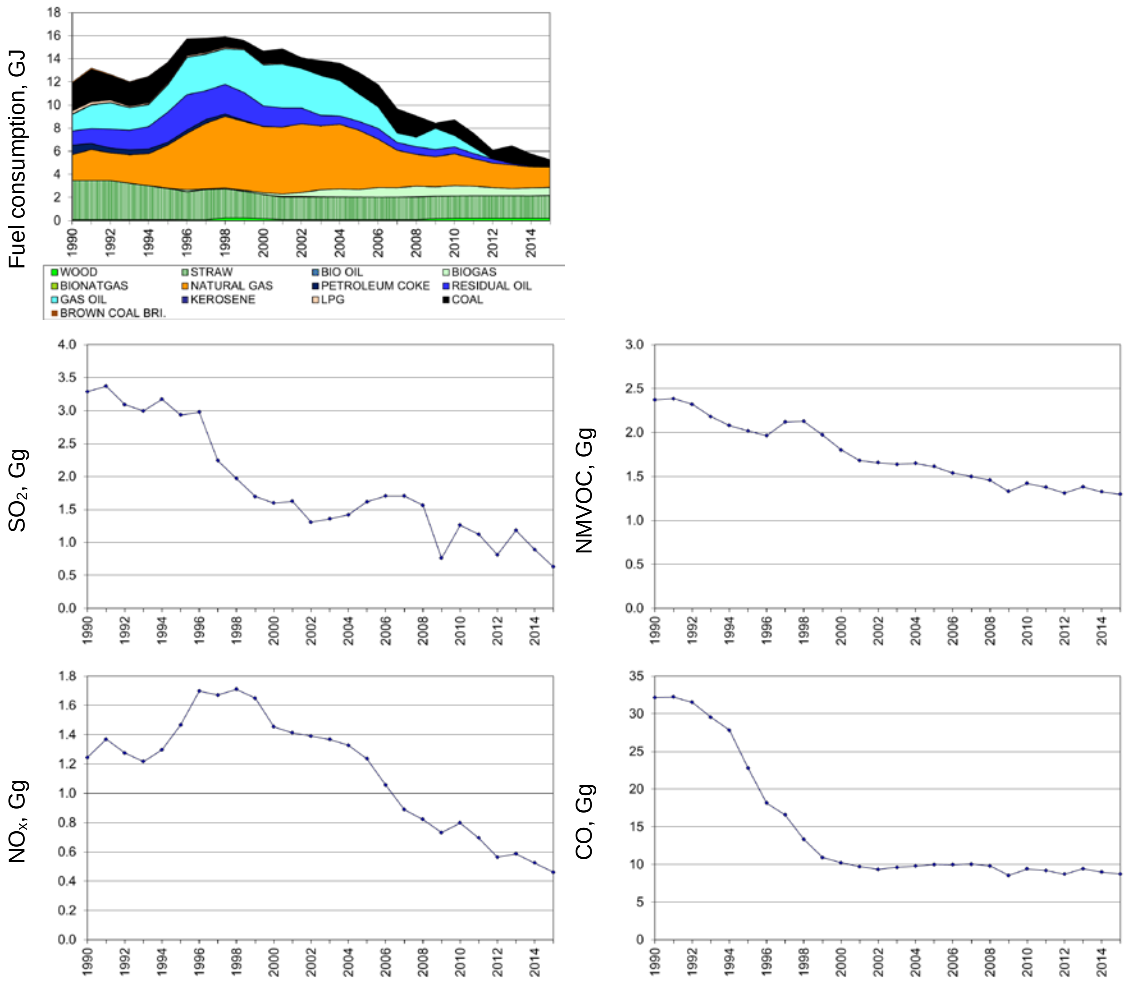


Figure 3.2.55 Time series for 1A4c Agriculture/Forestry.

3.2.5 Methodological issues

The Danish emission inventory is based on the CORINAIR (CORe INventory on AIR emissions) system, which is a European program for air emission inventories. CORINAIR includes methodology structure and software for inventories. The methodology is described in the EMEP/EEA Guidebook (EEA, 2013). Emission data are stored in an Access database, from which data are transferred to the reporting formats.

The emission inventory for stationary combustion is based on activity rates from the Danish energy statistics. General emission factors for various fuels, plants and sectors have been determined. Some large plants, such as power plants, are registered individually as large point sources and plant-specific emission data are used.

Large point sources

Large emission sources such as power plants, industrial plants and refineries are included as large point sources in the Danish emission database. Each point source may consist of more than one part, e.g. a power plant with several units. By registering the plants as point sources in the database, it is possible to use plant-specific emission factors.

In the inventory for the year 2015, 76 stationary combustion plants are specified as large point sources. Plant specific emission data are available from 70 of the plants. The point sources include:

- Power plants and decentralised CHP plants.
- Waste incineration plants.
- Large industrial combustion plants.
- Petroleum refining plants.

The criteria for selection of point sources consist of the following:

- All centralized power plants, including smaller units.
- All units with a capacity of above 25 MW_e.
- All district heating plants with an installed effect of 50 MW_{th} or above and significant fuel consumption.
- All waste incineration plants obligated to report environmental data annually according to Danish law (DEPA, 2010b).
- Industrial plants,
  - With an installed effect of 50 MW_{th} or above and significant fuel consumption.
  - With a significant process related emission.

The fuel consumption of stationary combustion plants registered as large point sources in the 2015 inventory was 199 PJ. This corresponds to 50 % of the overall fuel consumption for stationary combustion.

A list of the large point sources for 2015 is provided in Annex 3A-6. The number of large point sources registered in the databases increased from 1990 to 2015. Aggregated fuel consumption rates for the large point sources are also shown in Annex 3A-6.

The emissions from a point source are based either on plant specific emission data or, if plant specific data are not available, on fuel consumption data and the general Danish emission factors. Annex 3A-6 shows which of the emission data for large point sources are plant-specific and the corresponding share of the emission from stationary combustion.

The emission shares from point sources with plant specific data are shown in Table 3.2.15.

Table 3.2.15 Emission share, plant specific data.

Pollutant	Share from plant specific data, %
SO_2	45
NO_x	41
NMVOC	0.10
CO	3
NH_3	3.8
TSP	2.0
PM_{10}	1.7
$PM_{2.5}$	1.2
BC	0.4
As	12
Cd	0.9
Cr	3
Cu	5
Hg	50
Ni	4
Pb	2
Se	57
Zn	1.0
PCDD/F	0.9

SO_2 and NO_x emissions from large point sources are often plant-specific based on continuous emission measurements. Emissions of CO, NMVOC, PM, heavy metals and PCDD/F are also plant-specific for some plants. Plant-specific emission data are obtained from:

- Annual environmental reports / environmental reporting available on the Danish EPA home page[8] (PRTR data), DEPA (2016)
- Annual plant-specific reporting of SO_2 and NO_x from power plants >25MW_e prepared for the Danish Energy Agency (DEA) and Energinet.dk
- Emission data reported by DONG Energy, the major power plant operator
- Emission data reported from industrial plants

Annual environmental reports for the plants include a considerable number of emission data sets. Emission data from annual environmental reports are, in general, based on emission measurements, but some emissions have potentially been calculated from general emission factors.

If plant-specific emission factors are not available, general area source emission factors are used.

Area sources

Fuels not combusted in large point sources are included as source category specific area sources in the emission database. Plants such as residential boilers, small district heating plants, small CHP plants and some industrial boilers are defined as area sources. Emissions from area sources are based on fuel consumption data and emission factors. Further information on emission factors is provided below.

Activity rates, fuel consumption

The fuel consumption rates are based on the official Danish energy statistics prepared by DEA. DCE aggregates fuel consumption rates to SNAP categories. Some fuel types in the official Danish energy statistics are added to obtain a less detailed fuel aggregation level cf. Annex 3A-3. The calorific values

[8] http://www3.mst.dk/Miljoeoplysninger/PrtrPublicering/Index

on which the energy statistics are based are also enclosed in Annex 3A-3. The calorific values shown in the annex are default values but plant specific reporting to the energy statistics is based on plant specific calorific values if data are available. The correspondence list between the energy statistics and SNAP categories is enclosed in Annex 3A-9.

The fuel consumption of the NFR category *Manufacturing industries and construction* (corresponding to SNAP category 03) is disaggregated into industrial subsectors based on the DEA data set aggregated for the Eurostat reporting (DEA, 2016c).

Both traded and non-traded fuels are included in the Danish energy statistics. Thus, for example, estimation of the annual consumption of non-traded wood is included.

Petroleum coke purchased abroad and combusted in Danish residential plants (border trade of 628 TJ in 2015) is not included in the Danish inventory. This is in agreement with the IPCC Guidelines (1996).

The fuel consumption data for large point sources refer to the EU Emission Trading Scheme (EU ETS) data for plants for which the Danish CO_2 emission inventory also refer to EU ETS.

For all other large point sources, the fuel consumption refers to a DEA database (DEA, 2016b). The DEA compiles a database for the fuel consumption of each district heating and power-producing plant, based on data reported by plant operators.

The fuel consumption of area sources is calculated as total fuel consumption minus fuel consumption of large point sources.

The Danish national energy statistics includes three fuels used for non-energy purposes, bitumen, white spirit and lubricants. The total consumption for non-energy purposes is relatively low, e.g. 10.5 PJ in 2015. The use of fuels for non-energy purposes is included in the inventory in sector 2D Non-energy products from fuels and solvent use, see Chapter 4.5.

In Denmark, all waste incineration is utilised for heat and power production. Thus, incineration of waste is included as stationary combustion in the source category *Energy*.

Fuel consumption data are presented in Chapter 3.2.2.

Town gas

Town gas has been included in the fuel category natural gas. The consumption of town gas in Denmark is very low, e.g. 0.6 PJ in 2015. In 1990, the town gas consumption was 1.6 PJ and the consumption has been steadily decreasing throughout the time series.

In Denmark, town gas is produced based on natural gas. The use of coal for town gas production ceased in the early 1980s.

An indicative composition of town gas according to the largest supplier of town gas in Denmark is shown in Table 3.2.16 (KE, 2015).

Table 3.2.16 Composition of town gas currently used (KE, 2015).

Component	Town gas, % (mol.)
Methane	43.9
Ethane	2.9
Propane	1.1
Butane	0.5
Carbon dioxide	0.4
Nitrogen	40.5
Oxygen	10.7

Biogas has been added to the town gas grid since 2015. This biogas distributed in the town gas grid is treated as a separate fuel in the emission inventory and thus not included in the data for town gas in this report and not included in the town gas composition shown above.

In earlier years, the composition of town gas was somewhat different. Table 3.2.17 is constructed with the input from Københavns Energi (KE) (Copenhagen Energy) and Danish Gas Technology Centre (DGC), (Jeppesen, 2007; Kristensen, 2007). The data refer to three measurements performed several years apart; the first in 2000 and the latest in 2005.

Table 3.2.17 Composition of town gas, information from the period 2000-2005.

Component	Town gas, % (mol.)
Methane	22.3-27.8
Ethane	1.2-1.8
Propane	0.5-0.9
Butane	0.13-0.2
Higher hydrocarbons	0-0.6
Carbon dioxide	8-11.6
Nitrogen	15.6-20.9
Oxygen	2.3-3.2
Hydrogen	35.4-40.5
Carbon monoxide	2.6-2.8

Due to the scarce data available and the very low consumption of town gas compared to consumption of natural gas, the methodology will be applied unchanged in future inventories.

Upgraded biogas distributed in the natural gas grid and the town gas grid

Biogas upgraded for distribution in the natural gas grid is included as a separate fuel[9] in the emission inventory. The upgraded biogas has been implemented as a new fuel category in the Danish energy statistics (DEA, 2016a).

Biogas distributed in the town gas grid has been included in the fuel category biogas.

Emission factors

For each fuel and SNAP category (sector and e.g. type of plant), a set of general area source emission factors has been determined. The emission factors are either nationally referenced or based on the international guidebooks: EMEP/EEA Guidebook (EEA, 2013)[10] and IPCC Guidelines (IPCC, 2006).

[9] BIONATGAS in tables and figures in this report.

[10] And former editions of the EMEP/EEA Guidebook.

A complete list of emission factors including time series and references is provided in Annex 3A-4.

SO_2 and NO_x emission factors

Emission factors for SO_2 and NO_x are listed in Annex 3A-4. The appendix includes references and time series. Further details about the references, additional references, assumptions and discussions are included in Nielsen et al. (2014).

The emission factors refer to:

- The EMEP/EEA Guidebook: EEA (2013) and former editions.
- The IPCC Guidelines (IPCC, 2006).
- Danish legislation:
- Danish research reports including:
  - Two emission measurement programs for decentralised CHP plants (Nielsen et al. 2010; Nielsen & Illerup, 2003).
  - Research and emission measurements programs for biomass fuels
  - Research and environmental data from the gas sector
- Aggregated emission factors for residential wood combustion based on technology distribution (DEPA, 2013) and technology specific emission factors (EEA, 2013; DEPA, 2010a).
- Calculations based on plant-specific emissions from a considerable number of power plants.
- Calculations based on plant-specific emission data from a considerable number of waste incineration plants. These data refer to annual environmental reports published by plant operators.
- Sulphur content data from oil companies and the Danish gas transmission company, Energinet.dk.
- Additional personal communication.

Emission factor time series have been estimated for a considerable number of the emission factors. These are provided in Annex 3A-4.

NMVOC emission factors

Emission factors for NMVOC are listed in Annex 3A-4. The annex includes references and time series. The emission factors for NMVOC refer to:

- An emission measurement program for decentralised CHP plants (Nielsen et al., 2010a).
- The EMEP/EEA Guidebook (EEA, 2013) and former editions.
- Aggregated emission factor based on the technology distribution for residential wood combustion and guidebook (EEA, 2013) emission factors. Technology distribution based on DEPA (2013).
- DGC Danish Gas Technology Centre 2001, Naturgas – Energi og miljø (DGC, 2001).
- Gruijthuijsen & Jensen (2000). Energi- og miljøoversigt, Danish Gas Technology Centre, 2000 (In Danish).

CO emission factors

Emission factors for CO are listed in Annex 3A-4. The annex includes references and time series. The emission factors for CO refer to:

- The EMEP/EEA Guidebook (EEA, 2013) and the former editions.

- IPCC Guidelines (IPCC, 2006)
- An emission measurement program for decentralised CHP plants (Nielsen et al., 2010a).
- Danish legislation (DEPA, 2001)
- Aggregated emission factor based on the technology distribution for residential wood combustion and guidebook (EEA, 2013) emission factors. Technology distribution based on DEPA (2013).
- DCE estimate based on annual environmental reports for Danish waste incineration plants without power production, year 2000.
- Nikolaisen et al. (1998)
- Jensen & Nielsen (1990)
- Bjerrum (2002)
- Sander (2002)
- Gruijthuijsen & Jensen (2000)

NH_3 emission factors

Emission factors have been included for residential wood combustion, residential straw combustion, waste incineration in public power production and residential combustion of coal, BKB and coke oven coke. The emission factor for waste incineration plants refers to a Danish emission measurement programme (Nielsen et al., 2010a) and all other emission factors refer to the EMEP/EEA Guidebook (EEA, 2009). Time series have been estimated for residential wood combustion.

Particulate matter (PM) emission factors

Emission factors for PM and references for the emission factors are listed in Annex 3A-4. The emission factors are based on:

- The TNO/CEPMEIP emission factor database (CEPMEIP, 2001).

In addition, a considerable number of country-specific factors referring to:

- Danish legislation:
  - DEPA (2001), The Danish Environmental Protection Agency, Luftvejledningen (legislation from Danish Environmental Protection Agency).
  - DEPA (1990), The Danish Environmental Protection Agency, Bekendtgørelse 698 (legislation from Danish Environmental Protection Agency).
- Calculations based on plant-specific emission data from a considerable number of waste incineration plants.
- Aggregated emission factors for residential wood combustion based on technology distribution (DEPA, 2013) and technology specific emission factors (EEA, 2013; DEPA, 2010a).
- Two emission measurement programs for decentralised CHP plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003).
- An emission measurement program for large power plants (Livbjerg et al., 2001).
- Research leading to the first Danish PM emission inventory for stationary combustion (Nielsen et al., 2003)
- Additional personal communication concerning straw combustion in residential plants.

Emission factor time series have been estimated for residential wood combustion and waste incineration. All other emission factors have been considered constant in 2000-2015.

Black carbon (BC) emission factors

Emission factors for BC all refer to EEA (2013). All emission factors are expressed as percentage of $PM_{2.5}$. The applied emission factors and references are shown in Annex 3A-4.

Time series have been estimated for residential wood combustion and for waste incineration. The BC fraction of $PM_{2.5}$ is considered constant for each fuel/technology.

Heavy metals emission factors

Emission factors for 2015 for heavy metals (HM) are shown in Annex 3A-4. The annex includes references and time series. The emission factors refer to:

- Two emission measurement programs carried out on Danish decentralised CHP plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003).
- Implied Emission Factors for power plants based on plant specific data reported by the power plant owners.
- Research concerning heavy metal emission factors representative for Denmark (Illerup et al., 1999).
- A CONCAWE study (Denier van der Gon & Kuenen, 2010)
- Data for Danish natural gas (Gruijthuijsen, 2001; Energinet.dk, 2012)
- Emission factors without national reference all refer to EEA (2009).

Time series have been estimated for coal and for waste incineration. For all other sources, the same emission factors have been applied for 1990-2015.

The heavy metal emission inventory has been documented in detail in Nielsen et al. (2013c).

PAH emission factors

Emission factors for PAH are shown in Annex 3A-4. The appendix includes references. The PAH emission factors refer to:

- Research carried out by TNO (Berdowski et al., 1995).
- Research carried out by Statistics Norway (Finstad et al., 2001).
- An emission measurement program performed on biomass fuelled plants. The project was carried out for the Danish Environmental Protection Agency (Jensen & Nielsen, 1996).
- Jensen & Blinksbjerg (2000)
- Finstad et al. (2001)
- Two emission measurement programs carried out on Danish decentralised CHP plants (Nielsen et al., 2010a; Nielsen & Illerup, 2003).
- Additional information from the gas sector (Jensen, 2001).

For residential wood combustion, country specific emission factors have been aggregated based on technology distribution in the sector (DEPA, 2013) and technology specific emission factors (EEA, 2013; DEPA 2010a).

Emission factor time series have been estimated for residential wood combustion, natural gas fuelled engines, biogas fuelled engines and waste incineration plants. All other emission factors have been considered constant from 1990 to 2015. In general, emission factors for PAH are uncertain.

PCDD/F emission factors

Emission factors 2015 for PCDD/F are shown in Annex 3A-4.

The emission factor for residential wood combustion refers to technology specific emission factors (EEA 2013; DEPA 2010a) and to updated technology distribution data (DEPA, 2013).

The emission factors for decentralised CHP plants[11] refer to an emission measurement program for these plants (Nielsen et al. 2010a).

All other emission factors refer to research regarding PCDD/F emission carried out by NERI (now DCE) to prepare a new PCDD/F emission inventory (Henriksen et al., 2006).

Time series have been estimated for residential wood combustion and for incineration of waste. For all other sources, the same emission factors have been applied for 1990-2015.

HCB emission factors

The HCB emission inventory has been documented in Nielsen et al. (2014).

Table 3.2.18 shows the emission factors and references for the Danish emission factors.

Table 3.2.18 Emission factors for HCB, stationary combustion.

Fuel	NFR (SNAP)	Emission factor, ng/GJ	Reference
Coal	1A1, 1A2	6,700	Grochowalski & Konieczyński (2008); EEA (2013)
Coal	1A4b	1,200,000	Syc et al. (2011)
Coal	1A4a and 1A4c	23,000	Syc et al. (2011)
Other solid fuels	1A1, 1A2	6,700	Assumed equal to coal.
Other solid fuels	1A4	1,200,000	Assumed equal to coal.
Liquid fuels[1)]	1A1, 1A2, 1A4	220	Nielsen et al. (2010)
Gaseous fuels	1A1, 1A2, 1A4	-	Negligible
Waste	1A1, 1A2, 1A4	4300	Nielsen et al. (2010). A time series have been estimated. The emission factor for 1990 (190,000 ng/GJ) refer to Pacyna et al. (2003).
Wood	1A1, 1A2	5,000	EEA (2013)
Wood	1A4	5,000	EEA (2013)
Straw	1A1, 1A2	113	Nielsen et al. (2010)
Straw	1A4	5,000	EEA (2013)
Biogas	1A1, 1A2, 1A4	190	Nielsen et al. (2010)
Producer gas	1A1, 1A2, 1A4	800	Nielsen et al. (2010)

1) The emission factor for LPG and refinery gas is negligible.

[11] Natural gas fueled engines, biogas fueled engines, gas oil fueled engines, engines fueled by biomass producer gas, CHP plants combusting straw or wood and waste incineration plants.

For coal, the emission factor from Grochowalski & Konieczyński (2008) is applied for energy industries and for industrial plants. This emission factor is also applied in the EEA Guidebook (EEA, 2013).

For residential plants, the emission factor 1,200,000 ng/GJ is applied referring to Syc et al. (2011). For commercial/institutional plants and for plants in agriculture / forestry the lower end of the value in Syc et al. (2011) (23,000 ng/GJ) is applied.

The emission factor for gas oil fuelled CHP engines (220 ng/GJ) referring to Nielsen et al. (2010) is applied for all liquid fuels except for LPG and refinery gas.

For gaseous fuels, LPG and refinery gas no data are available and the emission is negligible.

For waste combustion, emission data from Danish plants are available and these data are applied (Nielsen et al., 2010). The emission factor 4,300 ng/GJ is applied for 2005 onwards. The HCB emission factor for 1990 refers to Pacyna et al. (2003). The emission of HCB is related to emission of PCDD/F and the decline rate between 1990 and 2005 is based on the decline rate for PCDD/F.

Recent emission measurements from Polish industrial waste incineration plants confirms the emission factor level for waste incineration considering that the PCDD/F emission level is 15 times the PCDD/F emission level for Danish plants.

For wood combustion, the emission factors from EEA (2013) are applied for both energy industries, industrial plants and for non-industrial plants. For residential wood combustion, it would be relevant to estimate a time series. However, the currently available data are considered insufficient for this estimate.

The Cl content in straw is higher than in wood (Villeneuve et al., 2013) and thus the emission from straw combustion might potentially be higher. However, the emission factor for CHP plants combusting straw reported in Nielsen et al. (2010) is lower than the emission factor applied for wood.

The emission factor for energy industries and industrial combustion refer to Nielsen et al. (2010). For non-industrial plants, the EEA (2013) emission factor is applied.

The emission factors for biogas and producer gas both refer to Nielsen et al (2010).

PCB emission factors

The PCB emission inventory has been documented in Nielsen et al. (2014).

PCB emission is strongly related to the Cl content of the fuel (Syc et al., 2011) and to the emission level for PCDD/F (Hedman et al., 2006; Syc et al., 2011; Pandelova et al., 2009).

The Cl content of straw, bark and manure is higher than for wood (Villeneuve et al., 2012). Villeneuve et al. (2012) states the Cl contents 50-60 mg/kg wood, 100-370 mg/kg bark, 1000-7000 mg/kg straw.

Different references for PCB emissions are not directly comparable because some PCB emission data are reported for individual PCB congeners, some as a sum of a specified list of PCB congeners and some PCB emission data are reported as toxic equivalence (teq) based on toxicity equivalence factors (TEF) for 12 dioxin-like PCB congeners. The emission measurements reported by Thistlethwaite (2001a and 2001b) show that the emission of non-dioxin-like PCBs is high compared to the emission of dioxin-like PCBs.

Furthermore, teq values based on TEF are reported as WHO_{2005}-teq or WHO_{1998}-teq. This difference is however typically less than 50% [12].

Table 3.2.19 shows the emission factors that have been selected for the Danish PCB emission inventory and reference for each emission factor. All emission factors are dioxin-like PCBs (but not teq values). PCB emission factors have been added for all fuels except LPG, refinery gas and natural gas. The emission from these three fuels is considered negligible.

Table 3.2.19 Emission factors for ∑dl-PCB, stationary combustion, 2015.

Fuel	NFR (SNAP)	Emission factor, ∑ dl-PCB, ng/GJ	Emission factor, PCB, ng WHO_{1998}-teq/GJ	Reference
Coal	1A1	839	3.16	Grochowalski & Konieczyński (2008)
Coal	1A2	5,700	53	Thistlethwaite (2001a)
Coal	1A4	7,403	66	Syc et al. (2011)
Other solid fuels	1A1	839	3.16	Assumed equal to coal.
Other solid fuels	1A2	5,700	53	Assumed equal to coal.
Other solid fuels	1A4	7,403	66	Assumed equal to coal.
Residual oil	1A1, 1A2, 1A4	839	3.2	The teq value refers to Dyke et al. (2003). The TEQ value is equal to the emission factor for coal combustion in power plants and the sum of dioxin-like PCB congeners has been assumed equal to the corresponding factor for coal.
Gas oil	1A1, 1A2, 1A4	93	0.11	Nielsen et al. (2010)
Other liquid fuels[1)]	1A1, 1A2, 1A4	93	0.11	Assumed equal to gas oil.
Gaseous fuels	1A1, 1A2, 1A4	-	-	Negligible
Waste	1A1, 1A2, 1A4	109 (time series)	0.28 (time series)	Nielsen et al. (2010). A time series have been estimated. The emission factor for 1990 (46,000 ng/GJ or 117 ng WHO1998teq/GJ) have been estimated based on the assumption that the PCB emission factor time series follow the PCDD/F time series.
Wood	1A1, 1A2, 1A4a/c	2,800	21	Thistlethwaite (2001a)
Wood	1A4b	2,752 (time series)	20.6)	Hedman et al. (2006). A time series have been estimated based on time series for technologies applied in Denmark.
Straw	1A1, 1A2	3,110	31.2	Assumed equal to residential plants.
Straw	1A4	3,110	31.2	Syc et al. (2011)
Biogas	1A1, 1A2, 1A4	90	0.13	Nielsen et al. (2010)
Producer gas	1A1, 1A2, 1A4	144	0.17	Nielsen et al. (2010)

1) Except LPG and refinery gas.

[12] Data have been compared for a few datasets in which each dioxin-like PCB congener was specified.

The emission factor for waste incineration refers to recent Danish field measurements. Historical data are not available, but a time series have been estimated based on the assumption that the dl-PCB emission factor follows the PCDD/-F emission factor. The estimated emission factor for 1990 is 45,671 ng/GJ or 117 ng WHO-teq/GJ. This emission level is confirmed by other references (Kakareka & Kukharchyk, 2005; Andrijewski et al., 2004). The emission factor time series is shown in Table 3.2.20.

For residential wood combustion, technology specific emission factors in toxicological equivalence are available from Hedman et al. (2006). However, sums of dioxin-like PCBs are not included in the reference. The emission factors for dioxin-like PCBs have been estimated based on the data for toxicological equivalence and the sum of dioxin-like PCBs in Thistlethwaite (2001a). Thus, the teq factors referring to Hedman (2006) have been multiplied by 2800/21. This assumption is highly uncertain, but the resulting emission factors seem to be in agreement with other references for residential wood combustion. A technology distribution time series for residential wood combustion in Denmark is available and have been applied for estimating the time series for the aggregated emission factor shown in Table 3.2.20.

Emission factor time series for waste incineration and for residential wood combustion are shown in Table 3.2.20.

Table 3.2.20 Emission factor time series for waste incineration and for residential wood combustion

Year	Waste incineration ∑dl-PCB, ng/GJ	Residential wood combustion ∑dl-PCB, ng/GJ
1990	45671	6648
1991	38063	6622
1992	30433	6588
1993	22825	6559
1994	19773	6510
1995	16721	6445
1996	13690	6327
1997	10638	6231
1998	7586	6101
1999	5515	5708
2000	3423	5390
2001	3423	4834
2002	3423	4609
2003	3423	4548
2004	1766	4477
2005	109	4267
2006	109	4028
2007	109	4050
2008	109	3801
2009	109	3496
2010	109	3309
2011	109	3138
2012	109	2974
2013	109	2710
2014	109	2362
2015	109	2308

Emission factors for residential wood combustion

For the pollutants NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, PCDD/F, PCB and PAH emission factors have been based on fuel consumption data and emission factors for 13 different technologies. Technology categories, emission factors and implied emission factors for 2015 are shown in Table 3.2.21. For other pollutants, time series have not been estimated and the emission factors are shown in Annex 3A-4.

References and assumptions for each of the emission factors shown in Table 3.2.21 are included in Annex 3A-4.

Table 3.2.21 Technology specific emission factors for residential wood combustion.

Technology	NO_x, g/GJ	NMVOC, g/GJ	CO, g/GJ	NH_3, g/GJ	TSP, g/GJ	PM_{10}, g/GJ	$PM_{2.5}$, g/GJ	BC, g/GJ	PCDD/F, ng/GJ	dl-PCB, ng/GJ	Benzo (a) pyrene, mg/GJ	Benzo (b) fluoran-thene, mg/GJ	Benzo (k) fluoran-thene, mg/GJ	Indeno (1.2.3-c,d) pyrene, mg/GJ
Old stove	50	1200	430	8000	70	1000	950	930	93	800	7049	121	111	42
New stove	50	600	215	4000	70	800	760	740	74	800	7049	121	111	42
Stove according to resent Danish legislation (2008-2015)	80	350	125	4000	37	556	528	514	82	250	931	61	56	21
Modern stove (2015-2017)	80	350	125	4000	37	278	264	257	41	250	931	61	56	21
Modern stove (2017-)	80	350	125	4000	37	222	211	205	33	250	931	61	56	21
Eco labelled stove / new advanced stove (-2015)	95	175	2	1117	37	222	211	206	58	100	466	10	16	5
Eco labelled stove / new advanced stove (-2015)	95	175	2	1117	37	167	159	155	43	100	466	10	16	5
Other stoves	50	600	430	4000	70	800	760	740	74	800	7049	121	111	42
Old boilers with hot water storage	80	350	211	4000	74	1000	950	900	144	550	7049	121	111	42
Old boilers without hot water storage	80	350	256	4000	74	2000	1900	1800	288	550	7049	121	111	42
New boilers with hot water storage	95	175	50	1117	37	222	211	206	58	100	466	10	16	5
New boilers without hot water storage	95	350	50	2234	37	444	422	413	116	200	931	20	32	10
Pellet boilers	80	10	3	300	12	31	29	29	4	100	466	10	16	5
IEF residential wood combustion, 2015	**77**	**293**	**2158**	**37**	**367**	**348**	**340**	**51**	**304**	**2308**	**44471**	**45593**	**16511**	**24782**

Implied emission factors

A considerable part of the emission data for waste incineration plants and large power plants are plant-specific. Thus, the area source emission factors do not necessarily represent average values for these plant categories. To attain a set of emission factors that expresses the average emission for power plants combusting coal and for waste incineration plants, implied emission factors have been calculated for these two plant categories. The implied emission factors are presented in Annex 3A-5. The implied emission factors are calculated as total emission divided by total fuel consumption.

3.2.6 Uncertainty

According to the EEA Guidelines (EEA, 2013) uncertainty estimates should be estimated

Uncertainty estimates include uncertainty with regard to the total emission inventory as well as uncertainty with regard to trends.

Methodology

The Danish uncertainty estimates are based on the simple Tier 1 approach.

The uncertainty estimates are based on emission data for the base year and year 2015 as well as on uncertainties for fuel consumption and emission factors for each of the NFR source categories. Residential plants have however been split in two parts: Residential wood combustion and other residential plants.

The base year for all pollutants is 1990.

The uncertainty for fuel consumption in stationary combustion plants is based on EEA (2013). The uncertainties are shown in Table 3.2.22.

The applied uncertainties for activity rates and emission factors are based on EEA (2013). The uncertainty for emission factors that are based on recent Danish emission measurements are however estimated lower than suggested in the Guidebook. The applied uncertainties for emission factors are listed in Table 3.2.23.

Table 3.2.22 Uncertainty rates for fuel consumption, %.

Sector	%
1A1a Public electricity and heat production	1
1A1b Petroleum refining	1
1A1c_ii Oil and gas extraction	1
1A2 Manufacturing industries and construction	2
1A4a_i Commercial / institutional	3
1A4b_i Residential (excluding wood)	3
1A4b_i Residential wood	20
1A4c_i Agriculture / forestry / fishing	3

Table 3.2.23 Uncertainty rates for emission factors, %.

Sector	SO_2	NO_x	NMVOC	CO	PM	HM	PAH	HCB	Dioxin	NH_3	PCB	BC
1A1a Public electricity and heat production	10	15	50	20	20	50	100	1000	200	1000	1000	1000
1A1b Petroleum refining	10	20	50	20	50	100	100	1000	1000	1000	1000	1000
1A1c_ii Oil and gas extraction	10	20	50	20	50	100	100	1000	1000	1000	1000	1000
1A2 Manufacturing industries and construction	10	20	50	20	30	100	100	1000	1000	1000	1000	1000
1A4a_i Commercial / institutional	20	50	50	50	50	300	1000	1000	1000	1000	1000	1000
1A4b_i Residential (excluding wood)	20	30	50	50	50	300	1000	1000	1000	1000	1000	1000
1A4b_i Residential wood	20	50	100	100	200	1000	1000	500	600	100	1000	1000
1A4c_i Agriculture / forestry / fishing	20	50	50	50	50	300	1000	1000	1000	1000	1000	1000

Results

The uncertainty estimates for stationary combustion emission inventories are shown in Table 3.2.24. Detailed calculation sheets are provided in Annex 3A-7.

The total emission uncertainty is 6.0 % for SO_2 and 10 % for NO_x.

Table 3.2.24 Uncertainty estimates, tier 1 approach, 2015.

Pollutant	Uncertainty Total emission, %	Trend 1990-2015, %	Uncertainty Trend, %-age points
SO_2	±6.0	-95	±0.3
NO_x	±10	-77	±2
NMVOC	±72	-3	±32
CO	±70	-20	±32
NH_3	±102	130	±111
TSP	±171	20	±51
PM_{10}	±173	21	±50
$PM_{2.5}$	±176	24	±50
BC	±871	85	±327
As	±54	-82	±8
Cd	±513	-41	±260
Cr	±303	-79	±62
Cu	±398	-84	±61
Hg	±41	-91	±3
Ni	±74	-90	±5
Pb	±192	-86	±26
Se	±40	-83	±3
Zn	±180	-23	±117
HCB	±747	-80	±34
PCDD/F	±456	-67	±125
Benzo(b)fluoranthene	±778	56	±290
Benzo(k)fluoranthene	±791	64	±180
Benzo(a)pyrene	±828	43	±242
Indeno(1,2,3-c,d)pyrene	±789	8	±362
PCB	±645	-67	±79

3.2.7 Source specific QA/QC and verification

An updated quality manual for the Danish emission inventories was published in 2013 (Nielsen et al., 2013). The quality manual describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Point for Measuring (PM). Details about the source specific QA/QC is included in Annex 3A-11.

Documentation concerning verification of the Danish emission inventories was published by Fauser et al. (2013).

A reviewed sector report for stationary combustion was published in 2014 (Nielsen et al., 2014b). Former editions of the sector report for stationary combustion have been reviewed by external experts in 2004, 2006 and 2009.

3.2.8 Source specific improvements and recalculations

For stationary combustion plants, the emission estimates for the years 1990-2014 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation sectors as well as a source category update. The changes in the energy statistics are largest for the years 2012, 2013 and 2014.

In addition the disaggregation of fuels applied for manufacturing industries and construction have been updated according to the latest reporting from DEA. The consumption and emissions for the sector *1A2b Stationary combustion in manufacturing industries and construction: Non-ferrous metals* is now reported NO which is in agreement with the updated DEA data.

Recalculations for stationary combustion as a whole are shown in Table 3.2.25.

The largest recalculations are related to a recalculation of the consumption of wood in residential plants in 2013-2014 in the energy statistics.

SO_2 emission measurements for 2014 have been implemented for a number of plants for which the data were not available prior to the reporting in 2016. In addition, the emission factor for one plant has been improved based on measurements from former years.

Table 3.2.25 Recalculations for stationary combustion, emissions reported in 2017 compared to emissions reported in 2016.

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
							Percent						
SO_2	100.1	100.1	100.3	100.4	100.3	100.5	100.6	100.7	100.9	101.0	99.9	99.5	96.9
NO_x	100.2	100.2	100.3	100.3	100.4	100.3	100.4	100.5	100.5	100.1	100.2	100.4	100.5
NMVOC	100.1	100.1	100.1	100.1	100.1	100.2	100.2	100.1	100.2	100.3	100.4	103.6	104.7
CO	100.0	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.2	103.2	104.5
TSP	New	New	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	104.0	105.8
PM_{10}	New	New	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	104.0	105.9
$PM_{2.5}$	New	New	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	104.1	106.0
BC	New	New	100.5	100.3	100.4	100.1	100.2	100.3	100.2	100.1	100.0	104.0	106.6
NH_3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	101.2	102.0	107.1	109.6
As	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0	100.1	99.8	100.2
Cd	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	102.7	103.6
Cr	100.0	100.0	100.1	100.0	100.1	100.1	100.1	100.1	100.1	100.1	100.2	102.2	103.2
Cu	100.0	100.0	100.0	100.0	100.1	100.0	100.1	100.1	100.1	100.1	100.3	100.9	101.6
Hg	100.0	100.0	100.0	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.4	100.3	100.5
Ni	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.9
Pb	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.4	101.2	101.8
Se	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.2	100.0	100.1
Zn	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0	100.1	102.8	103.8
HCB	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.1	100.1	100.2	100.6
PCDD/F	100.0	100.0	100.1	100.1	100.1	100.1	100.2	100.1	100.2	100.2	100.4	103.3	104.5
Benzo(a)pyrene	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.2	103.6	105.1
Benzo(b)fluoranthene	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.2	103.2	104.4
Benzo(k)fluoranthene	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.1	103.4	104.8
Indeno(123cd)pyrene	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.6	103.3	104.8
PCB	100.0	100.0	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.2	100.6	101.3

3.2.9 Source specific planned improvements

The reporting of, and references for, the applied emission factors will be further developed in future inventories.

3.2.10 References for chapter 3.2

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3.3 Transport and other mobile sources (NFR sector 1A2, 1A3, 1A4 and 1A5)

The emission inventory basis for mobile sources is fuel consumption information from the Danish energy statistics. In addition, background data for road transport (fleet and mileage), air traffic (aircraft type, flight numbers, origin and destination airports), national sea transport (fuel surveys, ferry technical data, number of return trips, sailing time) and non-road machinery (engine no., engine size, load factor and annual working hours) are used to make the emission estimates sufficiently detailed. Emission data mainly comes from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013). However, for railways, measurements specific to Denmark are used.

In the Danish emission database, all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution), according to the CollectER system. The emission inventories are prepared from a complete emission database based on the SNAP sectors. The aggregation to the sector codes used for both the UNFCCC and UNECE Conventions is based on a correspondence list between SNAP and CRF/NFR classification codes shown in Table 3.3.1 below (mobile sources only).

Table 3.3.1 SNAP – CRF/NFR correspondence table for transport.

SNAP classification	CRF/NFR classification
07 Road transport	1A3bi Road transport: Passenger cars
	1A3bii Road transport:Light duty vehicles
	1A3biii Road transport:Heavy duty vehicles
	1A3biv Road transport: Mopeds & motorcycles
0801 Military	1A5b Other, Mobile
0802 Railways	1A3c Railways
0803 Inland waterways	1A5b Other, Mobile
080402 National sea traffic	1A3dii National navigation (Shipping)
080403 National fishing	1A4ciii Agriculture/Forestry/Fishing: National fishing
080404 International sea traffic	1A3di (i) International navigation (Shipping)
080501 Dom. airport traffic (LTO < 1000 m)	1A3aii (i) Civil aviation (Domestic,LTO
080502 Int. airport traffic (LTO < 1000 m)	1A3ai (i) Civil aviation (International, LTO)
080503 Dom. cruise traffic (> 1000 m)	1A3aii (ii) Civil aviation (Domestic,Cruise)
080504 Int. cruise traffic (> 1000 m)	1A3ai (ii) Civil aviation (International, Cruise)
0806 Agriculture	1A4cii Agriculture/Forestry/Fishing: Off-road agriculture/forestry
0807 Forestry	1A4cii Agriculture/Forestry/Fishing: Off-road agriculture/forestry
0808 Industry	1A2gvii Manufacturing industries/Construction (mobile)
0809 Household and gardening	1A4bii Residential: Household and gardening (mobile)
0811 Commercial and institutional	1A4aii Commercial/Institutional: Mobile

Military transport activities (land and air) refer to the CRF/NFR sector Other (1A5), the latter sector also including recreational craft (SNAP code 0803).

For aviation, Landing and Take Off ((LTO)[1] refers to the part of flying, which is below 1000 m. This part of the aviation emissions (SNAP codes 080501 and 080502) are included in the national emissions total as prescribed by the UNECE reporting rules. According to UNFCCC the national emissions for aviation comprise the emissions from domestic LTO (0805010) and domestic cruise (080503). The fuel consumption and emission development for aviation explained in the following are based on UNFCCC categorization, in order to be consistent with the Danish NIR report.

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 (SNAP code 080403).

For mobile sources, internal database models for road transport, air traffic, sea transport and non-road machinery have been set up at DCE, Aarhus University, in order to produce the emission inventories. The output results from the DCE models are calculated in a SNAP format, as activity rates (fuel consumption) and emission factors, which are then exported directly to the central Danish CollectER database.

Apart from national inventories, the DCE models are used also as a calculation tool in research projects, environmental impact assessment studies, and to produce basic emission information which requires various aggregation levels.

3.3.1 Source category description

The following description of source categories explains the development in fuel consumption and emissions for road transport and other mobile sources.

[1] 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.

Fuel consumption

Table 3.3.2 Fuel consumption (PJ) for domestic transport in 2015 in NFR sectors.

NFR ID	Fuel consumption (PJ)
Manufacturing industries/Construction (mobile)	9.8
Civil aviation (Domestic)	1.8
Road transport: Passenger cars	95.9
Road transport:Light duty vehicles	19.6
Road transport:Heavy duty vehicles	47.9
Road transport: Mopeds & motorcycles	1.0
Railways	3.4
National navigation (Shipping)	4.9
Commercial/Institutional: Mobile	2.3
Residential: Household and gardening (mobile)	0.8
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	14.8
Agriculture/Forestry/Fishing: National fishing	7.2
Other, Mobile	2.7
Road transport total	164.3
Other mobile total	47.8
Domestic total	212.2
Civil aviation (International)	36.5
Navigation (international)	30.5

Table 3.3.2 shows the fuel consumption for domestic transport based on DEA statistics for 2015 in NFR sectors. The fuel consumption figures in time series 1985-2015 are given in Annex 2.B.16 (NFR format) and are shown for 2015 in Annex 2.B.15 (CollectER format). Road transport has a major share of the fuel consumption for domestic transport. In 2015 this sector's fuel consumption share is 77 %, while the fuel consumption shares for Off road agriculture/forestry and Manufacturing industries (mobile) are 7 % and 5 %, respectively. For the remaining sectors the total fuel consumption share is 11 %.

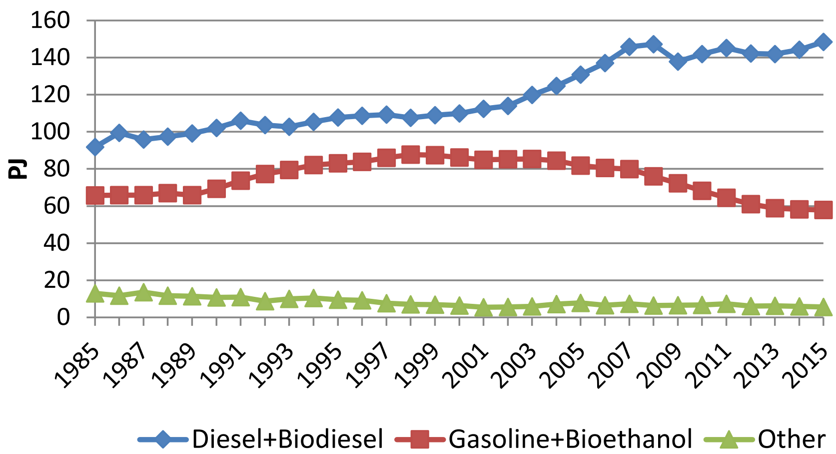


Figure 3.3.1 Fuel consumption per fuel type for domestic transport 1985-2015.

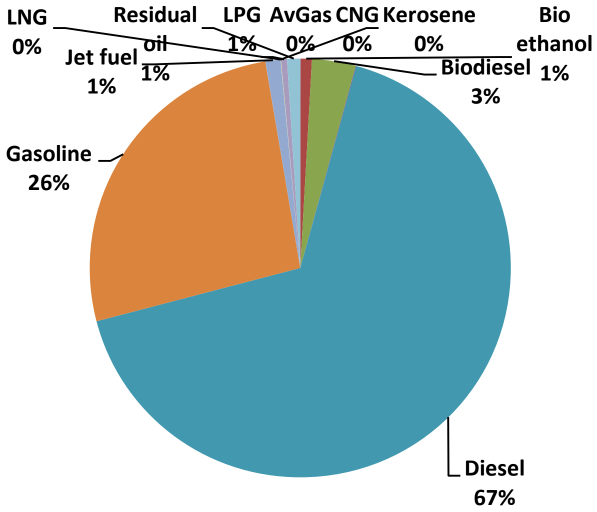


Figure 3.3.2 Fuel consumption share per fuel type for domestic transport in 2015.

From 1985 to 2015, diesel (sum of diesel and biodiesel) and gasoline (sum of gasoline and E5) fuel consumption has changed by 57 % and - 11 %, respectively (Figure 3.3.1), and in 2015 the fuel consumption shares for diesel and gasoline were 70 % and 27 %, respectively (not shown). Other fuels only have a 3 % share of the domestic transport total (Figure 3.3.2). Almost all gasoline is used in road transportation vehicles. Gardening machinery and recreational craft are merely small consumers. Regarding diesel, there is considerable fuel consumption in most of the domestic transport categories, whereas a more limited use of residual oil and jet fuel is being used in the navigation sector and by aviation (civil and military flights), respectively[2].

Road transport

As shown in Figure 3.3.3, the fuel consumption for road transport[3] has generally increased until 2007, except from a small fuel consumption decline noted in 2000. The impact of the global financial crisis on fuel consumption for road transport becomes visible for 2008 and 2009. The fuel consumption development is due to a decreasing trend in the use of gasoline fuels from 1999 to 2013 combined with a steady growth in the use of diesel until 2007. Within sub-sectors, passenger cars represent the most fuel-consuming vehicle category, followed by heavy-duty vehicles, light duty vehicles and 2-wheelers, in decreasing order (Figure 3.3.4).

[2] Biofuels are sold at gas filling stations and are assumed to be used by road transport vehicles.

[3] The sum share of bioethanol and biodiesel in the gasoline and diesel fuel blends for road transport is 5.5 %, in 2015.

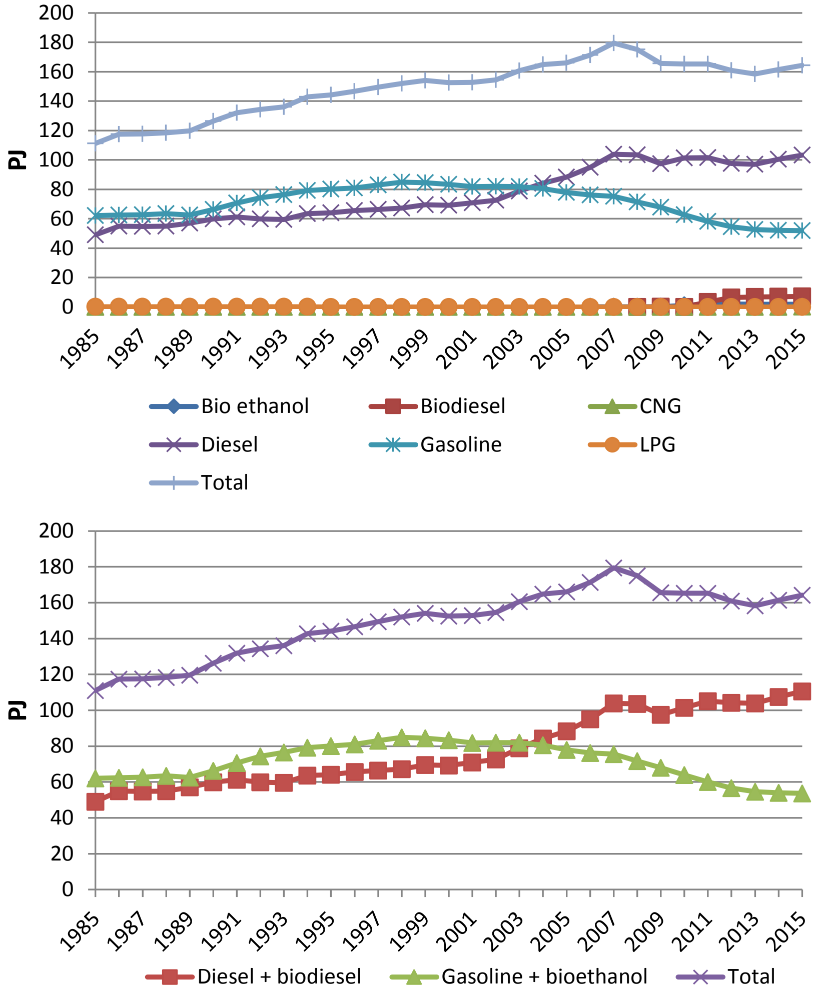


Figure 3.3.3 Fuel consumption per fuel type and as totals for road transport 1985-2015.

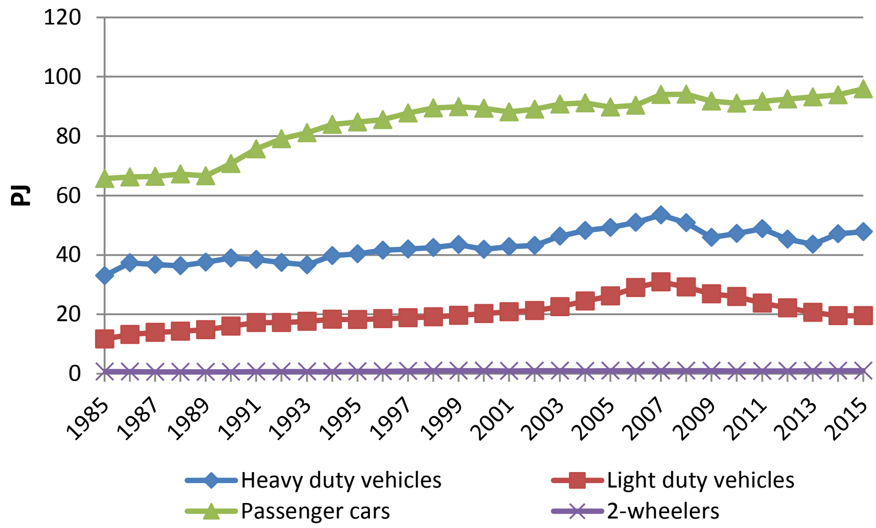


Figure 3.3.4 Total fuel consumption per vehicle type for road transport 1985-2015.

As shown in Figure 3.3.5 fuel consumption for gasoline passenger cars dominates the overall gasoline consumption trend. The development in diesel fuel consumption in recent years (Figure 3.3.6) is characterised by increasing fuel consumption for diesel passenger cars, while declines in the fuel consumption for trucks and buses (heavy-duty vehicles) and light duty vehicles are noted for 2008- 2009, 2012-2013, and 2008-2014, respectively.

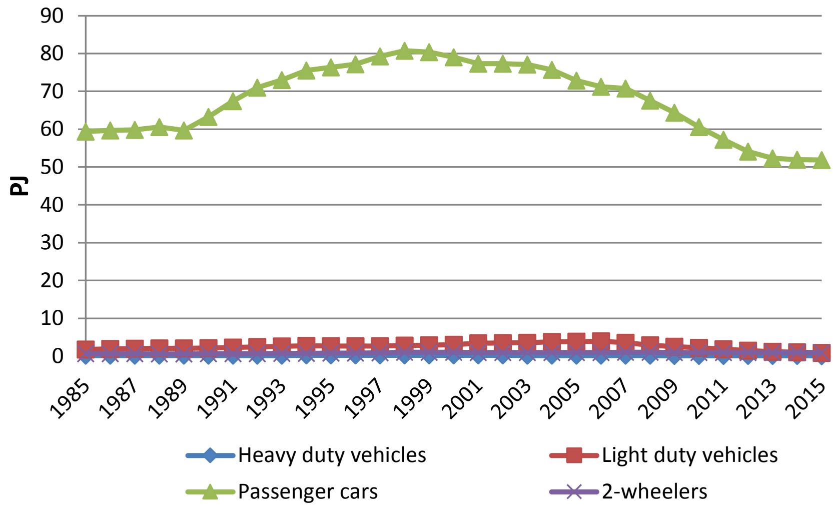


Figure 3.3.5 Gasoline fuel consumption per vehicle type for road transport 1985-2015.

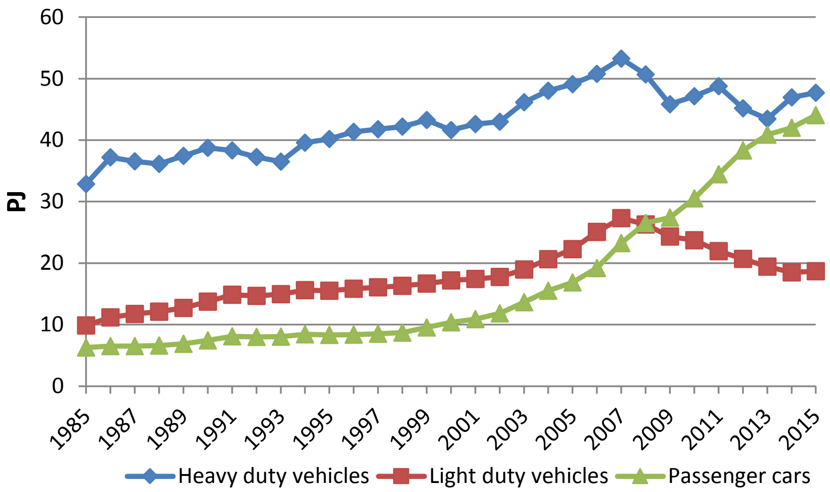


Figure 3.3.6 Diesel fuel consumption per vehicle type for road transport 1985-2015.

In 2015, fuel consumption shares for gasoline passenger cars, diesel heavy-duty vehicles, diesel passenger cars, diesel light duty vehicles and gasoline light duty vehicles were 32, 29, 27 and 11 %, respectively (Figure 3.3.7).

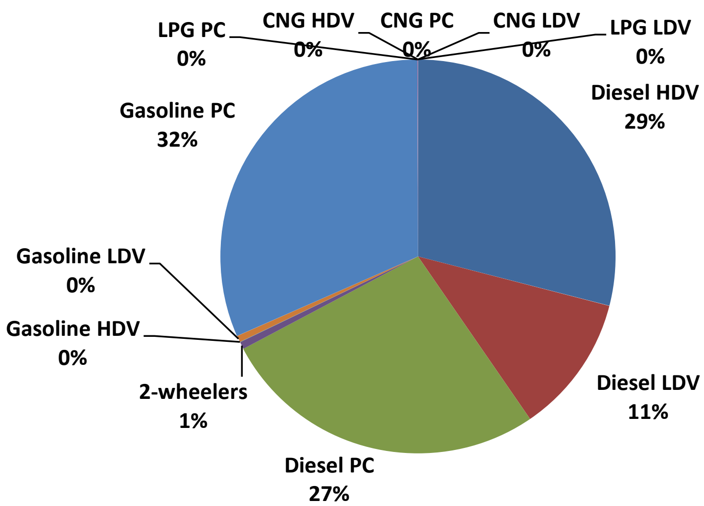


Figure 3.3.7 Fuel consumption share (PJ) per vehicle type for road transport in 2015.

Other mobile sources

It must be noted that the fuel consumption figures behind the Danish inventory for mobile equipment in the agriculture, forestry, industry, household and gardening (residential), and inland waterways (part of navigation) sectors, are less certain than for other mobile sectors. For these types of machinery, the DEA statistical figures do not directly provide fuel consumption information, and fuel consumption totals are subsequently estimated from activity data and fuel consumption factors. For recreational craft the latest historical year is 2004.

As seen in Figure 3.3.8, classified according to CRF the most important sectors are Agriculture/forestry/fisheries (1A4c), Industry-other (mobile machinery part of 1A2g) and Navigation (1A3d). Minor fuel consuming sectors are Civil Aviation (1A3a), Railways (1A3c), Other (military mobile and recreational craft: 1A5b), Commercial/institutional (1A4a) and Residential (1A4b).

The 1985-2015 time series are shown per fuel type in Figures 3.3.9-3.3.12 for diesel, gasoline, residual oil and jet fuel, respectively.

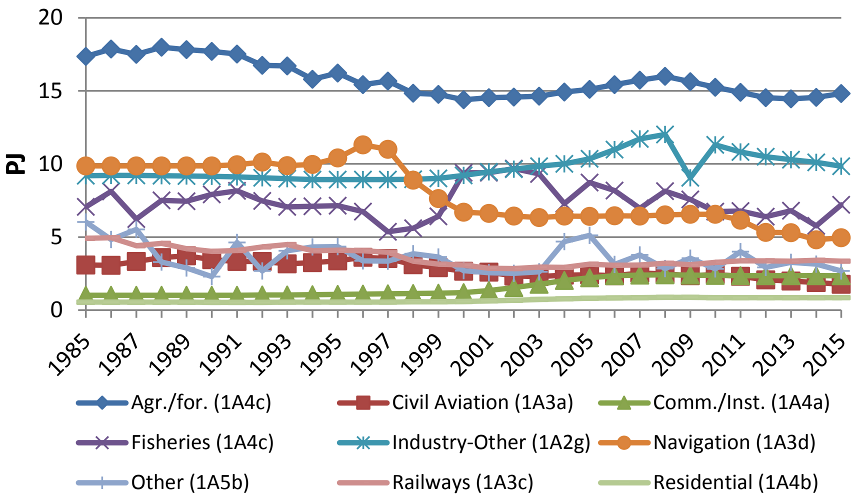


Figure 3.3.8 Total fuel consumption in CRF sectors for other mobile sources 1985-2015.

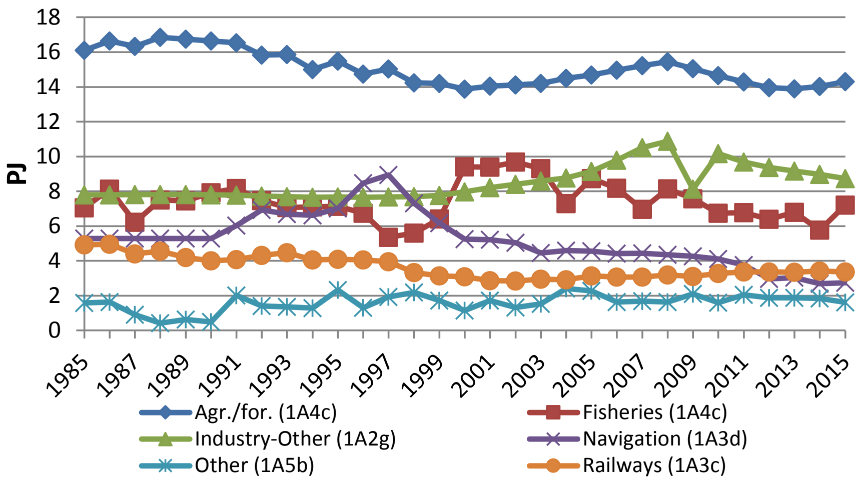


Figure 3.3.9 Diesel fuel consumption in CRF sectors for other mobile sources 1985-2015.

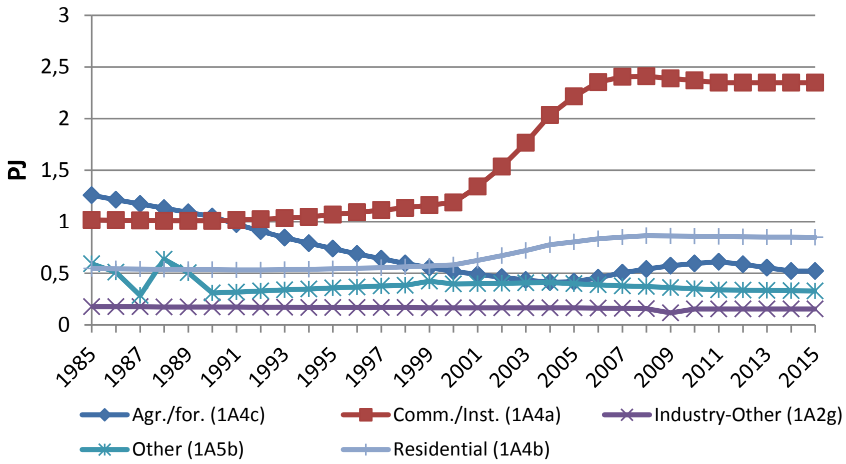


Figure 3.3.10 Gasoline fuel consumption in CRF sectors for other mobile source 1985-2015.

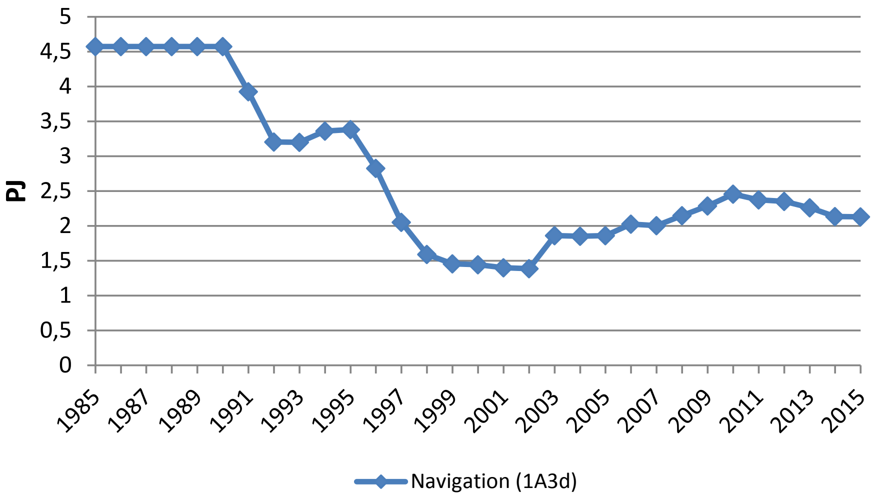


Figure 3.3.11 Residual oil fuel consumption in CRF sectors for other mobile sources 1985-2015.

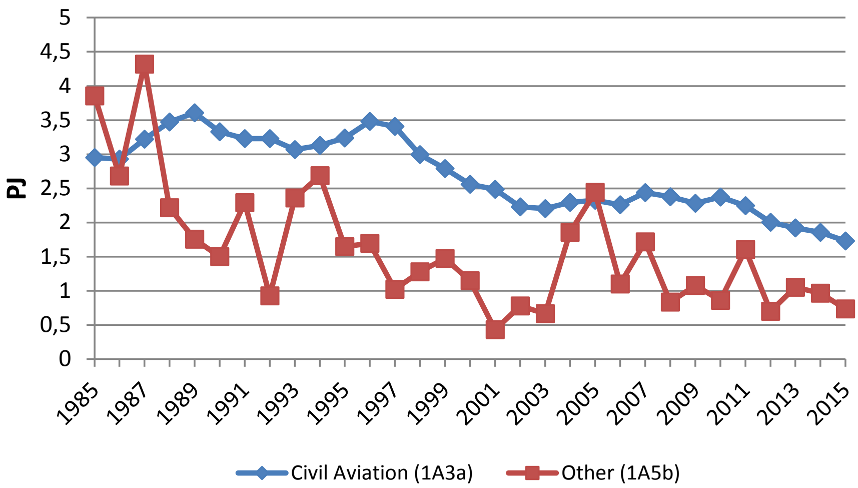


Figure 3.3.12 Jet fuel consumption in CRF sectors for other mobile sources 1985-2015.

In terms of diesel, the fuel consumption decreases for agricultural machines until 2000, due to a decline in the number of tractors and harvesters. After 2000, the increase in the engine sizes of new sold machines makes the total fuel consumption grow until 2008, whereas from 2008 to 2013 the turnover of old less fuel efficient machinery is the key factor for the total fuel consumption decrease. The fuel consumption for industry has increased from the beginning of the 1990's, due to an increase in the activities for construction machinery. The fuel consumption increase has been very pronounced in 2005-2008, for 2009; however, the global financial crisis has a significant impact on the building and construction activities. From 2009 onwards the fuel efficiency improvements for new sold vehicles is the main reason for total fuel consumption decline. For fisheries, the development in fuel consumption reflects the activities in this sector.

The Navigation sector comprises national sea transport (fuel consumption between two Danish ports including sea travel directly between Denmark and Greenland/Faroe Islands). For national sea transport, the diesel fuel consumption curve reflects the combination of traffic and ferries in use for regional ferries. From 1998 to 2000, a significant decline in fuel consumption is apparent. The most important explanation here is the closing of ferry service routes in connection with the opening of the Great Belt Bridge in 1997. The fuel consumption decreases in 2011 and 2012 are due to reductions in the number of round trips made by regional ferries. For railways, the gradual shift towards electrification explains the lowering trend in diesel fuel consumption and the emissions for this transport sector. The fuel consumed (and associated emissions) to produce electricity is accounted for in the stationary combustion part of the Danish inventories.

The largest gasoline fuel consumption is found for household and gardening machinery in the Commercial/Institutional (1A4a) and Residential (1A4b) sectors. Especially from 2001-2006, a significant fuel consumption increase is apparent due to considerable growth in the machinery stock. The decline in gasoline fuel consumption for Agriculture/forestry/fisheries (1A4c) is due to the gradual phasing out of gasoline-fuelled agricultural tractors.

In terms of residual oil there has been a substantial decrease in the fuel consumption for regional ferries. The fuel consumption decline is most significant from 1990-1992 and from 1997-1999.

The considerable variations from one year to another in military jet fuel consumption are due to planning and budgetary reasons, and the passing demand for flying activities. Consequently, for some years, a certain amount of jet fuel stock-building might disturb the real picture of aircraft fuel consumption. Civil aviation has decreased until 2004, since the opening of the Great Belt Bridge in 1997, both in terms of number of flights and total jet fuel consumption. From 2011 to 2012 the total consumption of jet fuel decreased significantly due to a drop in the number of domestic flights.

Bunkers

The residual oil and diesel oil fuel consumption fluctuations reflect the quantity of fuel sold in Denmark to international ferries, international warships, other ships with foreign destinations, transport to Greenland and the Faroe Islands, tank vessels and foreign fishing boats. For jet petrol, the sudden fuel consumption drop in 2002 is explained by the recession in the air traffic sector due to the events of September 11, 2001 and structural changes in the aviation business. In 2009, the impact of the global financial crisis on flying activities becomes very visible.

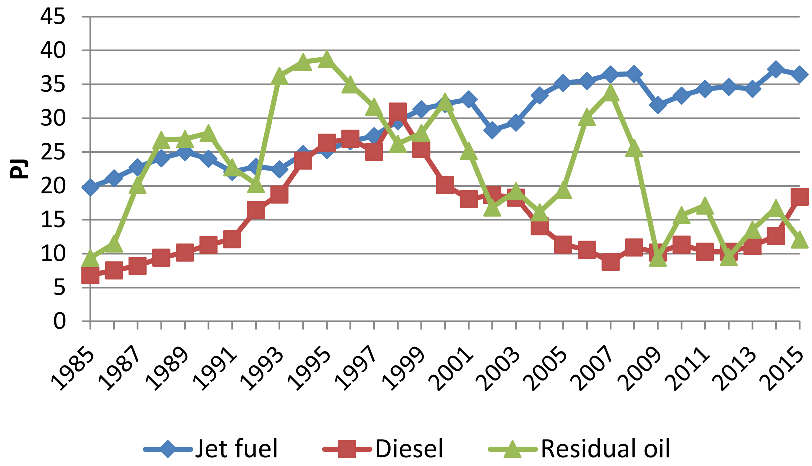


Figure 3.3.13 Bunker fuel consumption 1985-2015.

Emissions of SO_2, NO_X, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$ and BC

In Table 3.3.3 the SO_2, NO_X, NMVOC, CO NH_3, TSP, PM_{10}, $PM_{2.5}$ and BC emissions for road transport and other mobile sources are shown for 2015 in NFR sectors. The emission figures in the time series 1985-2015 are given in Annex 2.B.16 (NFR format) and are shown for 2015 in Annex 2.B.15 (CollectER format).

From 1985 to 2015, the road transport emissions of SO_2, NO_X, NMVOC, CO, PM (exhaust emissions; all size fractions) and BC have decreased by 99, 60, 90, 87, 74 and 64 %, respectively (Figures 3.3.14-3.3.18), whereas the NH_3 emissions have increased by 1589 % during the same time period (Figure 3.3.19).

For other mobile sources, the emission changes for SO_2, NO_X, NMVOC, CO and PM (all size fractions) are -96, -35, -43, -5, -78 and -76 %, respectively (Figures 3.3.21-3.3.25). The NH_3 emissions have increased by 11 % during the same time period (Figure 3.3.26).

Table 3.3.3 Emissions of SO_2, NO_X, NMVOC, CO NH_3, TSP, PM_{10}, $PM_{2.5}$ and BC in 2015 for road transport and other mobile sources.

	SO_2 tonnes	NO_x tonnes	NMVOC tonnes	CO tonnes	NH_3 tonnes	TSP tonnes	PM_{10} tonnes	$PM_{2.5}$ tonnes	BC tonnes
Manufacturing industries/Construction (mobile)	4	5187	901	5 102	2	368	368	368	245
Civil aviation (Domestic)	41	650	69	466	0	5	5	5	2
Road transport: Passenger cars	42	17 269	4 528	59 373	1 013	395	395	395	286
Road transport:Light duty vehicles	9	6 693	330	2 456	20	210	210	210	167
Road transport:Heavy duty vehicles	21	13 480	310	5 050	35	214	214	214	149
Road transport: Mopeds & motorcycles	0	140	1 384	7 407	1	23	23	23	3
Road transport: Gasoline evaporation	0	0	1 381	0	0	0	0	0	0
Road transport: Brake wear	0	0	0	0	0	521	510	203	14
Road transport: Tyre wear	0	0	0	0	0	937	562	393	143
Road transport: Road abrasion	0	0	0	0	0	1 157	578	312	0
Railways	2	2 010	138	295	1	50	50	50	32
National navigation (Shipping)	233	7 474	258	895	0	107	106	106	24
Commercial/Institutional: Mobile	1	219	3 573	72 587	0	67	67	67	3
Residential: Household and gardening (mobile)	0	92	1 826	27 020	0	15	15	15	1
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	7	6 288	1 388	15 268	4	466	466	466	286
Agriculture/Forestry/Fishing: National fishing	338	9 243	421	1 310	0	155	154	153	48
Other, Mobile	64	1 298	304	2 931	1	87	87	87	34
Road transport exhaust total	72	37 582	7 933	74 285	1 069	842	842	842	605
Road transport non exhaust total	0	0	0	0	0	2 614	1 651	909	157
Other mobile sources total	690	32 461	8 877	125 873	7	1 320	1 317	1 316	675
Domestic total	762	70 044	16 810	200 158	1 076	4 776	3 810	3 067	1 437
Civil aviation (International)	838	13 641	201	2 201	0	189	189	189	97
Navigation (International)	1 453	54 822	1 867	6 004	0	668	662	658	156

Road transport

The step-wise lowering of the sulphur content in diesel fuel has given rise to a substantial decrease in the road transport emissions of SO_2 (Figure 3.3.14). In 1999, the sulphur content was reduced from 500 ppm to 50 ppm (reaching gasoline levels), and for both gasoline and diesel the sulphur content was reduced to 10 ppm in 2005. Since Danish diesel and gasoline fuels have the same sulphur percentages, at present, the 2015 shares for SO_2 emissions and fuel consumption for passenger cars, heavy-duty vehicles, light-duty vehicles and 2-wheelers are the same in each case: 58, 29, 12 and 1 %, respectively (Figure 3.3.20).

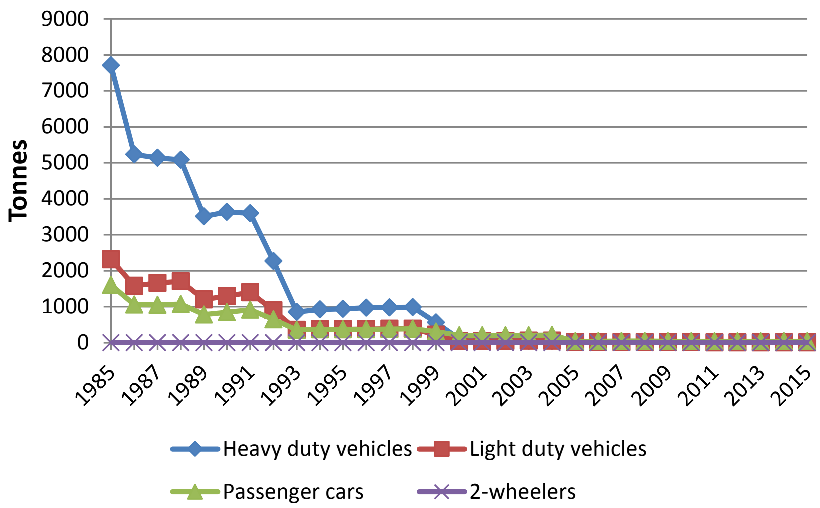


Figure 3.3.14 SO_2 emissions (tonnes) per vehicle type for road transport 1985-2015.

Historically, the emission totals of NMVOC and CO have been very dominated by the contributions coming from private cars, as shown in Figures 3.3.16- 3.3.17. However, the NMVOC and CO (and NO_x) emissions from this vehicle type have shown a steady decreasing tendency since the introduction of private catalyst cars in 1990 (EURO I) and the introduction of even more emission-efficient EURO II, III, IV and V private cars (introduced in 1997, 2001, 2006 and 2011, respectively).

For NO_x the emission decrease for passenger cars is composed of a significant drop in emissions from gasoline cars driven by technology improvements, and an increase in emissions from diesel cars due to the dieselization of the Danish vehicle fleet, and almost unchanged emission factors for diesel passenger cars throughout the period regardless of EU emission legislation demands. For light duty vehicles the NO_x emission trend is also the result of a technology driven emission reduction for gasoline vehicles, and a traffic induced emission increase for diesel vehicles; the emission factors for the latter vehicle category have been relatively constant over the years just as for diesel cars.

For heavy duty vehicles the real traffic emissions are not reduced in the order as intended by the EU emission legislation. Most markedly for Euro II engines the emission factors are even higher than for Euro I due to the so-called engine cycle-beating effect. Outside the legislative test cycle stationary measurement points, the electronic engine control for heavy duty Euro II engines switches to a fuel efficient engine running mode, thus leading to increasing NO_x emissions (Figure 3.3.15). However, the reduction in transport activities due to the global financial crisis causes the NO_x emissions for heavy duty vehicles to decrease significantly in 2008 and 2009.

Exhaust particulate emissions from road transportation vehicles are well below $PM_{2.5}$. The emissions from light- and heavy-duty vehicles have significantly decreased since the mid-1990s due to gradually stricter EURO emission standards. In recent years until 2008 the environmental benefit of introducing gradually cleaner diesel private cars has been somewhat outbalanced by an increase in sales of new vehicles. After 2008 the PM emissions gradually become lower due to the increasing number of Euro V cars equipped with particulate filter sold in Denmark from 2006 onwards (Figure 3.3.18).

An undesirable environmental side effect of the introduction of catalyst cars is the increase in the emissions of NH_3 from the first two generations of catalyst cars (Euro I and II) compared to conventional cars. The emission factors for later catalytic converter technologies are considerably lower than the ones for Euro I and II, thus causing the emissions to decrease from 2001 onwards (Figure 3.3.19).

The 2015 emission shares for passenger cars, heavy-duty vehicles, light-duty vehicles and 2-wheelers for NO_x (46, 36, 18 and 0 %), NMVOC (57, 4, 4 and 18 %), CO (80, 7, 3 and 10 %), PM (47, 25, 25 and 3 %) and NH_3 (95, 3, 2 and 0 %), are also shown in Figure 3.3.20.4

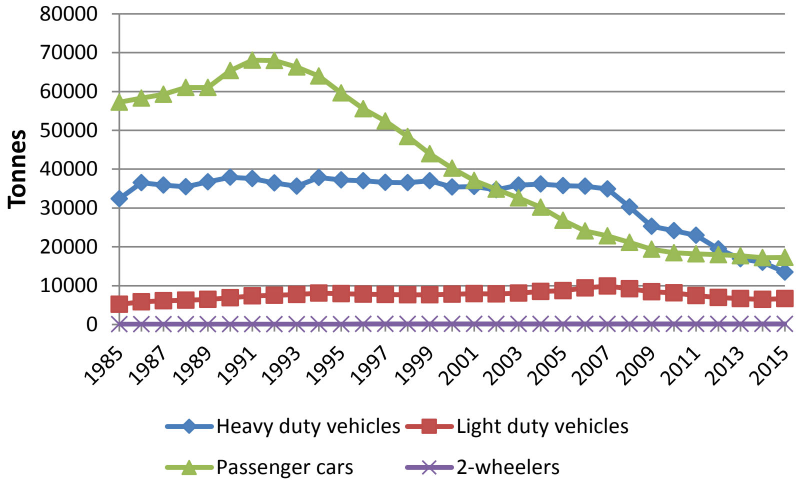


Figure 3.3.15 NO_X emissions (tonnes) per vehicle type for road transport 1985-2015.

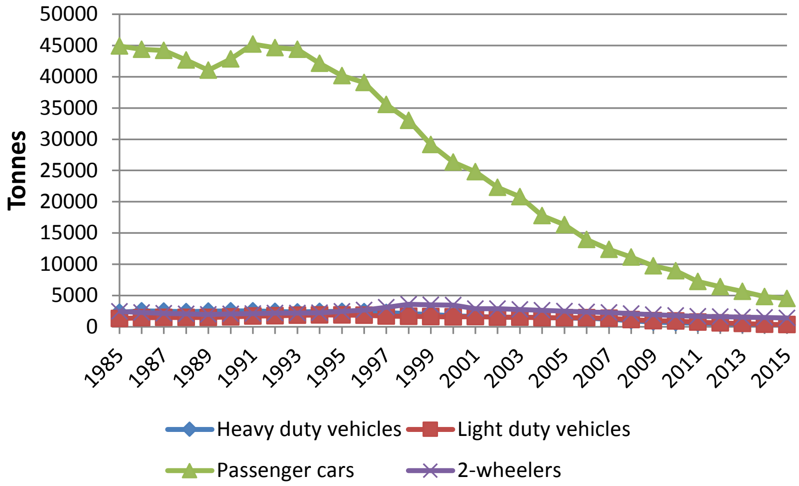


Figure 3.3.16 NMVOC emissions (tonnes) per vehicle type for road transport 1985-2015.

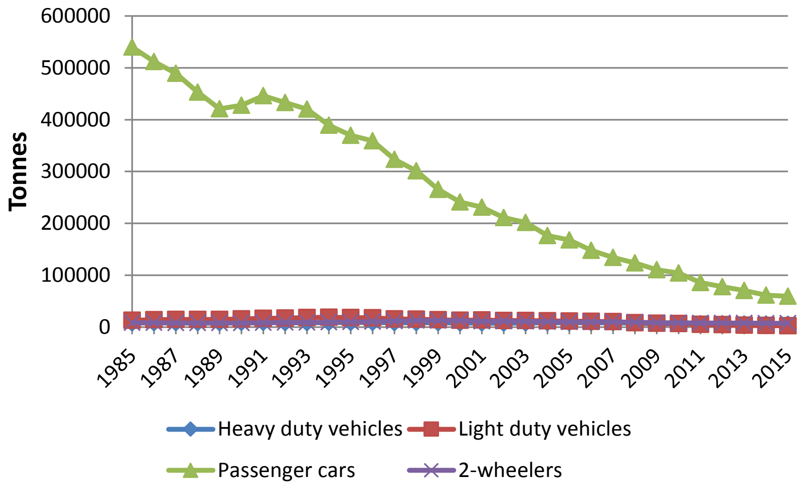


Figure 3.3.17 CO emissions (tonnes) per vehicle type for road transport 1985-2015.

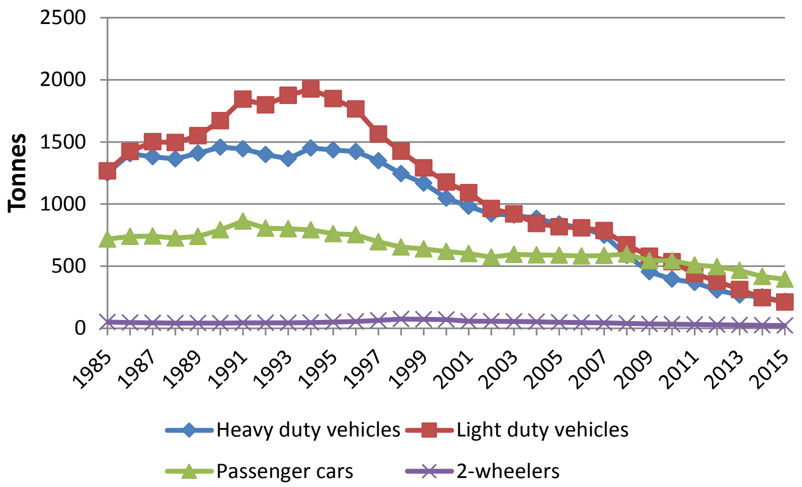


Figure 3.3.18 PM emissions (tonnes) per vehicle type for road transport 1985-2015.

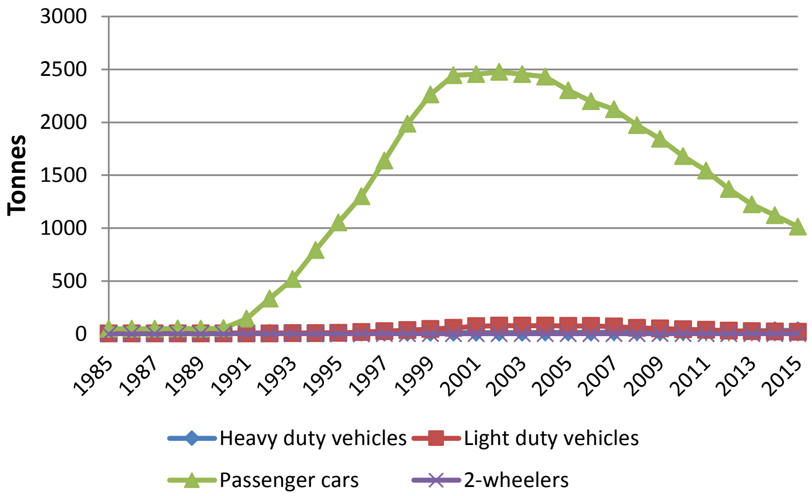


Figure 3.3.19 NH_3 emissions (tonnes) per vehicle type for road transport 1985-2015.

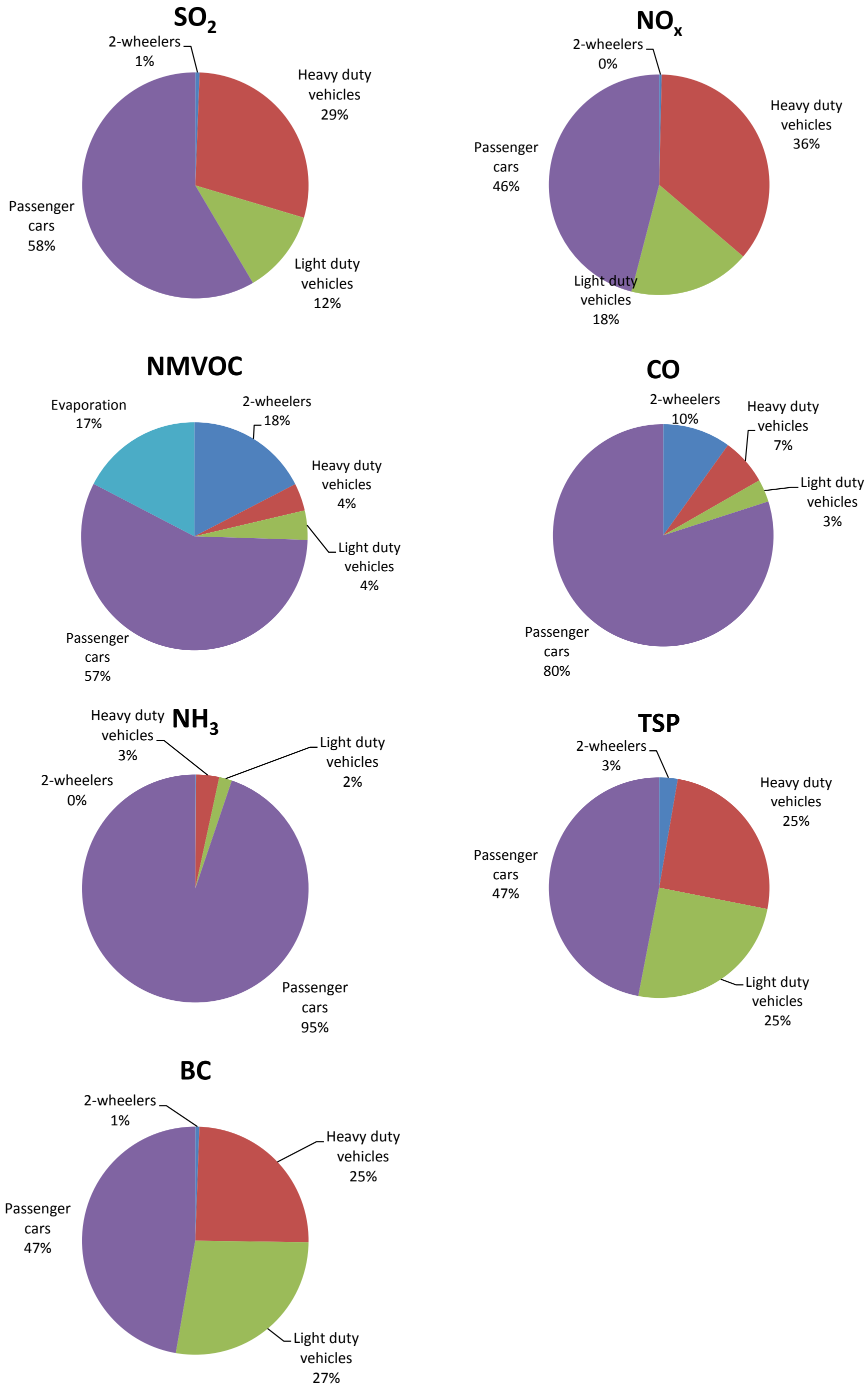


Figure 3.3.20 SO_2, NO_X, NMVOC, CO, NH_3, PM and BC emission shares pr vehicle type for road transport in 2015.

Non-exhaust emissions of TSP, PM_{10}, $PM_{2.5}$ and BC

Apart from the exhaust emission estimates of particulate matter (PM), the Danish emission inventories also comprise the non-exhaust PM emissions coming from road transport brake and tyre wear, and road abrasion.

In Table 3.3.3, the non-exhaust TSP, PM_{10}, $PM_{2.5}$ and BC emissions for road transport are shown for 2015 in NFR sectors. The activity data and emission factors are also shown in Annex 2.B.15.

The respective source category distributions for TSP, PM_{10} and $PM_{2.5}$ emissions are identical for each of the non-exhaust emission type's brake wear, tyre wear and road abrasion, and, hence, only the PM_{10} distributions are shown in Figure 3.3.28. Passenger cars caused the highest emissions in 2015, followed by trucks, light-duty vehicles, buses and 2-wheelers.

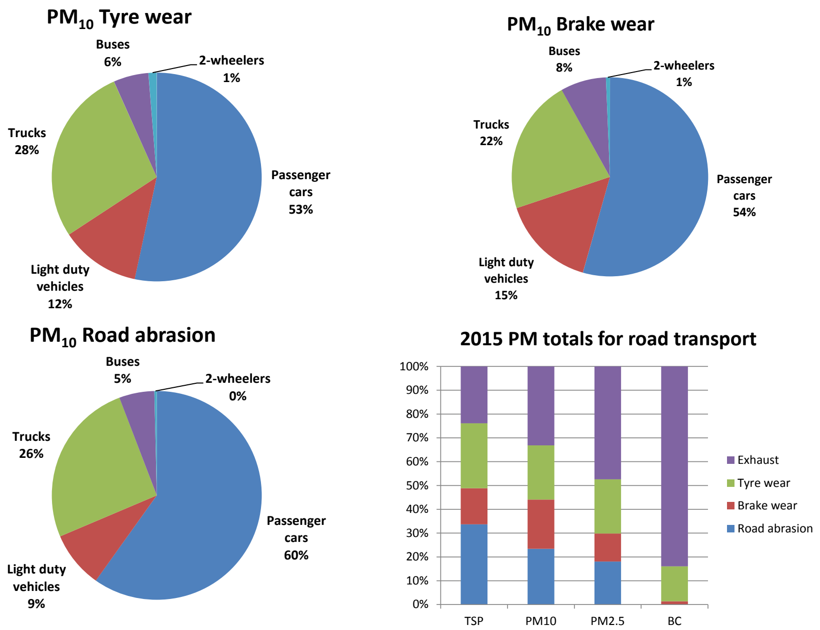


Figure 3.3.21 Brake and tyre wear and road abrasion PM_{10} emission shares and PM and BC exhaust/non-exhaust distributions for road traffic in 2015.

Figure 3.3.21 also shows the exhaust/non-exhaust distribution of the total particulate emissions from road transport, for each of the size classes TSP, PM_{10} and $PM_{2.5}$ and for BC. The exhaust emission shares of total road transport TSP, PM_{10}, $PM_{2.5}$ and BC are 24, 33, 47 and 84 %, respectively, in 2015. For brake and tyre wear and road abrasion the TSP shares are 15, 27 and 34 %, respectively. The same three sources have PM_{10} shares of 21, 23 and 21 %, respectively, $PM_{2.5}$ shares of 12, 23 and 18 %, and BC shares of 1, 15 and 0 %, respectively. In general, the non-exhaust shares of total particulate emissions are expected to increase in the future as total exhaust emissions decline. The latter emission trend is due to the stepwise strengthening of exhaust emission standards for all vehicle types.

Other mobile sources

For SO_2 the trends in the Navigation (1A3d) emissions shown in Figure 3.3.22 mainly follow the development of the heavy fuel oil consumption (Figure 3.3.11). Though, from 1993 to 1995 relatively higher contents of sulphur in the fuel (estimated from sales) cause a significant increase in the emissions of SO_2. The SO_2 emissions for Fisheries (1A4c) correspond with the development in the consumption of marine gas oil. The main explanation for the development of the SO_2 emission curves for Railways (1A3c) and non-road machinery in Agriculture/forestry (1A4c) and Industry (1A2f), are the stepwise sulphur content reductions for diesel used by machinery in these sectors.

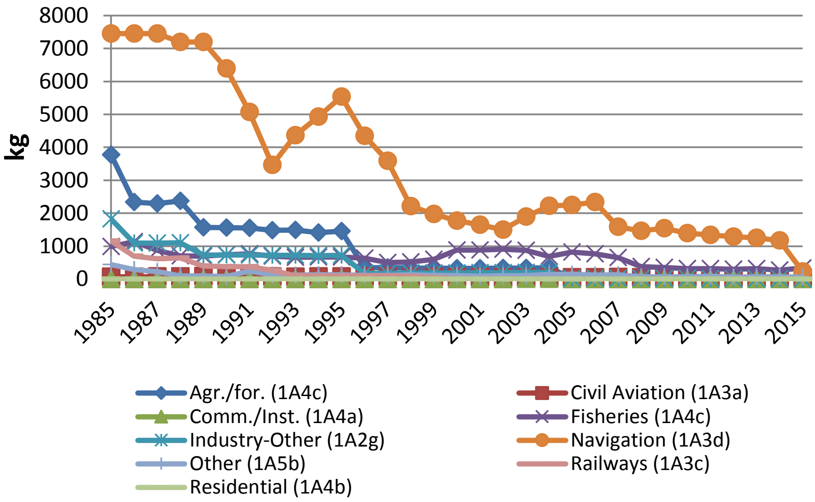


Figure 3.3.22 SO_2 emissions (ktonnes) in NFR sectors for other mobile sources 1985-2015.

In general, the emissions of NO_X, NMVOC and CO from diesel-fuelled working equipment and machinery in agriculture, forestry and industry have decreased slightly since the end of the 1990s due to gradually strengthened emission standards given by the EU emission legislation directives. For industry, the emission impact from the global financial crisis becomes very visible for 2009.

NO_X emissions mainly come from diesel machinery, and the most important sources are Agriculture/forestry/fisheries (1A4c), Navigation (1A3d), Industry (1A2f) and Railways (1A3c), as shown in Figure 3.3.23. The 2015 emission shares are 43, 22, 21 and 7 %, respectively (Figure 3.3.28). Minor emissions come from the sectors, Civil Aviation (1A3a), Other (1A5) and Residential (1A4b).

The NO_X emission trend for Navigation, Fisheries and Agriculture is determined by fuel consumption fluctuations for these sectors, and the development of emission factors. For ship engines the emission factors tend to increase for new engines until mid-1990s. After that, the emission factors gradually reduce until 2000, bringing them to a level comparable with the emission limits for new engines in this year. For agricultural machines, there have been somewhat higher NO_x emission factors for 1991-stage I machinery, and an improved emission performance for stage I and II machinery since the late 1990s.

The emission development from 1985 to 2008 for industry NO_x is the product of a fuel consumption increase, most pronounced from 2005-2008, and a development in emission factors as explained for agricultural machinery. For railways, the gradual shift towards electrification explains the declining trend in diesel fuel consumption and NO_X emissions for this transport sector until 2001.

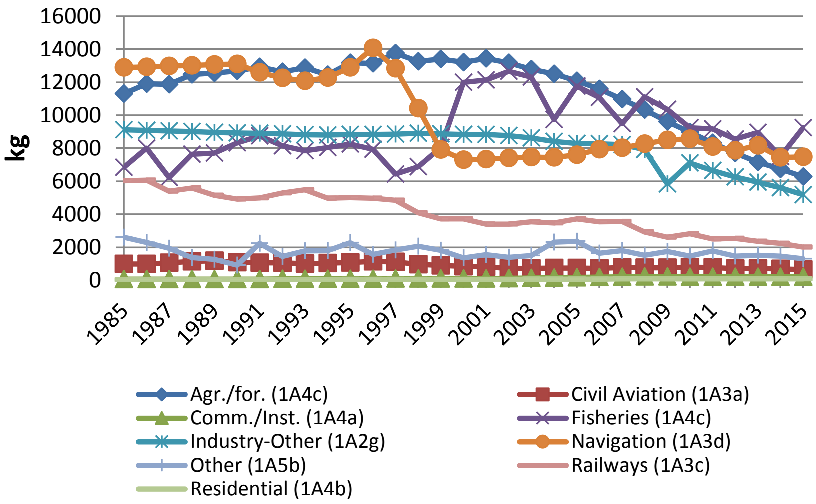


Figure 3.3.23 NO_X emissions (tonnes) in NFR sectors for other mobile sources 1985-2015.

The 1985-2015 time series of NMVOC and CO emissions are shown in Figures 3.3.24 and 3.3.25 for other mobile sources. The 2015 sector emission shares are shown in Figure 3.3.28. For NMVOC, the most important sectors are Commercial/Institutional (1A4a), Agriculture/forestry/-fisheries (1A4c), Residential (1A4b) and Industry (1A2g) with 2015 emission shares of 40, 21, 21 and 10 %, respectively. The same five sectors also contribute with most of the CO emissions. For Commercial/Institutional (1A4a), Residential (1A4b), Agriculture/forestry/fisheries (1A4c) and Industry (1A2g) the emission shares are 58, 22, 13 and 4 %, respectively. Minor NMVOC and CO emissions come from Navigation (1A3d), Railways (1A3c), Civil Aviation (1A3a) and Other (1A5).

For NMVOC and CO, the significant emission increases for the commercial/institutional and residential sectors after 2000 are due to the increased number of gasoline working machines. Improved NMVOC emission factors for diesel machinery in agriculture and gasoline equipment in forestry (chain saws) are the most important explanations for the NMVOC emission decline in the Agriculture/forestry/fisheries sector. This explanation also applies for the industrial sector, which is dominated by diesel-fuelled machinery. From 1997 onwards, the NMVOC emissions from Navigation decrease due to the gradually phase-out of the 2-stroke engine technology for recreational craft. The main reason for the significant 1985-2006 CO emission decrease for Agriculture/forestry-/fisheries is the phasing out of gasoline tractors.

As shown in Figure 3.3.28, for other mobile sources the largest TSP contributors in 2015 are Agriculture/forestry/fisheries (1A4c), Industry (1A2f) and Navigation (1A3d), with emission shares of 47, 28 and 8 %, respectively. The remaining sectors: Railways (1A3c), Civil aviation (1A3a), Other (1A5) and Residential (1A4b) represent only minor emission sources.

The 1985-2015 TSP emissions for navigation and fisheries are determined by the fuel consumption fluctuations in these years, and the development of the emission factors, which to a major extent is a function of the fuel sulphur content. With fuel consumption being at a rather constant level for 1985-2015 (Figure 3.3.9), the emission development for Agriculture/forestry is mainly determined by the gradually reducing emission factors over the time period.

The TSP emission development for industrial non-road machinery is the product of a fuel consumption increase from 1985 to 2008 and decreasing fuel consumption from 2009 onwards (Figure 3.3.9), and a development in emission factors, as explained for agricultural machinery. The TSP emission explanations for railways are the same as for NO_x (Figure 3.3.23).

The amounts of NH_3 emissions calculated for other mobile sources are very small. The largest emission sources are Agriculture-/forestry/fisheries (1A4c), Industry (1A2f), Other (1A5b) and Railways (1A3c), with emission shares of 50, 26, 10 and 9 %, respectively.

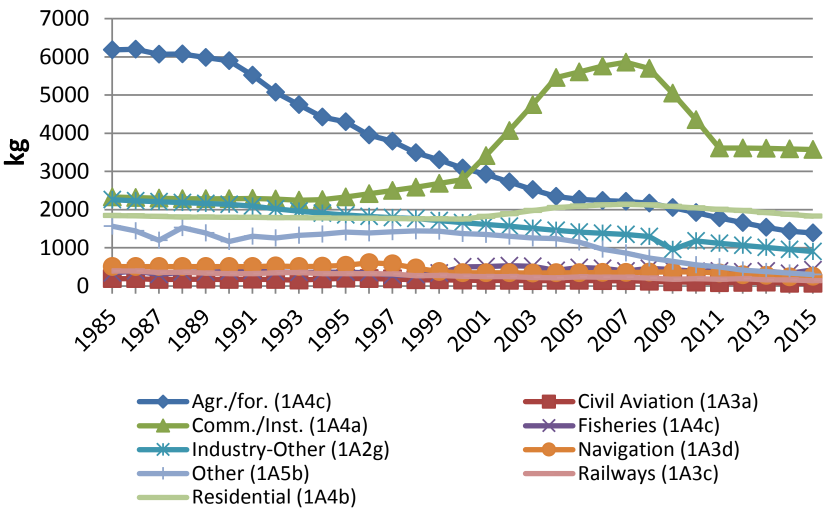


Figure 3.3.24 NMVOC emissions (tonnes) in NFR sectors for other mobile sources 1985-2015.

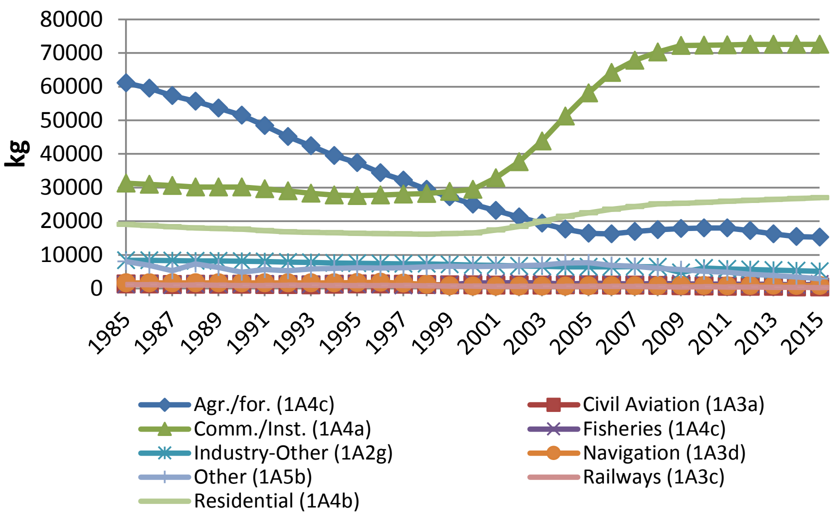


Figure 3.3.25 CO emissions (tonnes) in NFR sectors for other mobile sources 1985-2015.

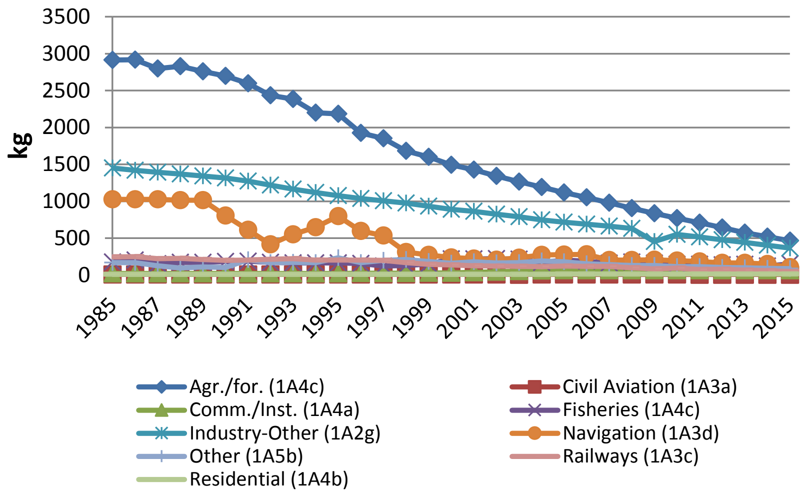


Figure 3.3.26 TSP emissions (tonnes) in NFR sectors for other mobile sources 1985-2015.

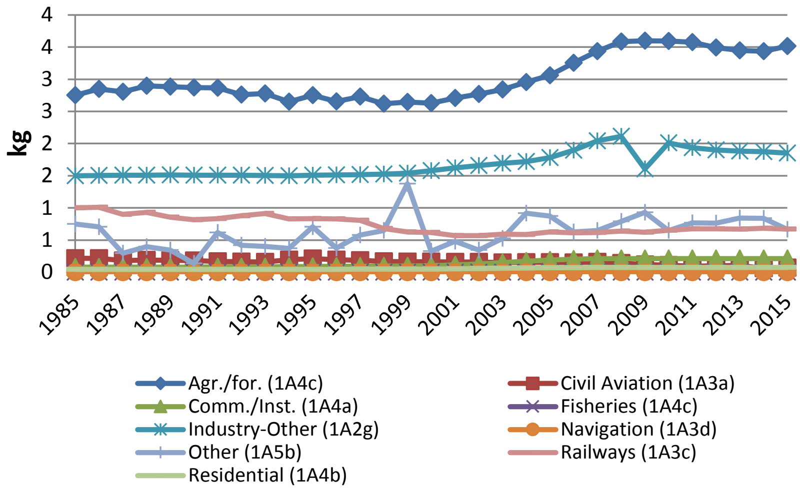


Figure 3.3.27 NH_3 emissions (tonnes) in NFR sectors for other mobile sources 1985-2015.

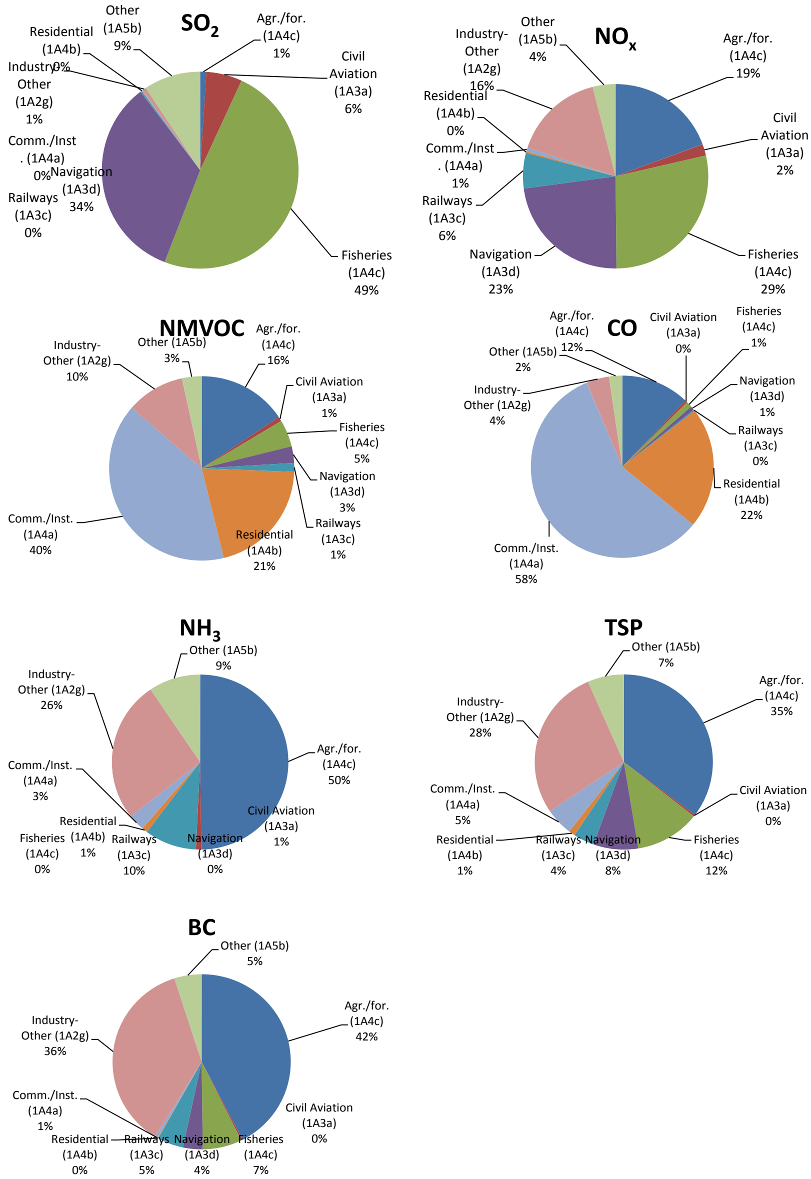


Figure 3.3.28 SO_2, NO_X, NMVOC, CO, NH_3, PM and BC emission shares pr vehicle type for other mobile sources in 2015.

Heavy metals

In Table 3.3.4, the heavy metal emissions for road transport and other mobile sources are shown for 2015 in NFR sectors. The emission figures in the time series 1990-2015 are given in Annex 2.B.16 (NFR format) and are shown for 1990 and 2015 in Annex 2.B.15 (CollectER format).

Table 3.3.4 Heavy metal emissions in 2015 for road transport and other mobile sources.

	Arsenic	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Selenium	Zinc
	kg	kg	kg	kg	kg	kg	kg	kg	kg
Manufacturing industri-es/Construction (mobile)	0	2	6	5	1	2	10	0	358
Civil aviation (Domestic)	0	0	0	0	0	0	575	0	2
Road transport: Passenger cars	0	29	63	89	15	32	128	0	5 837
Road transport:Light duty vehicles	0	4	14	10	2	4	24	0	831
Road transport:Heavy duty vehicles	0	7	26	18	6	7	41	0	1 367
Road transport: Mopeds & motorcycles	0	0	0	0	0	0	0	0	21
Road transport: Gasoline evaporation	0	0	0	0	0	0	0	0	0
Road transport: Brake wear	5	4	60	40 008	0	58	5 166	10	8 633
Road transport: Tyre wear	1	2	3	15	0	24	75	19	10 245
Road transport: Road abrasion	0	0	23	12	0	18	54	0	87
Railways	0	1	2	2	0	1	4	0	125
National navigation (Shipping)	29	2	13	29	4	1 568	17	34	79
Commercial/Institutional: Mobile	0	1	1	2	0	1	2	0	118
Residential: Household and gar-dening (mobile)	0	0	0	1	0	0	1	0	43
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	0	3	10	7	2	3	16	0	560
Agriculture/Forestry/Fishing: National fishing	8	2	7	8	8	12	17	34	84
Other, Mobile	0	0	1	1	0	0	50	0	81
Road transport exhaust total	1	40	102	118	23	43	194	0	8 056
Road transport non exhaust total	6	7	86	40 034	0	100	5 296	29	18 965
Other mobile sources total	38	10	40	55	17	1 587	692	68	1 451
Domestic total	44	57	228	40 207	40	1 730	6 182	97	28 472
Civil aviation (International)	0	0	0	0	0	0	94	0	0
Navigation (International)	169	13	76	169	27	8 890	102	204	481

The heavy metal emission estimates for road transport are based on a national research study made by Winther and Slentø (2010). The latter study calculate the exhaust related emissions from fuel and engine oil as well as the wear related emissions from tyre, brake and road wear. Apart from Pb, the emission factors only deviate to a less extent due to changes in fleet and mileage composition over the years, which bring relative changes in fuel consumption per fuel type, engine oil use and aggregated emission factors for brake, tyre and road wear.

The most important exhaust related emissions for road transport are Cd, Cr, Hg and Zn. the most important wear related emissions are Cu and Pb almost solely coming from tyre wear, and Zn from brake and tyre wear. For other mobile sources, the most important emission contributions are calculated for Ni, Se and As, coming from the use of marine diesel oil in fisheries and navigation and residual oil in navigation.

The Figures 3.3.29 and 3.3.30 show the heavy metal emission distributions for all road transport sources split into vehicle categories, and for other mobile sectors, respectively.

For non-road mobile machinery in agriculture, forestry, industry, commercial/institutional and recreational, as well as military and railways, fuel related emission factors from road transport are used derived for the year 2009.

For civil aviation jet fuel no emissions are estimated due to lack of emission data, whereas for aviation gasoline fuel related emission factors for road transport gasoline is used derived for the year 2009, except for Pb where national data exist.

For navigation and fisheries, the heavy metal emission factors are fuel related, and are taken from the EMEP/EEA guidebook.

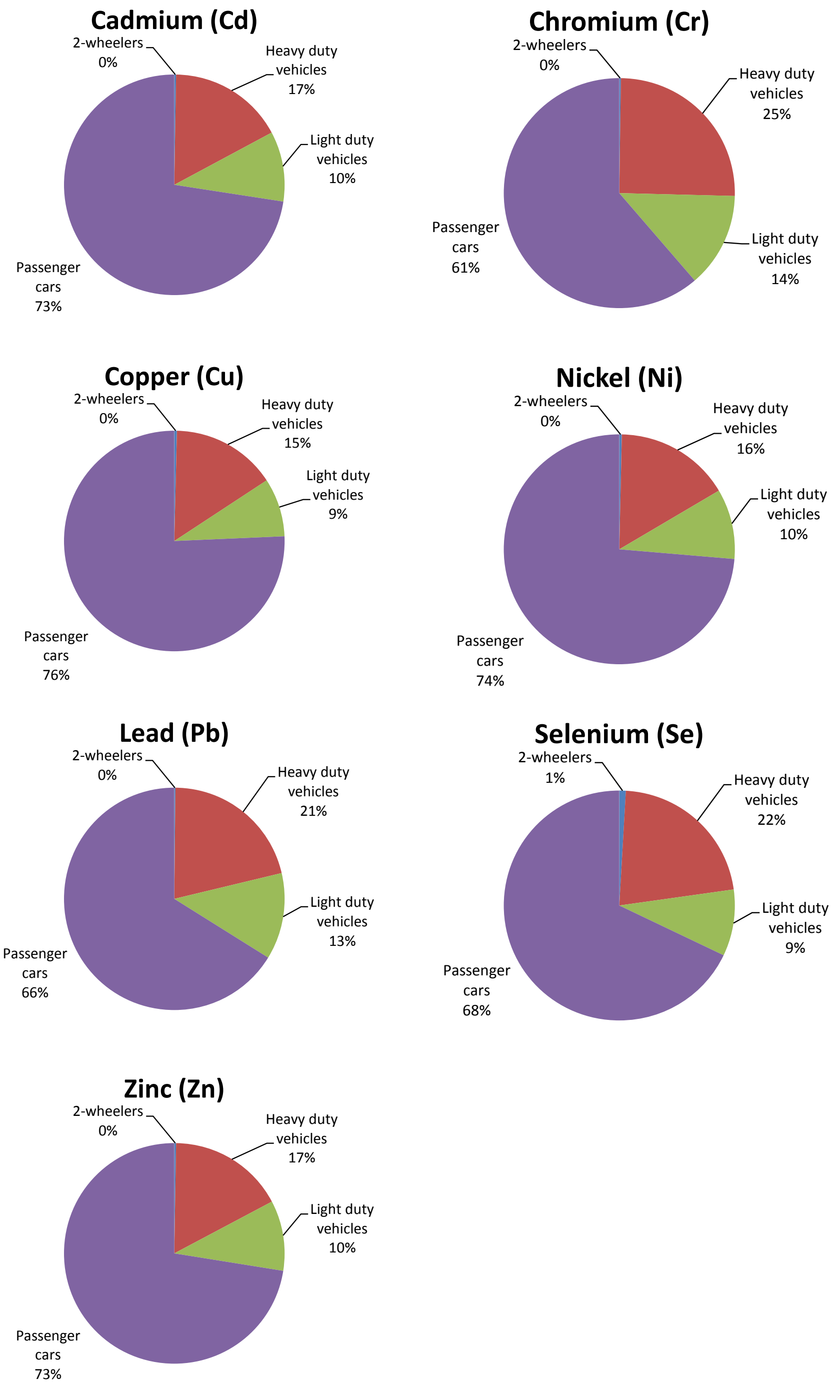
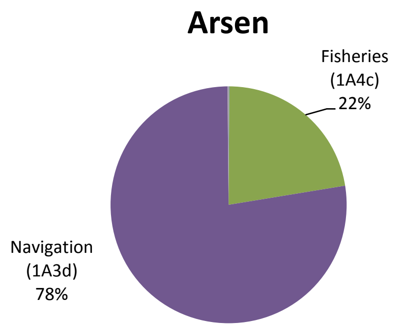
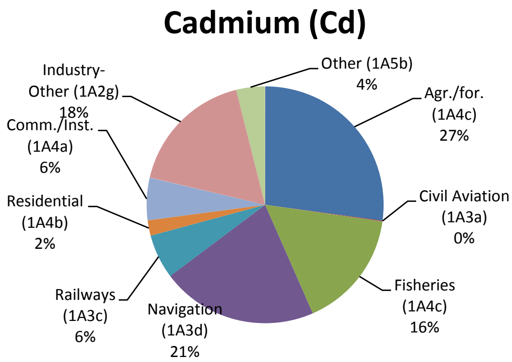
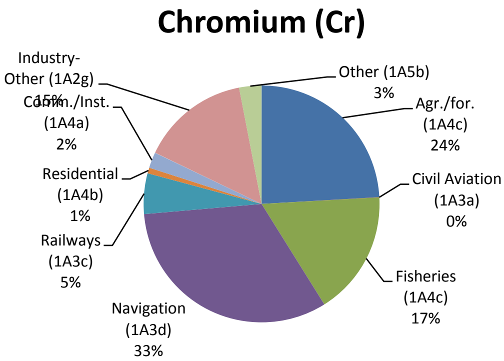
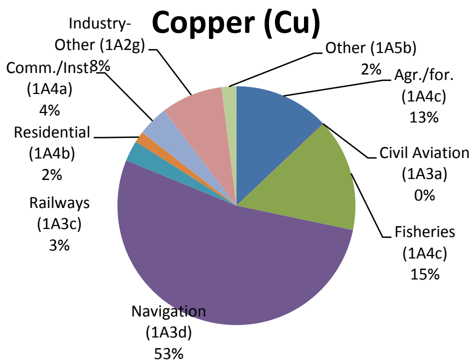


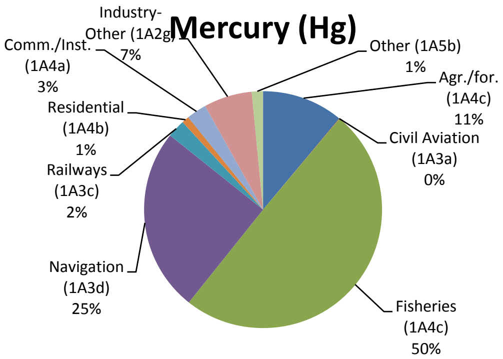
Figure 3.3.29 Heavy metal emission shares for road transport in 2015.

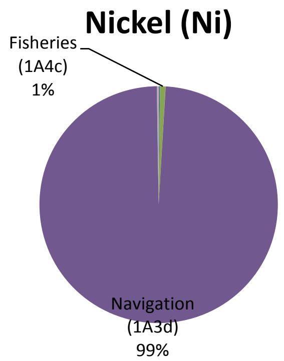

Arsen
Fisheries (1A4c) 22%
Navigation (1A3d) 78%

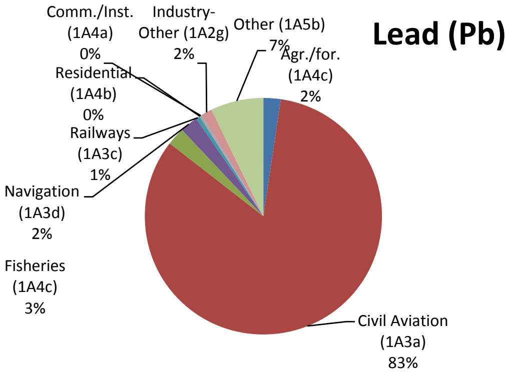

Cadmium (Cd)
Industry-Other (1A2g) 18%
Other (1A5b) 4%
Agr./for. (1A4c) 27%
Comm./Inst. (1A4a) 6%
Civil Aviation (1A3a) 0%
Residential (1A4b) 2%
Fisheries (1A4c) 16%
Railways (1A3c) 6%
Navigation (1A3d) 21%

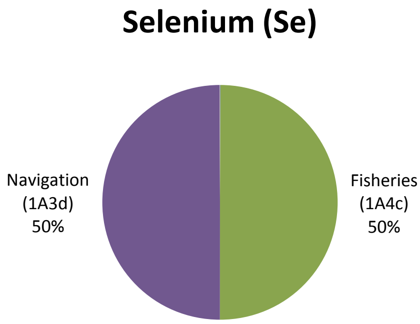

Chromium (Cr)
Industry-Other (1A2g) 15%
Other (1A5b) 3%
Comm./Inst. (1A4a) 2%
Agr./for. (1A4c) 24%
Residential (1A4b) 1%
Civil Aviation (1A3a) 0%
Railways (1A3c) 5%
Fisheries (1A4c) 17%
Navigation (1A3d) 33%


Copper (Cu)
Industry-Other (1A2g) 8%
Other (1A5b) 2%
Comm./Inst. (1A4a) 4%
Agr./for. (1A4c) 13%
Residential (1A4b) 2%
Civil Aviation (1A3a) 0%
Railways (1A3c) 3%
Fisheries (1A4c) 15%
Navigation (1A3d) 53%


Mercury (Hg)
Industry-Other (1A2g) 7%
Comm./Inst. (1A4a) 3%
Other (1A5b) 1%
Agr./for. (1A4c) 11%
Residential (1A4b) 1%
Civil Aviation (1A3a) 0%
Railways (1A3c) 2%
Navigation (1A3d) 25%
Fisheries (1A4c) 50%


Nickel (Ni)
Fisheries (1A4c) 1%
Navigation (1A3d) 99%


Lead (Pb)
Comm./Inst. (1A4a) 0%
Industry-Other (1A2g) 2%
Other (1A5b) 7%
Agr./for. (1A4c) 2%
Residential (1A4b) 0%
Railways (1A3c) 1%
Navigation (1A3d) 2%
Fisheries (1A4c) 3%
Civil Aviation (1A3a) 83%


Selenium (Se)
Navigation (1A3d) 50%
Fisheries (1A4c) 50%

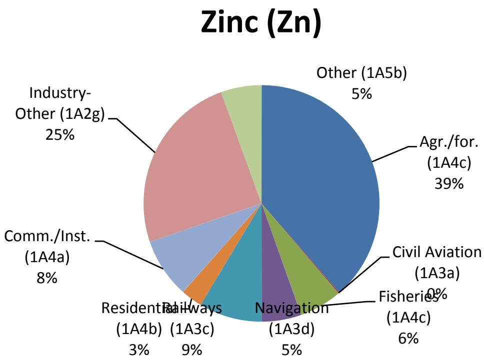

Zinc (Zn)
Other (1A5b) 5%
Industry-Other (1A2g) 25%
Agr./for. (1A4c) 39%
Comm./Inst. (1A4a) 8%
Civil Aviation (1A3a) 0%
Residential (1A4b) 3%
Railways (1A3c) 9%
Navigation (1A3d) 5%
Fisheries (1A4c) 6%

Figure 3.3.30 Heavy metal emission shares for other mobile sources in 2015.

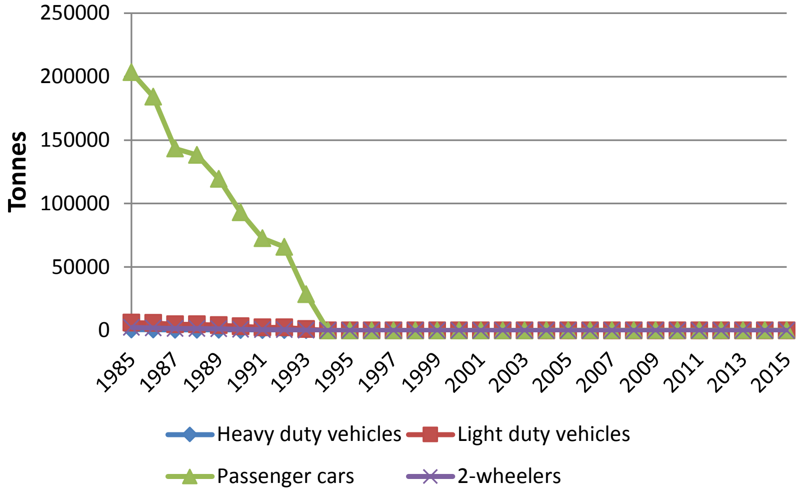


Figure 3.3.31 Pb emissions (kg) pr vehicle type for road transport 1985-2015.

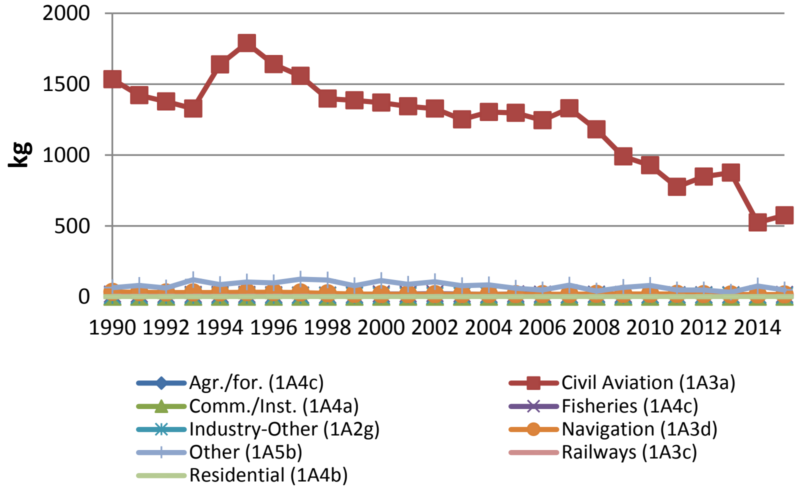


Figure 3.3.32 Pb emissions (kg) in NFR sectors for other mobile sources 1990-2015.

Dioxin and PAH

In Table 3.3.5, the dioxin, PAH, HCB and PCB emissions for road transport and other mobile sources are shown for 2015 in NFR sectors. The emission figures in the time series 1990-2015 are given in Annex 2.B.16 (NFR format) and are shown for 1990 and 2015 in Annex 2.B.15 (CollectER format).

Table 3.3.5 Dioxin, PAH, HCB and PCB emissions in 2015 for road transport and other mobile sources.

	HCB	Dioxins/Furans	Benzo(b) flouranthene	Benzo(k) flouranthene	Benzo(a) pyrene	Indeno (1,2,3-c,d) pyrene	PCB
	g	g	kg	kg	kg	kg	g
Manufacturing industries/Construction (mobile)	0.054	0.007	4	4	2	2	5
Civil aviation (Domestic)	0.000	0.000	0	0	0	0	0
Road transport: Passenger cars	0.272	0.048	52	40	46	46	1
Road transport:Light duty vehicles	0.115	0.010	13	10	11	11	0
Road transport:Heavy duty vehicles	0.293	0.051	26	29	4	7	25
Road transport: Mopeds & motorcycles	0.000	0.014	0	0	0	0	0
Road transport: Gasoline evaporation	0.000	0.000	0	0	0	0	0
Road transport: Brake wear	0.000	0.000	0	0	0	0	0
Road transport: Tyre wear	0.000	0.000	0	0	0	0	0
Road transport: Road abrasion	0.000	0.000	0	0	0	0	0
Railways	0.021	0.002	1	1	0	0	2
National navigation (Shipping)	0.013	0.062	2	1	0	3	0
Commercial/Institutional: Mobile	0.000	0.012	0	0	0	1	0
Residential: Household and gardening (mobile)	0.000	0.004	0	0	0	0	0
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	0.088	0.013	7	7	4	4	8
Agriculture/Forestry/Fishing: National fishing	0.014	0.087	5	2	1	9	0
Other, Mobile	0.010	0.003	1	1	0	1	1
Road transport exhaust total	0.680	0.123	91	79	62	63	26
Road transport non exhaust total	0.000	0.000	0	0	0	0	0
Other mobile sources total	0.199	0.190	22	17	9	20	15
Domestic total	0.879	0.313	113	96	71	83	41
Civil aviation (International)	0.000	0.000	0	0	0	0	0
Navigation (International)	0.078	0.383	14	7	4	24	0

For mobile sources, road transport displays the largest emission of dioxins and PAH. The dioxin emission share for road transport is 39 % of all mobile emissions in 2015, whereas Agriculture/forestry-/fisheries and Navigation have smaller shares of 32 and 20 %. For the different PAH components, road transport shares are around 80 % of total emissions for mobile sources. The remaining emissions almost solely come from Agriculture/forestry-/fisheries, Navigation and Industry with Agriculture/forestry/fisheries as the largest source.

Figures 3.3.33 and 3.3.34 show the dioxin and PAH emission distributions into vehicle categories and other mobile sectors, respectively.

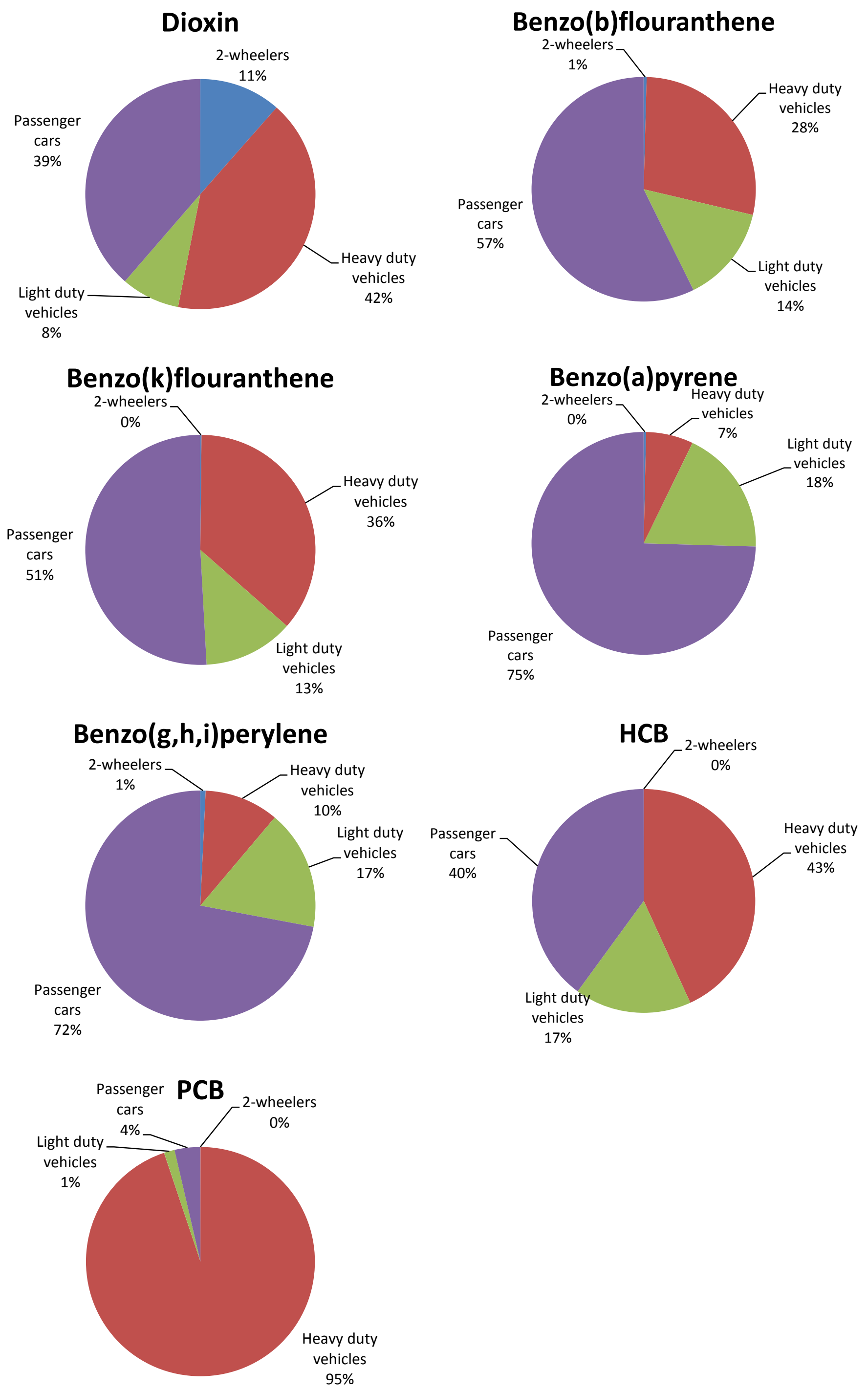


Figure 3.3.33 Dioxin, PAH, HCB and PCB emission shares for road transport in 2015.

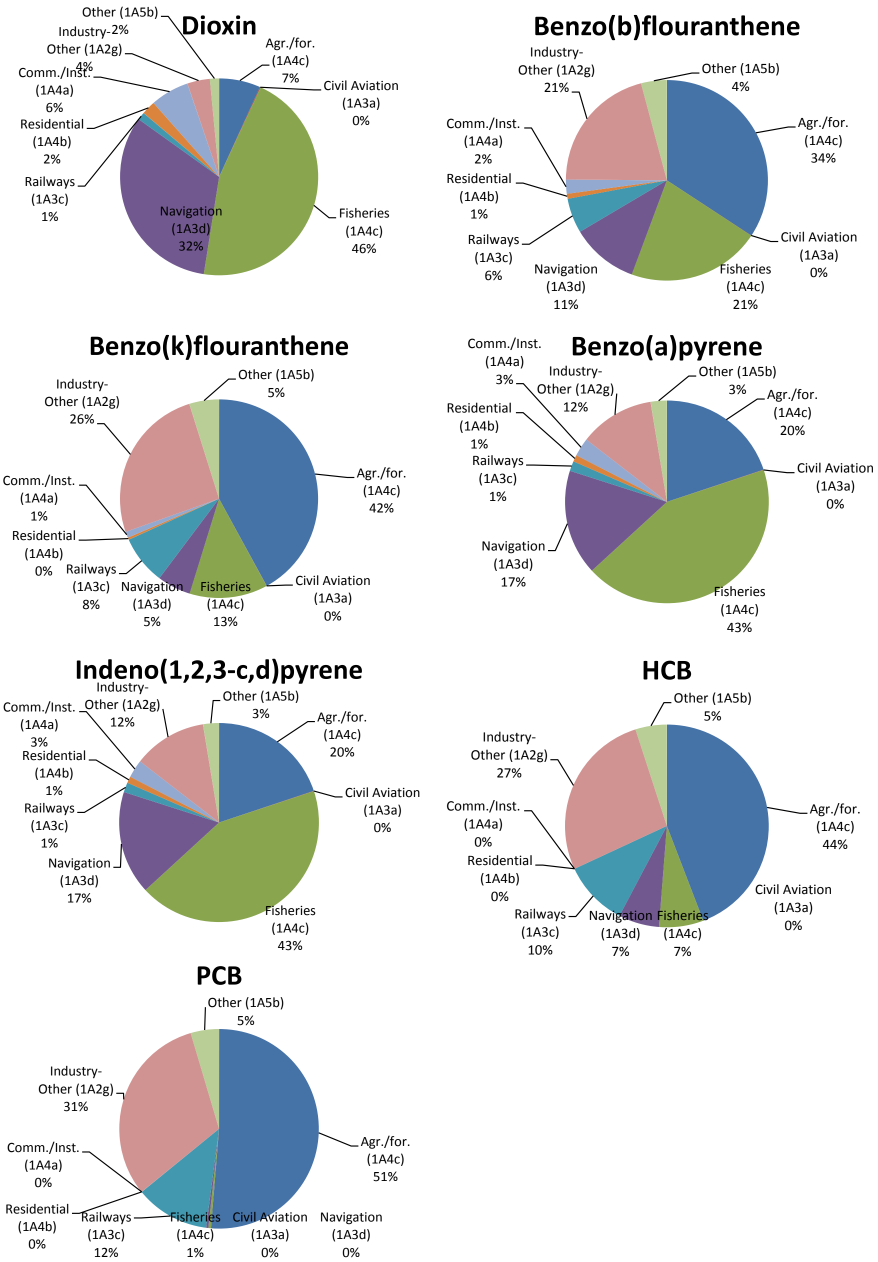


Figure 3.3.34 Dioxin, PAH, HCB and PCB emission shares for other mobile sources in 2015.

Bunkers

The most important emissions from bunker fuel consumption (fuel consumption for international transport) are SO_2 and NO_x. The bunker emission totals are shown in Table 3.3.3 for 2015, split into sea transport and civil aviation. All emission figures in the 1985-2015 time series are given in Annex 2.B.16 (NFR format). In Annex 2.B.15, the emissions are also given in CollectER format for 2015.

The differences in emissions between navigation and civil aviation are much larger than the differences in fuel consumption and display a poor emission performance for international sea transport. In broad terms, the emission trends shown in Figure 3.3.35 are similar to the fuel consumption development.

However, for navigation minor differences occur for the emissions of SO_2 and NO_X due to varying amounts of marine gas oil and residual oil, and for

SO_2 and NO_X the development in the emission factors also have an impact on the emission trends. For civil aviation, apart from the annual consumption of jet fuel, the development of the NO_X emissions is also due to yearly variations in LTO/aircraft type (earlier than 2001) and city-pair statistics (2001 onwards).

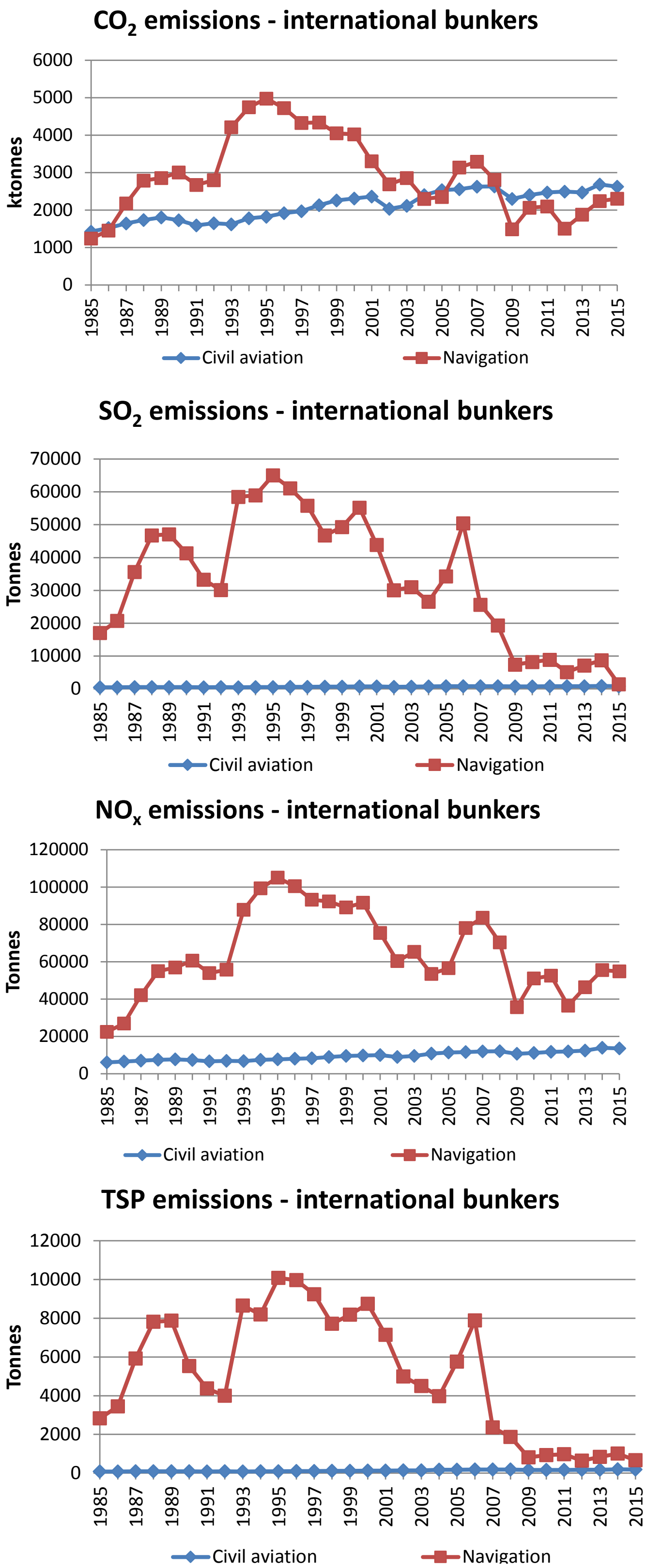


Figure 3.3.35 CO_2, SO_2, NO_X and TSP emissions for international transport 1985-2015.

3.3.2 Methodological issues

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.

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 Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013). The actual calculations are made with a model developed by ENVS, using the European COPERT 5 model methodology (EMEP/EEA, 2013)[4]. In COPERT, fuel consumption and emission simulations can be made for operationally hot engines, taking into account gradually stricter emission standards and emission degradation due to catalyst wear. Furthermore, the emission effects of cold-start and evaporation are simulated.

Vehicle fleet and mileage data

Corresponding to the COPERT 5 fleet classification, all present and future vehicles in the Danish fleet are grouped into vehicle classes, sub-classes and layers. The layer classification is a further division of vehicle sub-classes into groups of vehicles with the same average fuel consumption and emission behaviour, according to EU emission legislation levels. Table 3.3.6 gives an overview of the different model classes and sub-classes, and the layer level with implementation years are shown in Annex 2.B.1.

Fleet and annual mileage data are provided by DTU Transport for the vehicle categories present in COPERT 5 (Jensen, 2016). DTU Transport use data from the Danish vehicle register kept by Statistics Denmark. The vehicle register data consist of vehicle type (passenger cars, vans, trucks, buses, mopeds, motorcycles), fuel type, vehicle weight, gross vehicle weight, engine size (passenger cars registered from 2005+), Euro class (trucks and buses registered from 1997+), NEDC type approval fuel efficiency value (passenger cars registered from 1997+) and vehicle first registration year.

In order to establish engine size data for passenger cars registered before 2005, a weight class-engine size transformation key is used examined by Cowi (2008) for new Danish cars from 1998. For the years before 1998, data for 1998 is used, and for the years 1999-2004 a linear interpolation between 1998 and 2005 weight class-engine size relations is used. For trucks, truck driver registration notes gathered by Statistics Denmark are used to split the fleet figures of ordinary trucks into number of solo trucks and truck-trailer combinations. Further the registration notes make it possible to assume the average total vehicle weight of the truck trailer combination. For articulated trucks also, the registration notes make it possible to assume the average total vehicle weight of the full articulated truck.

Danish mileage data comes from the Danish Road Directorate based on the Danish vehicle inspection program. Total mileage per year and vehicle category are derived for the years 1985-2015, together with a more detailed mileage matrix examined for the year 2008 (based on detailed vehicle inspection

[4] The main difference between the previous COPERT 4 model version and COPERT 5 is NO_x emission factor updates for Euro 6 diesel cars and Euro 5 and 6 diesel vans. Official documentation for COPERT 5 still awaits, the previous model version – Copert 4 - is explained by EMEP/EEA (2013).

data analysis). The detailed mileage matrix contains annual mileage per vehicle subcategory for new vehicles and for every vintage back in time, which determines the yearly mileage reduction percentages as a function of vehicle age. In a first step, the detailed mileage matrix is combined with corresponding fleet numbers in order to estimate intermediate total mileages for each year on a detailed fleet level. Next, each year's detailed (intermediate) mileage figures are scaled according to the difference between true and intermediate total mileage per vehicle subcategory.

DTU Transport (Jensen, 2016) also provides information of the mileage split between urban, rural and highway driving based on traffic monitoring data. The respective average speeds come from The Danish Road Directorate (e.g. Winther & Ekman, 1998). Additional data for the moped fleet and motorcycle fleet disaggregation is given by The National Motorcycle Association (Markamp, 2013).

Table 3.3.6 Model vehicle classes and sub-classes, trip speeds and mileage split.

Vehicle classes	Fuel type	Engine size/weight	Trip speed [km pr h] Urban	Rural	Highway
PC	Gasoline	< 0.8 l.	40	70	100
PC	Gasoline	0.8 - 1.4 l.	40	70	100
PC	Gasoline	1.4 – 2 l.	40	70	100
PC	Gasoline	> 2 l.	40	70	100
PC	Diesel	< 1.4 l.	40	70	100
PC	Diesel	1.4 2 l.	40	70	100
PC	Diesel	> 2 l.	40	70	100
PC	LPG		40	70	100
PC	2-stroke		40	70	100
LDV	Gasoline		40	65	80
LDV	Diesel		40	65	80
LDV	LPG		40	65	80
Trucks	Gasoline		35	60	80
Trucks	Diesel	Rigid 3,5 - 7,5t	35	60	80
Trucks	Diesel	Rigid 7,5 - 12t	35	60	80
Trucks	Diesel	Rigid 12 - 14 t	35	60	80
Trucks	Diesel	Rigid 14 - 20t	35	60	80
Trucks	Diesel	Rigid 20 - 26t	35	60	80
Trucks	Diesel	Rigid 26 - 28t	35	60	80
Trucks	Diesel	Rigid 28 - 32t	35	60	80
Trucks	Diesel	Rigid >32t	35	60	80
Trucks	Diesel	TT/AT 14 - 20t	35	60	80
Trucks	Diesel	TT/AT 20 - 28t	35	60	80
Trucks	Diesel	TT/AT 28 - 34t	35	60	80
Trucks	Diesel	TT/AT 34 - 40t	35	60	80
Trucks	Diesel	TT/AT 40 - 50t	35	60	80
Trucks	Diesel	TT/AT 50 - 60t	35	60	80
Trucks	Diesel	TT/AT >60t	35	60	80
Urban buses	Gasoline		30	50	70
Urban buses	Diesel	< 15 tonnes	30	50	70
Urban buses	Diesel	15-18 tonnes	30	50	70
Urban buses	Diesel	> 18 tonnes	30	50	70
Coaches	Gasoline		35	60	80
Coaches	Diesel	< 15 tonnes	35	60	80
Coaches	Diesel	15-18 tonnes	35	60	80
Coaches	Diesel	> 18 tonnes	35	60	80
Mopeds	Gasoline	2 stroke	30	30	-
Mopeds	Gasoline	4 stroke	30	30	-
Motorcycles	Gasoline	2 stroke	40	70	100
Motorcycles	Gasoline	< 250 cc.	40	70	100
Motorcycles	Gasoline	250 – 750 cc.	40	70	100
Motorcycles	Gasoline	> 750 cc.	40	70	100

In addition data from a survey made by the Danish Road Directorate (Hansen, 2010) has given information of the total mileage driven by foreign trucks on Danish roads in 2009. This mileage contribution has been added to the total mileage for Danish trucks on Danish roads, for trucks > 16 tonnes of gross vehicle weight. The data has been further processed by DTU Transport; by using appropriate assumptions the mileage have been backcasted to 1985 and forecasted to 2015.

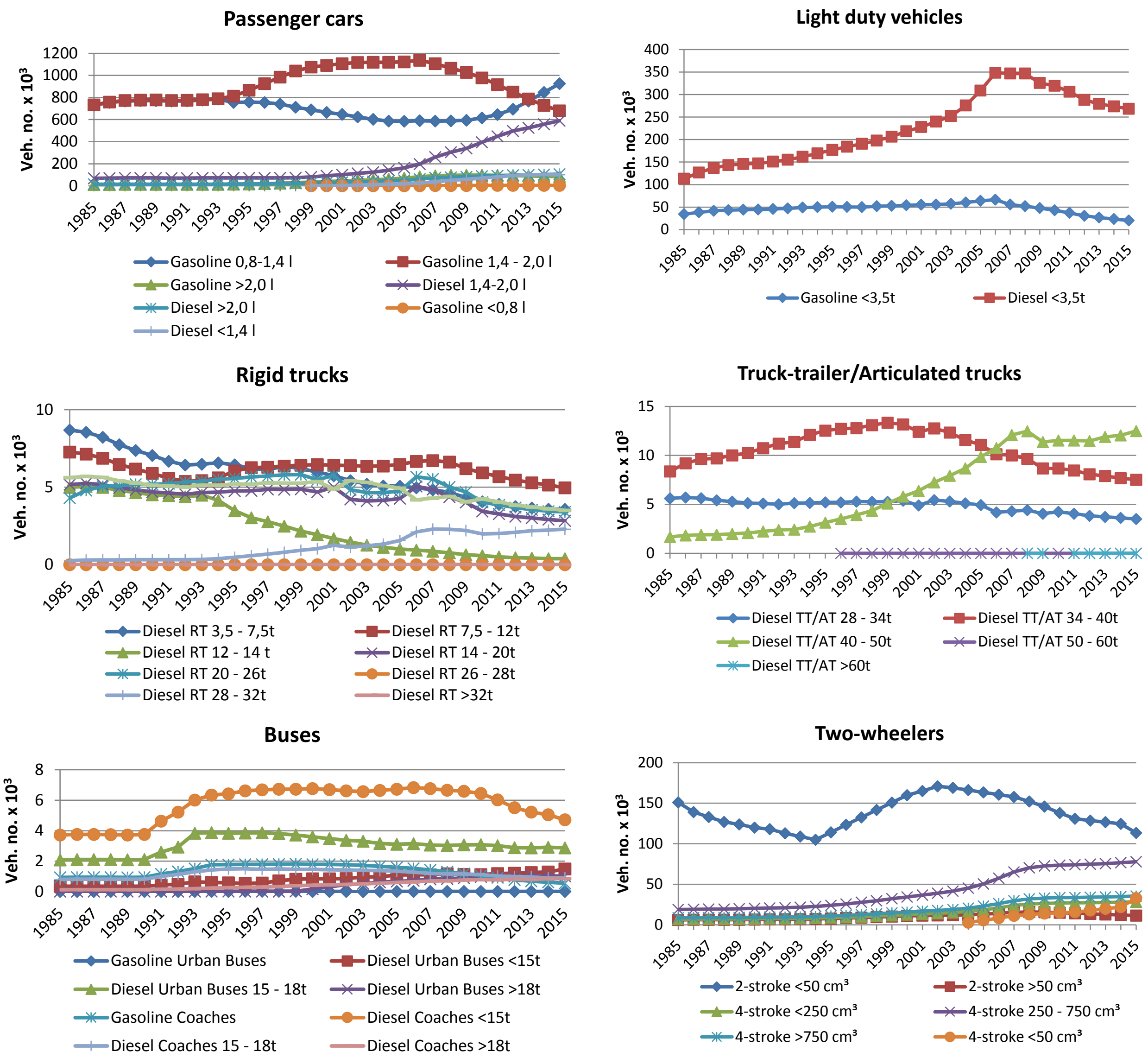


Figure 3.3.36 Number of vehicles in sub-classes in 1985-2015.

For passenger cars, the engine size differentiation is less certain for the years before 2005. The increase in the total number of passenger cars is mostly due to a growth in the number of diesel cars between 1.4 and 2 litres (from the 2000's up to now). Until 2005, there has been a decrease in the number of gasoline cars with an engine size between 0.8 and 1.4 litres. These cars, however, have also increased in numbers during the later years, while the number of 1.4-2 litres gasoline cars has decreased. Since the late 1990's small cars (< 0.8 l gasoline and <1.4 l. diesel) has slowly begun to penetrate the fleet.

There has been a considerable growth in the number of diesel light-duty vehicles from 1985 to 2006; the number of vehicles has however decreased somewhat after 2006 due to the restructuring of car taxes that made it less advantageous buying vans for private use.

For the truck-trailer and articulated truck combinations there is a tendency towards the use of increasingly fewer but larger trucks throughout the time period. The decline in fleet numbers for many of the truck categories is due to the combined effects of the global financial crisis, the fleet shift towards fewer and larger trucks, international market competition (foreign transport companies are effectively gaining Danish market shares), and the reflagging of Danish commercial trucks to companies based in the neighbouring countries.

The sudden change in the level of urban bus and coach numbers from 1991 to 1995 is due to uncertain fleet data from Statistics Denmark.

The reason for the significant growth in the number of mopeds from 1994 to 2002 is the introduction of the so-called Moped 45 vehicle type. From 2004 onwards there is a gradual switch from 2-stroke to 4-stroke in new sales for this vehicle category. For motorcycles, the number of vehicles has grown in general throughout the entire 1985-2015 period. The increase is, however, most visible from the mid-1990s and onwards.

The vehicle numbers are summed up in layers for each year (Figure 3.3.37) by using the correspondence between layers and first year of registration:

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

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

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

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

Since 2006 economical incitements have been given to private vehicle owners to buy Euro 5 diesel passenger cars and vans in order to bring down the particulate emissions from diesel vehicles. The estimated sales between 2006 and 2010 have been examined by the Danish EPA and are included in the fleet data behind the Danish inventory (Winther, 2011).

For heavy duty trucks, there is a slight deviation from the strict correspondence between EU emission layers and first registration year.

In this case, specific Euro class information for most of the vehicles from 2001 onwards is incorporated into the fleet and mileage data model developed by Jensen (2015). For inventory years before 2001, and for vehicles with no Euro information the normal correspondence between layers and first year of registration is used.

Vehicle numbers and weighted annual mileages pr layer are shown in Annex 2.B.1 and 2.B.2 for 1985-2015. The trends in vehicle numbers pr layer are also shown in Figure 3.3.37. The latter figure shows how vehicles complying with the gradually stricter EU emission levels (EURO 1-5, Euro I-VI etc.) have been introduced into the Danish motor fleet.

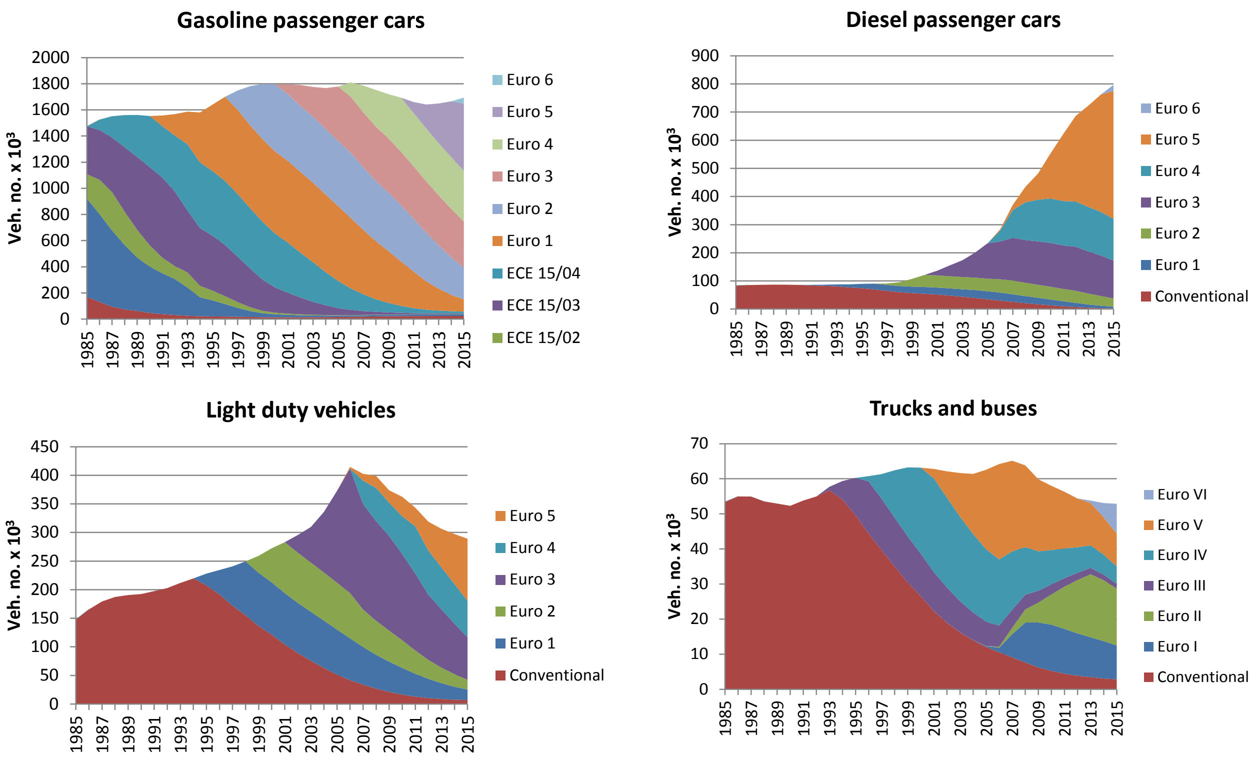


Figure 3.3.37 Layer distribution of vehicle numbers pr vehicle type in 1985-2015.

Emission legislation

For Euro 1-6 passenger cars and vans, the chassis dynamometer test cycle used in the EU for emission approval is the NEDC (New European Driving Cycle), see e.g. www.dieselnet.com. The test cycle is also used 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[5] (average speed: 19 km per 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.

The NEDC test cycle is not adequately describing real world driving behavior, and as an effect, for diesel cars and vans, there is an increasing mismatch between the step wise lowered EU emission limits the vehicles comply with during the NEDC test cycle, and the more or less constant emissions from the same vehicles experienced during real world driving. In order to bridge this emission inconsistency gap a new test procedure for future Euro 6 vehicles, the so-called Euro 6c vehicles, the "World-Harmonized Light-Duty Vehicles Test Procedure" (WLTP), has been developed which simulates much more closely real world driving behavior. The new test procedure still awaits it's final adoption by the EU and the announcement of new legislative emission limits. This is expected to happen in September 2017.

For the new Euro 6c vehicles it has been decided that emission measurements must also be made with portable emission measurement systems (PEMS) during real traffic driving conditions with random acceleration and

[5] 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.

deceleration patterns. During the new Real Driving Emission (RDE) test procedure the emissions of NO_x are not allowed to exceed the existing (NEDC based) emission limits by more than 110 % by January 2017 for all new car models and by January 2019 for all new cars[6]. From January 2020 the NO_x emission not-to-exceed levels are adjusted downwards to 50 % for all new car models and by January 2021 for all new cars[7]. Implementation dates for vans are one year later.

In the road transport emission model, the dates for implementation of the Euro 6c technology is set to 1/9 2018 and 1/9 2019, for diesel cars and vans, respectively. For "Euro 6c+" the implementation dates are set to 1/1 2021 and 1/1 2022 for cars and vans, respectively.

For NOx, VOC (NMVOC + CH4), CO and PM, the emissions from road transport vehicles have to comply with the different EU directives listed in Table 3.3.7. The emission directives distinguish between three vehicle classes according to vehicle reference mass[8]: 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 Annex 2.B.3.

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 ECE R-49, EU ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles, depending on the Euro norm and exhaust gas after-treatment system installed. For Euro VI engines the WHSC (World Harmonized Stationary Cycle) and WHTC (World Harmonized Transient Cycle) test cycles are used. For a description of the test cycles see e.g. www.dieselnet.com.

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

[6] For ambient test temperatures below 3 degrees Celcius, not-to-exceed emission limits are 60 % higher. For ambient test temperatures below minus 2 degrees Celcius the emission limits no longer apply.
[6] For ambient test temperatures below 0 degrees Celcius, not-to-exceed emission limits are 60 % higher. For ambient test temperatures below minus 7 degrees Celcius the emission limits no longer apply.
[8] Reference mass: net vehicle weight + mass of fuel and other liquids + 100 kg.

Table 3.3.7 Overview of the existing EU emission directives for road transport vehicles.

Vehicle category	Emission layer	EU directive	First reg.
Passenger cars (gasoline)	PRE ECE	-	-
	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
	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(692/2008)	1.1.2011
	Euro VI	715/2007(692/2008)	1.9.2015
	Euro VIc	459/2012	1.9.2018
Passenger cars (diesel and LPG)	Conventional	-	-
	ECE 15/04	83/351	1987[d]
	Euro I	91/441	1.10.1990
	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(692/2008)	1.1.2011
	Euro VI	715/2007(692/2008)	1.9.2015
	Euro VIc	459/2012	1.9.2018
Light duty trucks (gasoline and diesel)	Conventional	-	-
	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(692/2008)	1.1.2011
	Euro VI	715/2007(692/2008)	1.9.2016
	Euro VIc	459/2012	1.9.2019
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	1.10.2013
Mopeds	Conventional	-	-
	Euro I	97/24	2000
	Euro II	2002/51	2004
	Euro III	2002/51	2014[f]
	Euro IV	168/2013	2017
	Euro V	168/2013	2021
Motor cycles	Conventional		0
	Euro I	97/24	2000
	Euro II	2002/51	2004

Continued

	Euro III	2002/51	2007
	Euro IV	168/2013	2017
	Euro V	168/2013	2021

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).

Fuel consumption and emission factors

In practice, the emissions from vehicles in traffic are different from the legislation limit values and, therefore, the latter figures are not suited for total emission calculations. Besides difference in test versus real world driving behaviour, as discussed in the previous section, the emission limit values do not reflect the emission impact of cumulated mileage driven, and engine and exhaust after treatment maintenance levels for the vehicle fleet as a whole.

Therefore, in order to represent the Danish fleet and to support average national emission estimates, the selected emission factors must be derived 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).

The fuel consumption and emission factors used in the Danish inventory come from the COPERT 5 model. The source for these data is various European measurement programmes. In general the COPERT data are transformed into trip-speed dependent fuel consumption and emission factors for all vehicle categories and layers by using trip speeds as shown in Table 3.3.8. The factors are listed in Annex 2.B.4.

Adjustment for fuel efficient vehicles

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.

In the Danish fleet and mileage database kept by DTU Transport, the type approval fuel efficiency value based on the NEDC driving cycle (TA_{NEDC}) is registered for each single car. Further, a modified fuel efficiency value (TA_{inuse}) is calculated using TA_{NEDC}, vehicle weight and engine size as input parameters. The TA_{inuse} value better reflects the fuel consumption associated with the NEDC driving cycle under real ("inuse") traffic conditions (Emisia, 2012).

From 2006 up to last historical year represented by fleet data, the average CO_2 emission factor (average from all new registrations) is calculated for each year's new sold cars, based on the registered TA_{NEDC} values. Using the average CO_2 emission factor for the last historical year as starting point, the average emission factor for each year's new sold cars are linearly reduced, until the emission factor reaches 95 g CO_2 /km in 2020. For years beyond 2020 annual fuel efficiency improvement rates are used for new cars depending on fuel type as suggested by DEA (2016b).

From 2006 up to last historical year, CO_2 emission factors are also calculated for each year's new sold cars, as new registrations average for each fuel type/engine size combination, based on TA_{NEDC} and TA_{inuse}.

The linear reduction of the average emission factor for each year's new sold cars is then used to reduce the CO_2 emission factors for new sold cars based on TA_{inuse}, between last historical year and 2020, for each of the fuel type/engine size fleet segments.

Subsequently for each layer and inventory year, CO_2 emission factors are calculated based on TA_{inuse} and weighted by total mileage. On the same time corresponding layer specific CO_2 factors from COPERT 5 are set up valid for Euro 4+ vehicles in the COPERT model. The COPERT 5 CO_2 factors are derived from fuel consumption factors included in the COPERT 5 model, that represent the COPERT test vehicles under the NEDC driving cycle in real world traffic ($TA_{COPERT\ IV,inuse}$).

In a final step the ratio between the layer specific CO_2 emission factors for the Danish fleet and the COPERT Euro 4 vehicles under TA_{inuse} are used to scale the trip speed dependent fuel consumption factors provided by COPERT 5 for Euro 4 layers onwards.

For vans, trucks, urban buses and coaches, annual fuel efficiency improvement rates are used for new vehicles depending on fuel type as suggested by DEA (2016b).

Adjustment for EGR, SCR and filter retrofits

In COPERT 5 emission factors are available for Euro V heavy duty vehicles using EGR and SCR exhaust emission aftertreatment systems, respectively. The estimated new sales of Euro V diesel trucks equipped with EGR and SCR during the 2006-2010 time periods has been examined by Hjelgaard and Winther (2011). These inventory fleet data are used in the Danish inventory to calculate weighted emission factors for Euro V trucks in different size categories.

During the 2000's urban environmental zones have been established in Danish cities in order to bring down the particulate emissions from diesel fuelled heavy duty vehicles. Driving in these environmental zones prescribe the use of diesel particulate filters. The Danish EPA has provided the estimated number of Euro I-III urban buses and Euro II-III trucks and tourist buses which have been retrofitted with filters during the 2000's. These retrofit data are included in the Danish inventory by assuming that particulate emissions are lowered by 80 % compared with the emissions from the same Euro technology with no filter installed (Winther, 2011).

For all vehicle categories/technology levels not represented by measurements, the emission factors are produced by using reduction factors. 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.

Adjustment for biofuel usage

A literature review carried out in the Danish research project REBECA revealed no significant changes in emission factors between neat gasoline and E5 gasoline-ethanol blends for the combustion related emission components; NO_x, CO and VOC (Winther et al., 2012). Hence, due to the current low ethanol content in today's road transport gasoline, no modifications of the neat gasoline based COPERT emission factors are made in the inventories in order to account for ethanol usage.

REBECa results published by Winther (2009) have shown that the emission impact of using diesel-biodiesel blends is very small at low biodiesel blend ratios. Consequently no bio fuel emission factor adjustments are needed for diesel vehicles as well. However, adjustment of the emission factors for diesel vehicles will be made if the biodiesel content of road transport diesel fuel increases to a more significant level in the future.

Deterioration factors

For three-way catalyst cars the emissions of NO_X, NMVOC and CO gradually increase due to catalyst wear and are, therefore, modified as a function of total mileage by the so-called deterioration factors. Even though the emission curves may be serrated for the individual vehicles, on average, the emissions from catalyst cars stabilise after a given cut-off mileage is reached due to OBD (On Board Diagnostics) and the Danish inspection and maintenance programme.

For each year, the deterioration factors are calculated pr first registration year by using deterioration coefficients and cut-off mileages, as given in EMEP/EEA (2013), for the corresponding layer. The deterioration coefficients are given for the two driving cycles: "Urban Driving Cycle" (UDF) and "Extra Urban Driving Cycle" (EUDF: urban and rural), with trip speeds of 19 and 63 km pr hour, respectively.

Firstly, the deterioration factors are calculated for the corresponding trip speeds of 19 and 63 km pr h in each case determined by the total cumulated mileage less than or exceeding the cut-off mileage. The Formulas 3 and 4 show the calculations for the "Urban Driving Cycle":

$$UDF = U_A \cdot MTC + U_B \text{, MTC < } U_{MAX} \quad (3)$$

$$UDF = U_A \cdot U_{MAX} + U_B \text{, MTC >= } U_{MAX} \quad (4)$$

where UDF is the urban deterioration factor, U_A and U_B the urban deterioration coefficients, MTC = total cumulated mileage and U_{MAX} urban cut-off mileage.

In the case of trip speeds below 19 km per hour the deterioration factor, DF, equals UDF, whereas for trip speeds exceeding 63 km per hour, DF=EUDF (Danish rural and highway trip speed; c.f. Table 3.3.6). For trip speeds between 19 and 63 km per hour (Danish urban trip speed; c.f. Table 3.3.6) the deterioration factor, DF, is found as an interpolation between UDF and EUDF. Secondly, the deterioration factors, one for each of the three road types, are aggregated into layers by taking into account vehicle numbers and annual mileage levels per first registration year:

$$DF_{j,y} = \frac{\sum_{i=FYear(j)}^{LYear(j)} DF_{i,y} \cdot N_{i,y} \cdot M_{i,y}}{\sum_{i=FYear(j)}^{LYear(j)} DF_{i,y} \cdot N_{i,y}} \quad (5)$$

where DF is the deterioration factor.

For N_2O and NH_3, COPERT 5 takes into account deterioration as a linear function of mileage for gasoline fuelled EURO 1-6 passenger cars and light duty vehicles. The level of emission deterioration also relies on the content of sulphur in the fuel. The deterioration coefficients are given in EMEP/EEA (2013), for the corresponding layer. A cut-off mileage of 250.000 km is behind the calculation of the modified emission factors, and for the Danish situation the low sulphur level interval is assumed to be most representative. The deterioration factors are shown in Annex 2.B.6 for 2015.

Emissions and fuel consumption for hot engines

Emissions and fuel-use results for operationally hot engines are calculated for each year and for layer and road type. The procedure is to combine fuel consumption and emission factors (and deterioration factors for catalyst vehicles), number of vehicles, annual mileage levels and the relevant road-type shares given in Table 3.3.8. For non-catalyst vehicles this yields:

$$E_{j,k,y} = EF_{j,k,y} \cdot S_k \cdot N_{j,y} \cdot M_{j,y} \qquad (6)$$

Here E = fuel consumption/emission, EF = fuel consumption/emission factor, S = road type share and k = road type.

For catalyst vehicles the calculation becomes:

$$E_{j,k,y} = DF_{j,k,y} \cdot EF_{j,k,y} \cdot S_k \cdot N_{j,y} \cdot M_{j,y} \qquad (7)$$

Extra emissions and fuel consumption for cold engines

Extra emissions of NO_x, VOC, CH_4, CO, PM, N_2O, NH_3 and fuel consumption from cold start are simulated separately. For SO_2 and CO_2, the extra emissions are derived from the cold start fuel consumption results.

Each trip is associated with a certain cold-start emission level and is assumed to take place under urban driving conditions. The number of trips is distributed evenly across the months. First, cold emission factors are calculated as the hot emission factor times the cold:hot emission ratio. Secondly, the extra emission factor during cold start is found by subtracting the hot emission factor from the cold emission factor. Finally, this extra factor is applied on the fraction of the total mileage driven with a cold engine (the β-factor) for all vehicles in the specific layer.

The cold:hot ratios depend on the average trip length and the monthly ambient temperature distribution. The Danish temperatures for 2015 are given in Cappelen et al. (2016). For previous years, temperature data are taken from similar reports available from The Danish Meteorological Institute (www.dmi.dk). The cold:hot ratios are equivalent for gasoline fuelled conventional passenger cars and vans and for diesel passenger cars and vans, respectively, see EMEP/EEA (2013). For conventional gasoline and all diesel vehicles the extra emissions become:

$$CE_{j,y} = \beta \cdot N_{j,y} \cdot M_{j,y} \cdot EF_{U,j,y} \cdot (CEr - 1) \qquad (8)$$

Where CE is the cold extra emissions, β = cold driven fraction, CEr = Cold:Hot ratio.

For catalyst cars, the cold:hot ratio is also trip speed dependent. The ratio is, however, unaffected by catalyst wear. The Euro I cold:hot ratio is used for all future catalyst technologies. However, in order to comply with gradually stricter emission standards, the catalyst light-off temperature must be reached in even shorter periods of time for future EURO standards. Correspondingly, the β-factor for gasoline vehicles is reduced step-wise for Euro II vehicles and their successors.

For catalyst vehicles the cold extra emissions are found from:

$$CE_{j,y} = \beta_{red} \cdot \beta_{EUROI} \cdot N_{j,y} \cdot M_{j,y} \cdot EF_{U,j,y} \cdot (CEr_{EUROI} - 1) \qquad (9)$$

where β_{red} = the β reduction factor.

For CH_4, specific emission factors for cold driven vehicles are included in COPERT 5. The β and β_{red} factors for VOC are used to calculate the cold driven fraction for each relevant vehicle layer. The NMVOC emissions during cold start are found as the difference between the calculated results for VOC and CH_4.

For N_2O and NH_3, specific cold start emission factors are also proposed by COPERT 5. For catalyst vehicles, however, just like in the case of hot emission factors, the emission factors for cold start are functions of cumulated mileage (emission deterioration). The level of emission deterioration also relies on the content of sulphur in the fuel. The deterioration coefficients are given in EMEP/EEA (2013), for the corresponding layer. For cold start, the cut-off mileage and sulphur level interval for hot engines are used, as described in the deterioration factors paragraph.

Evaporative emissions from gasoline vehicles

For each year, evaporative emissions of hydrocarbons are simulated in the forecast model as hot and warm running losses, hot and warm soak loss and diurnal emissions. The calculation approach is the same as in COPERT III. All emission types depend on RVP (Reid Vapour Pressure) and ambient temperature. The emission factors are shown in EMEP/EEA (2013).

Running loss emissions originate from vapour generated in the fuel tank while the vehicle is running. The distinction between hot and warm running loss emissions depends on engine temperature. In the model, hot and warm running losses occur for hot and cold engines, respectively. The emissions are calculated as annual mileage (broken down into cold and hot mileage totals using the β-factor) times the respective emission factors. For vehicles equipped with evaporation control (catalyst cars), the emission factors are only one tenth of the uncontrolled factors used for conventional gasoline vehicles.

$$R_{j,y} = N_{j,y} \cdot M_{j,y} \cdot ((1-\beta) \cdot HR + \beta \cdot WR) \qquad (10)$$

Where R is running loss emissions and HR and WR are the hot and warm running loss emission factors, respectively.

In the model, hot and warm soak emissions for carburettor vehicles also occur for hot and cold engines, respectively. These emissions are calculated as number of trips (broken down into cold and hot trip numbers using the β-factor) times respective emission factors:

$$S_{j,y}^{C} = N_{j,y} \cdot \frac{M_{j,y}}{l_{trip}} \cdot ((1-\beta) \cdot HS + \beta \cdot WS) \qquad (11)$$

Where S^C is the soak emission, l_{trip} = the average trip length, and HS and WS are the hot and warm soak emission factors, respectively. Since all catalyst vehicles are assumed to be carbon canister controlled, no soak emissions are estimated for this vehicle type. Average maximum and minimum temperatures pr month are used in combination with diurnal emission factors to estimate the diurnal emissions from uncontrolled vehicles $E^d(U)$:

$$E_{j,y}^{d}(U) = 365 \cdot N_{j,y} \cdot e^{d}(U) \qquad (12)$$

Each year's total is the sum of each layer's running loss, soak loss and diurnal emissions.

Fuel consumption balance

The calculated fuel consumption in COPERT 5 must equal the statistical fuel sale totals according to the UNFCCC and UNECE emissions reporting format. The statistical fuel sales for road transport are derived from the Danish Energy Authority data (see DEA, 2016).

For gasoline the DEA data for road transport are adjusted at first, in order to account for e.g. non-road machinery and recreational craft fuel consumption, which are not directly stated in the statistics. Please refer to paragraph 3.3.1 for further information regarding the transformation of DEA fuel data. Next, the fuel and emission results for all gasoline vehicles are scaled with the percentage difference between the adjusted bottom-up gasoline fuel consumption obtained after step one and total gasoline fuel sold.

The DEA data for diesel consist of fuel sold in Denmark and used on Danish roads and fuel sold in Denmark and used abroad. The latter diesel fuel contribution is estimated by the Danish Ministry of Taxation based on studies on fuel price differences across borders, fuel discount for haulage contractors and fuel tanking behavior of truck and bus operators as well as private cars (see e.g. the Danish Ministry of Taxation, 2015).

The amount of diesel fuel sold in Denmark and used abroad is allocated to trucks and coaches in a first step and emissions are scaled accordingly (Figure 3.3.38). Next, the percentage difference between the adjusted bottom-up diesel fuel consumption obtained after step one and total diesel fuel sold is used to scale fuel and emission results for all diesel vehicles regardless of vehicle category (Figure 3.3.39). The data behind the Figures 3.3.38 and 3.3.39 are also listed in Annex 2.B.8.

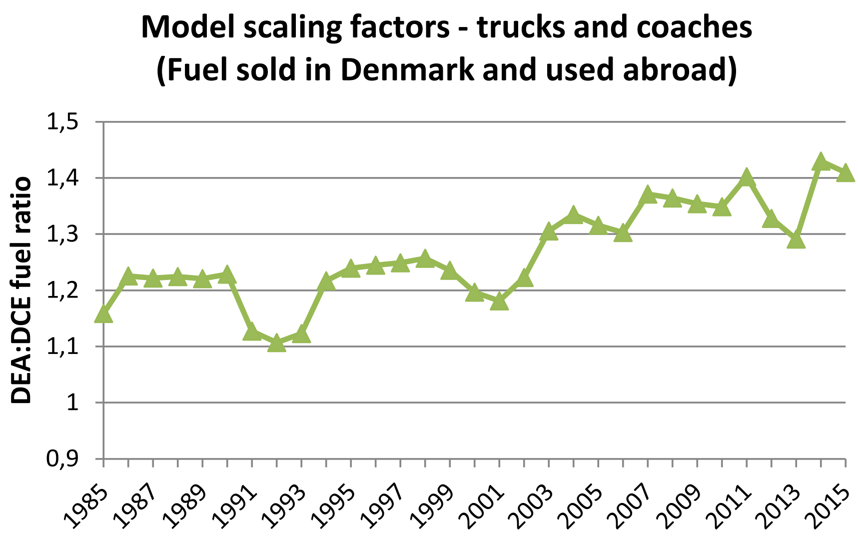


Figure 3.3.38 Fuel ratios (fuel and emission adjustment factors) for trucks and coaches: Bottom-up fuel consumption plus diesel used abroad vs bottom-up fuel consumption.

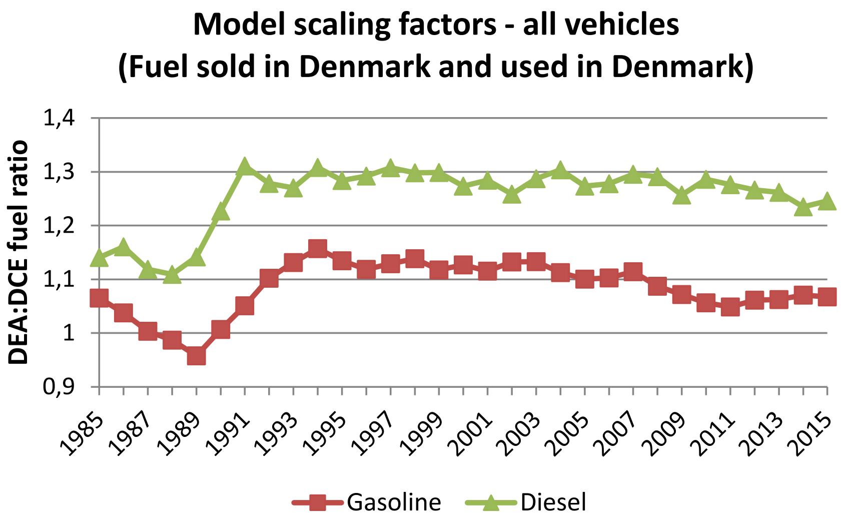


Figure 3.3.39 Gasoline and diesel fuel ratios (fuel and emission adjustment factors) regardless of vehicle category: Fuel sold and used in Denmark vs adjusted bottom-up fuel consumption

The reasons for the differences between DEA sales figures and bottom-up fuel estimates shown in Figure 3.3.39 are mostly due to a combination of the uncertainties related to COPERT 5 fuel consumption factors, allocation of vehicle numbers in sub-categories, annual mileage, trip speeds and mileage splits for urban, rural and highway driving conditions.

The final fuel consumption and emission factors are shown in Annex 2.B.7 for 1985-2015. The total fuel consumption and emissions are shown in Annex 2.B.8, pr vehicle category and as grand totals, for 1985-2015 (and NFR format in Annex 2.B.16. In Annex 2.B.15, fuel consumption and emission factors as well as total emissions are given in CollectER format for 2015.

In Table 3.3.8, the aggregated emission factors for SO_2, NO_X, NMVOC, CO, NH_3, TSP and BC are shown in CollectER format for Danish road transport.

Table 3.3.8 Fuel-based emission factors for SO_2, NO_X, NMVOC, CO, NH_3, TSP and BC for road transport in Denmark (2015).

SNAP ID	Category	Mode	Fuel type	Emission factors[1] [g pr GJ]						
				SO_2	NO_X	NMVOC	CO	NH_3	TSP	BC
070101	Passenger cars	Highway	Bio ethanol	0.00	87.85	22.09	572.36	26.53	0.69	0.12
070101	Passenger cars	Highway	Biodiesel	0.00	305.53	1.96	7.94	0.82	7.80	6.17
070101	Passenger cars	Highway	CNG	0.00	6.00	26.75	219.21	9.04	0.49	0.07
070101	Passenger cars	Highway	Diesel	0.47	305.53	1.96	7.94	0.82	7.80	6.17
070101	Passenger cars	Highway	Gasoline	0.46	87.85	22.09	572.36	26.53	0.69	0.12
070101	Passenger cars	Highway	LPG	0.00	181.36	32.88	974.16	8.84	0.58	0.09
070102	Passenger cars	Rural	Bio ethanol	0.00	77.70	25.74	448.39	23.15	0.63	0.11
070102	Passenger cars	Rural	Biodiesel	0.00	280.76	2.62	19.02	0.88	6.64	5.12
070102	Passenger cars	Rural	CNG	0.00	9.92	22.95	124.37	3.53	0.36	0.05
070102	Passenger cars	Rural	Diesel	0.47	280.76	2.62	19.02	0.88	6.64	5.12
070102	Passenger cars	Rural	Gasoline	0.46	77.70	25.74	448.39	23.15	0.63	0.11
070102	Passenger cars	Rural	LPG	0.00	201.32	47.31	408.54	3.95	0.57	0.09
070103	Passenger cars	Urban	Bio ethanol	0.00	106.57	227.50	2629.06	5.51	0.54	0.10
070103	Passenger cars	Urban	Biodiesel	0.00	278.29	7.41	49.62	0.59	11.50	8.70
070103	Passenger cars	Urban	CNG	0.00	14.78	34.41	162.41	1.66	0.33	0.05
070103	Passenger cars	Urban	Diesel	0.47	278.29	7.41	49.62	0.59	11.50	8.70
070103	Passenger cars	Urban	Gasoline	0.46	106.57	227.50	2629.06	5.51	0.54	0.10
070103	Passenger cars	Urban	LPG	0.00	104.02	101.49	719.24	2.81	0.58	0.09
070201	Light duty vehicles	Highway	Bio ethanol	0.00	147.66	17.79	507.67	22.07	0.55	0.10
070201	Light duty vehicles	Highway	Biodiesel	0.00	365.47	10.10	66.96	0.36	11.18	8.96
070201	Light duty vehicles	Highway	CNG	0.00	8.24	25.83	147.09	6.31	0.52	0.08
070201	Light duty vehicles	Highway	Diesel	0.47	365.47	10.10	66.96	0.36	11.18	8.96
070201	Light duty vehicles	Highway	Gasoline	0.46	147.66	17.79	507.67	22.07	0.55	0.10
070201	Light duty vehicles	Highway	LPG	0.00	123.47	28.54	386.05	0.00	0.57	0.08
070202	Light duty vehicles	Rural	Bio ethanol	0.00	129.60	26.05	385.68	20.07	0.43	0.08
070202	Light duty vehicles	Rural	Biodiesel	0.00	361.42	11.12	55.74	0.39	8.90	7.05
070202	Light duty vehicles	Rural	CNG	0.00	10.86	22.64	114.60	2.36	0.36	0.05
070202	Light duty vehicles	Rural	Diesel	0.47	361.42	11.12	55.74	0.39	8.90	7.05
070202	Light duty vehicles	Rural	Gasoline	0.46	129.60	26.05	385.68	20.07	0.43	0.08
070202	Light duty vehicles	Rural	LPG	0.00	126.84	33.22	267.59	0.00	0.45	0.06
070203	Light duty vehicles	Urban	Bio ethanol	0.00	118.88	176.99	3313.25	4.04	0.34	0.06
070203	Light duty vehicles	Urban	Biodiesel	0.00	322.77	22.91	77.22	0.26	15.02	11.90
070203	Light duty vehicles	Urban	CNG	0.00	14.81	35.04	158.92	1.13	0.34	0.05
070203	Light duty vehicles	Urban	Diesel	0.47	322.77	22.91	77.22	0.26	15.02	11.90
070203	Light duty vehicles	Urban	Gasoline	0.46	118.88	176.99	3313.25	4.04	0.34	0.06
070203	Light duty vehicles	Urban	LPG	0.00	68.22	69.96	532.29	0.00	0.44	0.06
070301	Heavy duty vehicles	Highway	Bio ethanol	0.00	723.63	291.28	434.89	0.31	0.00	0.00
070301	Heavy duty vehicles	Highway	Biodiesel	0.00	216.82	4.54	100.86	0.85	3.98	2.80
070301	Heavy duty vehicles	Highway	CNG	0.00	53.91	2.86	15.02	0.77	0.72	0.38
070301	Heavy duty vehicles	Highway	Diesel	0.47	216.82	4.54	100.86	0.85	3.98	2.80
070301	Heavy duty vehicles	Highway	Gasoline	0.46	723.63	291.28	434.89	0.31	0.00	0.00
070302	Heavy duty vehicles	Rural	Bio ethanol	0.00	675.01	405.15	495.34	0.32	0.00	0.00
070302	Heavy duty vehicles	Rural	Biodiesel	0.00	293.57	6.35	103.96	0.72	4.53	3.16
070302	Heavy duty vehicles	Rural	CNG	0.00	71.05	3.25	18.55	0.50	0.83	0.47
070302	Heavy duty vehicles	Rural	Diesel	0.47	293.57	6.35	103.96	0.72	4.53	3.16
070302	Heavy duty vehicles	Rural	Gasoline	0.46	675.01	405.15	495.34	0.32	0.00	0.00
070303	Heavy duty vehicles	Urban	Bio ethanol	0.00	614.81	597.14	600.64	0.28	0.00	0.00
070303	Heavy duty vehicles	Urban	Biodiesel	0.00	438.41	9.92	123.21	0.44	5.82	3.99
070303	Heavy duty vehicles	Urban	CNG	0.00	91.86	3.84	24.26	0.27	1.05	0.62
070303	Heavy duty vehicles	Urban	Diesel	0.47	438.41	9.92	123.21	0.44	5.82	3.99
070303	Heavy duty vehicles	Urban	Gasoline	0.46	614.81	597.14	600.64	0.28	0.00	0.00
070400	Mopeds	Urban	Bio ethanol	0.00	162.93	3646.02	6001.94	1.09	57.52	7.85
070400	Mopeds	Urban	Gasoline	0.46	162.93	3646.02	6001.94	1.09	57.52	7.85
070501	Motorcycles	Highway	Bio ethanol	0.00	218.60	646.96	8723.41	1.09	12.32	2.11
070501	Motorcycles	Highway	Gasoline	0.46	218.60	646.96	8723.41	1.09	12.32	2.11
070503	Motorcycles	Rural	Bio ethanol	0.00	150.43	710.96	7960.41	1.32	14.95	2.56
070503	Motorcycles	Rural	Gasoline	0.46	150.43	710.96	7960.41	1.32	14.95	2.56
070503	Motorcycles	Urban	Bio ethanol	0.00	96.07	986.72	7689.54	1.27	14.36	2.45
070503	Motorcycles	Urban	Gasoline	0.46	96.07	986.72	7689.54	1.27	14.36	2.45

[1] References. SO_2: Country specific; NO_X, NMVOC, CO, NH_3, PM and BC: COPERT IV.

Non-exhaust particulate emissions from road transport

The TSP, PM_{10} and $PM_{2.5}$ emissions arising from tyre and brake wear (SNAP 0707) and road abrasion (SNAP 0708) are estimated for the years 2000-2015 as prescribed by the UNECE convention reporting format. The emissions are calculated by multiplying the total annual mileage pr vehicle category with the correspondent average emission factors for each source type. The calculation procedure is consistent with the COPERT IV model approach used to estimate the Danish national emissions coming from exhaust. A more thorough explanation of the calculations is given by Winther and Slentø (2010). Emission factors are taken from EMEP/EEA (2013) and specific Danish tyre wear data are gathered by Winther and Slentø (2010). The emission factors and total emissions for 2015 are shown in Annex 2.B.15.

Methodologies and references for 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 in internal DCE models using the detailed method as described in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2013) for air traffic, off-road working machinery and equipment, and ferries, while for the remaining sectors the simple method is used.

3.3.3 Activity data

Air traffic

The activity data used in the DCE emission model for aviation consists of air traffic statistics provided by the Danish Transport and Construction Agency and Copenhagen Airport. Fuel statistics for jet fuel consumption and aviation gasoline is obtained from the Danish energy statistics (DEA, 2016).

For 2001 onwards, the Danish Transport and Construction Agency provides data records per flight (city-pairs). Each flight record consists of e.g. ICAO codes for aircraft type, origin and destination airport, maximum takeoff mass (MTOM), flight call sign and aircraft registration number.

In the DCE model each aircraft type is paired with a representative aircraft type, for which fuel consumption and emission data exist in the EMEP/EEA databank. As a basis the type relation table is taken from the Eurocontrol AEM model which is the primary source for the present EMEP/EEA fuel consumption and emission data. Supplementary aircraft types are assigned to representative aircraft types based on the type relation table already established in the previous version of the DCE model (e.g. Winther, 2012).

Additional aircraft types not present in the type relation table are identified by using different aircraft dictionaries and internet look-ups. In order to select the most appropriate aircraft representative type, the main selection criterias are the identified aircraft type, aircraft maximum takeoff mass, engine types, and number of engines. During this sequence, small aircraft with piston engines using aviation gasoline are excluded from the calculations.

Annex 2.B.10 shows the correspondence table between the actual aircraft type codes and representative aircraft types behind the Danish inventory. Annex 2.B.10 also show the number of LTO's per representative aircraft type for domestic and international flights starting from Copenhagen Airport and other airports, respectively[9], in a time series from 2001-2015. The airport split is necessary to make due to the differences in LTO emission factors (cf. section 3.3.4).

The same type of LTO activity data for the flights for Greenland and the Faroe Islands are shown in Annex 2.B.10 also, further detailed into an origin-destination airport matrix and having flight distances attached. This level of detail satisfies the demand from UNFCCC to provide precise documentation for the part of the inventory for the Kingdom of Denmark being outside the Danish mainland.

The ideal flying distance (great circle distance) between the city-pairs is calculated by DCE in a separate database. The calculation algorithm uses a global latitude/altitude coordinate table for airports. In cases when airport coordinates are not present in the DCE database, these are looked up on the internet and entered into the database accordingly.

For inventory years prior to 2001, detailed LTO/aircraft type statistics are obtained from Copenhagen Airport (for this airport only), while information of total takeoff numbers for other Danish airports is provided by the Danish Transport and Construction Agency. The assignment of representative aircraft types for Copenhagen Airport is done as described above. For the remaining Danish airports representative aircraft types are not directly assigned. Instead appropriate average assumptions are made relating to the fuel consumption and emission data part.

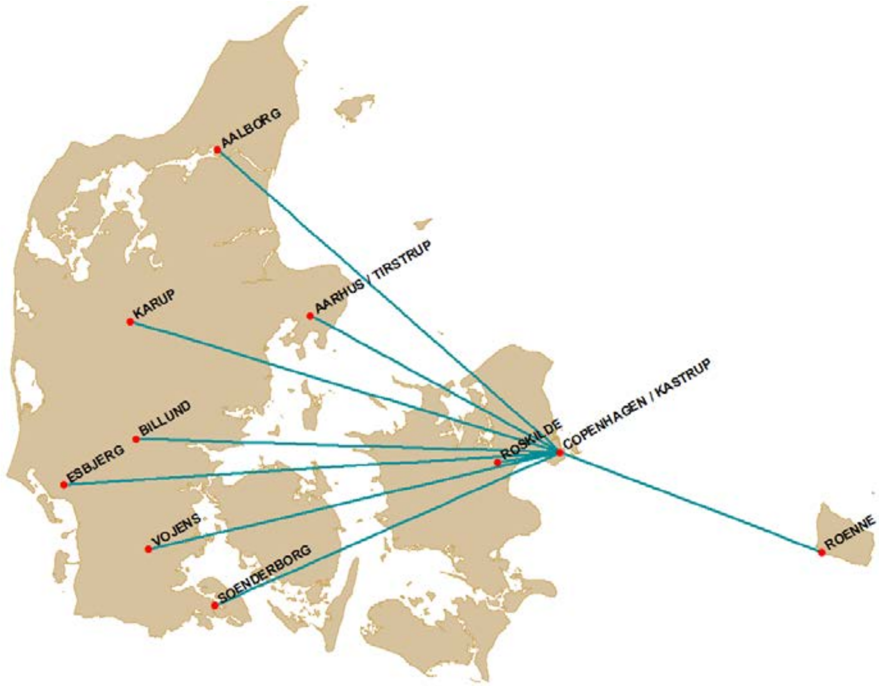


Figure 3.3.40 Most frequent domestic flying routes for large aircraft in Denmark.

Copenhagen Airport is the starting or end point for most of the domestic aviation made by large aircraft in Denmark (Figure 3.3.40; routes to Greenland/Faroe Islands are not shown). Even though many domestic flights not touching Copenhagen Airport are also reported in the flight statistics kept

[9] Excluding flights for Greenland and the Faroe Islands. These flights are separately listed in Annex 2.B.10.

by the Danish Transport and Construction Agency, these flights, however, are predominantly made with small piston engine aircraft using aviation gasoline. Hence, the consumption of jet fuel by flights not using Copenhagen is merely marginal.

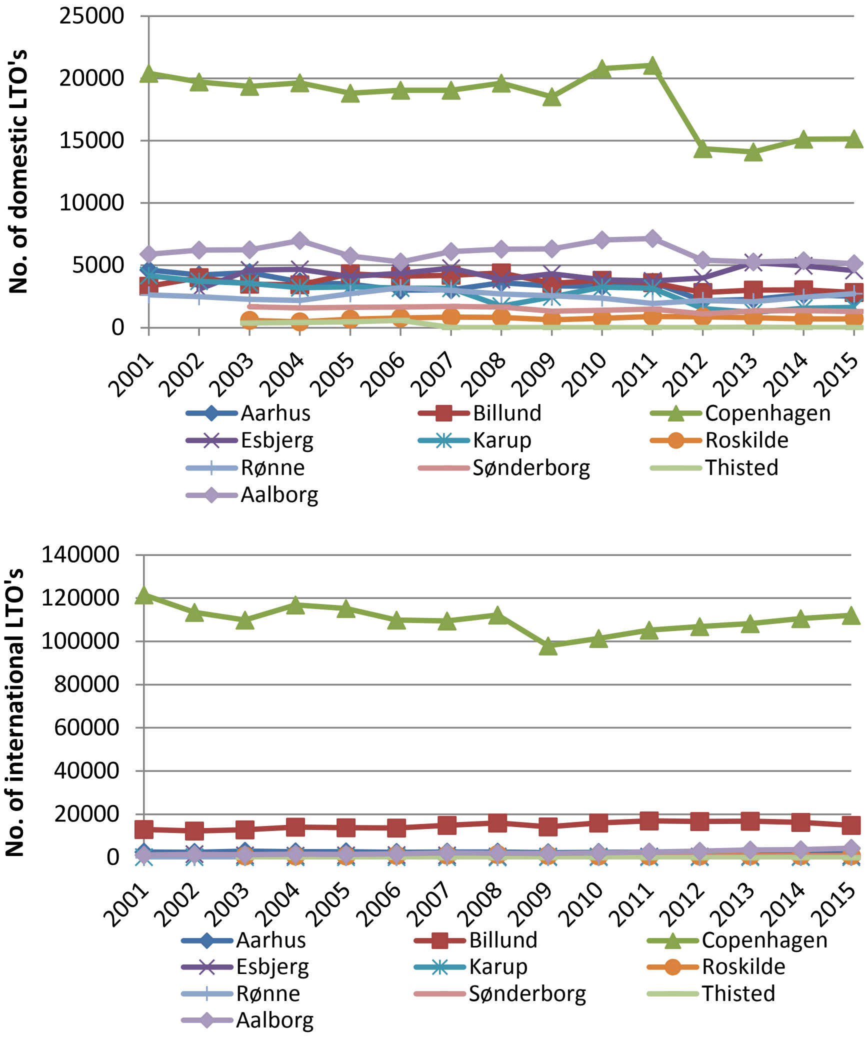


Figure 3.3.41 No. of LTO's for the most important airports in Denmark 2001-2015.

Figure 3.3.41 shows the number of domestic and international LTO's for Danish airports[10], in a time series from 2001-2015.

Non-road working machinery and equipment

Non-road working machinery and equipment are used in agriculture, forestry and industry, for household/gardening purposes and for sailing purposes (recreational craft).

For the most important types of building and construction machinery (industrial non road) annual new sales data for 1996 onwards has been provided by the Association of Danish Agricultural Machinery Dealers. From engine manufacturers engine load factors have been provided based on electronic engine power registrations (Sjøgren 2016; Mikkelsen 2016). Further, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of machinery age has been included in the model (Sjøgren 2016; Mikkelsen 2016).

[10] Flights for Greenland and the Faroe Islands are included under domestic in the figure.

For other machinery types information on the number of different types of machines, their respective load factors, engine sizes and annual working hours has been provided by Winther et al. (2006) for the years until 2004. For later inventory years, supplementary stock data are annually provided by the Association of Danish Agricultural Machinery Dealers and the Association of Producers and Distributors of Fork Lifts in Denmark.

The stock development from 1985-2015 for the most important types of machinery are shown in Figures 3.3.42-3.3.49 below. The stock data are also listed in Annex 2.B.11, together with figures for load factors, engine sizes and annual working hours. As regards stock data for the remaining machinery types, please refer to (Winther et al., 2006).

It is important to note that key experts in the field of industrial non-road activities assume a significant decrease in the activities for 2009 due to the global financial crisis. This reduction is in the order of 25 % for 2009 for industrial non-road in general (pers. comm. Per Stjernqvist, Volvo Construction Equipment 2010). For fork lifts 5 % and 20 % reductions are assumed for 2008 and 2009, respectively (pers. comm. Peter H. Møller, Rocla A/S).

For agriculture, the total number of agricultural tractors and harvesters per year are shown in the Figures 3.3.42-3.3.43, respectively. The figures clearly show a decrease in the number of small machines, these being replaced by machines in the large engine-size ranges.

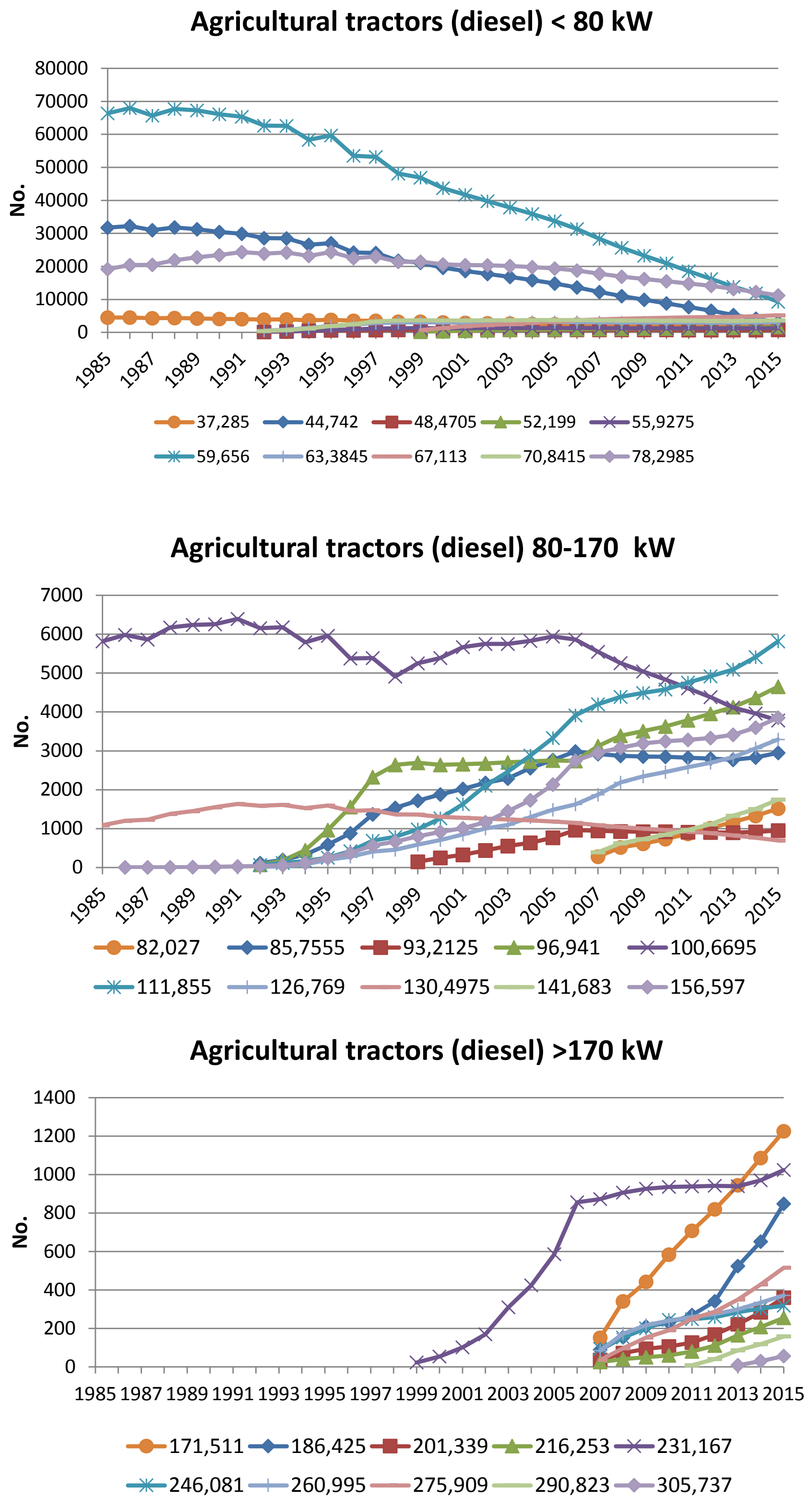


Figure 3.3.42 Total numbers in kW classes for tractors from 1985 to 2015.

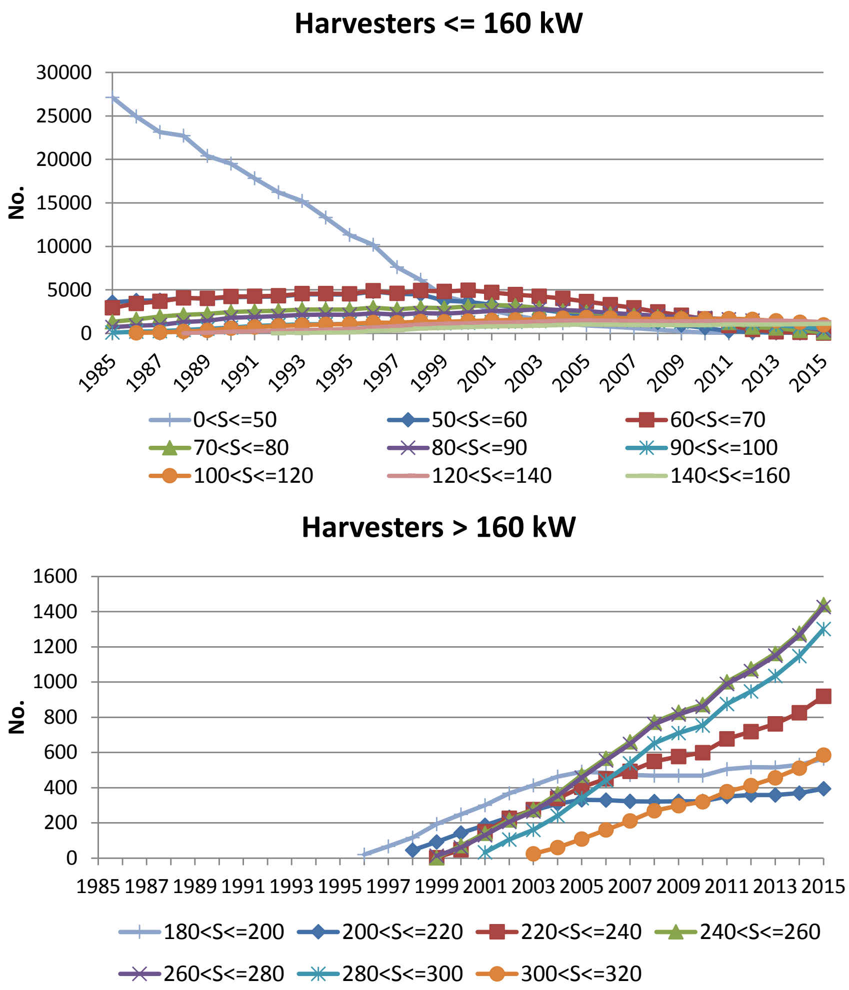


Figure 3.3.43 Total numbers in kW classes for harvesters from 1985 to 2015.

The tractor and harvester developments towards fewer vehicles and larger engines, shown in Figure 3.3.44, are very clear. From 1985 to 2015, tractor and harvester numbers decrease by around 41 % and 67 %, respectively, whereas the average increase in engine size for tractors is 55 %, and 188 % for harvesters, in the same time period.

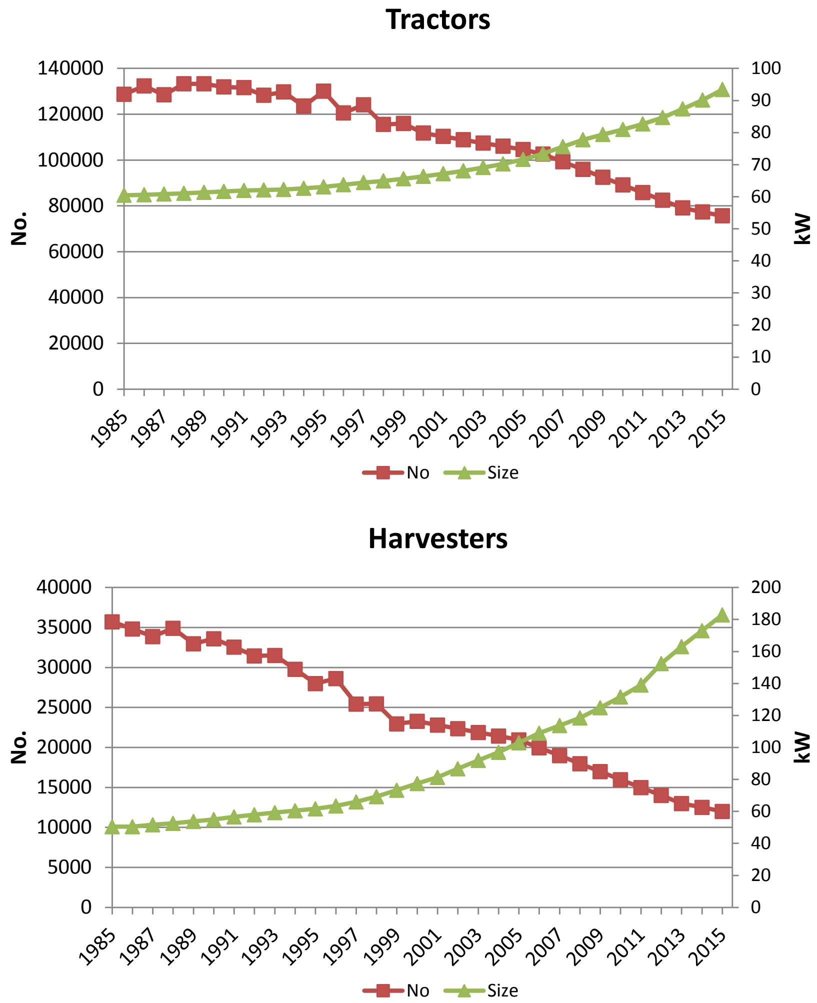


Figure 3.3.44 Total numbers and average engine size for tractors and harvesters from 1985 to 2015.

The most important machinery types for industrial use are different types of construction machinery and fork lifts. The Figures 3.3.45 and 3.3.46 show the 1985-2015 stock development for specific types of construction machinery and diesel fork lifts. Due to lack of data, 1996-1999 average sales data for construction machinery is used for 1995 and back. It is, however, assumed that telescopic loaders first enter into use in 1986 (Jensen, Scantruck 2016). For most of the machinery types there is an increase in machinery numbers from 1990 onwards, due to increased construction activities.

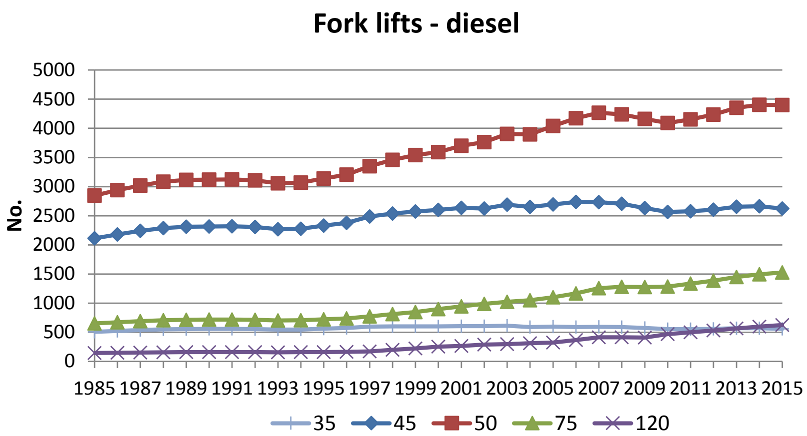


Figure 3.3.45 Total numbers of diesel fork lifts in kW classes from 1985 to 2015.

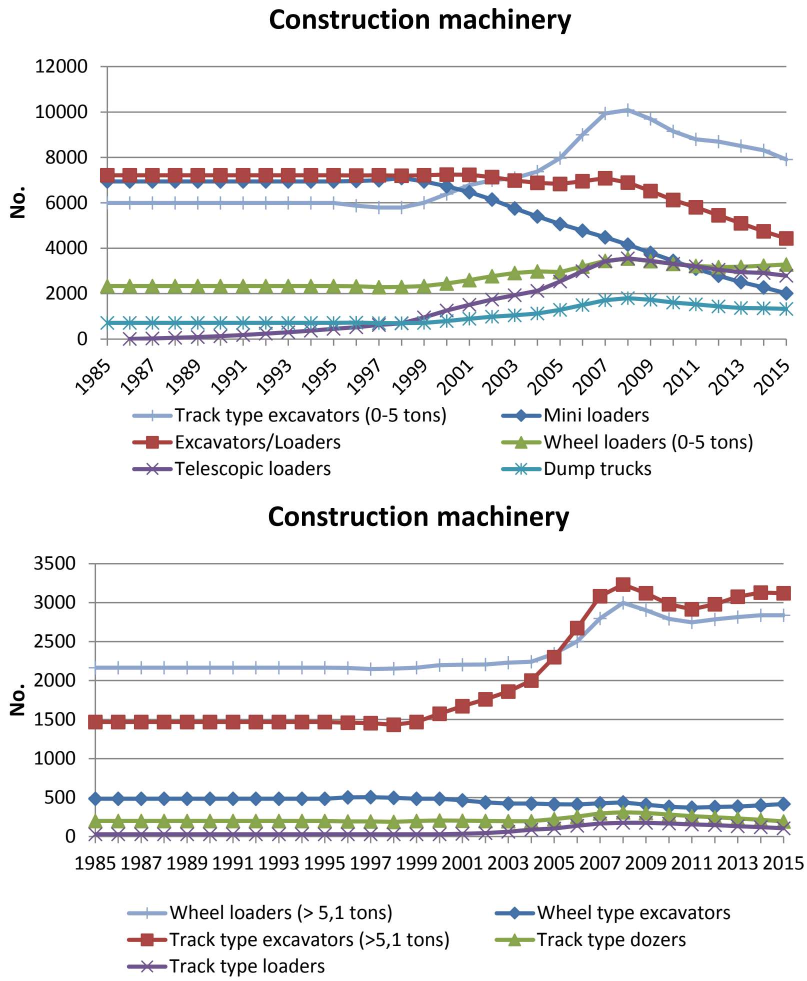


Figure 3.3.46 1985-2015 stock development for specific types of construction machinery.

The emission level shares for tractors, harvesters, construction machinery and diesel fork lifts are shown in Figure 3.3.47, and present an overview of the penetration of the different pre-Euro engine classes, and engine stages complying with the gradually stricter EU stage I and II emission limits. The average lifetimes of 30, 25, 20 and 10 years for tractors, harvesters, fork lifts and construction machinery, respectively, influence the individual engine technology turn-over speeds.

The EU emission directive Stage I and II implementation years relate to engine size, and for all four machinery groups the emission level shares for the specific size segments will differ slightly from the picture shown in Figure 3.3.47. Due to scarce data for construction machinery, the emission level penetration rates are assumed to be linear and the general technology turnover pattern is as shown in Figure 3.3.47.

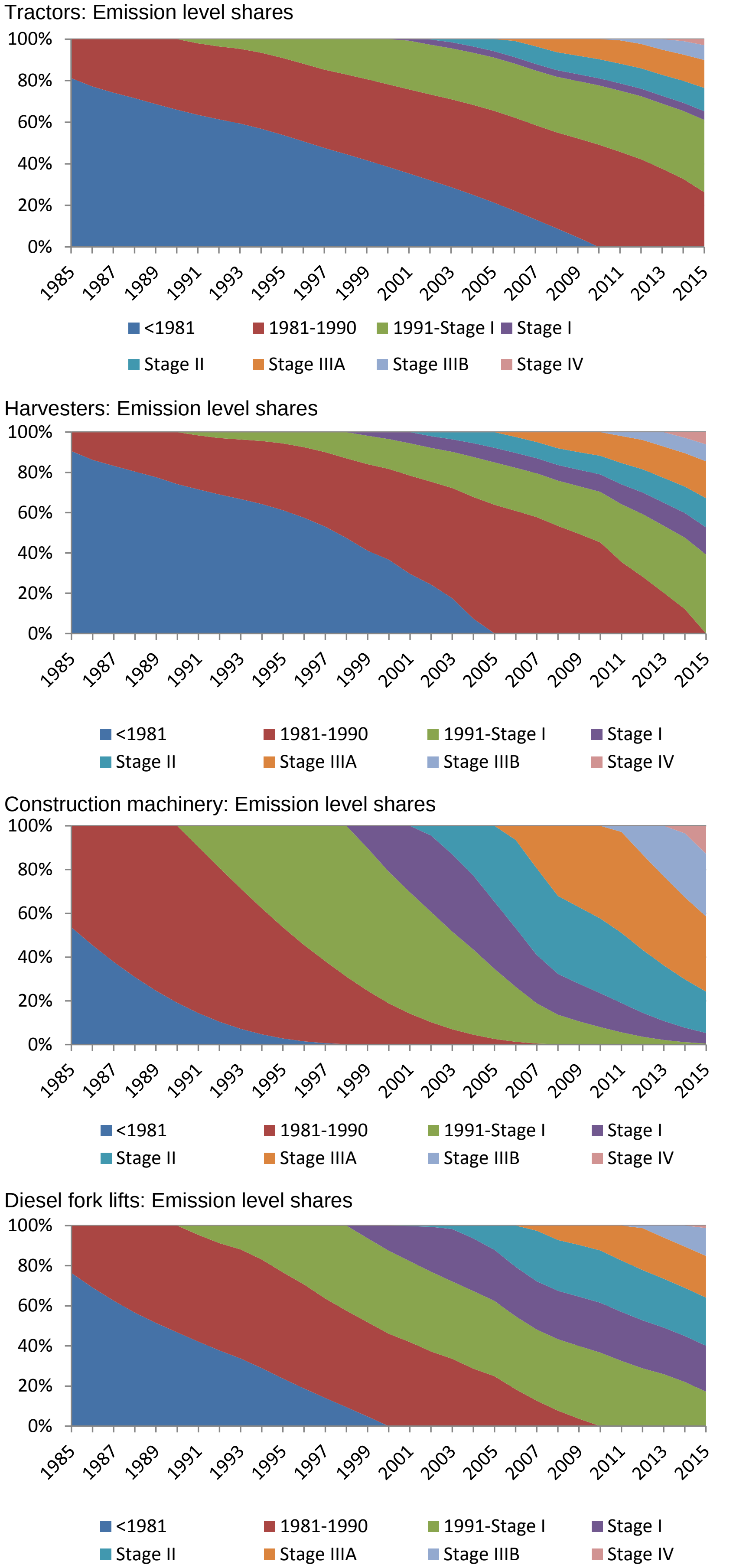


Figure 3.3.47 Emission level shares for tractors, harvesters, construction machinery and diesel fork lifts (1985 to 2015).

The 1985-2015 stock development for the most important household and gardening machinery types is shown in Figure 3.3.48.

For lawn movers and cultivators, the machinery stock remains approximately the same for all years, whereas the stock figures for riders, chain saws, shrub clearers, trimmers and hedge cutters increase from 1990 onwards. The yearly stock increases, in most cases, become larger after 2000. The lifetimes for gasoline machinery are short and, therefore, there new emission levels (not shown) penetrate rapidly.

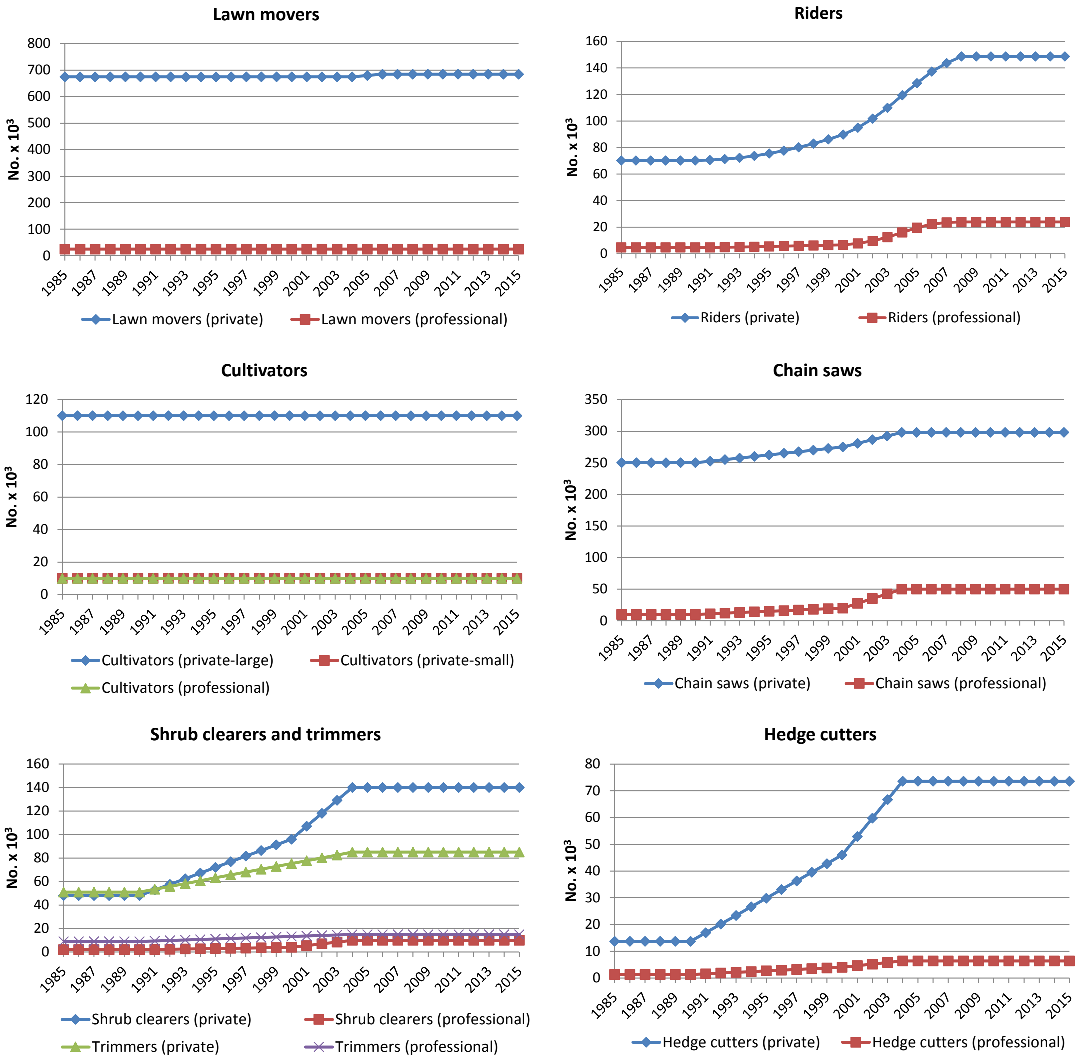


Figure 3.3.48 Stock developments 1985-2015 for the most important household and gardening machinery types.

Figure 3.3.49 shows the development in numbers of different recreational craft from 1985-2015. The 2004 stock data for recreational craft are repeated for 2005+, due to lack of data from the Danish Sailing Association.

For diesel boats, increases in stock and engine size are expected during the whole period, except for the number of motor boats (< 27 ft.) and the engine sizes for sailing boats (<26 ft.), where the figures remain unchanged. A decrease in the total stock of sailing boats (<26 ft.) by 21 % and increases in the total stock of yawls/cabin boats and other boats (<20 ft.) by around 25 % are expected. Due to a lack of information specific to Denmark, the shifting rate from 2-stroke to 4-stroke gasoline engines is based on a German non-road study (IFEU, 2004).

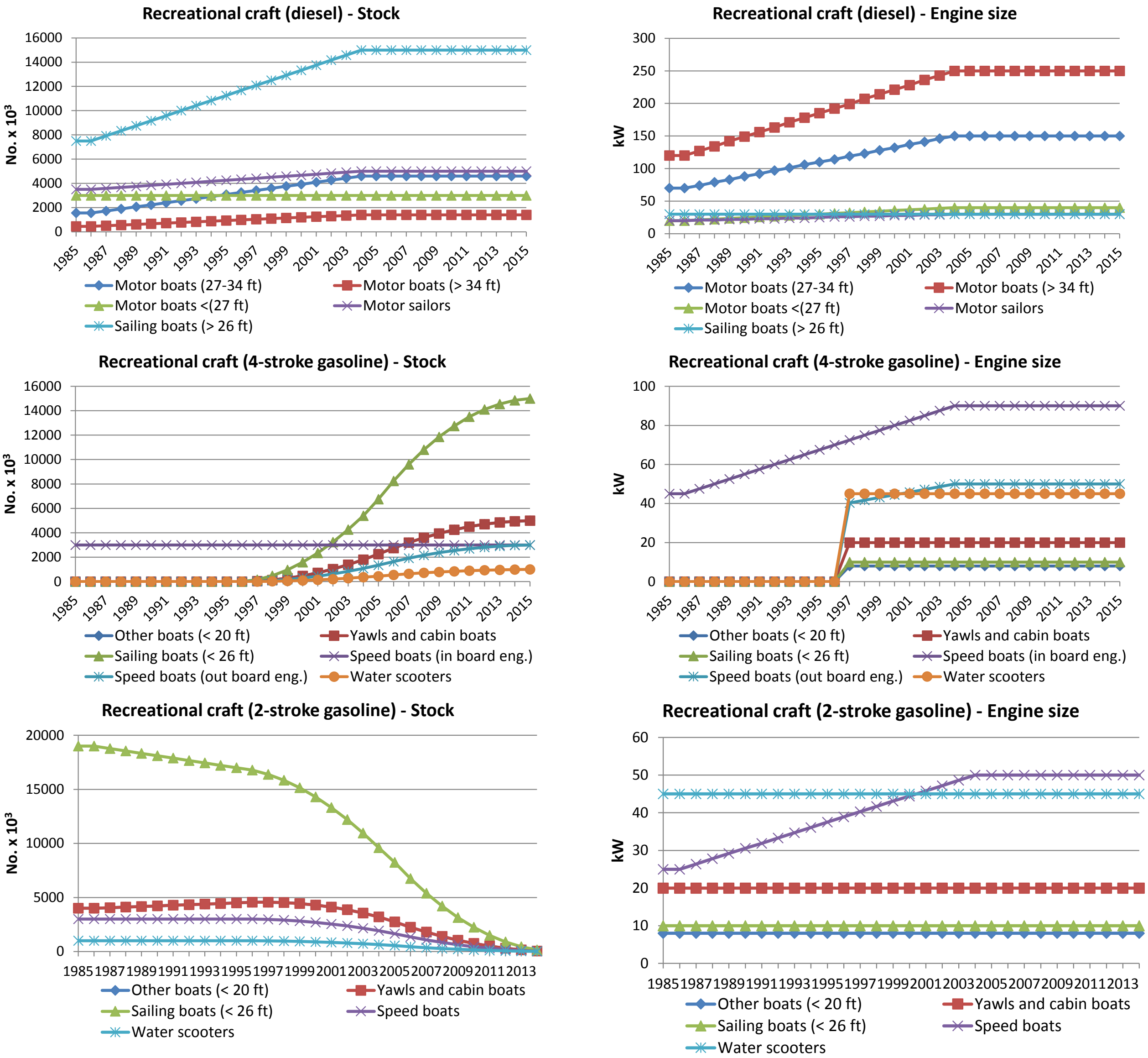


Figure 3.3.49 1985-2015 Stock and engine size development for recreational craft.

National sea transport

The methodology used to estimate the fuel consumption figures for national sea transport, based on fleet activity estimates for regional ferries, local ferries and other national sea transport is described by Winther (2008).

Table 3.3.9 lists the most important domestic ferry routes in Denmark in the period 1990-2015. For these ferry routes and the years 1990-2005, the following detailed traffic and technical data have been gathered by Winther (2008): Ferry name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip).

For 2006-2015, the above mentioned traffic and technical data for specific ferries have been provided by Nielsen (2016) in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus), by Jørgensen (2016) for Færgen A/S (Køge-Rønne, Tårs-Spodsbjerg), by Jørgensen (2015) and Kruse (2015) for Samsø Rederi (Hou-Sælvig), by Mortensen (2015) for Færgeselskabet Læsø (Frederikshavn-Læsø) and by Møller (2015) for Ærøfærgerne (Svendborg-Ærøskøbing). For Esbjerg/Hanstholm/Hirtshals-Torshavn traffic and technical data have been provided by Dávastovu (2010).

Table 3.3.9 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+
Hirtshals-Torshavn	2010
Hou-Sælvig	1990+
Hundested-Grenaa	1990-1996
Frederikshavn-Læsø	1990+
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+
Svendborg-Ærøskøbing	1990+
Tårs-Spodsbjerg	1990+

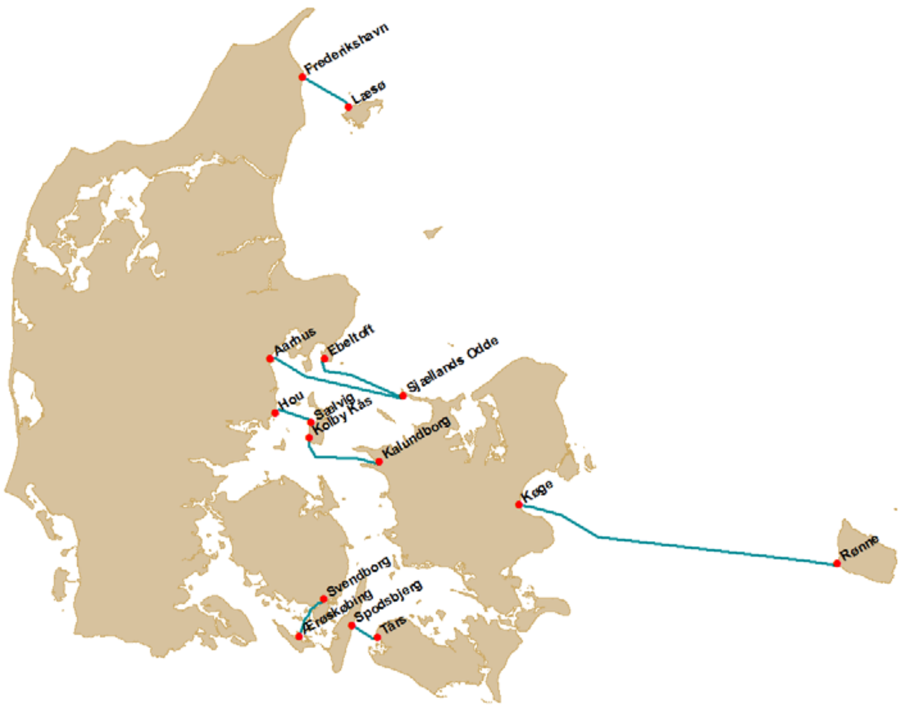


Figure 3.3.50 Domestic regional ferry routes in Denmark (2015).

The number of round trips per ferry route from 1990 to 2015 is provided by Statistics Denmark (2016), see Figure 3.3.51 (Esbjerg/Hanstholm/Hirtshals-Torshavn not shown). The traffic data are also listed in Annex 2.B.12, together with different ferry specific technical and operational data.

For each ferry, Annex 2.B.12 lists the relevant information as regards ferry route, name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip). There is a lack of historical traffic data for 1985-1989, and hence, data for 1990 is used for these years, to support the fuel consumption and emission calculations.

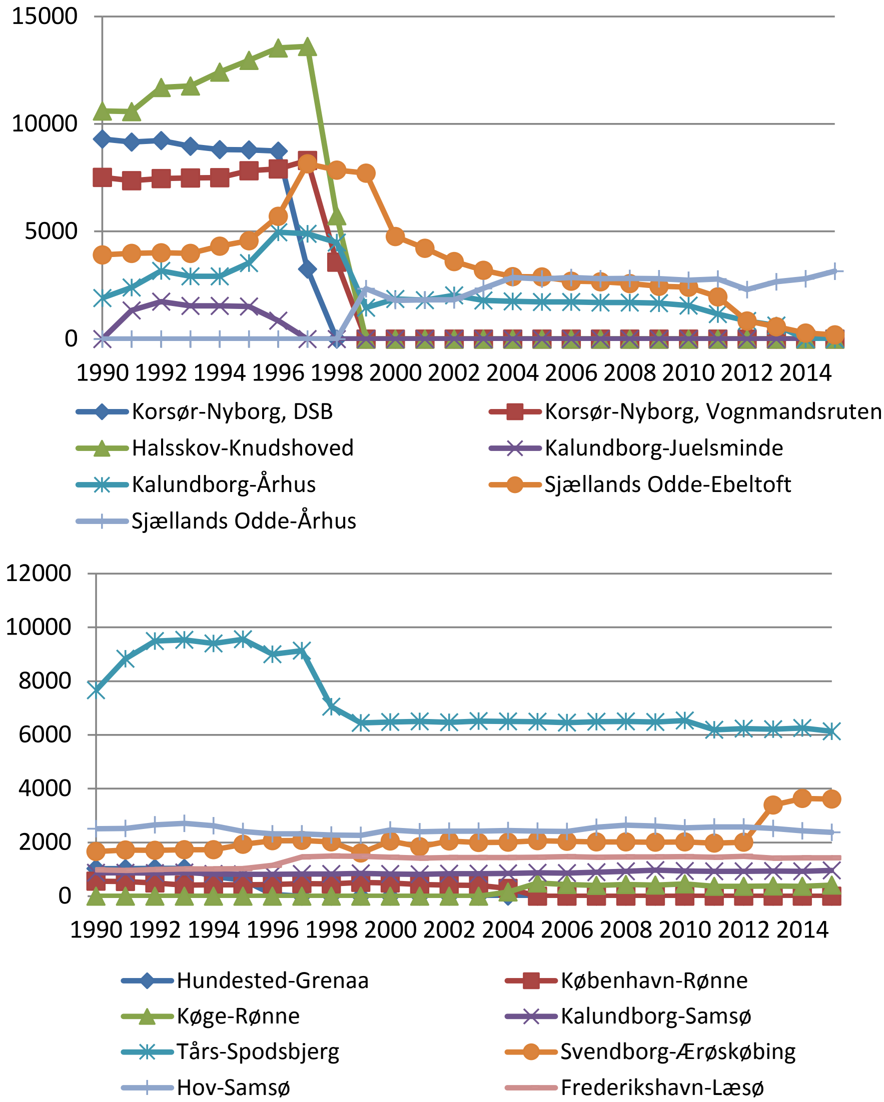


Figure 3.3.51 No. of round trips for the most important ferry routes in Denmark 1990-2015.

It is seen from Table 3.3.11 (and Figure 3.3.51) that several ferry routes were closed in the time period from 1996-1998, mainly due to the opening of the Great Belt Bridge (connecting Zealand and Funen) in 1997. Hundested-Grenaa and Kalundborg-Juelsminde was closed in 1996, Korsør-Nyborg (DSB) closed in 1997, and Halsskov-Knudshoved and Korsør-Nyborg (Vognmandsruten) was closed in 1998. The ferry line København-Rønne was replaced by Køge-Rønne in 2004 and from 1999 a new ferry connection was opened between Sjællands Odde and Århus.

For the local ferries, a bottom-up estimate of fuel consumption for 1996 has been taken from the Danish work in Wismann (2001). The latter project calculated fuel consumption and emissions for all sea transport in Danish waters in 1995/1996 and 1999/2000. In order to cover the entire 1990-2015 inventory period, the fuel figure for 1996 has been adjusted according to the developments in local ferry route traffic shown in Annex 2.B.12.

Fuel sold for freight transport by Royal Arctic Line between Aalborg (Denmark) and Greenland and by Eim Skip - East route between Aarhus (Denmark) and Torshavn (Faroe Islands) are included under other national sea transport in the Danish inventories. In both cases all fuel is being bought in Denmark (Rasmussen, 2016 and Thorarensen, 2016).

For the remaining part of the traffic between two Danish ports, other national sea transport, bottom-up estimates for fuel consumption have been calculated for the years 1995 and 1999 by Wismann (2007). These fuel consumption estimates are used as activity data for the inventory years until 1995 and 1999 onwards. Interpolated figures are used for the inventory years 1996-1998.

The calculations use the database set up for Denmark in the Wismann (2001) study, with actual traffic data from the Lloyd's LMIS database (not including ferries). The database was split into three vessel types: bulk carriers, container ships, and general cargo ships; and five size classes: 0-1000, 1000-3000, 3000-10000, 10000-20000 and >20000 DTW. The calculations assume that bulk carriers and container ships use heavy fuel oil, and that general cargo ships use gas oil. For further information regarding activity data for local ferries and other national sea transport, please refer to Winther (2008).

The fleet activity based fuel consumption estimates for regional ferries, local ferries and other national sea transport replace the fuel based activity data which originated directly from the DEA statistics.

Other sectors

The activity data for military, railways, international sea transport and fishery consists of fuel consumption information from DEA (2016). For international sea transport, the basis is in principle fuel sold in Danish ports for vessels with a foreign destination, as prescribed by the IPCC guidelines.

However, it must be noted that fuel sold for sailing activities between Denmark and Greenland/Faroe Islands are reported as international in the DEA energy statistics. Hence, for inventory purposes in order to follow the IPCC guidelines the bottom-up fuel estimates for the ferry routes Esbjerg/Hanstholm/Hirtshals-Torshavn, and fuel reports from Royal Arctic Line and Eim Skip is being subtracted from the fuel sales figures for international sea transport prior to inventory fuel input.

For fisheries, the calculation methodology described by Winther (2008) remains fuel based. However, the input fuel data differ from the fuel sales figures previously used. The changes are the result of further data processing of the DEA reported gas oil sales for national sea transport and fisheries, prior to inventory input. For years when the fleet activity estimates of fuel consumption for national sea transport (not including trips to Greenland/Faroe Islands) are smaller than DEA reported fuel sold for national sea transport, fuel is added to fisheries in the inventory. In the opposite case, fuel is being subtracted from the original DEA fisheries fuel sales figure in order to make up the final fuel consumption input for fisheries in the inventories.

The updated fuel consumption time series for national sea transport lead, in turn, to changes in the energy statistics for fisheries (gas oil) and industry (heavy fuel oil), so the national energy balance can remain unchanged.

For all sectors, fuel consumption time series are given in Annex 2.B.14 for 2015 in CollectER format.

Emission legislation

For other modes of transport and non-road machinery, the engines have to comply with the emission legislation limits agreed by the EU and different UN organisations in terms of NO_x, CO, VOC and TSP emissions and fuel sulphur content. In terms of greenhouse gases, the emission legislation requirements for VOC influence the emissions of CH_4, the latter emission component forming a part of total VOC. Only for ships legislative limits for specific fuel consumption have been internationally agreed in order to reduce the emissions of CO_2.

For non-road working machinery and equipment, and recreational craft and railway locomotives/motor cars, 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 engine market date).

For diesel, the directives 97/68 and 2004/26 (Table 3.3.10) relate to Stage I-IV non-road machinery other than agricultural and forestry tractors and the directives have different implementation dates for machinery operating under transient and constant loads. The latter directive also comprises emission limits for Stage IIIA and IIIB railways machinery (Table 3.3.14). For Stage I-IV tractors the relevant directives are 2000/25 and 2005/13 (Table 3.3.10).

For emission approval of the EU Stage I, II and IIIA engine technologies, emissions (and fuel consumption) measurements are made using the steady state test cycle ISO 8178 C1, referred to as the Non-Road Steady Cycle (NRSC), see e.g. www.dieselnet.com. In addition to the NRSC test, the newer Stage IIIB and IV (and optionally Stage IIIA) engine technologies are tested under more realistic operational conditions using the new Non-Road Transient Cycle (NRTC).

For gasoline, the directive 2002/88 distinguishes between Stage I and II hand-held (SH) and not hand-held (NS) types of machinery (Table 3.3.11). Emissions are tested using one of the specific constant load ISO 8178 test cycles (D2, G1, G2, G3) depending on the type of machinery.

For Stage V machinery, EU directive 2016/1628 relate to non road machinery other than agricultural tractors and railways machinery (Table 3.3.10) and non road gasoline machinery (Table 3.3.11). EU directive 167/2013 relate to Stage V agricultural and forestry tractors (Table 3.3.10). The Stage V emission limits are also shown in Annex 2.B.11.

Table 3.3.10 Overview of EU emission directives relevant for diesel fuelled non-road machinery.

Stage	Engine size [kW]	CO [g/kWh]	VOC [g/kWh]	NO_x [g/kWh]	VOC+NO_x [g/kWh]	PM [g/kWh]	Diesel machinery EU Directive	Diesel machinery Implement. date Transient	Diesel machinery Implement. date Constant	Tractors EU Directive	Tractors Implement. Date
Stage I											
A	130<=P<560	5	1.3	9.2	-	0.54	97/68	1/1 1999	-	2000/25	1/7 2001
B	75<=P<130	5	1.3	9.2	-	0.7		1/1 1999	-		1/7 2001
C	37<=P<75	6.5	1.3	9.2	-	0.85		1/4 1999	-		1/7 2001
Stage II											
E	130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
F	75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
G	37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
D	18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA											
H	130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
I	75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
J	37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
K	19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB											
L	130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
M	75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
N	56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
P	37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV											
Q	130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014	1/1 2014	2005/13	1/1 2014
R	56<=P<130	5	0.19	0.4	-	0.025		1/10 2014	1/10 2014		1/10 2014
Stage V[A]											
NRE-v/c-7	P>560	3.5	0.19	3.5		0.045	2016/1628		2019	167/2013[B]	2019
NRE-v/c-6	130≤P≤560	3.5	0.19	0.4		0.015			2019		2019
NRE-v/c-5	56≤P<130	5.0	0.19	0.4		0.015			2020		2020
NRE-v/c-4	37≤P<56	5.0			4.7	0.015			2019		2019
NRE-v/c-3	19≤P<37	5.0			4.7	0.015			2019		2019
NRE-v/c-2	8≤P<19	6.6			7.5	0.4			2019		2019
NRE-v/c-1	P<8	8.0			7.5	0.4			2019		2019
Generators	P>560	0.67	0.19	3.5		0.035			2019		2019

A = For selected machinery types, Stage V includes emission limit values for particle number.

B = Article 63 in 2016/1628 revise Article 19 in 167/2013 to include Stage V limits as described in 2016/1628.

Table 3.3.11 Overview of the EU Emission Directives relevant for gasoline fueled 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
EU Directive 2002/88	Stage I						
Hand held	SH1	S<20	805	295	5.36	-	1/2 2005
	SH2	20≤S<50	805	241	5.36	-	1/2 2005
	SH3	50≤S	603	161	5.36	-	1/2 2005
Not hand held	SN3	100≤S<225	519	-	-	16.1	1/2 2005
	SN4	225≤S	519	-	-	13.4	1/2 2005
	Stage II						
Hand held	SH1	S<20	805	-	-	50	1/2 2008
	SH2	20≤S<50	805	-	-	50	1/2 2008
	SH3	50≤S	603	-	-	72	1/2 2009
Not hand held	SN1	S<66	610	-	-	50	1/2 2005
	SN2	66≤S<100	610	-	-	40	1/2 2005
	SN3	100≤S<225	610	-	-	16.1	1/2 2008
	SN4	225≤S	610	-	-	12.1	1/2 2007
EU Directive 2016/1628	Stage V						
Hand held (<19 kW)	NRSh-v-1a	S<50	805	-	-	50	2019
	NRSh-v-1b	50≤S	805	-	-	72	2019
Not hand held (P<19 kW)	NRS-vr/vi-1a	80≤S<225	610	-	-	10	2019
	NRS-vr/vi-1b	S≥225	610	-	-	8	2019
Not hand held (19=<P<30 kW)	NRS-v-2a	S≤1000	610	-	-	8	2019
	NRS-v-2b	S>1000	4.40*	-	-	2.70*	2019
Not hand held (30=<P<56 kW)	NRS-v-3	any	4.40*	-	-	2.70*	2019

* Or any combination of values satisfying the equation $(HC+NOx) \times CO^{0.784} \leq 8.57$ and the conditions CO ≤ 20.6 g/kWh and (HC+NOx) ≤ 2.7 g/kWh

For recreational craft, Directive 2003/44 comprises the Stage I emission legislation limits for diesel engines, 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 presented in the calculation formulas in Table 3.3.12. 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.

In Table 3.3.13 the Stage II emission limits are shown for recreational craft. CO and HC+NOx limits are provided for gasoline engines depending on the rated engine power and the engine type (stern-drive vs. outboard) while CO, HC+NOx, and particulate emission limits are defined for Compression Ignition (CI) engines depending on the rated engine power and the swept volume.

Table 3.3.12 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 3.3.13 Overview of the EU Emission Directive 2013/53 for recreational craft.

Diesel engines					
Swept Volume, SV	Rated Engine Power, P_N	Implement date	CO	HC + NO_x	PM
l/cyl.	kW		g/kWh	g/kWh	g/kWh
SV < 0.9	P_N < 37				
	37 <= P_N < 75 (*)	18/1 2017	5	4.7	0.30
	75 <= P_N < 3 700	18/1 2017	5	5.8	0.15
0.9 <= SV < 1.2	P_N < 3 700	18/1 2017	5	5.8	0.14
1.2 <= SV < 2.5		18/1 2017	5	5.8	0.12
2.5 <= SV < 3.5		18/1 2017	5	5.8	0.12
3.5 <= SV < 7.0		18/1 2017	5	5.8	0.11
Gasoline engines					
Engine type	Rated Engine Power, P_N		CO	HC + NO_x	PM
	kW		g/kWh	g/kWh	g/kWh
Stern-drive and inboard engines	P_N <= 373	18/1 2017	75	5	-
	373 <= P_N <= 485	18/1 2017	350	16	-
	P_N > 485	18/1 2017	350	22	-
Outboard engines and PWC engines (**)	P_N <= 4.3	18/1 2017	500 – (5.0 x P_N)	15.7 + (50/$PN^{0.9}$)	-
	4.3 <= P_N <= 40	18/1 2017	500 – (5.0 x P_N)	15.7 + (50/$PN^{0.9}$)	-
	P_N > 40	18/1 2017	300		-

(*) Alternatively, this engine segment shall not exceed a PM limit of 0.2 g/kWh and a combined HC + NO_x limit of 5.8 g/kWh.
(**) Small and medium size manufacturers making outboard engines <= 15 kW have until 18/1 2020 to comply.

Table 3.3.14 Overview of the EU Emission Directives relevant for railway locomotives and motorcars.

				CO	HC	NO_x	HC+NO_x	PM	
	EU directive	Engine size [kW]		g/kWh					Imp. date
Locomotives	2004/26	Stage IIIA							
		130<=P<560	RL A	3.5	-	-	4	0.2	1/1 2007
		560<P	RH A	3.5	0.5	6	-	0.2	1/1 2009
		2000<=P and piston displacement >= 5 l/cyl.	RH A	3.5	0.4	7.4	-	0.2	1/1 2009
	2004/26	Stage IIIB	RB	3.5	-	-	4	0.025	1/1 2012
	2016/1628	Stage V							
		0<P	RLL-v/c-1	3.5	-	-	4	0.025	2021
Motor cars	2004/26	Stage IIIA							
		130<P	RC A	3.5	-	-	4	0.2	1/1 2006
	2004/26	Stage IIIB							
		130<P	RC B	3.5	0.19	2	-	0.025	1/1 2012
	2016/1628	Stage V							
		0<P	RLR-v/c-1	3.5	0.19	2	-	0.015	2021

Aircraft engine emissions of NO_x, CO, VOC and smoke are regulated by ICAO (International Civil Aviation Organization). The engine emission certification standards are contained in Annex 16 — Environmental Protection, Volume II — Aircraft Engine Emissions to the Convention on International Civil Aviation (ICAO Annex 16, 2008, plus amendments). The emission standards relate to the total emissions (in grams) from the so-called LTO (Landing and Take Off) cycle divided by the rated engine thrust (kN). The ICAO LTO cycle contains the idealised aircraft movements below 3000 ft (915 m) during approach, landing, airport taxiing, take off and climb out.

For smoke all aircraft engines manufactured from 1 January 1983 have to meet the emission limits agreed by ICAO. For NO_x, CO, VOC The emission legislation is relevant for aircraft engines with a rated engine thrust larger than 26.7 kN. In the case of CO and VOC, the ICAO regulations apply for engines manufactured from 1 January 1983.

For NO_x, the emission regulations fall in five categories

1) For engines of a type or model for which the date of manufacture of the first individual production model was before 1 January 1996, and for which the production date of the individual engine was before 1 January 2000.
2) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 1996, or for individual engines with a production date on or after 1 January 2000.
3) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 2004.
4) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 2008, or for individual engines with a production date on or after 1 January 2013.
5) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 2014.

The regulations published by ICAO are given in the form of the total quantity of pollutants (D_p) emitted in the LTO cycle divided by the maximum sea level thrust (F_{oo}) and plotted against engine pressure ratio at maximum sea level thrust.

The limit values for NO_x are given by the formulae in Table 3.3.15.

Table 3.3.15 Current certification limits for NO_x for turbo jet and turbo fan engines.

	Engines first produced before 1.1.1996 & for engines manufactured before 1.1.2000	Engines first produced on or after 1.1.1996 & for engines manufactured on or after 1.1.2000	Engines for which the date of manufacture of the first individual production model was on or after 1 January 2004	Engines first produced on or after 1.1.2008 & for engines manufactured on or after 1.1.2013	Engines for which the date of manufacture of the first individual production model was on or after 1.1.2014
Applies to engines >26.7 kN	$Dp/F_{oo} = 40 + 2\pi_{oo}$	$Dp/F_{oo} = 32 + 1.6\pi_{oo}$			
Engines of pressure ratio less than 30					
Thrust more than 89 kN			$Dp/F_{oo} = 19 + 1.6\pi_{oo}$	$Dp/F_{oo} = 16.72 + 1.4080\pi_{oo}$	$7.88 + 1.4080\pi_{oo}$
Thrust between 26.7 kN and not more than 89 kN			$Dp/F_{oo} = 37.572 + 1.6\pi_{oo} - 0.208F_{oo}$	$Dp/F_{oo} = 38.54862 + (1.6823\pi_{oo}) - (0.2453F_{oo}) - (0.00308\pi_{oo}F_{oo})$	$Dp/F_{oo} = 40.052 + 1.5681\pi_{oo} - 0.3615F_{oo} - 0.0018\ \pi_{oo} \times F_{oo}$
Engines of pressure ratio more than 30 and less than 62.5 (104.7)					
Thrust more than 89 kN			$Dp/F_{oo} = 7+2.0\pi_{oo}$	$Dp/F_{oo} = -1.04+(2.0*\pi_{oo})$	
Thrust between 26.7 kN and not more than 89 kN			$Dp/F_{oo} = 42.71 +1.4286\pi_{oo} - 0.4013F_{oo} +0.00642\pi_{oo}F_{oo}$	$Dp/F_{oo} = 46.1600 + (1.4286\pi_{oo}) - (0.5303F_{oo}) - (0.00642\pi_{oo}F_{oo})$	
Engines with pressure ratio 62.5 or more					
Engines with pressure ratio 82.6 or more			$Dp/F_{oo} = 32+1.6\pi_{oo}$	$Dp/F_{oo} = 32+1.6\pi_{oo}$	
Engines of pressure ratio more than 30 and less than (104.7)					
Thrust more than 89 kN					$Dp/F_{oo} = -9.88 + 2.0\pi_{oo}$
Thrust between 26.7 kN and not more than 89 kN					$Dp/F_{oo} = 41.9435 + 1.505\pi_{oo} - 0.5823F_{oo} + 0.005562\pi_{oo} \times F_{oo}$
Engines with pressure ratio 104.7 or more					$Dp/F_{oo} = 32 + 1.6\pi_{oo}$

Source: International Standards and Recommended Practices, Environmental Protection, ICAO Annex 16 Volume II , 3rd edition July 2008, plus amendments: Amendment 7 (17 November 2011), Amendment 8 (July 2014)

where:

D_p = the sum of emissions in the LTO cycle in g.

F_{oo} = thrust at sea level take-off (100 %).

π_{oo} = pressure ratio at sea level take-off thrust point (100 %).

The equivalent limits for HC and CO are $D_p/F_{oo} = 19.6$ for HC and $D_p/F_{oo} = 118$ for CO (ICAO Annex 16 Vol. II paragraph 2.2.2). Smoke is limited to a regulatory smoke number = 83 $(F_{oo})^{-0.274}$ or a value of 50, whichever is the lower.

A further description of the technical definitions in relation to engine certification as well as actual engine exhaust emission measurement data can be found in the ICAO Engine Exhaust Emission Database. The latter database is accessible from "http://www.easa.europa.eu" hosted by the European Aviation Safety Agency (EASA).

Marpol 73/78 Annex VI agreed by IMO (International Maritime Organisation) concerns the control of NO_x emissions (Regulation 13 plus amendments) and SO_x and particulate emissions (Regulation 14 plus amendments) from ships (DNV, 2009). Recently the so called Energy Efficiency Design Index (EEDI) fuel efficiency regulations for new built ships was included in Chapter 4 of Annex VI in the Marpol convention for the purpose of controlling the CO_2 emissions from ships (Lloyd's Register, 2012).

The baseline NO_x emission regulation of Annex VI apply for diesel engines with a power output higher than 130 kW, which are installed on a ship constructed on or after 1 January 2000 and diesel engines with a power output higher than 130 kW which undergo major conversion on or after 1 January 2000.

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

- 17 g pr kWh, n < 130 RPM
- 45 x n-0.2 g pr kWh, 130 ≤ n < 2000 RPM
- 9.8 g pr kWh, n ≥ 2000 RPM

The further amendment of Annex VI Regulation 13 contains a three tiered approach in order to strengthen the emission standards for NO_x. The three tier approach 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 (initial regulation).
- Tier II: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2011.
- Tier III[11]: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2016.

The three tier NOx emission limit functions are shown in Table 3.3.16.

Table 3.3.16 Tier I-III NOx emission limits for ship engines in MARPOL Annex VI.

	NO_x limit	RPM (n)
Tier I	17 g pr kWh	n < 130
	45 · n-0.2 g pr kWh	130 ≤ n < 2000
	9,8 g pr kWh	n ≥ 2000
Tier II	14.4 g pr kWh	n < 130
	44 · n-0.23 g pr kWh	130 ≤ n < 2000
	7.7 g pr kWh	n ≥ 2000
Tier III	3.4 g pr kWh	n < 130
	9 · n-0.2 g pr kWh	130 ≤ n < 2000
	2 g pr kWh	n ≥ 2000

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

In relation to the sulphur content in heavy fuel and marine gas oil used by ship engines, Table 3.3.17 shows the EU and IMO (Regulation 14 plus amendments) legislation in force for SECA (Sulfur Emission Control Area) areas and outside SECA's.

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

Table 3.3.17 Current legislation in relation to marine fuel quality.

Legislation		Heavy fuel oil		Gas oil	
		S- %	Implement. date (day/month/year)	S- %	Implement. date (day/month/year)
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.

For non-road machinery, the EU directive 2003/17/EC gives a limit value of 10 ppm sulphur in diesel (from 2011).

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 Danish legal announcements. However, for jet fuel the default factor from 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.

For all mobile sources, the emission factor source for BC, NH_3, heavy metals and PAH is the EMEP/EEA guidebook (EMEP/EEA, 2013). The heavy metal emission factors for road transport and other mobile sources except national sea transport and fisheries originate from Winther and Slentø (2010). For civil aviation jet fuel, no heavy metal emission factors are proposed due to lack of data.

In the case of military ground equipment, aggregated emission factors for gasoline and diesel are derived from road traffic emission simulations. For piston engine aircraft using aviation gasoline, aggregated emission factors for conventional cars are used.

For railways, specific Danish measurements from the Danish State Railways (DSB) (Mølgård, 2016) are used to calculate the emission factors of NO_x, VOC, CO and TSP, and a NMVOC/CH_4 split is made based on expert judgment.

For agriculture, forestry, industry, household gardening and recreational craft, the NO_x, VOC, CO and TSP emission factors are derived from various

European measurement programmes; see IFEU (2004, 1999) and Winther et al. (2006). The NMVOC/CH_4 split is taken from IFEU (1999).

For national sea transport and fisheries, the NO_x emission factors predominantly come from the engine manufacturer MAN Diesel & Turbo, as a function of engine production year. The CO, VOC and TSP emission factors come from the Danish TEMA2010 emission model (Trafikministeriet, 2010), whereas the PM_{10} and $PM_{2.5}$ size fractions are obtained from MAN Diesel & Turbo.

Specifically for the ferries used by Mols Linjen new NO_x, VOC and CO emission factors are provided by Kristensen (2008), originating from measurement results by Hansen et al. (2004), Wismann (1999) and PHP (1996). Kristensen (2013) has provided complimentary emission factor data for new ferries used by Mols Linjen. For the LNG fueled ferry in service on the Hou-Sælvig route NO_x, NMVOC, CO and TSP emission factors are taken from Bengtsson et al. (2011).

For ship diesel and residual oil fuelled engines VOC/CH_4 splits are taken from EMEP/EEA (2013), and all emission factors are shown in Annex 2.B.13.

The source for aviation (jet fuel) emission factors is the EMEP/EEA guidebook (EMEP/EEA, 2013). For a number of different representative aircraft types, the EMEP/EEA guidebook comprises fuel flow and NO_x, CO and VOC emission indices for the four LTO modes and distance based emission factors for cruise. For Auxiliary power units (APU), ICAO (2011) is the data source for APU load specific NO_x, CO and VOC emission factors for different APU aircraft groups to be linked with the different representative aircraft types. VOC/CH_4 splits for aviation are taken from EMEP/EEA (2013).

For all sectors, emission factors are given in CollectER format in Annex 2.B.15 for 2015. Table 3.3.19 shows the emission factors for SO_2, NO_X, NMVOC, CO, NH_3, TSP and BC in CollectER format used to calculate the emissions from other mobile sources in Denmark.

Factors for deterioration, transient loads and gasoline evaporation for non-road machinery

The emission effects of engine wear are taken into account for diesel and gasoline engines by using the so-called deterioration factors. For diesel engines alone, transient factors are used in the calculations, to account for the emission changes caused by varying engine loads. The evaporative emissions of NMVOC are estimated for gasoline fuelling and tank evaporation. The factors for deterioration, transient loads and gasoline evaporation are taken from IFEU (2004, 1999, 2014), and are shown in Annex 2.B.10. For more details regarding the use of these factors, please refer to paragraph 3.1.4 or Winther et al. (2006).

Table 3.3.18 Fuel based emission factors for SO_2, NO_X, NMVOC, CO, NH_3, TSP and BC for other mobile sources in Denmark (2015).

			Emission factors[1] [g pr GJ]						
SNAP ID	Category	Fuel type	SO_2	NO_X	NMVOC	CO	NH_3	TSP	BC
080100	Military	AvGas	22.99	859.00	1242.60	6972.00	1.60	10.00	1.50
080100	Military	Diesel	0.44	295.81	6.49	65.97	0.69	7.12	5.39
080100	Military	Gasoline	0.44	91.10	134.29	1246.89	18.47	1.03	0.17
080300	Recreational craft	Diesel	46.84	735.70	130.85	377.07	0.17	80.21	29.68
080300	Recreational craft	Gasoline	0.46	588.77	444.73	7060.69	0.11	4.29	0.21
080402	National sea traffic	Diesel	46.84	1239.91	37.44	157.78	0.00	21.55	6.68
080402	National sea traffic	LNG	0.00	165.16	268.88	275.27	0.00	0.19	0.03
080402	National sea traffic	Residual oil	48.90	1901.99	63.92	207.54	0.00	22.50	2.70
080403	Fishing	Diesel	46.84	1281.46	58.31	181.60	0.00	21.55	6.68
080404	International sea traffic	Diesel	46.84	1589.81	58.87	189.35	0.00	21.55	6.68
080404	International sea traffic	Residual oil	48.90	2115.55	64.81	208.46	0.00	22.50	2.70
080501	Air traffic, Dom. < 3000 ft.	AvGas	22.83	859.00	1242.60	6972.00	1.60	10.00	1.50
080501	Air traffic, Dom. < 3000 ft.	Jet fuel	22.99	302.13	18.55	167.88	0.00	1.96	0.98
080502	Air traffic, Int. < 3000 ft.	AvGas	22.83	859.00	1242.60	6972.00	1.60	10.00	1.50
080502	Air traffic, Int. < 3000 ft.	Jet fuel	22.99	303.10	22.30	201.26	0.00	2.38	0.98
080503	Air traffic, Dom. > 3000 ft.	Jet fuel	22.99	372.92	6.94	101.02	0.00	1.93	0.93
080504	Air traffic, Int. > 3000 ft.	Jet fuel	22.99	311.95	6.71	88.81	0.00	4.17	1.65
080600	Agriculture	Diesel	0.47	437.48	42.37	283.07	0.20	31.34	20.00
080600	Agriculture	Gasoline	0.46	108.75	1154.93	22096.03	1.46	29.96	1.50
080700	Forestry	Diesel	0.47	277.59	23.58	209.66	0.21	18.49	14.23
080700	Forestry	Gasoline	0.46	54.79	3754.36	17915.98	0.09	82.19	4.11
080800	Industry	Diesel	0.47	444.40	59.28	316.52	0.19	41.19	28.04
080800	Industry	Gasoline	0.46	215.25	1561.94	14359.20	0.10	23.93	1.20
080800	Industry	LPG	0.00	1328.11	146.09	104.85	0.21	4.89	0.24
080900	Household and gardening	Gasoline	0.46	109.01	2152.85	31859.88	0.09	17.58	0.88
081100	Commercial and institutional	Gasoline	0.46	93.28	1521.57	30913.57	0.09	28.53	1.43
080501	Air traffic, Dom. < 3000 ft.	AvGas	22.83	859.00	1242.60	6972.00	1.60	10.00	0.00
080501	Air traffic, Dom. < 3000 ft.	Jet fuel	22.99	302.54	20.47	181.17	0.00	1.90	0.86
080502	Air traffic, Int. < 3000 ft.	AvGas	22.83	859.00	1242.60	6972.00	1.60	10.00	0.00
080502	Air traffic, Int. < 3000 ft.	Jet fuel	22.99	339.84	15.60	161.96	0.00	2.89	1.54
080503	Air traffic, Dom. > 3000 ft.	Jet fuel	22.99	376.14	4.77	48.65	0.00	2.90	1.12
080504	Air traffic, Int. > 3000 ft.	Jet fuel	22.99	386.06	3.53	40.49	0.00	5.64	2.94

[1] References. SO_2: Country-specific; Military: Aggregated emission factors for road transport; Railways (NO_x, CO, NMVOC and TSP): Danish State Railways; Agriculture, forestry, industry, household gardening and inland waterways (NO_x, CO, VOC and TSP): IFEU (2004, 1999, 2014); National sea transport and fishing: MAN B&W (NO_x), TEMA2000 (CO, NMVOC, TSP), specific data from Mols Linjen (NO_x, CO, NMVOC, TSP) and LNG emission factors (NO_x, CO, NMVOC, TSP) from Bengtsson et al. (2011); Aviation - jet fuel (NO_X, CO, NMVOC): EMEP/EEA; Aviation - av.gasoline: Aggregated emission factors for conventional gasoline cars.

3.3.4 Calculation method

Air traffic

For aviation, the domestic and international estimates are made separately for landing and takeoff (LTOs < 3000 ft), and cruising (> 3000 ft).

By using the LTO mode specific fuel flow and emission indices from EMEP/EEA (2013), the fuel consumption and emission factors for the full LTO cycle are estimated for each of the representative aircraft types used in the Danish inventory.

The fuel consumption for one LTO cycle is calculated according to the following sum formula:

$$FC^{a}_{LTO} = \sum_{m=1}^{5} t_m \cdot ff_{a,m} \qquad (13)$$

Where FC = fuel consumption (kg), m = LTO mode (approach/landing, taxi in, taxi out, take off, climb out), t = times in mode (s), ff = fuel flow (kg per s), a = representative aircraft type.

The emissions for one LTO cycle are estimated as follows:

$$E^{a}_{LTO} = \sum_{m=1}^{5} FC_{a,m} \cdot EI_{a,m} \qquad (14)$$

Where EI = emission index (g per kg fuel). Due to lack of specific airport data for approach/descent, take off and climb out, standardised times-in-modes of 4, 0.7 and 2.2 minutes are used as defined by ICAO (ICAO, 1995). For taxi in and taxi out, specific times-in-modes data are provided by Eurocontrol for the airports present in the Danish inventory. The taxi times-in-modes data are shown in Annex 2.B.10 for the years 2001-2015.

The fuel consumption and emissions for aircraft auxiliary power units (APU's) are calculated with the same method used to estimate LTO fuel consumption and emissions for aircraft main engines (formulas 13 and 14). ICAO (2011) is the data source for APU load specific fuel flows (kg per s) and emission rates (g per kg fuel) for different APU aircraft groups (characterised by seating capacity and age). APU times-in-modes for arrival, start-up, boarding and main engine start are also provided by ICAO (2011), whereas push back time intervals are taken from an emission study made in Copenhagen Airport (Ellermann et al., 2011; Winther et al., 2015).

For each representative aircraft type, the calculated fuel consumption and emission factors per LTO are shown in Annex 2.B.10 for Copenhagen Airport and other airports (aggregated) for 2015. APU data for fuel flows, emission rates and times-in-modes are also shown in Annex 2.B.10, together with the correspondence table for APU group-representative aircraft type.

The calculations for cruise use the distance specific fuel consumption and emissions given by EMEP/EEA (2013) per representative aircraft type. Data interpolations or extrapolations are made – in each case determined by the great circle distance between the origin and the destination airports.

If the great circle distance, y, is smaller than the maximum distance for which fuel consumption and emission data are given in the EMEP/EEA data bank the fuel consumption or emission E (y) becomes:

$$E(y) = E_{x_i} + \frac{(y - x_i)}{x_{i+1} - x_i} \cdot (E_{x_{i+1}} - E_{x_i}) \quad y<x_{max},\ i = 0,1,2\ldots max-1 \qquad (15)$$

In (15) x_i and x_{max} denominate the separate distances and the maximum distance, respectively, with known fuel consumption and emissions. If the flight distance y exceeds x_{max} the maximum figures for fuel consumption and emissions must be extrapolated and the equation then becomes:

$$E(y) = E_{x_{max}} + \frac{(y - x_{max})}{x_{max} - x_{max-1}} \cdot (E_{x_{max}} - E_{x_{max-1}}) \quad y>x_{max} \qquad (16)$$

Total results are summed up and categorised according to each flight's destination airport code in order to distinguish between domestic and international flights.

Annex 2.B.10 shows the average fuel consumption and emission factors per representative aircraft type for cruise flying, as well as total distance flown, for 2015[12]. The factors are split between Copenhagen Airport and other airports and distinguish between domestic and international flights.

Specifically for flights between Denmark and Greenland or the Faroe Islands, for each representative aircraft type, the flight distances are directly shown in Annex 2.B.10, which go into the cruise calculation expressions 15 and 16.

The overall fuel precision (fuel balance) in the model is 0.93 in 2015, derived as the fuel ratio between model estimates and statistical sales. The fuel difference is accounted for by adjusting cruising fuel consumption and emissions in the model according to domestic and international cruising fuel shares.

For inventory years before 2001, the calculation procedure is to estimate each year's fuel consumption and emissions for LTO based on LTO/aircraft type statistics from Copenhagen Airport, and total take off numbers for other airports provided by the Danish Transport and Construction Agency. Due to lack of aircraft type specific LTO data, fuel consumption and emission factors derived for domestic LTO's in Copenhagen Airport is used for all LTO's in other airports. In a next step, the total fuel consumption for cruise (true cruise fuel consumption) is found year by year as the statistical fuel consumption total minus the calculated fuel consumption for LTO.

For each inventory year, intermediate cruise fuel consumption figures split into four parts (Copenhagen/Other airports; domestic/international) are found as proportional values between part specific LTO fuel consumption values estimated as described previously, and part specific cruise:LTO fuel consumption ratios for 2001 derived from the detailed city-pair emission inventory.

Each inventory year's true cruise fuel consumption is finally split into four parts by using the intermediate cruise fuel consumption values as a distribution key. As emission factor input data for cruise, aggregated fuel related emission factors for 2001 are derived from the detailed city-pair emission inventory.

Non-road working machinery and recreational craft

Prior to adjustments for deterioration effects and transient engine operations, the fuel consumption and emissions in year X, for a given machinery type, engine size and engine age, are calculated as:

[12] Excluding flights for Greenland and the Faroe Islands.

$$E_{Basis}(X)_{i,j,k} = N_{i,j,k} \cdot HRS_{i,j,k} \cdot P \cdot LF_i \cdot EF_{y,z} \tag{17}$$

where E_{Basis} = fuel consumption/emissions in the basic situation, N = number of engines, HRS = annual working hours, P = average rated engine size in kW, LF = load factor, EF = fuel consumption/emission factor in g pr kWh, i = machinery type, j = engine size, k = engine age, y = engine-size class and z = emission level. The basic fuel consumption and emission factors are shown in Annex 2.B.11.

The deterioration factor for a given machinery type, engine size and engine age in year X depends on the engine-size class (only for gasoline), y, and the emission level, z. The deterioration factors for diesel and gasoline 2-stroke engines are found from:

$$DF_{i,j,k}(X) = \frac{K_{i,j,k}}{LT_i} \cdot DF_{y,z} \tag{18}$$

where DF = deterioration factor, K = engine age, LT = lifetime, i = machinery type, j = engine size, k = engine age, y = engine-size class and z = emission level.

For gasoline 4-stroke engines the deterioration factors are calculated as:

$$DF_{i,j,k}(X) = \sqrt{\frac{K_{i,j,k}}{LT_i}} \cdot DF_{y,z} \tag{19}$$

The deterioration factors inserted in (18) and (19) are shown in Annex 2.B.11. No deterioration is assumed for fuel consumption (all fuel types) or for LPG engine emissions and, hence, DF = 1 in these situations.

The transient factor for any given machinery type, engine size and engine age in year X, relies only on emission level and load factor, and is denominated as:

$$TF_{i,j,k}(X) = TF_z \tag{20}$$

Where i = machinery type, j = engine size, k = engine age and z = emission level.

The transient factors inserted in (20) are shown in Annex 2.B.11. No transient corrections are made for gasoline and LPG engines and, hence, TF_z = 1 for these fuel types.

The final calculation of fuel consumption and emissions in year X for a given machinery type, engine size and engine age, is the product of the expressions 17-20:

$$E(X)_{i,j,k} = E_{Basis}(X)_{i,j,k} \cdot TF(X)_{i,j,k} \cdot (1 + DF(X)_{i,j,k}) \tag{21}$$

The evaporative hydrocarbon emissions from fuelling are calculated as:

$$E_{Evap,\,fueling,i} = FC_i \cdot EF_{Evap,\,fueling} \tag{22}$$

Where $E_{Evap,fueling}$, = hydrocarbon emissions from fuelling, i = machinery type, FC = fuel consumption in kg, $EF_{Evap,fueling}$ = emission factor in g NMVOC pr kg fuel.

For tank evaporation, the hydrocarbon emissions are found from:

$$E_{Evap,\tan k,i} = N_i \cdot EF_{Evap,\tan k,i} \tag{23}$$

Where $E_{Evap,tank,i}$ = hydrocarbon emissions from tank evaporation, N = number of engines, i = machinery type and $EF_{Evap,fueling}$ = emission factor in g NMVOC pr year.

Ferries, other national sea transport and fisheries

The fuel consumption and emissions in year X, for regional ferries are calculated as:

$$E(X) = \sum_i N_i \cdot T_i \cdot S_{i,j} \cdot P_i \cdot LF_j \cdot EF_{k,l,y} \tag{24}$$

Where E = fuel consumption/emissions, N = number of round trips, T = sailing time pr round trip in hours, S = ferry share of ferry service round trips, P = engine size in kW, LF = engine load factor, EF = fuel consumption/emission factor in g pr kWh, i = ferry service, j = ferry, k = fuel type, l = engine type, y = engine year.

For the remaining navigation categories, the emissions are calculated using a simplified approach:

$$E(X) = \sum_i EC_{i,k} EF_{k,l,y} \tag{25}$$

Where E = fuel consumption/emissions, EC = energy consumption, EF = fuel consumption/emission factor in g pr kg fuel, i = category (local ferries, other national sea, fishery, international sea), k = fuel type, l = engine type, y = average engine year.

The emission factor inserted in (25) is found as an average of the emission factors representing the engine ages which are comprised by the average lifetime in a given calculation year, X:

$$EF_{k,l,y} = \frac{\sum_{year=X}^{year=X-LT} EF_{k,l}}{LT_{k,l}} \tag{26}$$

Other sectors

For military and railways, the emissions are estimated with the simple method using fuel-related emission factors and fuel consumption from the DEA:

$$E = FC \cdot EF \tag{27}$$

where E = emission, FC = fuel consumption and EF = emission factor. The calculated emissions for other mobile sources are shown in CollectER format in Annex 2.B.15 for the years 2015 and as time series 1985-2015 in Annex 2.B.16 (NFR format).

Energy balance between DEA statistics and inventory estimates

Following convention rules, the DEA statistical fuel sales figures are the basis for the full Danish inventory. However, in some cases for mobile sources the DEA statistical sectors do not fully match the inventory sectors. This is the case for non-road machinery, where relevant DEA statistical sectors also include fuel consumed by stationary sources.

In other situations, fuel consumption figures estimated by DCE from specific bottom-up calculations are regarded as more reliable than DEA reported sales. This is the case for national sea transport.

In the following the transferral of fuel consumption data from DEA statistics into inventory relevant categories is explained for national sea transport and fisheries, non-road machinery and recreational craft, and road transport. A full list of all fuel consumption data, DEA figures as well as intermediate fuel consumption data, and final inventory input figures is shown in Annex 2.B.14.

National sea transport and fisheries

For national sea transport in Denmark, the fuel consumption estimates obtained by DCE (see 3.3.3 Activity data – national sea transport) are regarded as much more accurate than the DEA fuel sales data, since the large fluctuations in reported fuel sales cannot be explained by the actual development in the traffic between different national ports. As a consequence, the DCE bottom-up estimates are used in the Danish inventory for national sea transport.

There are different potential reasons for the differences between estimated fuel consumption and reported sales for national sea transport in Denmark. According to the DEA, the latter fuel differences are most likely explained by inaccurate costumer specifications made by the oil suppliers. This inaccuracy can be caused by a sector misallocation in the sales statistics between national sea transport and fisheries for gas oil, and between national sea transport and industry for heavy fuel oil (Peter Dal, DEA, personal communication, 2007). Further, fuel sold for vessels sailing between Denmark and Greenland/Faroe Islands are reported as international in the DEA statistics, and this fuel categorisation is different from the IPCC guideline definitions (see following paragraph “Bunkers”).

Following this, for fisheries and industry the updated fuel consumption time series for national sea transport lead, in turn, to changes in the fuel activity data for fisheries (gas oil), industry (heavy fuel oil) and international sea transport, so the national energy balance can remain unchanged.

From 2015 LNG is being used by one specific ferry route in Denmark. No LNG is reported in DEA statistics for national sea transport, and hence this ferry fuel consumption is taken from “non-industrial combustion plants” (020200) in order to obtain a fuel balance.

For fisheries, fuel investigations made prior to the initiation of the work made by Winther (2008) have actually pointed out a certain area of inaccuracy in the DEA statistics. No engines installed in fishing vessels use heavy fuel oil, even though a certain amount of heavy fuel oil is listed in the DEA numbers for some statistical years (H. Amdissen, Danish Fishermen's Association, personal communication, 2006). Hence, for fisheries small amounts of fuel oil are transferred to national sea transport, and in addition small amounts of gasoline and diesel are transferred to recreational craft.

Non-road machinery and recreational craft

For diesel and LPG, the non-road fuel consumption estimated by DCE is partly covered by the fuel consumption amounts in the following DEA sectors: agriculture and forestry, market gardening, and building and construction. The remaining quantity of non-road diesel and LPG is taken from the DEA industry sector.

For gasoline, the DEA residential sector, together with the DEA sectors mentioned for diesel and LPG, contribute to the non-road fuel consumption total. In addition, a certain amount of fuel from road transport is needed to reach the fuel consumption goal.

The amount of diesel and LPG in DEA industry not being used by non-road machinery is included in the sectors, "Combustion in manufacturing industry" (0301) and "Non-industrial combustion plants" (0203) in the Danish emission inventory.

For recreational craft, the calculated fuel consumption totals for diesel and gasoline are subsequently subtracted from the DEA fishery sector. For gasoline, the DEA reported fuel consumption for fisheries is far too small to fill the fuel gap, and hence the missing fuel amount is taken from the DEA road transport sector.

Road transport

For natural gas and LPG, the difference between fuel reported in DEA statistics and bottom-up estimates for road transport is outbalanced with fuel totals from "non-industrial combustion plants" (020200) in order to obtain a fuel balance.

Bunkers

The distinction between domestic and international emissions from aviation and navigation should be in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. For the national emission inventory, this, in principle, means that fuel sold (and associated emissions) for flights/sea transportation starting from a seaport/airport in the Kingdom of Denmark, with destinations inside or outside the Kingdom of Denmark, are regarded as domestic or international, respectively.

Aviation

As prescribed by the IPCC guidelines, for aviation, the fuel consumption and emissions associated with flights inside the Kingdom of Denmark are counted as domestic.

This report includes flights from airports in Denmark and associated jet fuel sales. Hence, the flights between airports in Denmark and flights from Denmark to Greenland and the Faroe Islands are classified as domestic and flights from Danish airports with destinations outside the Kingdom of Denmark are classified as international flights.

In Greenland and in the Faroe Islands, the jet fuel sold is treated as domestic. This decision becomes reasonable when considering that almost no fuel is bunkered in Greenland/the Faroe Islands by flights other than those going to Denmark.

Navigation

In DEA statistics, the domestic fuel total consists of fuel sold to Danish ferries and other ships sailing between two Danish ports. The DEA international fuel total consists of the fuel sold in Denmark to international ferries, international warships, other ships with foreign destinations, transport to Greenland and the Faroe Islands, tank vessels and foreign fishing boats.

In order to follow the IPCC guidelines the bottom-up fuel estimates for the ferry routes between Denmark and the Faroe Islands, and freight transport between Denmark and Greenland/Faroe Islands are being subtracted from the fuel sales figures for international sea transport prior to inventory fuel input.

In Greenland, all marine fuel sales are treated as domestic. In the Faroe Islands, fuel sold in Faroese ports for Faroese fishing vessels and other Faroese ships is treated as domestic. The fuel sold to Faroese ships bunkering outside Faroese waters and the fuel sold to foreign ships in Faroese ports or outside Faroese waters is classified as international (Lastein and Winther, 2003).

Conclusively, the domestic/international fuel split (and associated emissions) for navigation is not determined with the same precision as for aviation. It is considered, however, that the potential of incorrectly allocated fuel quantities is only a small part of the total fuel sold for navigational purposes in the Kingdom of Denmark.

3.3.5 Uncertainties and time series consistency

Emission uncertainty estimates are made for road transport and other mobile sources using the guidelines for estimating uncertainties in the EMP/EEA guidebook (EMEP/EEA, 2013). However, for TSP the latter source indicates no uncertainty factor and, instead, this factor is based on expert judgement.

The activity data uncertainty factor is assumed to be 2 and 10 % for road transport and other mobile sources, respectively, based on expert judgement.

The uncertainty estimates should be regarded as preliminary only and may be subject to changes in future inventory documentation. The calculations are shown in Annex 2.B.17 for all emission components.

Table 3.3.19 Uncertainties for activity data, emission factors and total emissions in 2015 and as a trend.

	Emission factor uncertainties [%]		Emission uncertainties [%]	
Pollutant	Road	Other	Overall 2015	Trend
SO_2	50	50	47	1
NO_x	50	100	54	8
NMVOC	50	100	58	8
CO	50	100	66	17
NH_3	1000	1000	993	1304
TSP	50	100	46	7
PM_{10}	50	100	48	5
$PM_{2.5}$	50	100	52	3
BC	50	100	54	3
Arsenic	1000	1000	865	68
Cadmium	1000	1000	840	193
Chromium	1000	1000	843	236
Copper	1000	1000	999	5
Mercury	1000	1000	715	122
Nickel	1000	1000	921	38
Lead	1000	1000	884	9
Selenium	1000	1000	759	153
Zinc	1000	1000	950	51
Dioxins	1000	1000	723	148
Benzo(b) flouranthene	1000	1000	830	218
Benzo(k) flouranthene	1000	1000	842	317
Benzo(a) pyrene	1000	1000	888	331
indeno(1,2,3-c,d) pyrene	1000	1000	799	191
HCB	1000	1000	806	291
PCB	1000	1000	736	99

As regards time series consistency, background flight data cannot be made available on a city-pair level from 2000 or earlier. However, aided by LTO/aircraft statistics for these years and the use of proper assumptions, a good level of consistency is still obtained in this part of the transport inventory.

The time series of emissions for mobile machinery in the agriculture, forestry, industry, household and gardening (residential), and inland waterways (part of navigation) sectors are less certain than time series for other sectors, since DEA statistical figures do not explicitly provide fuel consumption information for working equipment and machinery.

3.3.6 Quality assurance/quality control (QA/QC)

It is the intention to publish every second year a sector report for road transport and other mobile sources. The last sector report concerned the 2013 inventory (Winther, 2015).

The QA/QC descriptions of the Danish emission inventories for transport are given in Nielsen et al. (2016).

3.3.7 Recalculations

The following recalculations and improvements of the emission inventories have been made since the emission reporting in 2015.

Road transport

The fuel consumption and emission factors for road transport have been updated with data from the updated COPERT model – COPERT V. In addition CNG vehicles and gasoline hybrid cars and vans have been explicitly included in the model.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are: SO_2 (0 %), NO_x (-0.4 %; 3.5 %, 2014), NMVOC (1.1 %; 2.3 %, 2013), NH_3 (-1.7 %; 1.1 %, 1994), TSP (-22.2 %; -2.0 %, 1985) and BC (-2.6 %; -0.1 %, 1993).

Navigation

A few changes have been made in relation to engine load factors for two specific ferries in 2013 and 2014.

The following largest percentage differences (in brackets) for domestic navigation are noted for: SO_2 (0 %), NO_x (-0.1 %), NMVOC (-0.1 %), TSP (-0.1 %) and BC (-0.2 %).

Agriculture/forestry

Diesel fuel consumption has been updated for agricultural machinery due to changes in the non road emission calculation model. From Stage IIIA engine emission levels onwards, input factors for specific fuel consumption have been updated based on engine manufacturers advise.

The following largest percentage differences (in brackets) for domestic navigation are noted for: SO_2 (-9 %), NO_x (-3.6 %), NMVOC (-1.4 %), NH_3 (-1.7 %), TSP (-3.7 %) and BC (-2.9 %).

Fisheries

Small changes have been made in DEA fuel statistics for diesel in 2014 and fuel transferal made between fisheries and national sea transport has also resulted in minor changes in fuel consumption for fisheries.

The following largest percentage differences (in brackets) for fisheries are noted for: SO_2 (0.2 %), NO_x (0.2 %), NMVOC (0.2 %), TSP (0.2 %) and BC (0.2 %).

Industry

A complete revision of the non road model containing building and construction machinery has been made. From engine manufacturers new input data for engine load factors have been provided based on electronic engine power registrations. Further, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of engine age has been included in the model. From Stage IIIA engine emission levels onwards, specific fuel consumption factors have been updated also based on engine manufacturers advice.

The following largest percentage differences (in brackets) for industrial non road are noted for: SO_2 (-30 %), NO_x (-29 %), NMVOC (-16 %), NH_3 (-27 %), TSP (-33 %) and BC (-34 %).

Railways

No changes have been made.

Civil aviation
Small changes in the list of aircraft types – representative aircraft types has been made in the model used for calculating civil aviation emissions.

The following largest percentage differences (in brackets) for civil aviation are noted for: SO_2 (-0.4 %), NO_x (1.2 %), NMVOC (0.4 %), TSP (-0.2 %) and BC (-0.9 %).

Other (Military and recreational craft)
Emission factors derived from the updated road transport calculations have caused a few emission changes from 1985-2014. The following largest percentage differences (in brackets) for military are noted for: SO_2 (0.0 %), NO_x (1.7 %), NMVOC (-0.1 %), NH3 (-0.7 %), TSP (-2.3 %) and BC (-3.8 %).

3.3.8 Improvements

Fuel consumption and emission factors for road transport vehicles will be updated by the time when new data becomes available from COPERT model updates.

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3.4 Fugitive emissions

This chapter covers fugitive emissions from fuels in the NFR sector 1B. Fugitive emissions from fuels include emissions from production, storage, refining, transport, venting and flaring of oil and natural gas. Denmark has no production of solid fuels, and accordingly only emissions from storage in coal piles are included in the emission inventory. The fugitive sector consists of the following NFR categories:

- 1B1 Solid fuels
- 1B2a Oil
- 1B2b Natural gas
- 1B2c Venting and flaring
- 1B2d Other*

** not occurring in the Danish emission inventory*

Most fugitive emission sources are of minor importance compared to the total Danish emissions. Fugitive and national total emissions for selected pollutants are given in Table 3.4.1.

Table 3.4.1 National and fugitive emissions of SO_2, NO_x, CO, NMVOC, $PM_{2.5}$ and BC in 2015, and the fugitive emissions share of national total emissions.

	National emission, ktonnes	Fugitive emission, ktonnes	Fugitive/national emission, %
SO_2	11	0.53	4.9
NO_x	114	0.12	0.1
CO	327	0.21	0.1
NMVOC	109	9.25	8.5
$PM_{2.5}$	20	0.02	0.1
BC	4	0.28	7.0

3.4.1 Source category description

According to the IPCC sector definitions the category *fugitive emissions from fuels* is a sub-category under the main-category Energy (Sector 1). The category *fugitive emissions from fuels* (Sector 1B) is segmented into sub-categories covering emissions from solid fuels *(coal mining and handling (1B1a), solid fuel transformation (1B1b) and other (1B1c))*, oil *(1B2a)*, natural gas *(1B2b)*, venting and flaring *(1B2c)* and other *(1B2d)*. The sub-categories relevant for the Danish emission inventory are shortly described below according to Danish conditions:

- 1B1a: Fugitive emission from solid fuels: Coal mining is not occurring in Denmark. Accordingly only emissions from storage in coal piles are included in the emission inventory.
- 1B2a: Fugitive emissions from oil include emissions from exploration, production, storage, and transmission of crude oil, distribution of oil products and fugitive emissions from refining.
- 1B2b: Fugitive emissions from natural gas include emissions from exploration, production, transmission of natural gas and distribution of natural gas and town gas.
- 1B2c: Venting and flaring include activities onshore and offshore. Flaring occur both offshore in upstream oil and gas production, and onshore in gas treatment and storage facilities, in refineries and in natural gas transmission and distribution. Venting occurs in gas storage facilities. Venting of gas is assumed to be negligible in oil and gas production and in refineries as controlled venting enters the gas flare system.

Table 3.4.2 summarizes the Danish fugitive emissions in 2015 for selected pollutants.

Table 3.4.2 Summary of the Danish fugitive emissions in 2015.

NFR category	snap category	Pollutant	Emission	Unit	Share of total fugitive
1B1a	Storage of solid fuel	TSP	414	Mg	99,0%
1B1a	Storage of solid fuel	PM_{10}	165	Mg	97,6%
1B1a	Storage of solid fuel	$PM_{2,5}$	17	Mg	80,6%
1B1a	Storage of solid fuel	BC	276	Mg	99,7%
1B2ai	Land-based activities, oil	NMVOC	992	Mg	10,7%
1B2ai	Off-shore activities, oil	NMVOC	1342	Mg	14,5%
1B2ai	Exploration of oil	SO_2	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	NO_X	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	NMVOC	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	CO	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	TSP	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	PM_{10}	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	$PM_{2,5}$	<0.001	Mg	<0.01%
1B2ai	Exploration of oil	BC	<0.001	Mg	<0.01%
1B2aiv	Petroleum products processing	NMVOC	5556	Mg	60,1%
1B2aiv	Sulphur recovery plants	SO_2	406	Mg	76,2%
1B2av	Service stations (including refuelling of cars)	NMVOC	729	Mg	7,9%
1B2b	Off-shore activities, gas	NMVOC	412	Mg	4,4%
1B2b	Exploration of gas	SO_2	<0.001	Mg	<0.01%
1B2b	Exploration of gas	NO_X	0,036	Mg	<0.01%
1B2b	Exploration of gas	NMVOC	0,043	Mg	<0.01%
1B2b	Exploration of gas	CO	0,054	Mg	<0.01%
1B2b	Exploration of gas	TSP	0,001	Mg	<0.01%
1B2b	Exploration of gas	PM_{10}	0,001	Mg	<0.01%
1B2b	Exploration of gas	$PM_{2,5}$	0,001	Mg	<0.01%
1B2b	Exploration of gas	BC	<0.001	Mg	<0.01%
1B2b	Pipelines	NMVOC	8	Mg	0,1%
1B2b	Distribution networks	NMVOC	53	Mg	0,6%
1B2c	Venting in gas storage	NMVOC	8	Mg	0,1%
1B2c	Flaring in oil refinery	SO_2	126	Mg	23,6%
1B2c	Flaring in oil refinery	NO_X	11	Mg	8,8%
1B2c	Flaring in oil refinery	NMVOC	19	Mg	0,2%
1B2c	Flaring in oil refinery	CO	44	Mg	21,1%
1B2c	Flaring in oil refinery	TSP	0,223	Mg	0,1%
1B2c	Flaring in oil refinery	PM_{10}	0,223	Mg	0,1%
1B2c	Flaring in oil refinery	$PM_{2,5}$	0,223	Mg	1,1%
1B2c	Flaring in oil refinery	BC	0,056	Mg	<0.01%
1B2c	Flaring in gas and oil extraction	SO_2	1	Mg	0,2%
1B2c	Flaring in gas and oil extraction	NO_X	110	Mg	90,3%
1B2c	Flaring in gas and oil extraction	NMVOC	132	Mg	1,4%
1B2c	Flaring in gas and oil extraction	CO	166	Mg	78,7%
1B2c	Flaring in gas and oil extraction	TSP	4	Mg	0,9%
1B2c	Flaring in gas and oil extraction	PM_{10}	4	Mg	2,2%
1B2c	Flaring in gas and oil extraction	$PM_{2,5}$	4	Mg	18,3%

1B2c	Flaring in gas and oil extraction	BC	0,69	Mg	0,2%
1B2c	Flaring in gas storage	SO_2	0,003	Mg	<0.01%
1B2c	Flaring in gas storage	NO_X	1	Mg	0,8%
1B2c	Flaring in gas storage	NMVOC	0,097	Mg	<0.01%
1B2c	Flaring in gas storage	CO	0,473	Mg	0,2%
1B2c	Flaring in gas storage	TSP	0,011	Mg	<0.01%
1B2c	Flaring in gas storage	PM_{10}	0,011	Mg	<0.01%
1B2c	Flaring in gas storage	$PM_{2,5}$	0,011	Mg	0,1%
1B2c	Flaring in gas storage	BC	0,002	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	SO_2	<0.001	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	NO_X	0,037	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	NMVOC	0,045	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	CO	0,048	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	TSP	0,001	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	PM_{10}	0,001	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	$PM_{2,5}$	0,001	Mg	<0.01%
1B2c	Flaring in gas transmission and distribution	BC	<0.001	Mg	<0.01%

3.4.2 Activity data, emission factors and emissions for fugitive sources

The following paragraphs describe the methodology for emission calculation for fugitive sources, including activity data, emission factors and annual emissions. The order follow the IPCC structure (1B1 Solid fuels, 1B2a Oil, 1B2b Natural gas, 1B2c Venting and flaring), with the exception that exploration and production of gas are include in the paragraphs for exploration and production of oil, due to similar methodologies and data providers.

Fugitive emissions from solid fuels (1B1)

Coal mining is not occurring in Denmark, and emissions from solid fuels only include particulate matter and black carbon from storage of coal in piles.

Activity data

As coal production is not occurring in Denmark, the total amount of coal used is included in the import statistics provided by DEA (DEA 2016b). Coal is primarily used in power plants, and the annual fluctuations in the import rates mainly owe to variations in electricity import/export and temperature variations. The time series show a decreasing trend due to a shift of fuels in power and heat production from coal and oil to natural gas, waste and biomass.

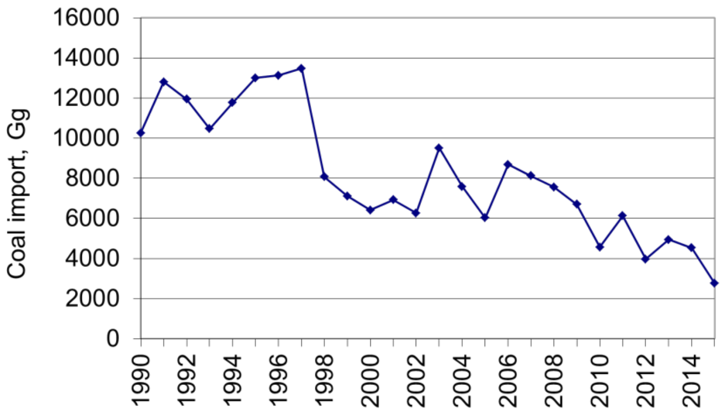

Figure 3.4.1 Import of coal.

Emission factors

The emission factors are listed in Table 3.4.3. Emissions of particulate matter (PM) from coal storage are estimated using emission factors from the Coordinated European Particulate Matter Emission Inventory Program, CEPMEIP (Visschedijk et al., 2004). The BC emission factor is estimated as a fraction of the TSP emission factor, based on characteristics for other bituminous coal included in the 2006 IPCC Guidelines (Equation 3.4.1).

$$EF_{BC} = EF_{TSP} \cdot C \cdot H \cdot 0.001 \qquad \text{(Equation 3.4.1)}$$

where EF_{BC} is the emission factor for BC [g/Mg], EF_{TSP} is the emission factor for TSP [g/Mg], C is the carbon content [kg C/GJ], and H is the heating value [GJ/Mg]. The EF_{BC} estimation is based on C = 25.8 kg C/GJ and H = 25.8 GJ/Mg, as given for other bituminous coal in IPCC (2006).

Table 3.4.3 Emission factors used to estimate particulate emissions from coal storage.

	TSP	PM_{10}	$PM_{2.5}$	BC
Emission factor, g per Mg	150	60	6	100

Emissions

Emissions from coal storage are proportional to the import rates, and the causes of the variations are described above.

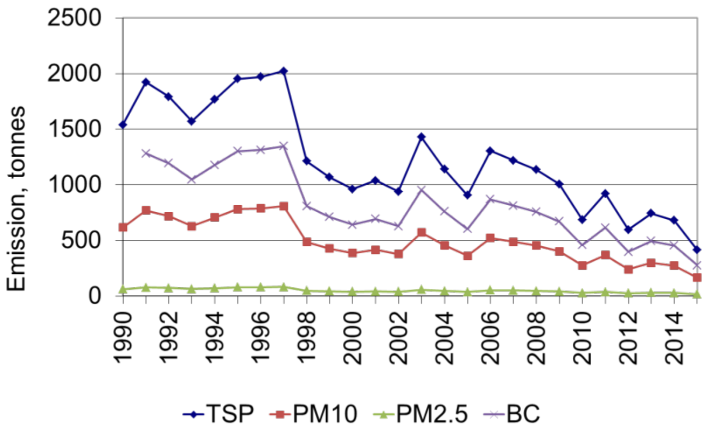

Figure 3.4.2 Emissions from coal storage.

Fugitive emissions from oil (1B2a)

The emissions from oil derive from exploration, production, onshore and offshore loading of ships, onshore oil tanks, service stations and refineries. Exploration and production of both oil and gas are described in this paragraph.

Exploration (1B2a1, 1B2b1)

Activity data

Activity data for oil and gas exploration are provided annually by the Danish Energy Agency (Andersen, 2016). Exploration of oil and gas is given separately for each exploration drilling, and fluctuate significantly over the time series. The largest oil rates are seen for 1990, 2002 and 2005, while relatively large gas rates are seen for more years of the time series. Explored rates are shown in Figure 3.5.1

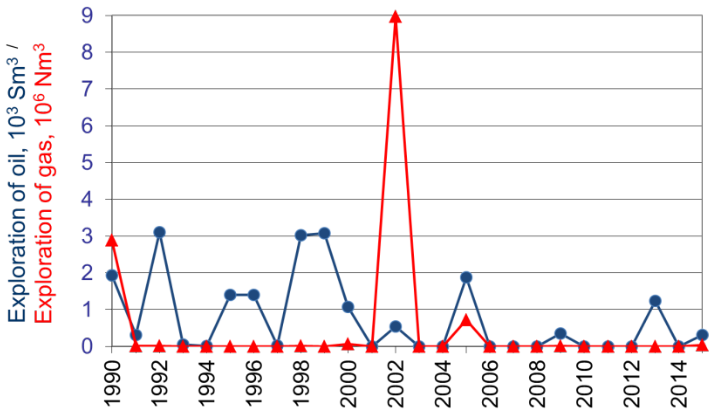

Figure 3.4.3 Exploration of oil and gas.

Emission factors

Emissions from exploration are calculated from the same emissions that are used for flaring in upstream oil and gas production. Further description on the emission factors, which are based on DEPA 2008 and EMEP/EEA 2016, is included in the Section *Fugitive emissions from venting and flaring (1B2c)* below and the emission factors are listed in Table 3.4.13.

Emissions

Calculated NMVOC emissions from exploration of oil and gas are shown in Figure 3.5.2. There is no correlation between emissions from oil and gas, as the individual exploration drillings have different ratios between oil and gas rates.

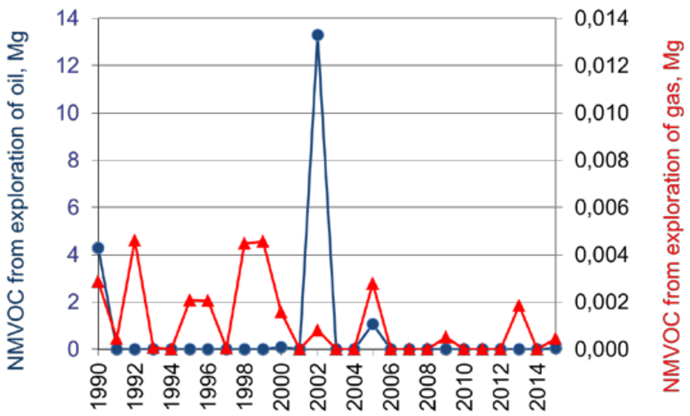

Figure 3.4.4 NMVOC emissions from exploration of oil and gas.

Production (1B2a2, 1B2b2)

Activity data

Activity data used for oil and gas production are provided by the Danish Energy Agency (DEA 2016a). As seen in Figure 3.4.5 the production of oil and gas in the North Sea has generally increased in the years 1990-2004, and since 2004 the production has decreased. Five major platforms were completed in 1997-1999, which is the main reason for the great increase in the oil production in the years 1998-2000.

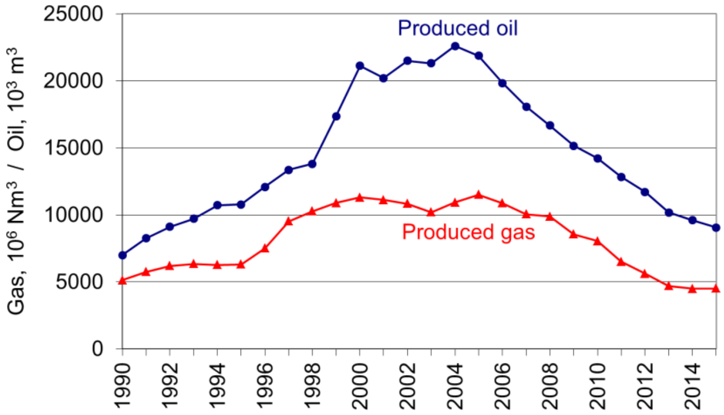

Figure 3.4.5 Production of oil and gas.

Emission factors

Standard emission factors from the 2006 IPCC Guidelines (IPCC, 2006) are used to calculate emissions from production of oil and gas (see Table 3.4.4).

Table 3.4.4 Emission factors for exploration of oil and gas.

	NMVOC	Reference
Production of oil, Gg/1000m^3	7.40E-07	IPCC 2006
Production of gas, Gg/Mm3	9.10E-05	IPCC 2006

Emissions

Calculated NMVOC emissions from oil and gas production are shown in Figure 3.4.6 for selected years. The annual variations follow the production rates.

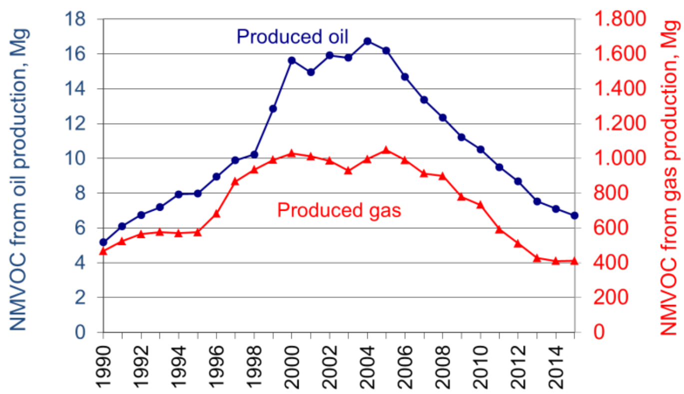

Figure 3.4.6 NMVOC emissions from production of oil and gas.

Transport (1B2a3)

Activity data

Fugitive emissions of oil transport include loading of ships from storage tanks or directly from the wells, and storage and handling at the oil terminal. Activity data for loading offshore and onshore are provided by the Danish Energy Agency (DEA 2016a) and from the annual self-regulating reports from DONG Oil Pipe A/S (DONG Oil Pipe A/S 2016c), respectively. The latter also provide annual emissions from storage and handling at the oil terminal.

The rates of oil loaded on ships roughly follow the trend of the oil production (see Figure 3.4.7). Offshore loading of ships was introduced in 1999. In earlier years the produced oil was transported to land via pipeline.

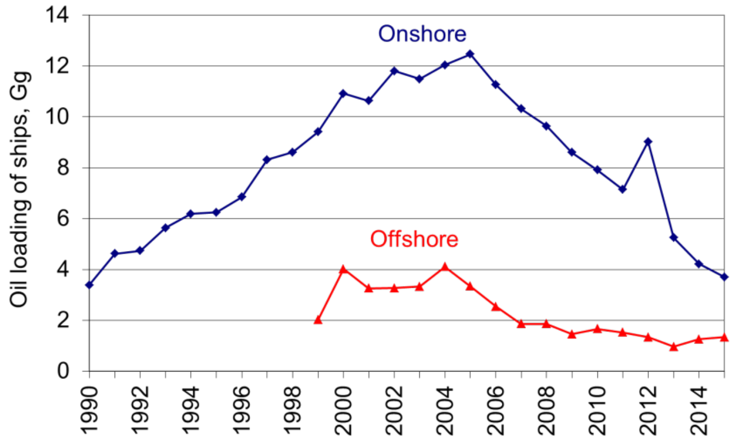

Figure 3.4.7 Onshore and offshore loading of ships.

Emission factors

The EMEP/EEA Guidebook provide standard emission factors for loading of ships onshore and offshore for different countries (EMEP/EEA, 2016). In the Danish inventory the Norwegian emission factors are used for estimation of fugitive emissions from loading of ships onshore and offshore for the years 1990-2009. During 2009 new emission reducing technologies (degassing unit) were installed at the crude oil terminal. Measurements were carried out at the terminal before and after installation show a decrease of 25 % of the NMVOC emission from loading of ships (Miljøcenter Odense, 2010). The reduced emission factors used for 2010 onwards are included in Table 3.4.5.

Table 3.4.5 NMVOC emission factors for loading of ships onshore and offshore.

	NMVOC, fraction of loaded	Reference
Ships off-shore	0.001	EMEP/EEA, 2016
Ships on-shore, 1990-2009	0.0002	EMEP/EEA, 2016
Ships on-shore, 2010 onwards	0.00015	EMEP/EEA, 2016; Miljøcenter Odense, 2012

Emissions

NMVOC emissions from transport of oil for selected years are shown in Figure 3.4.8.

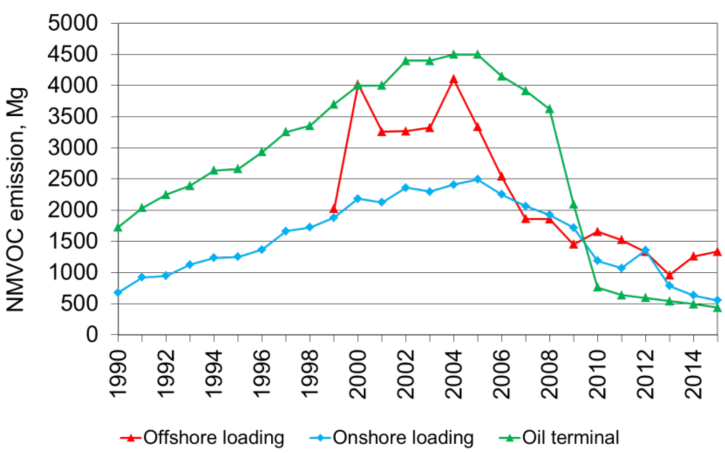

Figure 3.4.8 NMVOC emissions from the oil terminal and from onshore and offshore loading of ships.

Refining (1B2a4)

Activity data

Emissions from oil refinery processes include non-combustion emissions from handling and storage of feedstock (raw oil), from the petroleum product processing and from handling and storage of products. Emissions from flaring in refineries are included in the Section *Fugitive emissions from venting and flaring (1B2c)*. Emissions related to process furnaces in refineries are included in stationary combustion.

Rates of crude oil processed in the two Danish refineries are given in their annual environmental report (A/S Dansk Shell, 2016 and Statoil A/S, 2016). Until 1996 a third refinery was in operation, leading to a decrease in the crude oil rate from 1996 to 1997. Activity date is shown in Figure 3.4.9.

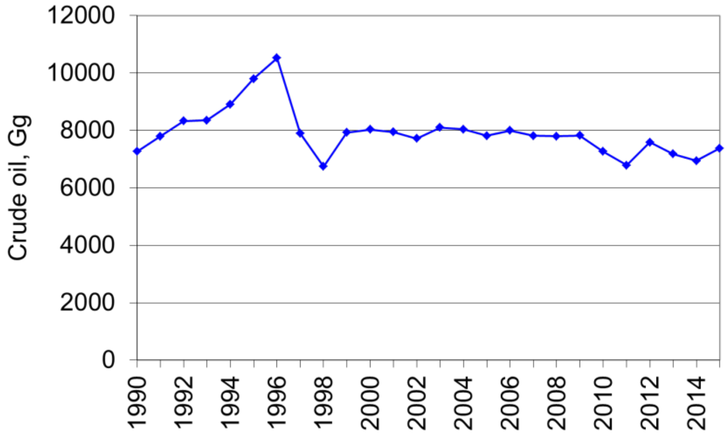

Figure 3.4.9 Crude oil processed in Danish refineries.

Emission factors

Emissions of SO_2 and VOC are given by the refineries. Only one of the two refineries has made a split between NMVOC and CH_4. For the other refinery it is assumed that 10 % of the VOC emission is CH_4 and the remaining 90 % is NMVOC (Hjerrild & Rasmussen, 2014).

Emissions

Refineries are a significant source to fugitive emissions of SO_2, the most important activity being flaring. In 1990-1993 emissions from petroleum product processing were included in emissions from flaring in refineries (NFR category 1B2c). From 1994 the data delivery format was changed, which made it possible to split the emissions into contributions from flaring and processing, respectively. Emissions from processing are from 1994 included in NFR category 1B2a iv.

SO_2 and NMVOC emissions are shown in Figure 3.4.10. One refinery was shut down in 1996 leading to larger emissions in 1990-1996. Technical improvements of the sulphur recovery system at one of the two Danish refineries lead to a decrease of SO_2 emissions from 1996-1998. The large emissions from 2005 and onwards owe to shut-downs due to maintenance and accidents. Further, construction and initialisation of new facilities and problems related to the ammonium thiosulphate (ATS) plant at the one refinery has led to increased emissions. In 2007 the capacity of the ATS plant was increased followed by commissioning difficulties.

The increase of NMVOC emissions from 2005 to 2006 owes a new measurement campaign at one refinery, which showed larger emissions than the previous. According to the environmental department at the refinery, fugitive emissions from oil processing in refineries does not correlate to any measured parameters, but are expected to follow a more random pattern. The refinery has chosen to report the latest measured emission for the years between measurement campaigns, and as no better methodology are available, the same approach is used in the national emission inventories.

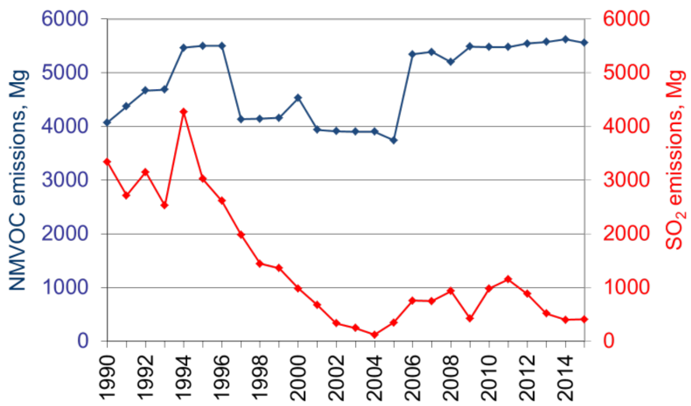

Figure 3.4.10 SO_2 and NMVOC emissions from crude oil processing including sulphur recovery in Danish refineries.

Service stations (1B2a5)

Activity data

Calculations of emissions from service stations are based on gasoline sales figures from the Danish Energy statistics (DEA, 2016b). The gasoline sales show an increase from 1990-1998 and a decreasing trend since 1999 as shown in Figure 3.4.11.

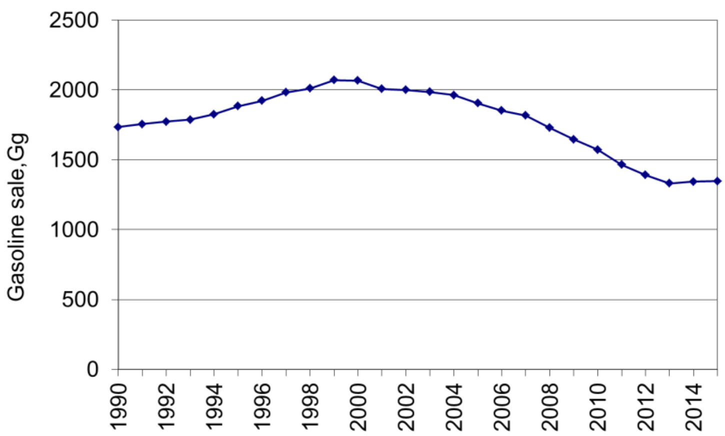

Figure 3.4.11 Gasoline sales in Denmark.

Emission factors

The NMVOC emission from service stations is calculated by use of different emission factors for the time series as shown in Table 3.4.6.

In 1994 the emission factors for NMVOC from service stations were investigated by Fenhann and Kilde (1994) for 1990 and 1991, individually. The emission factors reported for reloading for 1990 are used for the years 1985-1990, while the emission factor for 1991 is used for 1991 only. In 1995 Stage I was made obligatory, and the emission factor from the 2016 EMEP/EEA Guidebook (EMEP/EEA, 2013) is applied from 1995 and onwards. Linear interpolation is applied for the years 1992-1994.

Fenhann and Kilde (1994) also include NMVOC emission factors for refuelling for the years 1990, 1991, 1992, and 1993. The same value is given for the three years, and this emission factor is applied for the years 1994-1995, when the first legal acts on emission reduction from service stations turned into force. From 2005 the refuelling emission factor is based on the 2013 EMEP/EEA Guidebook (EMEP/EEA, 2016). An abatement rate of 85 % is given in the 2016 EMEP/EEA Guidebook, while 60 % were given in the 2006 EMEP/EEA Guidebook (EMEP/EEA, 2006). The Danish requirement is 85 % abatement under optimal conditions, but 70 % in practice occurrence (Danish Ministry of the Environment, 2011). Based on this, 70 % abatement is applied in the emission calculations. Linear interpolation is used from 1996-2004.

Table 3.4.6 Emission factors used for estimating NMVOC from service stations.

Year	Reloading of tankers, kg NMVOC per tonnes gasoline	Refuelling of vehicles, kg NMVOC per tonnes gasoline	Sum of reloading and refuelling, kg NMVOC per tonnes gasoline	Source
1985-1990	1,28	1,52	2,80	Fenhann & Kilde,1994
1991	0,64	1,52	2,16	Fenhann & Kilde,1994
1992	0,49	1,52	2,01	Interpolation / Fenhann & Kilde,1994
1993	0,35	1,52	1,87	Interpolation / Fenhann & Kilde,1994
1994	0,20	1,52	1,72	Interpolation / Fenhann & Kilde,1994
1995	0,05	1,52	1,57	EMEP/EEA 2016 / Fenhann & Kilde,1994
1996	0,05	1,42	1,47	EMEP/EEA 2016 / interpolation
1997	0,05	1,31	1,37	EMEP/EEA 2016 / interpolation
1998	0,05	1,21	1,26	EMEP/EEA 2016 / interpolation
1999	0,05	1,11	1,16	EMEP/EEA 2016 / interpolation
2000	0,05	1,00	1,06	EMEP/EEA 2016 / interpolation
2001	0,05	0,90	0,95	EMEP/EEA 2016 / interpolation
2002	0,05	0,80	0,85	EMEP/EEA 2016 / interpolation
2003	0,05	0,69	0,75	EMEP/EEA 2016 / interpolation
2004	0,05	0,59	0,64	EMEP/EEA 2016 / interpolation
2005 onwards	0,05	0,49	0,54	EMEP/EEA 2016

Emissions

Emissions from service stations are shown in Figure 3.4.12. The decrease from 1990 to 1999 owes to decreasing emission factors due to technological improvements. From 1999 to 2005 the decrease owe to a combination of decreasing gasoline sales and decreasing emission factors. Since 2005 the decreasing trend is less pronounced and only variates with the gasoline sales, which show a decreasing trend.

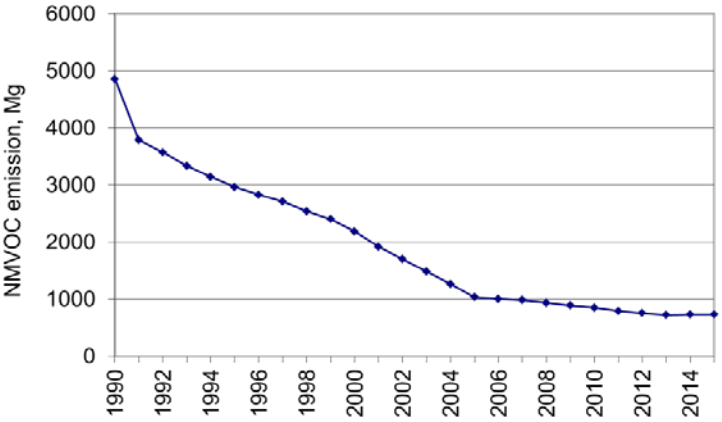

Figure 3.4.12 NMVOC emissions from service stations.

Fugitive emissions from natural gas (1B2b)

The emissions from natural gas derive from exploration, transmission, storage and distribution. Descriptions of exploration and production of natural gas are included in the sections covering exploration and production of oil *Exploration (1B2a1, 1B2b1)* and *Production (1B2a2, 1B2b2)*.

Exploration (1B2b1)

See Section *Exploration (1B2a1, 1B2b1)*.

Production (1B2b2)

See Section *Production (1B2a2, 1B2b2)*.

Transmission and storage (1B2b4)

Activity data

The fugitive emissions from transmission and storage of natural gas are based on information from the gas transmission companies, which provide data on transmission rates, pipeline losses, and length and material of the pipeline systems. The length of the transmission pipelines is approximately 900 km.

The activity data used in the calculation of the emissions from transmission of natural gas are shown in Figure 3.4.13. Transmission rates for 1990-1998 refer to annual environmental reports of DONG Energy. In 1999-2006 transmission rates refer to the Danish Gas Technology Centre (Karll 2002, Karll 2003, Karll 2004, Karll 2005, Oertenblad 2006, Oertenblad 2007). From 2008 onwards transmission rates refer to Energinet.dk (2016b). Transmission losses for 1991-1999 are based on annual environmental report of DONG Energy. The average for 1991-1995 is applied for 1990. From 2005 onwards transmission losses are given by Energinet.dk. The average for 2005-2010 is applied for the years 2000-2004.

The variation over the time series owes mainly to variations in the winter temperature and to the variation of import/export of electricity from Norway and Sweden. The transmission rate is less than the production rate, as part of the produced natural gas is exported through the NOGAT pipeline system.

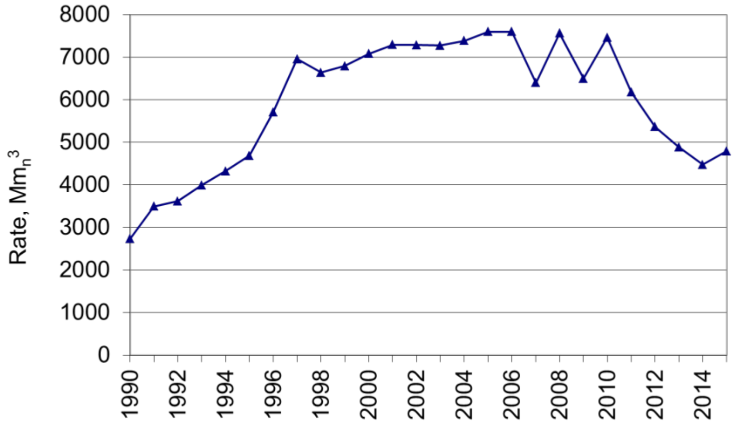

Figure 3.4.13 Rates for transmission of natural gas.

Emission factors

The fugitive emissions from transmission and storage of natural gas are based on data on gas losses from the companies and on the average annual natural gas composition given by Energinet.dk (2016c) (Table 3.4.7).

Table 3.4.7 Annual gas composition, lower heating value and density for Danish natural gas.

		Unit	1990	2000	2005	2010	2015
Methane	CH_4	molar-%	90.92	86.97	88.97	89.95	88.8
Ethane	C_2H_6	molar-%	5.08	6.88	6.14	5.71	6.08
Propane	C_3H_8	molar-%	1.89	3.17	2.50	2.19	2.47
i-Butane	i-C_4H_{10}	molar-%	0.36	0.43	0.40	0.37	0.39
n-Butane	n-C_4H_{10}	molar-%	0.50	0.61	0.55	0.54	0.59
i-Petane	i-C_5H_{12}	molar-%	0.14	0.11	0.11	0.13	0.13
n-Petane	n-C_5H_{12}	molar-%	0.10	0.08	0.08	0.08	0.1
n-Hexane and heavier hydrocarbons	C^{6+}	molar-%	0.09	0.06	0.05	0.06	0.05
Nitrogen	N_2	molar-%	0.31	0.34	0.29	0.31	0.32
Carbon dioxide	CO_2	molar-%	0.60	1.35	0.90	0.66	1.07
Lower heating value	H_n	MJ/m^3_n	39.176	40.154	39.671	39.461	39.635
Density	ρ	kg/m^3_n	0.808	0.846	0.825	0.816	0.8281

Emissions

Emissions of NMVOC from transmission of natural gas are shown in Figure 3.4.14. As the pipelines in Denmark are relatively new and made of plastic, most emissions are due to leaks during construction and maintenance. This leads to large annual fluctuations in emissions which are not correlated to the transmission rates. E.g. the large emission in 1995 owe to a large construction work covering four different locations. The increase in 2011 owe to venting for drainage of the pipes in preparation for construction work on a new compressor station, and the increase in 2014 owe to the construction of a new major railway line.

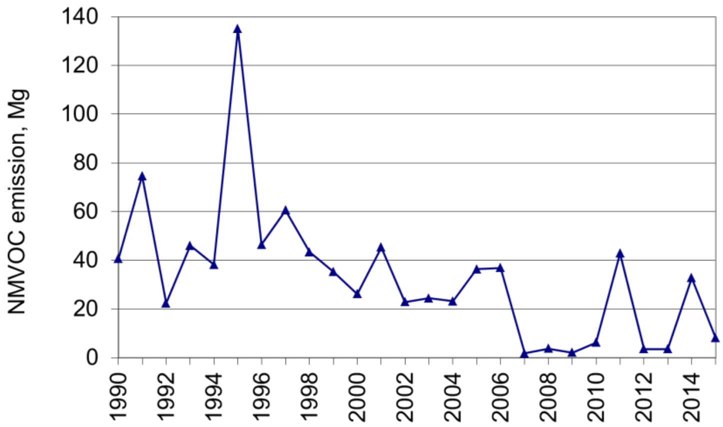

Figure 3.4.14 NMVOC emissions from transmission of natural gas.

Distribution (1B2b5)

Activity data

Distribution rates for 1990-1998 are estimated from the Danish energy statistics. Distribution rates are assumed to equal total Danish consumption rate minus the consumption rates of sectors that receive the gas at high pressure. The following consumers are assumed to receive high pressure gas: town gas production companies, production platforms and power plants. Distribution rates for 1999-2006 refer to DONG Energy/Danish Gas Technology Centre/Danish gas distribution companies (Karll 2002, Karll 2003, Karll 2004, Karll 2005, Oertenblad 2006, Oertenblad 2007). Since 2007 the distribution rates are given by the companies. The fugitive losses from distribution of natural gas are only given for some companies. The average of the available "loss/distribution"-ratios is used for the remaining companies.

Activity data for distribution of town gas is rather scarce, and calculations are based on the available data from the town gas distribution companies on losses from the pipelines. At present, there are two areas with town gas distribution and correspondingly two distribution companies. Two other companies in other areas were closed in 2004 and 2006, and it has not been possible to collect data for all years in the time series. The emissions have been calculated for the years with available data and the distribution loss for the first year with data has been applied for the previous years in the time series. Data is missing for the later years (1996-2003) for one of the distribution companies. The distribution rate is assumed to decrease linearly to cero over these years, and the share ("distribution loss/distribution rate") is assumed equal to the value for 1995.

Data on the distribution network are given by Energinet.dk, DGC and the distribution companies concerning length and material. The length of the distribution network is around 20.000 km. Because the distribution network in Denmark is relatively new most of the pipelines are made of plastic (approximately 90 %). For this reason the fugitive emission is negligible under normal operating conditions as the distribution system is basically tight with no fugitive losses. However, the plastic pipes are vulnerable and therefore most of the fugitive emissions from the pipes are caused by losses due to excavation damages, and construction and maintenance activities performed by the gas companies. These losses are either measured or estimated by calculation in each case by the gas companies. About 5 % of the distribution network is used for town gas. This part of the network is older and the fugitive losses are larger. The fugitive losses from this network are associated with more uncertainty as it is estimated as a percentage (15 %) of the meter differential. This assumption is based on expert judgement from one of the town gas companies (Jensen, 2008). Distribution rates are shown in Figure 3.5.11.

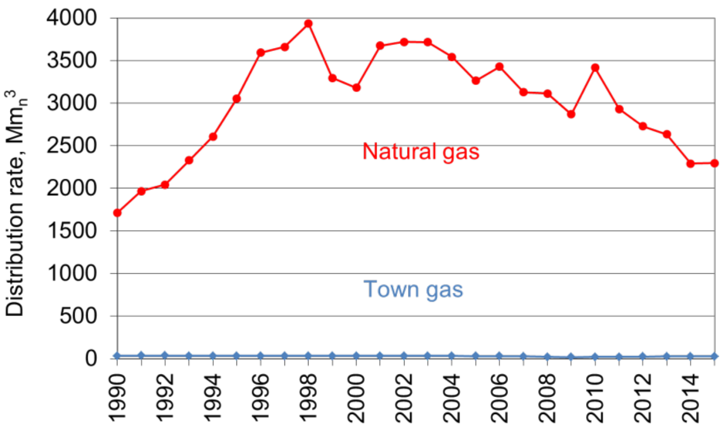

Figure 3.4.15 Distribution rates of natural gas and town gas.

Emission factors

Emissions from natural gas distribution are calculated from the fugitive losses from pipelines and the gas quality measured by Energinet.dk (see Table 3.4.7). The same approach is used for town gas, which is natural gas admixed ~ 50 % ambient air. From 2014 one town gas distribution company has started to admix biogas. In 2015 the share of biogas is 17.5 % which is expected to increase in the coming years. The admixed biogas has not been upgraded as tests of different appliances have shown that up to 40 % un-upgraded biogas can be added to the town gas without causing problems with the appliances' combustion. The gas composition of biogas is given in Table 3.4.8.

Table 3.4.8 Composition of biogas admixed to town gas (Jeppesen, 2014; Ea Energianalyse, 2014).

Methane	molar-%	60.98
Nitrogen	molar-%	0.001
Carbon dioxide	molar-%	39.02
Lower heating value	MJ/m^3_n	21.53
Density	kg/m^3_n	0.808

The distribution companies provide emissions of CH_4 for the years 1997 and onwards. For the years 1995-1996 CH_4 emissions are calculated from the registered loss from distribution and the annual composition of Danish natural gas given by Energinet.dk. As distribution losses are not available for the years 1990-1994, the percentage loss for 1995 is used.

Emissions

Emissions of NMVOC from distribution of natural gas and town gas are shown in Figure 3.5.12. The decreasing trend for town gas owe to phase-out of town gas distribution in two areas. Further relining of old pipelines has reduced the gas loss from town gas distribution.

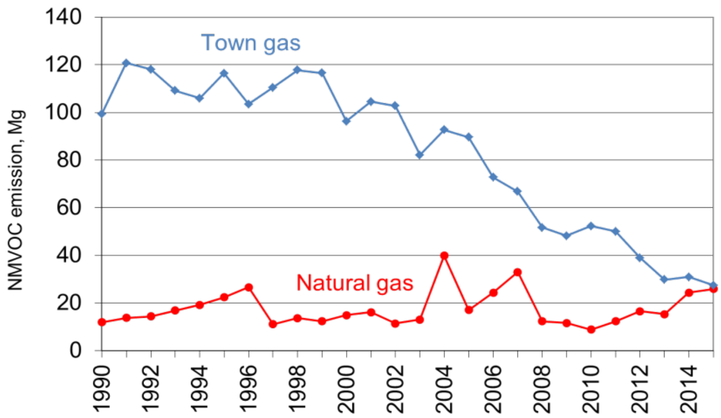

Figure 3.4.16 NMVOC emissions from transmission of natural gas.

Fugitive emissions from venting and flaring (1B2c)

Venting occur in the two Danish natural gas storage facilities. Flaring occurs in refineries, in oil and gas production, in gas treatment and storage facilities, and in gas transmission and distribution.

Venting

Activity data

The natural gas storage facilities are obligated to make environmental reports on annual basis, including data on venting. Venting of gas is assumed to be not occurring in extraction and in refineries, as controlled venting enters the gas flare system. Venting rates in gas storage facilities are shown in Figure 3.4.13. Data are not available for the years 1990-1994 for the one gas storage facility that was in operation over the entire time series, and the average for 1995-1998 is applied. The second gas storage facility was opened in 1994, leading to increasing venting rates.

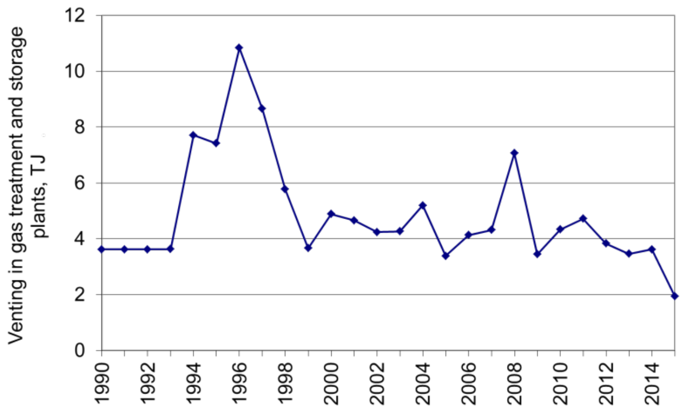

Figure 3.4.17 Venting rates in gas storage facilities.

Emission factors

Emissions of NMVOC from venting are given in the environmental reports for the gas storage facilities (Dong Energy, 2016a; Dong Energy, 2016b; Energinet.dk, 2016a).

Emissions

Venting is limited to the gas storage facilities and the emissions are of minor importance to the total fugitive emissions. Venting emissions are included in Figure 3.4.21.

Flaring

Flaring in refineries

Activity data

Flaring rates for the two Danish refineries are given in their environmental reports and in additional data provided by the refineries directly to DCE. From 2006 flaring rates are given in the EU ETS reporting. Data are not available for the years 1990-1993, why the flaring rate for 1994 has been adopted for the previous years. Flaring rates are shown in Figure 3.4.18.

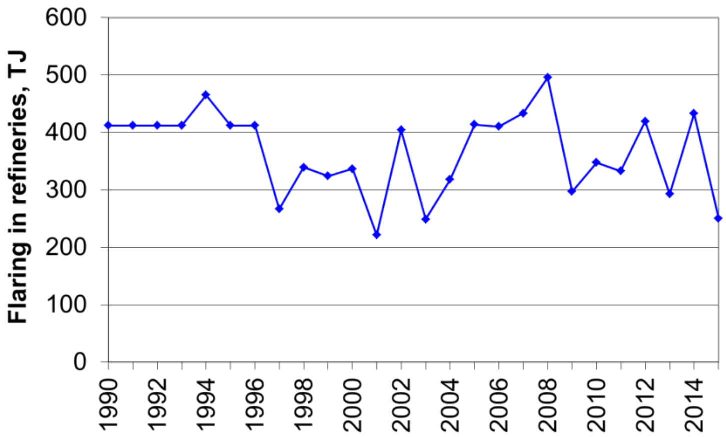

Figure 3.4.18 Flaring rates in refineries.

Emission factors

SO_2 emissions are provided annually by the refineries, while NO_x emissions are provided annually by only one refinery. The composition of refinery gas is given for 2008 by one of the two refineries. As the composition for refinery gas is very different from than the composition of natural gas, the 2008 refinery gas composition is used in calculations for both Danish. The NMVOC emission factors based on the 2008 refinery gas composition are applied for both refineries for the entire time series. Emissions of the remaining are based on standard emission factors from the 2016 EMEP/EEA Guidebook. Emission factors for selected pollutants are listed in Table 3.4.9.

Table 3.4.9 Emission factors for flaring in refineries.

Pollutant	Emission factor, g/GJ
NO_x	32.2
NMVOC	76.448
CO	177
TSP	0.89
PM_{10}	0.89
$PM_{2.5}$	0.89
BC	0.223

Emissions

Emissions of NMVOC and SO_2 are shown in figure 3.4.19. The variation over the time series mainly reflects the annual variation in the activity rate for flaring. SO_2 in the early years of the time series are very uncertain as one refinery is closed and as only very scarce amounts of information are available. It has not been possible to get further verification the data for 1990-1994.

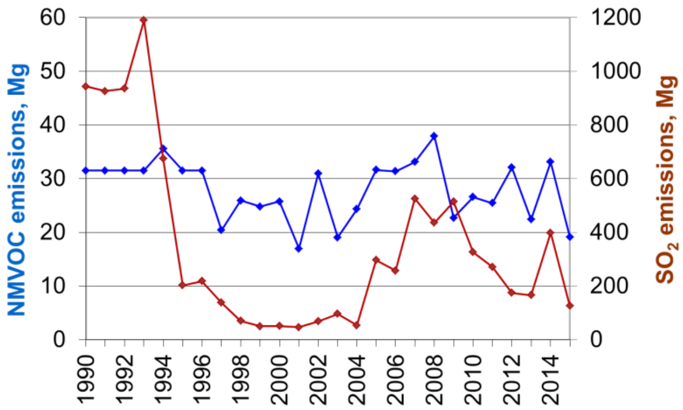

Figure 3.4.19 NMVOC and SO_2 emissions from flaring in refineries.

Flaring in upstream oil and gas production

Activity data

From 2006 data on flaring in upstream oil and gas production is given in the reports for the EU ETS and thereby emission calculation can be made for the individual production units. Before 2006 only the total flared amount is available in the annual report Denmark's oil and gas production (Danish Energy Agency, 2016a). Flaring rates are shown in Figure 3.4.20. Flaring rates in upstream oil and gas production have been decreasing over the last 10 years period in accordance with the decrease in production as seen in Figure 3.4.5. Further, there is focus on reduction of the amount being flared for environmental reasons.

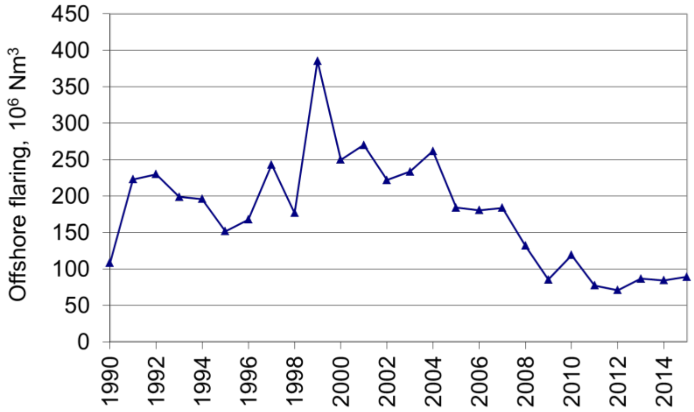

Figure 3.4.20 Flaring rates in upstream oil and gas production.

Emission factors

The emission factors for flaring in upstream oil and gas production are shown in Table 3.4.10. The NO_x emission factor is based on the conclusion in a Danish study of NO_x emissions from offshore flaring carried out by the Danish Environmental Protection Agency (DEPA, 2008). The recommended NO_x emission factor (31 008 g per GJ or 0.0015 tonnes NO_x per tonnes gas) corresponds well with the emission factors used to estimate NO_x emission in other countries with oil production in the North Sea (Netherlands: approximately 0.0014 tonnes NO_x per tonnes gas and United Kingdom: approximately 0.0013 tonnes NO_x per tonnes gas). Emission factors for all other pollutants are based on standard Tier 1 emission factors for stationary combustion of gaseous fuels in energy industries from the 2016 EMEP/EEA Guidebook.

Table 3.4.10 Emission factors for flaring in upstream oil and gas production.

Pollutant	Emission factor, g/GJ
SO_2	0.013
NO_x	1.227
NMVOC	1.482
CO	1.854
TSP	0.042
PM_{10}	0.042
$PM_{2.5}$	0.042
BC	0.008

Emissions

Emissions from flaring in upstream oil and gas production are estimated from the same emission factors for all years in the time series, and the variations reflect only the variations in the flared amounts. As shown in Figure 3.4.21, there was a marked increase in the rate of flaring in upstream oil and gas production in 1997 and especially in 1999. The increase in 1997 was due to the new Dan field and the completion of the Harald field. The increase in 1999 was due to the opening of the three new fields Halfdan, Siri and Syd Arne.

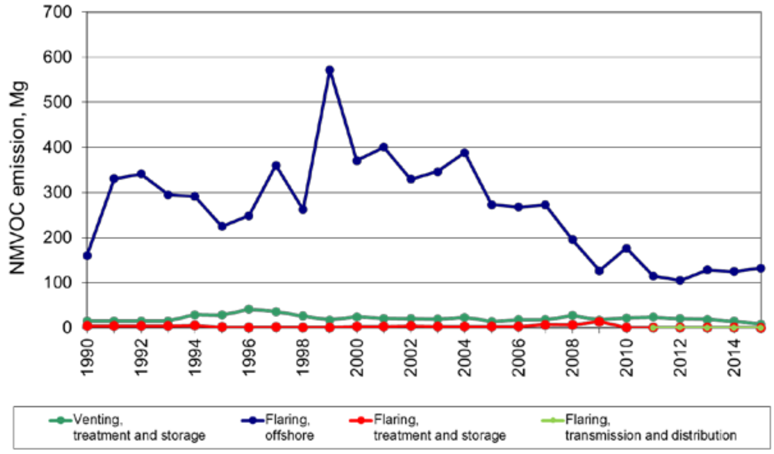

Figure 3.4.21 NMVOC emissions from flaring in upstream oil and gas production.

Flaring in gas treatment and storage facilities

Activity data

Activity data for flaring in gas treatment and storage facilities are given in DONG Energy's environmental reports (Dong Energy, 2016a; Dong Energy, 2016b; Energinet.dk, 2016a). Flaring rates in gas treatment and gas storage facilities are not available before 1994. The mean value for 1994-1998 has been adopted as basis for the emission calculation for the years 1990-1993. Note that one of the two gas storage facilities was not opened before 1994. The large amount of gas flared in 2007 owe to a larger maintenance work at the gas treatment plant.

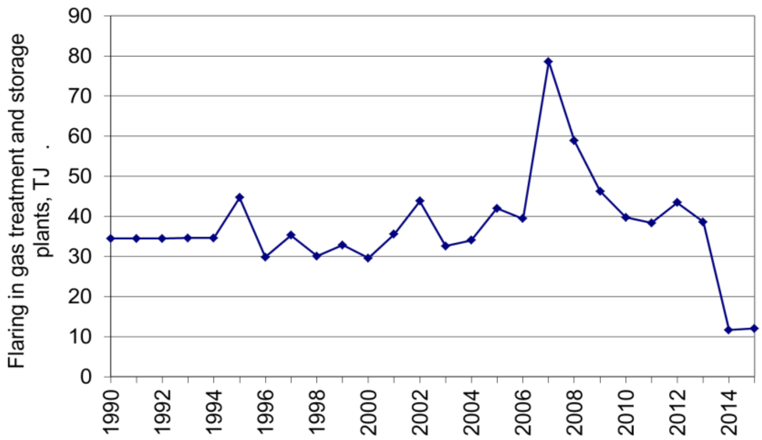

Figure 3.5.10 Flaring in gas treatment and storage facilities.

Emission factors

Emissions from flaring in gas treatment and storage facilities are calculated from the same emission factors which are used for flaring in upstream oil and gas production.

Emissions

Emissions from flaring in gas treatment and storage facilities are of minor importance to the total fugitive emissions. NMVOC emissions are included in Figure 3.4.21.

3.4.3 Uncertainties and time series consistency

The applied methodology for uncertainty estimates refers to Pulles & Aardenne (2004). The Danish uncertainty estimates are based on the simple Tier 1 approach described in IPCC Good Practice Guidance (IPCC, 2000).

Input data

The uncertainty estimates are based on the calculated emissions for the base year and for the latest inventory year, and on the uncertainty rates for both activity data and emission factors. Data is aggregated for the NFR category 1B - Fugitive Emissions from Fuels. Base year refers to 2000 for particulate matter and to 1990 for the remaining pollutants. Emission data, activity data and emission factors are described in Section *3.4.2 Activity data, emission factors and emissions for fugitive sources*.

For each pollutant the primary emission source/sources is the determinant for the overall uncertainty level. Uncertainty levels are based on IPCC Good Practice Guidance, EMEP/EEA Guidebook, reports under the EU ETS and DCE assumptions. Uncertainty levels for activity data and emission factors are listed in Table 3.4.11.

Table 3.4.11 Uncertainty levels for activity rates and emission factors for NFR category 1B - Fugitive Emissions from Fuels.

Pollutant	Activity data uncertainty level, %	Emission factor uncertainty level, %
SO_2	10	25
NO_x	7.5	125
NMVOC	2	125
CO	7.5	125
TSP	2	50
PM_{10}	2	50
$PM_{2.5}$	2	50
BC	2	100
As	7.5	500
Cd	7.5	500
Cr	7.5	500
Cu	7.5	500
Hg	7.5	500
Ni	7.5	500
Pb	7.5	500
Se	7.5	500
Zn	7.5	500
PCDD/F	7.5	500
Benzo(b) fluoranthene	7.5	500
Benzo(k) fluoranthene	7.5	500
Benzo(a)pyrene	7.5	500
Indeno (1,2,3-cd) pyrene	7.5	500

Results

The uncertainty model estimates uncertainties for both the emission level and the trend. The uncertainty on the emission level for SO_2, NO_x, NMVOC and CO is 27 %, 125 %, 125 % and 125 %, respectively.

For PM the uncertainty is 50 %, for BC the uncertainty is 100 % and for HM and PAHs the uncertainty is 500 %. The individual uncertainty estimates for the fugitive emission inventory are shown in Table 3.4.12. The trend refers to the years 1990-2014 for all pollutants except PM where the trend refers to 2000-2014. Uncertainties for PCDD/F are not included in the table, as the estimates are very large due to the methodology and as the base year emission is very close to zero.

Table 3.4.12 Estimated uncertainty levels for emissions and trends for fugitive emissions.

Pollutant	Emission uncertainty %	Trend uncertainty %
SO_2	27	2
NO_x	125	9
NMVOC	125	2
CO	125	8
TSP	50	1
PM_{10}	50	1
$PM_{2.5}$	50	1
BC	100	1
As	500	8
Cd	500	6
Cr	500	6
Cu	500	6
Hg	500	8
Ni	500	6
Pb	500	8
Se	500	6
Zn	500	8
PCDD/F	500	8
Benzo(b) fluoranthene	500	8
Benzo(k) fluoranthene	500	8
Benzo(a)pyrene	500	8
Indeno (1,2,3-cd) pyrene	500	8

3.4.4 Source specific QA/QC and verification

A list of QA/QC tasks are performed directly in relation to the fugitive emission part of the Danish emission inventories. The following procedures are carried out to ensure the data quality:

- The emission from the large point sources (refineries, gas treatment and gas storage plants) is compared with the emission reported the previous year.
- Annual environmental reports are kept for subsequent control of plant-specific emission data.
- Checks of data transfer are incorporated in the fugitive emission models, e.g. sum checks.
- Verification of activity data from external data when data are available through more data sources (offshore fuel and flaring rates).
- Data sources are incorporated in the fugitive emission models
- A manual log table in the emission databases is applied to collect information about recalculations.
- Comparison with the inventory of the previous year. Any major changes are verified.
- Total emission, when aggregated to reporting tables, is compared with totals based on SNAP source categories (control of data transfer).
- Checking of time series in the NFR and SNAP source categories. Significant dips and jumps are controlled and explained.

Data deliveries

Table 3.4.13 lists the external data deliveries used for the inventory of fugitive emissions. Further the table holds information on the contacts at the data delivery companies.

Table 3.4.13 List of external data sources.

Category	Data description	Activity data, emission factors or emissions	Reference	Contact(s)	Data agreement /comment
Exploration of oil and gas	Dataset for exploration of oil and gas, including rates and composition.	Activity data	The Danish Energy Agency	Jan H. Andersen	Data agreement
Production of oil and gas	Gas and oil production. Dataset, including rates of offshore loading of ships.	Activity data	The Danish Energy Agency	Jan H. Andersen	Not necessary due to obligation by law
Offshore flaring	Flaring in upstream oil and gas production (EU ETS data)	Activity data	The Danish Energy Agency	Dorte Maimann	Data agreement
Service stations	Data on gasoline sales from the Danish energy statistics.	Activity data	The Danish Energy Agency	Jane Rusbjerg	Data agreement
Gas transmission	Natural gas transmission rates from the transmission company, sales and losses.	Activity data	Energinet.dk	Christian F. B. Nielsen	Not necessary due to obligation by law
Onshore activities	Rates of oil transport in pipeline and onshore loading to ships. Emissions from storage of raw oil in the terminal.	Activity data and emission data	DONG Olierør A/S	Stine B. Bergmann	No formal data agreement.
Gas distribution	Natural gas and town gas distribution rates from the distribution company, sales and losses (meter differences)	Activity data	Naturgas Fyn, HMN Dong Energy Aalborg Forsyning	Hanne Mochau, Søren K. Andersen Thomas Bloch Andreas Bech Jensen	No formal data agreement.
Emissions from refinery	Fuel consumption and emission data.	Activity data and emission data	Statoil A/S, A/S Danish Shell	Anette Holst, Lis Rønnow Rasmussen	No formal data agreement.
Treatment and storage of gas	Environmental reports from plants defined as large point sources (Lille Torup, Stenlille, Nybro)	Activity data	Various plants		Not necessary due to obligation by law
CO_2 emission factors for different sources	Reports according to the CO_2 emission trading scheme (EU ETS)	Activity data	Various plants		Not necessary due to obligation by law
Emission factors	Emission factors origin from a large number of sources	Emission factors	See Section *3.5.4 Activity data, emission factors and emissions for fugitive sources* regarding emission factors		

National external review

In 2015 a documentation report for the sector "Fugitive emissions from fuels" was published, including detailed information on the methodology used in the emission inventories for greenhouse gases and air pollution (Plejdrup et al., 2015). The report was reviewed by Glen Thistlethwaite from Ricardo Energy & Environment, Oxfordshire, UK.

3.4.5 Recalculations

The following recalculations regarding fugitive emissions from fuels have been applied for the time series.

Oil transport(1B2a i)

Activity data for the oil terminal are updated for 2011-2014 according to the annual environmental report. The change of the total fugitive NMVOC emissions is negligible.

Distribution of oil products (1B2a v)

Activity data for service stations are updated according to the Danish Energy Statistics by the DEA. The statistics has revisions for 2013 and 2014. The recalculation has changed the total fugitive NMVOC emission by – 0.2 and +0.1 %, respectively.

Venting and flaring (1B2c)

Flaring in gas transmission has been updated for 2014 according to information from the Danish gas transmission company Energinet.dk.

Further, activity data and emissions are updated for one of the gas storage plants; for 2014 as the 2014 environmental report has become available, and for 2012 due to updated values in the 2015 environmental report.

The recalculations have decreased the total fugitive NMVOC emission by 0.06 %. For other pollutants the change is negligible.

3.4.6 Source specific planned improvements

The following future improvements are suggested.

- **Emissions from storage of fuels in tank facilities:** The current edition of the Danish emission inventory holds emissions from storage and refining of crude oil and from service stations. To make the inventory complete emissions from storage of fuels outside the refineries in tank facilities will be included in the future if data are available. Work is on-going to locate large tank facilities in Denmark and collect the available data. In cases where no emission estimates or measurements are available a set of emission factors have to be set up.

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4 Industrial processes and product use (NFR sector 2)

4.1 Overview of the sector

The chapter on *Industrial processes and product use* (IPPU) (NFR sector 2) is outlined as follows:

- Mineral products (NFR 2A)
- Chemical industry (NFR 2B)
- Metal production (NFR 2C)
- Non-energy products from fuels and solvent use (NFR 2D)
- Other product use (NFR 2G)
- Other industry production (NFR 2H)
- Wood processing (NFR 2I)
- Other production, consumption, storage, transportation or handling of bulk products (NFR 2L)

The industrial processes included in the Danish inventory are those in large companies, e.g. cement factories, as well as a number of smaller companies e.g. iron foundries.

Table 4.1.1 presents an overview of sources and groups of pollutants included in the present reporting. Explanations to the abbreviations are given below the table. In addition to the indicated groups of pollutants some groups do not include all relevant pollutants or the time series are not complete. For some processes, it is not possible to separate emissions from the fuels and the emissions stemming from the raw materials. This is especially the case for processes with contact, e.g. cement and lime production. Detailed information on this subject can be found in the following table.

Table 4.1.1 Survey of IPPU sector with SNAP-code and NFR-code included in the Danish inventory.

Industrial sector	SNAP	NFR	$SO_2/NO_X/NH_3$	NMVOC/ CO	PMs	HMs	POPs
Cement production	030311	2A1	IE	IE	IE	IE	IE
Lime production	030312	2A2	IE	IE	x	-	x
Container glass production	030315	2A3	-	-	x	x	-
Glass wool production	030316	2A3	x	x	x	-	-
Quarrying and mining of minerals other than coal	040616	2A5a	-	-	x	-	-
Construction and demolition	040624	2A5b	-	-	x	-	-
Storage, handling and transport of mineral products	040690	2A5c	-	-	x	-	-
Production of bricks and tiles	040691	2A6	x	-	-	-	x
Production of expanded clay products	040692	2A6	x	-	-	-	x
Stone wool production	030318	2A6	x	x	x	-	x
Sulphuric acid production	040401	2B10a	x	-	-	-	-
Nitric acid production	040402	2B2	x	-	x	-	-
Catalyst production	040416	2B10a	x	-	x	-	-
Production of chemical ingredients	040500	2B10a	-	x	-	-	-
Pesticide production	040525	2B10a	x	x	-	-	-
Production of tar products	040527	2B10a	x	x	-	x	-
Electric arc furnace steel production	040207	2C1	x	x	x	x	x
Rolling mills steel production	040208	2C1	IE	x	x	x	-
Grey iron foundries	030303	2C1	IE	IE	x	x	x
Secondary aluminium production	030310	2C3	IE	IE	x	x	x
Secondary lead production	030307	2C5	IE	IE	x	x	x
Allied metal manufacturing	040306	2C7c	IE	IE	-	x	-
Domestic solvent use incl. fungicides	060408/ 060411	2D3a	-	x	-	-	-
Road paving with asphalt	040611	2D3b	-	x	x	-	-
Asphalt roofing	040610	2D3c	-	x	x	-	-
Coating applications	060100	2D3d	-	x	-	-	-
Degreasing	060200	2D3e	-	x	-	-	-
Dry cleaning	060202	2D3f	-	x	-	-	-
Chemical products	060300	2D3g	-	x	-	-	-
Printing	060403	2D3h	-	x	-	-	-
Other solvent use	060400	2D3i	-	x	-	-	-
Paraffin wax use	060606	2D3h[1]	-	x	x	-	x
Use of fireworks	060601	2G4	x	x	x	x	-
Use of tobacco	060602	2G4	x	x	x	x	x
Use of charcoal for barbeques	060605	2G4	x	x	x	x	x
Bread production	040605	2H2	-	x	-	-	-
Wine production	040606	2H2	-	x	-	-	-
Beer production	040607	2H2	-	x	-	-	-
Spirits production	040608	2H2	-	x	-	-	-
Sugar production	040625	2H2	-	x	-	-	-
Meat curing	040627	2H2	-	x	-	-	-
Use of margarine and solid cooking fats	040698	2H2	-	x	-	-	-
Coffee roasting	040699	2H2	-	x	-	-	-
Flour production	040626	2H2	-	-	x	-	-
Wood processing	040620	2I	-	-	x	-	-
Slaughterhouse waste	040617	2L	x	-	-	-	-

x Included in the present inventory.

- Not included/not relevant.

IE Included elsewhere.

[1] No NFR category – placed in NFR 2D3h in this year's reporting.

Table 4.1.2 presents an overview of the most significant source categories for 1990 and 2015. Many changes have occurred over the time series; some factories have closed and others have opened, Table 4.1.2 is therefore only representable for the years 1990 and 2015.

Table 4.1.2 Overview of 1990 and 2015 emissions from Industrial processes and product use (IPPU).

	Total emission from IPPU		Fraction of national total, %	Largest contributor in IPPU	Emission from largest contributor		Fraction of IPPU, %
				1990			
SO_2	4.07	Gg	2.3	2A6 Other mineral products	2.90	Gg	71.3
NO_x	0.97	Gg	0.3	2B2 Nitric acid production	0.81	Gg	83.3
NMVOC	42.46	Gg	20.8	2D3i Other solvent use	25.31	Gg	59.6
CO	14.46	Gg	2.0	2A6 Other mineral products	11.97	Gg	82.8
NH_3	0.67	Gg	0.5	2A6 Other mineral products	0.30	Gg	44.3
TSP	5.49	Gg	5.1	2A5a Quarrying and mining of minerals other than coal	2.42	Gg	44.1
HMs	23.49	Mg	8.8	Zn from 2C1 Iron and steel production	12.02	Mg	51.1
POPs	0.35	Mg	6.3	PAHs from 2C1 Iron and steel production	0.29	Mg	83.6
				2015			
SO_2	1.33	Gg	12.3	2A6 Other mineral products	1.11	Gg	82.9
NO_x	0.09	Gg	0.1	2G Other product use	0.07	Gg	74.9
NMVOC	29.50	Gg	26.9	2D3i Other solvent use	19.41	Gg	65.8
CO	4.78	Gg	1.5	2G Other product use	4.25	Gg	89.0
NH_3	0.51	Gg	0.7	2A6 Other mineral products	0.24	Gg	47.2
TSP	5.36	Gg	6.0	2A5a Quarrying and mining of minerals other than coal	2.76	Gg	51.5
HMs	7.68	Mg	6.2	Cu from 2G Other product use	2.58	Mg	33.6
POPs	0.13	Mg	1.8	PAHs from 2G Other product use	0.13	Mg	99.6

4.2 Mineral products

4.2.1 Source category description

The sub-sector *Mineral products* (NFR 2A) covers the following processes relevant for the Danish inventories:

- 2A1 Cement production (SNAP 030311)
- 2A2 Lime production (SNAP 030312)
- 2A3 Glass production (SNAP 030315, 030316)
- 2A5a Quarrying and mining of minerals other than coal (SNAP 040616)
- 2A5b Construction and demolition (SNAP 040624)
- 2A5c Storage, handling and transport of mineral products (SNAP 040690)
- 2A6 Other mineral products (SNAP 030318, 040691, 040692)

The time series for emission of acidifying substances, NMVOC, particulate matter, heavy metals, and POPs from *Mineral products* (NFR 2A) is available in the NFR tables. Table 4.2.1 presents an overview of emissions from 2015.

Table 4.2.1 Overview of 2015 emissions from *Mineral products*.

	Total emission from mineral industries		Fraction of IPPU, %	Largest contributor in Mineral industries	Emission from largest contributor		Fraction of Mineral industries, %
SO_2	1.11	Gg	82.9	2A6 Other mineral products	1.11	Gg	100.0
NMVOC	0.07	Gg	0.2	2A3 Glass production	0.04	Gg	67.4
CO	0.02	Gg	0.3	2A6 Other mineral products	0.01	Gg	88.4
NH_3	0.39	Gg	75.4	2A6 Other mineral products	0.24	Gg	62.6
TSP	4.26	Gg	79.4	2A5a Quarrying and mining of minerals other than coal	2.76	Gg	64.8
HMs	0.09	Mg	1.2	Pb from 2A3 Glass production	0.05	Mg	48.0
POPs	0.01	kg	0.01	PCBs from 2A2 Lime production	0.01	kg	94.4

4.2.2 Cement production

It has not been possible to separate emissions from fuel consumption and emissions from process activities. Process emissions from the production of cement are therefore included in the energy section.

4.2.3 Lime production

The production of limestone and lime/burned lime/quicklime is located at a few localities: Faxe Kalk (Lhoist group) situated in Faxe, Scandinavian Calcium Oxide ApS situated in Støvring, dankalk A/S situated in Løgstør with limestone quarries/limeworks in Aggersund, Mjels, Poulstrup and Batum. The following SNAP-code is covered:

- 03 03 12 Lime production

The following pollutants are relevant for the lime production process:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Persistent organic pollutants: HCB, PCDD/F, PCB

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology
Data on the amount of lime produced is available from Statistics Denmark on a national level and emission factors are available from EMEP/EEA and national literature.

Activity data
The activity data regarding production of lime is obtained from Statistics Denmark (2016). The data are presented in Table 4.2.2 and the full time series in Annex 3C-1.

Table 4.2.2 Production of burnt lime, Mg (Statistics Denmark, 2016).

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Burnt lime	127978	100789	92002	71239	50397	59430	69136	66805	72994	63478

Slaking of lime does not emit any pollutants. All burnt lime that is later slaked, is included in the data presented in the table above. Adding the production of slaked lime to the activity data, would therefore result in a double counting.

Emission factors
The emission factors used to calculate the emissions from lime production are shown in Table 4.2.3 along with their respective sources. Emission factors from EMEP/EEA (2013) are valid for a controlled process (Tier 2).

Table 4.2.3 Emission factors for production of lime

Pollutant	Unit	Value	Source
TSP	kg/Mg	0.40	EMEP/EEA (2013)
PM_{10}	kg/Mg	0.20	EMEP/EEA (2013)
$PM_{2.5}$	kg/Mg	0.03	EMEP/EEA (2013)
BC	g/Mg	0.14	EMEP/EEA (2013)
HCB	mg/Mg	0.01	Nielsen et al. (2013)
PCDD/F	µg/Mg	0.02	Henriksen et al. (2006)
PCB	mg/Mg	0.15	Nielsen et al. (2013)

Emission trends

The emission trends for particles and POPs for lime production are shown in Table 4.2.4 and in Figure 4.2.1. Emission data for the entire time series are available in Annex 3C-2.

Table 4.2.4 Total Ammoniacal Nitrogen (TAN).

	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
TSP	Mg	51.2	40.3	36.8	28.5	20.2	23.8	27.7	26.7	29.2	25.4
PM_{10}	Mg	25.6	20.2	18.4	14.2	10.1	11.9	13.8	13.4	14.6	12.7
$PM_{2.5}$	Mg	3.8	3.0	2.8	2.1	1.5	1.8	2.1	2.0	2.2	1.9
BC	kg	17.7	13.9	12.7	9.8	7.0	8.2	9.5	9.2	10.1	8.8
HCB	g	1.0	0.8	0.7	0.6	0.4	0.5	0.6	0.5	0.6	0.5
PCDD/F	mg	2.3	1.8	1.7	1.3	0.9	1.1	1.2	1.2	1.3	1.1
PCB	g	19.2	15.1	13.8	10.7	7.6	8.9	10.4	10.0	10.9	9.5

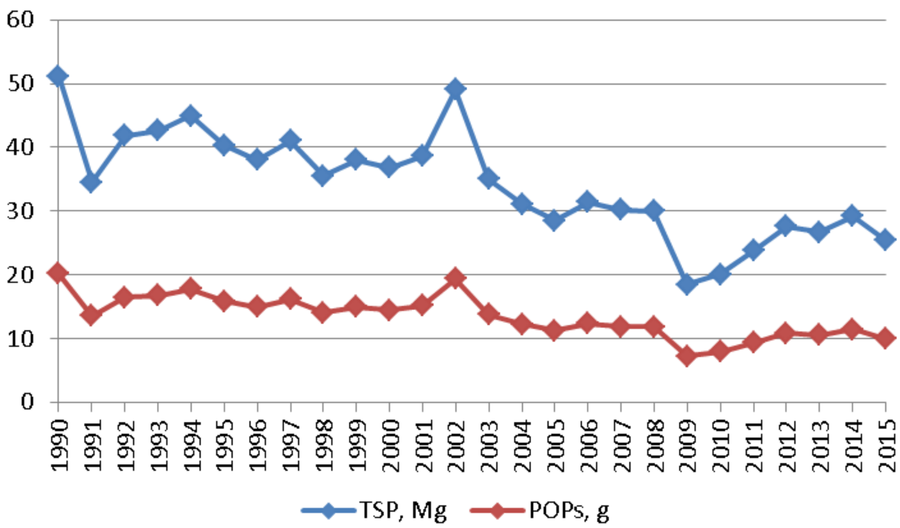

Figure 4.2.1 Emission trends for particles and POPs from lime production.

There is a peak in emissions in 2002 due to a corresponding peak for the activity data. The activity data are based on the official statistics from Statistics Denmark and there is no immediate explanation for this peak. There are very few producers in Denmark and therefore it will not be possible to obtain more detailed data from Statistics Denmark.

4.2.4 Glass production

Glass production covers production of:

- Flat glass
- Container glass
- Glass wool

The production of flat glass (SNAP 03 03 14 Flat glass) is concentrated at few European producers and none of these have plants in Denmark. The processes in Denmark are limited to mounting of sealed glazing units. The mounting process is not considered to contribute to emission of pollutants to air in Denmark.

The production of container glass for packaging is concentrated at one company: Ardagh Glass Holmegaard A/S (previously Rexam Glass Holmegaard A/S) and for art industrial glass products: Holmegaard A/S both situated in

Fensmark, Næstved. Saint-Gobain Isover situated in Vamdrup produces glass wool. The following SNAP-codes are covered:

- 03 03 15 Container glass
- 03 03 16 Glass wool

The following pollutants are relevant for the glass production process:

- NMVOC
- CO
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Heavy metals: As, Cd, Cr, Ni, Pb, Se, Zn

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

The annual produced amount of container glass is estimated based on the consumption of raw materials. Data on raw materials are gathered from environmental reports (1990-2005) and EU-ETS data (2006-2015) (Ardagh, 2016a, b)

The produced amount of glass wool is available in the company's environmental reports (1997-2015). Production data back to 1990 are estimated as the constant average of 1997-1999.

Emission factors for container glass are available from EMEP/EEA (2013) and for glass wool from company measurements.

Activity data

Activity data for the production of container glass and glass wool are presented in Table 4.2.5 and Figure 4.2.2. The full time series is available in Annex 3C-3.

Table 4.2.5 Production of container glass and glass wool, Gg.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Container glass	-	164.0	140.0	183.3	168.2	172.9	186.5	209.6	159.9	162.9	155.7
Glass wool	35.6	35.6	35.6	39.7	37.3	24.9	29.8	26.8	27.9	28.8	33.0

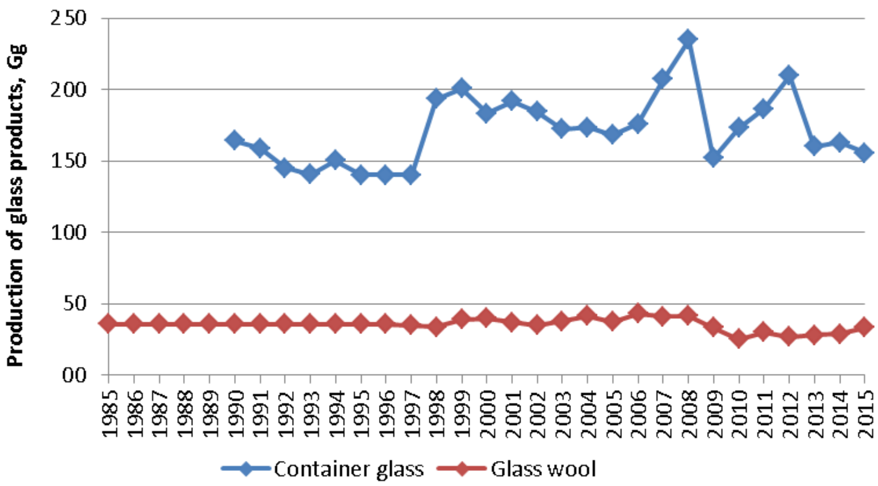

Figure 4.2.2 Activity data for container glass and glass wool production.

Both the container glass and glass wool production displays a significant decrease from 2008 to 2010 that can be explained by the financial crises.

Emission factors

Yearly measurements of the emissions from production of container glass provide emissions of TSP (1997-2014), Pb (1997-2014), Se (1997-2009; 2012-2013) and Zn (1997-2001) (Ardagh, 2016a). Emissions of As, Cd, Cr and Ni are estimated from standard emission factors, where direct emissions are not available for TSP, Pb, Se and Zn; these are calculated. PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.9/0.8) and BC is estimated as 0.062 % of $PM_{2.5}$, all available from EMEP/EEA (2013), Tier 2 container glass. All used emission factors are shown in Table 4.2.6. From 2006, measured particle emissions from the singular Danish container glass producer decrease 90 % due to installation of abatement equipment; all calculated particle and heavy metal emissions are therefore also lowered with 90 % from 2006.

Table 4.2.6 Emission factors for production of container glass.

Pollutant	Applied for the years	Unit	Value	Source
TSP	1990-1996	g/Mg	280	EMEP/EEA (2013)
	2015	g/Mg	13.7	EMEP/EEA (2013) with CS abatement[1]
PM_{10}	All	% of TSP	90	EMEP/EEA (2013)
$PM_{2.5}$	All	% of TSP	80	EMEP/EEA (2013)
BC	All	% of $PM_{2.5}$	0.06	EMEP/EEA (2013)
As	1990-2005	g/Mg	0.29	EMEP/EEA (2013)
	2006-2015	g/Mg	0.03	EMEP/EEA (2013) with CS abatement[1]
Cd	1990-2005	g/Mg	0.12	EMEP/EEA (2013)
	2006-2015	g/Mg	0.01	EMEP/EEA (2013) with CS abatement[1]
Cr	1990-2005	g/Mg	0.37	EMEP/EEA (2013)
	2006-2015	g/Mg	0.04	EMEP/EEA (2013) with CS abatement[1]
Ni	1990-2005	g/Mg	0.24	EMEP/EEA (2013)
	2006-2015	g/Mg	0.02	EMEP/EEA (2013) with CS abatement[1]
Pb	1990-1996	g/Mg	2.9	EMEP/EEA (2013)
	2015	g/Mg	0.29	EMEP/EEA (2013) with CS abatement[1]
Se	1990-1996	g/Mg	1.5	EMEP/EEA (2013)
	2010-2011; 2014-2015	g/Mg	0.19	Average IEF (2008-09;2012-13)
Zn	1990-1996; 2002-2005	g/Mg	0.23	Average IEF (2007-2001)
	2006-2015	g/Mg	0.02	Average IEF (2007-2001) with CS abatement[1]

[1] Country specific abatement is measured by the producer to 90 %.

The emission of NH_3 and TSP from the production of glass wool has been measured yearly for 1996-2012 and are available in the company's environmental reports (Saint-Gobain Isover, 2013). NMVOC and CO have also been measured for 2007-2012 and 1996-1997 respectively. For the years where no measured emission data are available, emissions are calculated using implied emission factors based on the available measurements. PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.9/0.8) from EMEP/EEA (2013). All used emission factors are shown in Table 4.2.7. Since it has not been possible to separate process emissions from the emissions from fuel combustion, the measured/calculated emissions from glass wool production presented here account for the entire production.

Table 4.2.7 Emission factors for production of glass wool.

Pollutant	Applied for the years	Unit	Value	Source
NMVOC	1985-2006	kg/Mg	1.35	Average IEF (2007-2009)
	2013-2015	kg/Mg	1.35	Average IEF (2010-2012)
CO	1985-1995; 1998-2015	kg/Mg	0.57	IEF (1997)
NH_3	1985-1995	kg/Mg	7.6	Average IEF (1996-1998)
	2013-2015	kg/Mg	4.4	Average IEF (2010-2012)
TSP	1990-1995	kg/Mg	2.9	Average IEF (1996-2000)
	2013-2015	kg/Mg	1.4	Average IEF (2010-2012)
PM_{10}	All	% of TSP	90	EMEP/EEA (2013)
$PM_{2.5}$	All	% of TSP	80	EMEP/EEA (2013)
BC	All	% of $PM_{2.5}$	2.0	EMEP/EEA (2013)

Emission trends

The only pollutants to which both container glass and glass wool productions contribute are particles. Therefore, only particle emissions are presented in the table below. Table 4.2.8 shows the individual emissions from the two sources.

Table 4.2.8 Emission of particles from glass production.

	Pollutant	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Container glass	TSP	Mg	46	39	26	7.0	1.7	1.8	4.5	1.6	0.9	2.1
	PM_{10}	Mg	41	35	23	6.3	1.5	1.6	4.0	1.4	0.8	1.9
	$PM_{2.5}$	Mg	36	31	20	5.5	1.3	1.4	3.5	1.3	0.7	1.7
	BC	kg	22	19	13	3.4	0.8	0.9	2.2	0.8	0.4	1.0
Glass wool	TSP	Mg	102	102	111	85	26	42	47	39	40	46
	PM_{10}	Mg	92	92	100	77	23	38	43	36	37	43
	$PM_{2.5}$	Mg	82	82	89	68	21	34	38	31	32	36
	BC	kg	1.6	1.6	1.8	1.4	0.4	0.7	0.8	0.6	0.6	0.7

Emissions of the remaining pollutants and for the entire time series can be found in Annex 3C-4, where NMVOC, CO and NH_3 emissions stem only from glass wool production and heavy metal emissions only from container glass production.

4.2.5 Quarrying and mining of minerals other than coal

Quarrying and mining of minerals other than coal covers several different types of minerals and occurs all over Denmark. The following SNAP-code is covered:

- 04 06 16 Quarrying and mining of minerals other than coal

The following pollutants are relevant for quarrying and mining:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$

Methodology

The annual amount of extracted minerals is available from national statistics. These resource extraction data cover "sand and gravel", "chalk and dolomite", "clay and kaolin", "salt", "marble, granite, sandstone, porphyry, basalt and building stone, etc." and "other".

Emission factors are available from EMEP/EEA (2013).

Activity data

Activity data for quarrying and mining of minerals other than coal are presented in Table 4.2.9; the full time series is available in Annex 3C-5.

Table 4.2.9 Extracted minerals other than coal, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Quarrying and mining	47493	56126	67122	77523	47113	57892	59414	52130	53975	54105

Emission factors

The applied emission factors are shown in Table 4.2.10. Emission factors are chosen for Tier 2 low emission level for plants having well maintained abatement/BAT.

Table 4.2.10 Emission factors for quarrying and mining of minerals other than coal

Pollutant	Value	Unit	Source
TSP	51	g/Mg mineral	EMEP/EEA (2013)
PM_{10}	25	g/Mg mineral	EMEP/EEA (2013)
$PM_{2.5}$	3.8	g/Mg mineral	EMEP/EEA (2013)

Emission trends

Emissions of TSP are presented in Figure 4.2.3. Emissions of TSP. PM_{10} and $PM_{2.5}$ are available in Annex 3C-6.

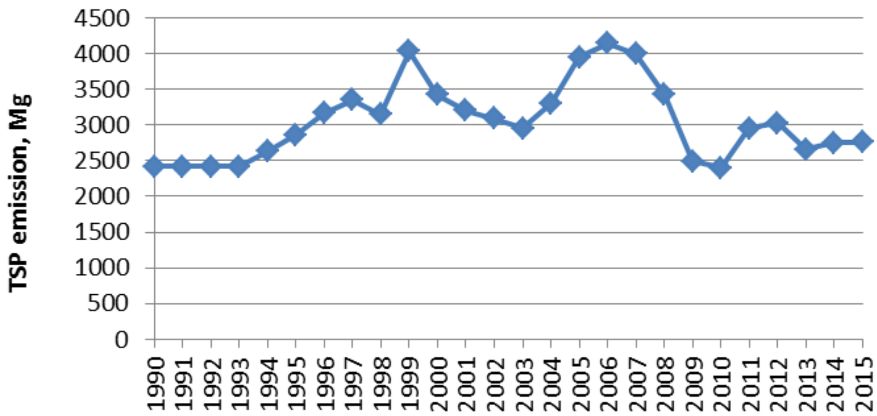

Figure 4.2.3 Emission of particulate matter (TSP) from quarrying and mining of other minerals than coal.

4.2.6 Construction and demolition

Construction and demolition covers the following SNAP-code:

- 04 06 24 Construction and demolition

The following pollutants are relevant for construction and demolition:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC

Methodology

The activity data for construction and demolition are calculated based on national statistics on completed constructions (m^2) and demolished floor area (m^2). Prior to 2007, demolition data are not available and these are therefore estimated based on statistics on total floor area in the building stock (m^2).

Emission factors are available from EMEP/EEA (2013).

Activity data

Activity data for construction and demolition are presented in Table 4.2.11. The full time series is available in Annex 3C-7.

Table 4.2.11 Activity of construction and demolition, mill. m^2.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Construction and demolition	8.6	6.6	12.1	10.8	12.0	6.6	9.1	7.5	8.7	8.1

Emission factors

The applied emission factors are shown in Table 4.2.12.

Table 4.2.12 Emission factors for construction and demolition

Pollutant	Value	Unit	Source
TSP	0.162	kg/m^2/year	EMEP/EEA (2013)
PM_{10}	0.0812	kg/m^2/year	EMEP/EEA (2013)
$PM_{2.5}$	0.00812	kg/m^2/year	EMEP/EEA (2013)
BC	81.2	mg/m^2/year	Authors expert judgement

Emission trends

Emissions of TSP are presented in Figure 4.2.4. Emissions of TSP, PM_{10}, $PM_{2.5}$ and BC are available in Annex 3C-8.

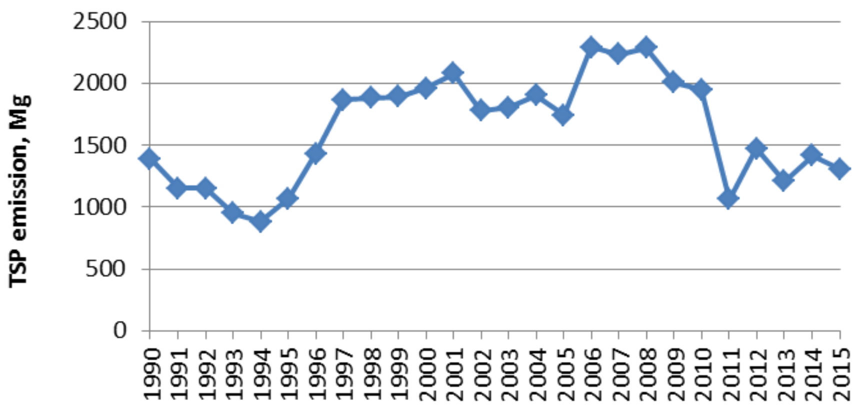

Figure 4.2.4 Emission of particulate matter (TSP) from construction and demolition.

4.2.7 Storage, handling and transport of mineral products

Storage, handling and transport of mineral products cover the following SNAP-code:

- 04 06 90 Storage, handling and transport of mineral products

The following pollutants are relevant for storage, handling and transport of mineral products:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$

Methodology

The activity data for storage, handling and transport of mineral products cover minerals used in cement production, ceramics production, other uses of soda ash, flue gas desulphurisation and stone wool. The particle emissions from storage, handling and transport of mineral products in lime production, glass production quarrying/mining and construction/demolition are already included in the respective categories.

The activity data for storage, handling and transport of mineral products are gathered from the five included sources (mass mineral).

The emission factor for TSP is assumed to be 0.1 % of activity data, PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.5/0.05).

Activity data

Activity data for storage, handling and transport of mineral products are presented in Table 4.2.13. The entire time series is available in Annex 3C-9.

Table 4.2.13 Activity of storage, handling and transport of mineral products, Gg mineral.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Storage, handling and transport of mineral product	462.8	580.3	524.8	545.1	556.0	458.6	422.6	438.1	464.1	450.9

Emission factors

The applied emission factors are shown in Table 4.2.14.

Table 4.2.14 Emission factors for storage, handling and transport of mineral products.

Pollutant	Value	Unit	Source
TSP	0.1	Mg/Gg	Expert judgement
PM_{10}	0.05	Mg/Gg	Expert judgement
$PM_{2.5}$	0.005	Mg/Gg	Expert judgement

Emission trends

Emissions are presented in Figure 4.2.5 and Annex 3C-10.

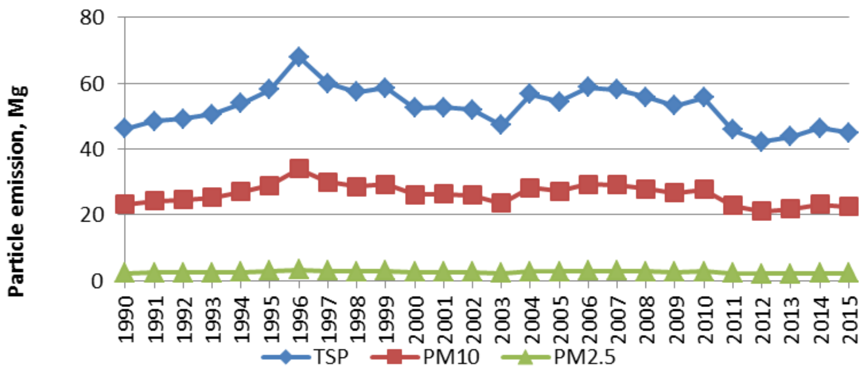

Figure 4.2.5 Emission of particulate matter from storage, handling and transport of mineral products.

4.2.8 Other mineral products

The sub-sector "Other" in the mineral industry section covers production of bricks and tiles (aggregates or bricks/blocks for construction), expanded clay products for different purposes (aggregates as absorbent for chemicals, cat litter, and for other miscellaneous purposes) and stone wool from the company Rockwool situated at three localities in Denmark: Hedehusene[1], Vamdrup and Øster Doense produces stone wool. The following SNAP-codes are covered:

- 04 06 91 Production of bricks and tiles
- 04 06 92 Expanded clay products
- 03 03 18 Stone wool

The following pollutants are covered:

[1] The melting of minerals (cupola) has been closed down in 2002.

- SO_2
- CO
- NMVOC
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- POPs: PCDD/F

NO_x from stone wool production is included in the energy sector.

Methodology

The production of bricks and tiles is found all over the country, where clay is available. Producers of expanded clay products are located in the northern part of Jutland. The SO_2 emission from the production of bricks/tiles and expanded clay products is related to sulphur content in the raw material. The PCDD/F emission factor is known from national literature.

Stone wool is produced from mineral fibres and a binder. The raw materials are melted in a cupola fired by coke and natural gas. The consumption of raw material as well as amount of produced stone wool is confidential. Information on emissions from some years has in combination with yearly raw material consumption been used to extrapolate the emissions to other years. The data have been extracted from the environmental reports (Rockwool, 2016). Measured emissions of CO and NH_3 are available for the years 2001, 2004 and 2007-2014 and emissions of particulate matter are available for 1995-2014. For NMVOC and PCDD/F, the inventory is based on measured emissions for 2012-2014 and 2004 respectively.

Activity data

National statistics on bricks, tiles and expanded clay (together called ceramics) contain a broad range of different products, most of them in units of numbers (no.). The consumption of limestone is therefore used as alternative activity data for these source categories; available for 2006-2015. The national statistics are used as surrogate data; available for 1985-2015. Prior to 1985 activity data are estimated as the 1985-1989 average.

Data on the produced amount of stone wool is confidential for 1985-2013; however the consumption of carbonates at the three Danish factories is available for 2006-2015 where the different raw materials such as lime, waste, bottom ash etc. are added up to the activity data of $CaCO_3$ equivalents. For 1995-2013 the amount of raw material used is used as surrogate data, previous to 1995 activity data are estimated as the 1995-1999 average.

The chosen activity data for "Other mineral products" are shown in Table 4.2.15, Figure 4.2.6 and Annex 3C-11.

Table 4.2.15 Production of "Other mineral products", Gg $CaCO_3$ equivalents.

	1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Brickworks	76.0	82.4	58.8	71.9	81.4	79.5	35.1	46.0	39.7	36.7	38.7	46.2
Expanded clay	41.3	40.6	37.1	38.1	35.3	34.7	13.7	15.1	13.4	23.8	22.5	19.4
Stone wool	-	17.9	17.9	18.0	17.3	18.0	17.1	16.8	15.0	13.8	11.6	13.5

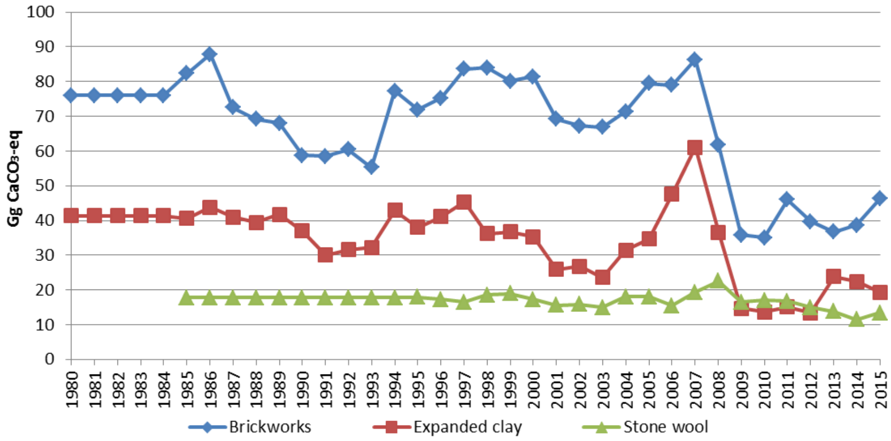

Figure 4.2.6 Consumption of $CaCO_3$ equivalents in the production of ceramics and stone wool.

Both the brickworks and expanded clay productions displays a significant decrease from 2007 to 2009 that can be explained by the financial crises

Emission factors

For production of ceramics the emission factors for SO_2 are determined from the individual companies reporting of SO_2 emission (environmental reports) for the years 2007-2014 and actual activity for the corresponding years. The SO_2 emissions have been adjusted for fuel related emissions to derive the process emissions. The PCDD/F emission factors shown in Table 4.2.16 are calculated from 0.018 µg per Mg product (Henriksen et al., 2006), using the total carbonate consumption (environmental reports), national production statistics (Statistics Denmark) and assumption of 2.5 kg per brick/tile.

Stone wool emission factors for CO, NH_3 and TSP are average values measured and reported in the annual environmental reports for each Rockwool factory for the years 2001, 2004 and 2007-2014 (TSP for 1995-2014). PM_{10} and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.9/0.7). The applied emission factor for BC is actually that of glass wool from EMEP/EEA (2013). PCDD/F is known from Henriksen et al. (2006).

Table 4.2.16 Emission factors for Other mineral products, units are per Mg $CaCO_3$ equivalent.

Pollutant	Applied for the years	Brickworks Value	Unit	Expanded clay Value	Unit	Stone wool Value	Unit	Source
SO_2	1980-2006	9.9	kg	62.6	kg			Average IEF[1] (2007-2010)
	2015	4.4	kg	46.6	kg			Average IEF[1] (2012-2014)
NMVOC	All					3.3	kg	Average IEF[1] (2012-2014)
CO	1985-2000; 2002-2003; 2005-2006					640.6	kg	Average IEF[1] (2001; 2004; 2007-2009)
	2015					0.9	kg	Average IEF[1] (2010-2014)
NH_3	1985-2000					16.0	kg	Average IEF[1] (2001; 2004; 2007-2013)
TSP	1990-1994					5.3	kg	Average IEF[1] (1995-1999)
	2015					5.5	kg	Average IEF[1] (2000-2012)
PM_{10}	All					90	% of TSP	Authors expert judgement
$PM_{2.5}$	All					70	% of TSP	Authors expert judgement
BC	All					2	% of $PM_{2.5}$	EMEP/EEA (2013)[2]
PCDD/F	All	0.25	µg	0.17	µg	3.2	kg	Henriksen et al. (2006)[3]

[1] Calculated with data from the companies' environmental reports.
[2] Valid for glass wool.
[3] Some calculations were necessary to derive the desired units.

Emission trends

The only pollutants to which more than one source category contributes are SO_2 and PCDD/F. Therefore, only these two emissions are presented in the figures below. Figure 4.2.7 and Figure 4.2.8 show the emissions of SO_2 and PCDD/F respectively, emissions are presented individual for the three sources.

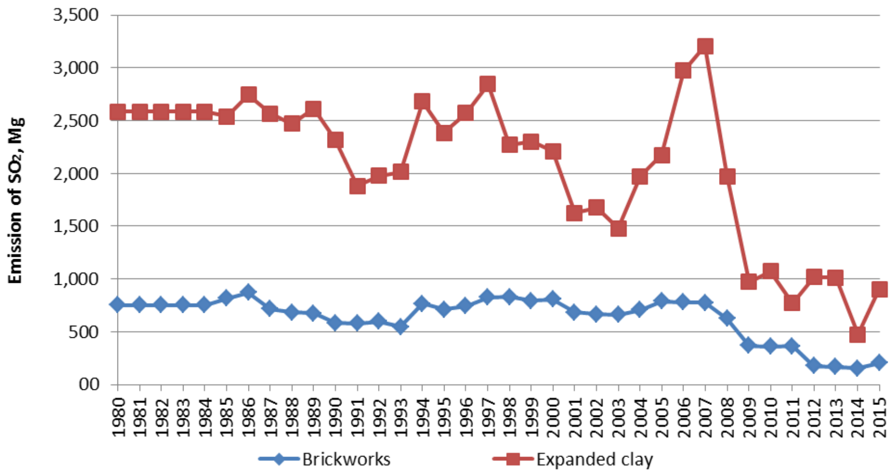

Figure 4.2.7 Emissions of SO_2 from ceramics.

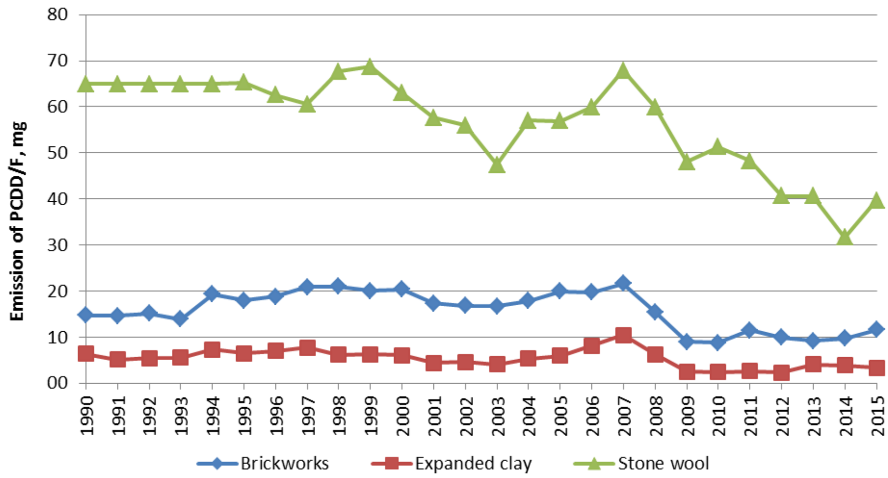

Figure 4.2.8 Emissions of PCDD/F from ceramics and stone wool.

Emissions of the remaining pollutants can be found in Annex 3C-12, where NMVOC, CO, NH_3 and particle emissions stem only from stone wool production.

The measurements of CO emissions show a strong decrease from the two stone wool factories in 2009 and 2010, respectively, due to installation of abatement equipment.

4.2.9 Source specific recalculations and improvements

All particle emissions are reported back to 1990.

Glass production

More decimals have been included for the container glass emission factors for BC (2013-2014), As, Cr, Ni (2006-2014), Se (2010-2011; 2014) and Zn (2002-2014). The resulting recalculations are between -8 % (Cr) and 20 % (Ni).

Quarrying and mining of minerals other than coal

Activity data are gathered from Statistics Denmark. Recalculations in activity data of -2 % to -4 % occur for 2010-2014.

Construction and demolition

BC from construction and demolition is new in this year's submission.

Activity data are gathered from Statistics Denmark. Recalculations in activity data of 0.02 % (2000) to 24.2 % (2014) occur for 2000-2014; 2.5 % in average.

Storage, handling and transport of mineral products

Emissions from storage, handling and transport of mineral products had by mistake not been reported in the NFR tables in last year's submission, this has been corrected.

Other mineral products

NMVOC emissions from the production of stone wool are new in this year's submission.

An error in the calculation of the emission factor for SO_2 emissions from ceramics has been corrected. This has resulted in an increase of emissions of 0.03-0.29 Gg SO_2 (2.2-14.9 %).

The 2014 environmental report for Rockwool was not available in time for last year's submission. An update to measured emissions for CO, NH_3 and particles has led to increases in emissions of 1 % (CO) to 31 % (TSP).

4.3 Chemical industry

4.3.1 Source category description

The sub-sector *Chemical industry* (NFR 2B) covers the following processes:

- 2B2 Nitric acid/fertiliser production (SNAP 040402/040407)
- 2B10a Other chemical industry
    - Sulphuric acid production (SNAP 040401)
    - Catalyst/fertiliser production (SNAP 040416/040407)
    - Production of chemical ingredients (SNAP 040500)
    - Pesticide production (SNAP 040525)
    - Production of tar products (SNAP 040527)

The time series for emission of acidifying substances, NMVOC, particulate matter, heavy metals, and POPs from *Chemical industry* (NFR 2B) is available in the NFR tables. Table 4.3.1 presents an overview of emissions from 2015.

Table 4.3.1 Overview of 2015 emissions from Chemical industry.

	Total emission from Chemical industries		Fraction of IPPU, %	Largest contributor in Chemical industries	Emission from largest contributor		Fraction of Chemical industries, %
SO_2	0.16	Gg	11.8	2B10a Other chemical industry	0.16	Gg	100.0
NO_x	0.02	Gg	25.1	2B10a Other chemical industry	0.02	Gg	100.0
NMVOC	0.03	Gg	0.1	2B10a Other chemical industry	0.03	Gg	100.0
NH_3	0.02	Gg	3.8	2B10a Other chemical industry	0.02	Gg	100.0
TSP	0.01	Gg	0.1	2B10a Other chemical industry	0.01	Gg	100.0

4.3.2 Nitric and sulphuric acid production

The production of sulphuric acid, nitric acid as well as NPK fertilisers has been concentrated at one company; Kemira GrowHow A/S (Kemira GrowHow, 2004). The production of sulphuric acid and nitric acid/fertiliser ceased in 1996/7 and in the middle of 2004, respectively. The following SNAP codes are covered:

- 04 04 01 Sulphuric acid
- 04 04 02 Nitric acid

The following pollutants are relevant for the nitric and sulphuric acid production processes:

- SO_2
- NO_x
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC

Methodology

In the NFR tables, SO_2 emissions from sulphuric acid production are reported under 2B10a Other chemical industry. In this report however, these emissions are reported alongside with emissions from nitric acid production since they are produced by the same company.

Information on emissions is obtained from environmental reports, contact to the company as well as information from the county. Information on emissions of SO_2, NO_x and NH_3 is available for 1990; 1994-2004, 1990; 1994-1997 and 1990-2004 respectively, TSP is available for 1996-2004. Implied emission factors (IEF) are calculated for the years where measurements are available; these implied emission factors are then used to calculate emissions for the remaining years.

Activity data

The activity data regarding production of nitric and sulphuric acid are obtained through personal communication with Kemira (Kemira GrowHow, 2004 and 2005). The data are presented in Table 4.3.2 and Annex 3C-13.

Table 4.3.2 Production of nitric and sulphuric acid, Mg.

	1980	1985	1990	1995	2000	2001	2002	2003	2004
Nitric acid	350	350	450	390	433	382	334	386	229
Sulphuric acid	188	188	148	102	NO	NO	NO	NO	NO

NO: Not occurring

Emission factors

The calculated implied emission factors for SO_2, NO_x, NH_3 and TSP are presented in Table 4.3.3.

Table 4.3.3 IEFs for production of nitric and sulphuric acid.

Process	Pollutant	IEF	Unit
Nitric acid	NO_x	0.95-1.79	kg/Mg
Nitric acid	NH_3	0.03-0.26	kg/Mg
Nitric acid	TSP	0.56-0.98	kg/Mg
Sulphuric acid	SO_2	1.40-2.69	kg/Mg

Due to the lack of information on the particle distributions PM_{10} and $PM_{2.5}$, these are put equal to TSP for nitric acid production. BC is estimated as 1.8 % of $PM_{2.5}$ according to EMEP/EEA (2013) (chemical industry, average).

Emission trends

The time series for SO_2 follows the amount of sulphuric acid produced, i.e. the fluctuation follows the activity until the activity ceased in 1997. The same is the case for NO_X from production of nitric acid. Emission data are presented in Figure 4.3.1 and Annex 3C-14.

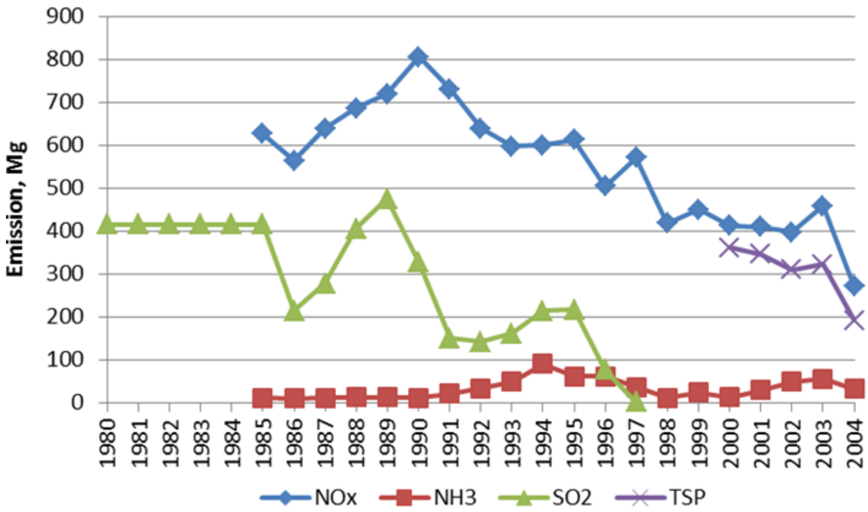

Figure 4.3.1 Emissions from nitric and sulphuric acid production.

4.3.3 Catalyst production

Production of a wide range of catalysts and potassium nitrate is concentrated at one company: Haldor Topsøe A/S situated in Frederikssund. The products are catalysts for many purposes (for hydro-processing, ammonia, $DeNO_x$, methanol, hydrogen and synthesis gas, sulphuric acid, formaldehyde, and combustion catalysts) and potassium nitrate (fertiliser). The following SNAP code is covered:

- 04 04 16 Other: catalysts

The following pollutants are relevant for the catalyst production processes:

- NO_x
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC

Methodology

The emissions of NO_X, NH_3 and PM_{10} from production of catalysts and fertilisers are measured yearly from 1996 to 2015 (Haldor Topsøe, 2016). The emissions from 1985-1995 were extrapolated.

The process related NO_X emission has been estimated as 80 % of the measured total NO_X emission; Haldor Topsøe reports this assumption in their environmental report. The plant is equipped with $DeNO_x$ flue gas cleaning systems and depending on the efficiency of the cleaning system emission of NH_3 will occur.

Activity data

The activity data regarding production of catalysts and fertiliser are obtained through environmental reports from Haldor Topsøe. The production data are presented in Table 4.3.4 and Annex 3C-15, the annex also includes the applied surrogate data.

Table 4.3.4 Production of catalysts and potassium nitrate, Gg (HaldorTopsøe, 2016).

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Catalysts produced	17.0	17.0	17.0	17.2	23.2	20.5	22.3	22.9	25.1	27.0	29.5
Potassium nitrate produced	18.4	18.4	18.4	19.2	23.3	25.9	25.3	32.9	31.9	34.3	35.2
Total produced	35.4	35.4	35.4	36.4	46.5	46.4	47.5	55.8	57.1	61.2	64.7

Production data for 1985-1995 assumed to be the average of 1997-2001. Production data for 2013-2014 are estimated using the consumption of raw materials as surrogate data. And production data for 2015 are estimated using the fuel consumption as surrogate data and the average produced fraction of each product in relation to total production for 2003-2012.

Emission factors

The calculated implied emission factors (IEFs) for NO_x, NH_3 and particles are presented in Table 4.3.5.

Table 4.3.5 IEFs for production of catalysts and potassium nitrate.

	NO_x	NH_3	TSP	PM_{10}	$PM_{2.5}$	BC
Unit	Mg/Gg	Mg/Gg	Mg/Gg	Mg/Gg	Mg/Gg	kg/Gg
Value	0.40-2.20	0.26-3.70	0.13-0.70	0.11-0.56	0.08-0.42	1.45-7.56

TSP and $PM_{2.5}$ are estimated from the distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.8/0.6) from CEPMEIP (Values for 'Production of nitrogen fertiliser'). The emission factor for BC is calculated based on 1.8 % of $PM_{2.5}$ (EMEP/EEA, 2013, chemical industry, average).

Emission trends

The emission of NH_3 shows an increasing trend throughout the 00's; from 14 Mg in 2000 to 165 Mg in 2009; in the same period the IEF fluctuates around the average 1.77 Mg per Gg product but shows no trend. For the remaining time series, the NH_3 emission only varies between 9-21 Mg with the exception of 2010 where 123 Mg were emitted.

The emission of NO_X decreases from the end of the 90's to the beginning of the 00's, in spite of the increasing production.

Emissions of NO_x, NH_3 and TSP are shown in Figure 4.3.2 and Annex 3C-16.

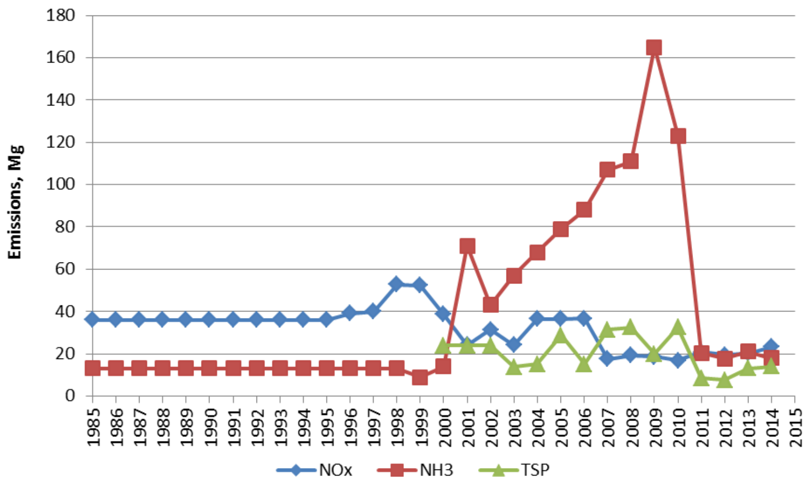

Figure 4.3.2 Emissions from catalyst and fertiliser production.

4.3.4 Production of chemical ingredients

The production of chemical ingredients takes place in a number of different companies. One of the major companies is Danisco Grindsted located in Grindsted (Danisco Grindsted, 2016). The following SNAP code is covered:

- 04 05 00

The following pollutant is relevant for the production process of chemical ingredients:

- NMVOC

Methodology

The following description of the production of chemical ingredients is based on the historical environmental reports from the company.

The raw materials are primarily natural or nature identical raw materials/substances: vegetable oils, animal fatty acids, glycerine, other organic substances, mineral acidic and alkaline compounds, solvents etc. The products are emulsifiers, stabilisers, flavours, enzymes, antioxidants, pharmaceuticals, and preservatives.

Activity data

Due to confidentiality no activity data are available.

Emission factors

Due to confidentiality no emission factors are available.

Emission trends

The emission of NMVOC from production of chemical ingredients has been measured from 1997 to 2009 (Danisco Grindsted, 2016). The emission has in this period decreased from 93 to 12 Mg. However, no explanation can be given on these conditions, as information on activity is not available. The NMVOC emissions are presented in Table 4.3.6 and Annex 3C-17.

Table 4.3.6 Emissions from the production of chemical ingredients, Mg.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
NMVOC	100	100	100	40	14	12	12	12	12	12	12

4.3.5 Pesticide production

The production of pesticides in Denmark is concentrated at one company: Cheminova A/S situated in Harboøre. The following SNAP code is covered:

- 04 05 25 Pesticide production

The following pollutants are relevant for the pesticide production process:

- SO_2
- NMVOC

Methodology

The air emissions from Cheminova are measured from a number of sources; e.g. exhaust from process plant, sulphur recovery plant and biological sewage treatment plant. The environmental reports do only include some of the emissions and they do only present aggregated data.

The produced amount of pesticides is known for 1996-2009 (Cheminova, 2010). Emissions of SO_2 and NMVOC are measured yearly for 1990-2014 and 1990-2000 respectively. For the years where data are not available, activity data are extrapolated and emissions are calculated using implied emission factors.

Activity data

Activity data for 1980-1995 are calculated using the national statistics on value of pesticides produced (million DKK) as surrogate data. For 2010-2015, no information on the production is available. Activity data on the production of pesticides are presented in Table 4.3.7 and Annex 3C-18.

Table 4.3.7 Production of pesticides, Mg.

	1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pesticide production	20796	42010	37671	45320	60284	53504	31000	31000	31000	30000	30000	30000

Emission factors

The implied emission factors for pesticide production are presented in Table 4.3.8.

Table 4.3.8 IEFs for pesticide production, Claus process.

	Substance	Interval, kg/Mg	Average, kg/Mg
Pesticides	SO_2	0.3-11.1	6.0[1]
	NMVOC	0.5-2.0	0.9[2]

[1] of 1996-2009.

[2] of 1996-2000.

Emission trends

The emission of NMVOC from production of pesticides is reduced significantly from 1985 to 1993. The decrease can be explained by introduction of flue gas cleaning equipment rather than any decrease in activity. The emission of SO_2 is from the sulphur regeneration plant (Claus plant).

Emissions are presented in Figure 4.3.3.

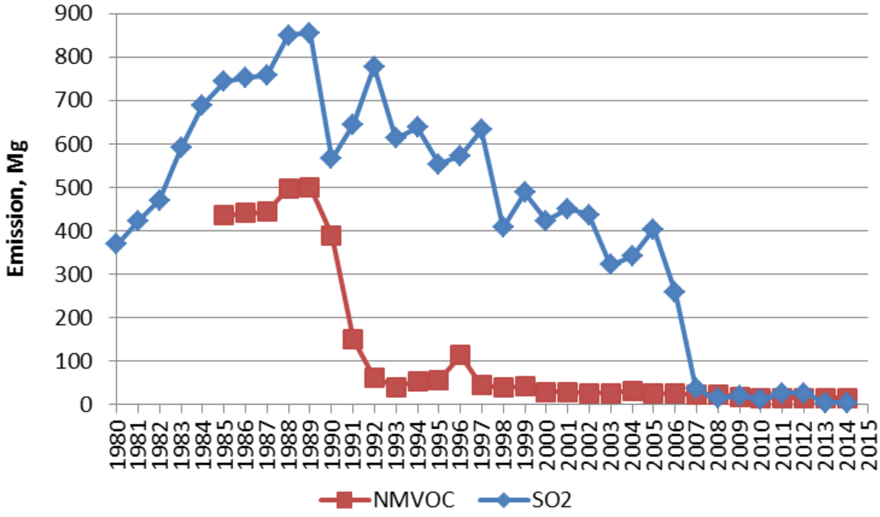

Figure 4.3.3 Emissions of SO_2 and NMVOC from pesticide production.

4.3.6 Production of tar products

One Danish factory situated in Nyborg produces tar products. The following SNAP code is covered:

- 04 05 27 Production of tar products

The following pollutants are relevant for the production process of tar products:

- SO_2
- NMVOC
- Hg

Methodology

Activity data

No activity data are available.

Emission factors

The emissions are based on yearly measured process emissions reported in the environmental reports (Koppers, 2015). The emissions for the years 1980-2004 are assumed to be the same as for 2005. No data are available after 2014 and emissions are therefore kept constant on the 2014 level.

Emission trends

Emissions are presented in Table 3.3.9 and Annex 3C-19.

Table 3.3.9 Emissions from production of tar products.

	Unit	1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
SO_2	Mg	210	210	210	210	210	212	105	166	203	167	136	153
NMVOC	Mg	-	0.9	0.9	0.9	0.9	0.9	1.3	1.1	1.2	0.6	2.6	0.9
Hg	kg	-	-	4.8	4.8	4.8	4.8	1.5	1.4	10.0	1.0	1.0	1.0

4.3.7 Source specific recalculations and improvements

All particle emissions are reported back to 1990.

NMVOC emissions from production of chemical ingredients have been extrapolated back to 1985.

For the production of tar products, SO_2 emissions have been extrapolated back to 1980 and Hg emissions have been estimated for 2013-2014.

BC emissions from the production of catalysts are calculated based on the $PM_{2.5}$ emission. This year's submission included an extra decimal to these calculated values leading to recalculations of between -20 % (2004, 2006, 2012) and 50 % (2003), 1 % in average.

4.3.8 Source specific planned improvements

For catalyst production, it will be attempted to verify the assumptions on the split between combustion and process emissions for NO_x.

For tar products, it will be evaluated whether the assumption to keep emissions constant back in time at the 2005 level is appropriate.

4.4 Metal production

4.4.1 Source category description

The processes within the sub-sector *Metal industry* (NFR 2C) in Denmark in relation to emission of other pollutants are:

- Steel production (SNAP 040207/040208)
- Iron production (SNAP 030303)
- Red bronze production (SNAP 040306)
- Secondary aluminium production (SNAP 030310)
- Secondary lead production (SNAP 030307)

The time series for emission of NMVOC, particulate matter, heavy metals, and POPs from *Metal production* is available in the NFR tables. Table 4.4.1 presents an overview of emissions from 2015.

Table 4.4.1 Overview of 2015 emissions from metal production.

	Total emission from Metal industries		Fraction of IPPU, %	Largest contributor in Metal industries	Emission from largest contributor		Fraction of Metal industries, %
NMVOC	0.004	Gg	0.01	2C1 Iron and steel production	0.004	Gg	100.0
TSP	0.20	Gg	3.7	2C1 Iron and steel production	0.20	Gg	98.9
HMs	3.07	Mg	40.0	Pb from 2C1 Iron and steel production	0.70	Mg	22.7
POPs	0.22	kg	0.1	HCBs from 2C3 Aluminium production	0.14	kg	63.0

In the NFR tables, steel production and iron production are summed into one category called "Iron and steel production". This NFR sector 2C1 comprises three activities: An electric arc furnace (EAF) (until 2001/2002 and in 2005), rolling mills (from 2003) and grey iron foundries (whole time series). The most interesting activity from an emission perspective is the EAF. After the closing of the EAF, the site has since 2003 been used for rolling steel slabs imported from steelworks in other countries. This change in production results in large changes in activity data and emissions reported for the year 2002. In 2005, the EAF was shortly reopened, which explains the higher activity level this year.

Regarding the steelworks that use iron and steel scrap as raw material, the emissions to a large degree depend on the quality of the scrap. This fact may result in large annual variations for one or more of the heavy metals. This may also be the case for iron foundries, as they also use scrap as raw material, but they have not been subject to the same requirements to analyse emissions of heavy metals to air.

4.4.1 Steel production

The production of semi-manufactured steel products (e.g. steel sheets/plates and bars) is concentrated at one company: Det Danske Stålvalseværk A/S situated in Frederiksværk. After the closure of the primary production in 2002, the two rolling mills were divided in two companies called DanSteel and Duferco. The following SNAP codes are covered:

- 04 02 07 Electric furnace steel plant
- 04 02 08 Rolling mill

The following pollutants are relevant for the steel production processes:

- SO_2
- NO_x
- NMVOC
- CO
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Heavy metals: As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- POPs: HCB, PCDD/F, PAHs, PCB

Methodology

The steelwork was closed down in January 2002 and then partly re-opened again in November 2002. The production of steel sheets/plates was reopened by DanSteel in 2003, the production of steel bars was reopened by DanScan Metal in March 2004, and the electro steelwork was reopened by DanScan Steel in January 2005. The production at DanScan Metal and Steel ceased in the last part of 2005 and in June 2006 DanScan Metal was taken over by Duferco; the electro steelwork (DanScan Steel) has still not been in operation since 2005. The timeline is presented in "Activity data".

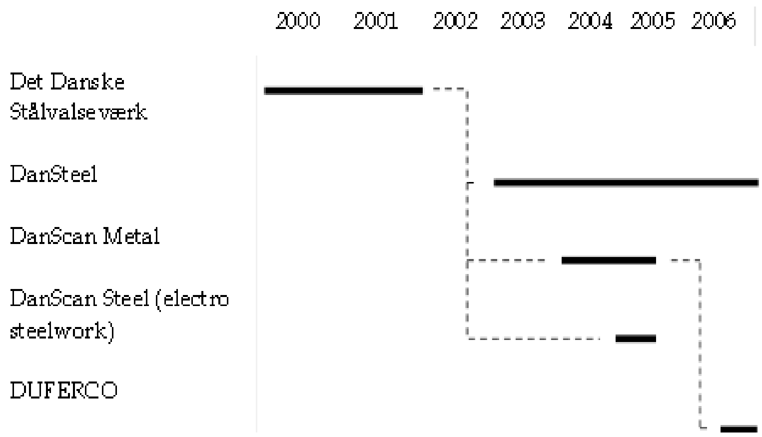

Figure 4.4.1 Timeline for production at the Danish steelwork.

Activity data

Statistical data on activities are available in environmental reports from the single Danish plant (Stålvalseværket) supplemented with other literature; see Table 4.4.2 and Annex 3C-20.

Table 4.4.2 Overall mass flow for Danish steel production, Gg (Stålvalseværket, 2002; DanSteel, 2016; Duferco, 2016).

		1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Det danske stålvalseværk													
Raw material	Iron and steel scrap	-	-	-	657	680	-	-	-	-	-	-	-
Intermediate product	Steel slabs etc.	-	-	-	654	803	-	-	-	-	-	-	-
Product	Steel sheets	444	444	444	478	380	-	-	-	-	-	-	-
	Steel bars	170	170	170	239	251	-	-	-	-	-	-	-
	Products, total	614[1]	614[1]	614[1]	717	631	250[2]	-	-	-	-	-	-
Dansteel													
Raw material	Steel slabs	-	-	-	-	-	515	457	490	338	460	483	525
Product	Steel sheets	-	-	-	-	-	433	381	390	275	379	403	441
Duferco													
Raw material	Steel billets	-	-	-	-	-	-	141	184	161	143	131	137
Product	Steel bars	-	-	-	-	-	-	129	169	150	136	123	129

[1] Extrapolation.
[2] Assumed.

The mass balances/flow sheets presented in the annual environmental reports do not for all years tell about the changes in the stock and therefore the balance cannot be checked off.

Emission factors

The applied emission factors are presented in Table 4.4.3. Regarding the electric arc furnace the emissions for all other pollutants than TSP have been estimated by use of emission factor from literature.

Table 4.4.3 Emission factors for steel production (EMEP/EEA, 2013).

	Unit	Electric Arc Furnace	Rolling Mill
SO_2	g/Mg	60	-
NO_x	g/Mg	130	-
NMVOC	g/Mg	46	7
CO	kg/Mg	1.7	-
TSP	g/Mg	61-68[4]	5-5781[4]
PM_{10}	g/Mg	80 % of TSP	5-5494[4]
$PM_{2.5}$	g/Mg	70 % of TSP	3-3465[4]
BC	g/Mg	0.36 % of $PM_{2.5}$	0.36 % of $PM_{2.5}$
As	mg/Mg	15	-
Cd	mg/Mg	10-80[2]	0.2-0.4[4]
Cr	mg/Mg	100	-
Cu	mg/Mg	20	-
Hg	mg/Mg	50-400[2]	-
Ni	g/Mg	0.4-1.4[2]	0.004-0.01[4]
Pb	g/Mg	1.0-5.0[2]	0.005[5]
Se	g/Mg	0.02	-
Zn	g/Mg	3.6-19.0[2]	0.005[5]
HCB	mg/Mg	3.2[3]	-
PCDD/F	mg/Mg	0.8	-
Total 4 PAHs	g/Mg	0.48[1]	-
PCB	mg/Mg	2.5[3]	-

[1] Divided by four for an estimate of the individual pollutants,
[2] Illerup et al. (1999),
[3] Nielsen et al. (2013),
[4] Implied emission factor,
[5] Estimated.

Emission trends

Emissions from the electro steelwork and rolling mills are presented in Table 4.4.4 and Annex 3C-21.

Table 4.4.4 Emissions from the electro steelwork and rolling mills.

	Unit	1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
SO_2	Mg	37	37	37	43	38	15	-	-	-	-	-	-
NO_x	Mg	-	80	80	93	82	33	-	-	-	-	-	-
NMVOC	Mg	-	28	28	33	29	15	3.6	3.9	3.0	3.6	3.7	4.0
CO	Mg	-	1.0	1.0	1.2	1.1	0.4	-	-	-	-	-	-
TSP	Mg	-	-	89	103	41	19	3.4	3.6	2.8	3.3	3.1	5.9
PM_{10}	Mg	-	-	71	82	33	15	3.2	3.4	2.7	3.1	2.9	5.6
$PM_{2.5}$	Mg	-	-	50	57	23	10	2.0	2.2	1.7	2.0	1.8	3.5
BC	Mg	-	-	0.18	0.21	0.08	0.04	0.01	0.01	0.01	0.01	0.01	0.01
As	kg	-	-	9.2	10.8	9.5	3.8	-	-	-	-	-	-
Cd	kg	-	-	39	22	16	7.1	0.1	0.1	0.1	0.1	0.2	0.1
Cr	kg	-	-	61	72	63	25	-	-	-	-	-	-
Cu	kg	-	-	12	14	13	5.0	-	-	-	-	-	-
Hg	kg	-	-	246	143	63	13	-	-	-	-	-	-
Ni	kg	-	-	757	430	252	104	3.9	3.0	2.7	3.5	2.6	2.8
Pb	kg	-	-	2967	1720	669	268	2.5	2.8	2.1	2.6	2.6	2.8
Se	kg	-	-	12	14	13	5.0	-	-	-	-	-	-
Zn	kg	-	-	11492	6547	3085	902	2.5	2.8	2.1	2.6	2.6	2.8
HCB	kg	-	-	2.0	2.3	2.0	0.8	-	-	-	-	-	-
PCDD/F	g	-	-	12.0	7.5	0.5	0.8	-	-	-	-	-	-
Benzo(b)flouranthene	kg	-	-	74	86	76	30	-	-	-	-	-	-
Benzo(k)flouranthene	kg	-	-	74	86	76	30	-	-	-	-	-	-
Benzo(a)pyrene	kg	-	-	74	86	76	30	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	kg	-	-	74	86	76	30	-	-	-	-	-	-
PCB	kg	-	-	1.5	1.8	1.6	0.6	-	-	-	-	-	-

Due to the change in production process in the beginning of the 00's, the emissions (and even more so the implied emission factors) change drastically from 2001 to 2002 and from 2002 to 2003. Please refer to Figure 4.4.1 and Table 4.4.2.

4.4.2 Iron production

Multiple grey iron foundries exist in Denmark, producing a wide range of products like e.g. cast iron pipes, central heating boilers and flywheels. The following SNAP code is covered:

- 03 03 03 Grey iron foundries

The following pollutants are relevant for the iron production process:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Heavy metals: As, Cd, Cr, Ni, Pb, Se, Zn
- POPs: HCB, PCB

Methodology

The emission of heavy metals from iron foundries is based on standard emission factors and yearly production statistics from Statistics Denmark (2016). The emission of TSP and distribution between TSP, PM_{10} and $PM_{2.5}$ (1/0.3/0.045) is obtained from CEPMEIP. Emission factors for HCB and PCB are obtained from Nielsen et al. (2013).

Activity data

Statistical data on production in grey iron foundries are available from Statistics Denmark (2016) for the entire time series. The activity data are presented in Table 4.4.5 and Annex 3C-22.

Table 4.4.5 Activity data, iron foundries, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Grey iron foundries	104.9	100.5	107.9	107.2	86.4	97.5	90.5	91.0	111.5	96.3

Emission factors

The applied emission factors are presented in Table 4.4.6.

Table 4.4.6 Emission factors for grey iron foundries.

	Unit	Grey iron foundries
TSP	g/Mg	2000
PM_{10}	g/Mg	600
$PM_{2.5}$	g/Mg	90
BC	% of $PM_{2.5}$	10
As	g/Mg	0.3
Cd	g/Mg	0.14
Cr	g/Mg	1.1
Ni	g/Mg	1.3
Pb	g/Mg	7.2
Se	g/Mg	5
Zn	g/Mg	5
HCB	mg/Mg	0.04
PCB	mg/Mg	0.5

Emission trends

Emissions from grey iron foundries are presented in Table 4.4.7 and Annex 3C-23.

Table 4.4.7 Emissions from grey iron foundries.

	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
TSP	Mg	210	201	216	214	173	195	181	182	223	193
PM_{10}	Mg	63	60	65	64	52	59	54	55	67	58
$PM_{2.5}$	Mg	9	9	10	10	8	9	8	8	10	9
BC	Mg	1	1	1	1	1	1	1	1	1	1
As	kg	31	30	32	32	26	29	27	27	33	29
Cd	kg	15	14	15	15	12	14	13	13	16	13
Cr	kg	115	110	119	118	95	107	100	100	123	106
Ni	kg	136	131	140	139	112	127	118	118	145	125
Pb	kg	755	723	777	772	622	702	651	655	803	693
Se	kg	524	502	539	536	432	488	452	455	558	482
Zn	kg	524	502	539	536	432	488	452	455	558	482
HCB	g	4	4	4	4	3	4	4	4	4	4
PCB	g	52	50	54	54	43	49	45	46	56	48

4.4.3 Secondary aluminium production

Two active Danish production sites have been identified for secondary aluminium; "Stena Aluminium" and "Jydsk Aluminium Industri". The following SNAP codes are covered:

- 03 03 10 Secondary aluminium production

The following pollutants are relevant for the secondary aluminium production:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Heavy metals: Cd, Pb

- POPs: HCB, PCDD/F, PCB

Methodology

Secondary aluminium industries were identified from a list of companies with the relevant environmental approvals acquired from the Danish Environmental Agency. The largest producer, called Stena Aluminium, stood for approximately 90 % of the total Danish production until the factory was closed in the end of 2008.

Activity data

The activity data are presented in Table 4.4.8 and Annex 3C-24.

Table 4.4.8 Activity data for secondary aluminium production (Stena Aluminium, 2008; Jydsk Aluminiums Industri, 2015), Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Stena Aluminium[1]	30.2	30.2	32.9	23.4 -	-	-	-	-	-	
Jydsk Aluminium[2, 3, 4]	1.3	2.2	3.9	5.4	5.2	6.3	6.5	5.4	5.6	7.0
Total	31.5	32.5	36.8	28.8	5.2	6.3	6.5	5.4	5.6	7.0

1990-1995: Calculated average of 1996-2000, [2]1993, 1996, 2007-2014: Estimated based on nformation from the environmental reports, [3]1990-1992: Estimated based on 1993, [4]1994-1995, 1997-2006: Interpolated.

Emission factors

Emission factors for the production of secondary aluminium are presented in Table 4.4.9.

Table 4.4.9 Emission factors for secondary aluminium production.

Pollutant	Unit	Value	Source
TSP	kg/Mg	0.12	Average IEF (1998-2000) from Stena
PM_{10}	% of TSP	70.0	EMEP/EEA (2013)
$PM_{2.5}$	% of TSP	27.5	EMEP/EEA (2013)
BC	% of $PM_{2.5}$	2.3	EMEP/EEA (2013)
Cd	g/Mg	0.03	Average IEF (1998-2000) from Stena
Pb	g/Mg	0.15	Average IEF (1998-2000) from Stena
HCB	mg/Mg	20.0	Nielsen et al. (2013)
PCDD/F	mg/Mg	0.035	EMEP/EEA (2013)
PCB	mg/Mg	3.4	Nielsen et al. (2013)

Emission trends

Emissions from secondary aluminium production are available in Table 4.4.10 and Annex 3C-35.

Table 4.4.10 Emissions from secondary aluminium production

	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
TSP	Mg	3.8	3.9	4.4	3.5	0.62	0.75	0.78	0.64	0.67	0.85
PM_{10}	Mg	2.6	2.7	3.1	2.4	0.44	0.53	0.55	0.45	0.47	0.59
$PM_{2.5}$	Mg	1.0	1.1	1.2	1.0	0.17	0.21	0.21	0.18	0.18	0.23
BC	kg	23.9	24.7	28.0	21.9	3.95	4.8	4.9	4.1	4.2	5.4
Cd	kg	0.94	1.0	1.1	0.9	0.16	0.19	0.19	0.16	0.17	0.21
Pb	kg	4.7	4.9	5.5	4.3	0.78	0.94	0.97	0.81	0.84	1.06
HCB	kg	0.63	0.65	0.74	0.58	0.10	0.13	0.13	0.11	0.11	0.14
PCDD/F	g	1.1	1.1	1.3	1.0	0.18	0.22	0.23	0.19	0.19	0.25
PCB	kg	0.11	0.11	0.13	0.10	0.02	0.02	0.02	0.02	0.02	0.02

4.4.4 Secondary lead production

One Danish company producing secondary lead has been identified; Hals Metal. The following SNAP code is covered:

- 03 03 07 Secondary lead production

The following pollutants are relevant for the secondary lead production:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$
- Heavy metals: As, Cd, Hg, Pb, Zn
- POPs: HCB, PCDD/F, PCB

Methodology

Only one Danish company, called Hals metal, has been identified as producing secondary lead from scrap metal. In addition to Hals metal, old lead tiles from castles, churches etc. are melted and recast on site during preservation of the many historical buildings in Denmark.

Activity data

Activity data from Hals metal is provided by the company. A clause affected in 2002 meant that Hals metal could no longer burn cables containing lead. The processing of cables was therefore stopped and the company's activity changed to melting. This transition resulted in a low activity in 2003.

The activity of recasting lead tiles is not easily found because it is spread out on many craftsmen and poorly regulated. However, an estimate by Lassen et al. (2004) stated that 200-300 Mg lead tiles were recast in 2000. Since the building stock worthy of preservation is constant, it is considered reasonable to also let the activity of recasting of lead tiles be constant.

Activity data for secondary lead is shown in Table 4.4.11 and Annex 3C-26.

Table 4.4.11 Activity data for secondary lead production (Hals metal, 2015 and Lassen et al., 2004), Mg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Hals metal	540	750	540	691	635	938	412	533	625	625
Lead tiles	250	250	250	250	250	250	250	250	250	250
Total	790	1000	790	941	885	1188	662	783	875	875

Emission factors

Emission factors are presented in Table 4.4.12.

Table 4.4.12 Emission factors for secondary lead production.

Pollutant	Value	Unit	Reference
TSP	1.63	kg/Mg	EMEP/EEA (2013)
PM_{10}	1.30	kg/Mg	EMEP/EEA (2013)
$PM_{2.5}$	0.65	kg/Mg	EMEP/EEA (2013)
As	3.5	g/Mg	EMEP/EEA (2013)
Cd	1.1	g/Mg	EMEP/EEA (2013)
Hg	0.47	g/Mg	Average IEF (2008-2010)
Pb	426	g/Mg	EMEP/EEA (2013)
Zn	2.6	g/Mg	EMEP/EEA (2013)
HCB	0.3	mg/Mg	Nielsen et al. (2013)
PCDD/F	8.0	µg/Mg	EMEP/EEA (2013)
PCB	7.3	mg/Mg	Nielsen et al. (2013)

Emission trends

Emissions from secondary lead production are available in Table 4.4.13 and Annex 3C-27.

Table 4.4.13 Emissions from secondary lead production.

	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
TSP	Mg	1.3	1.6	1.3	1.5	1.4	1.9	1.1	1.3	1.4	1.4
PM_{10}	Mg	1.0	1.3	1.0	1.2	1.2	1.5	0.9	1.0	1.1	1.1
$PM_{2.5}$	Mg	0.5	0.7	0.5	0.6	0.6	0.8	0.4	0.5	0.6	0.6
As	kg	2.8	3.5	2.8	3.3	3.1	4.2	2.3	2.7	3.1	3.1
Cd	kg	0.9	1.1	0.9	1.0	1.0	1.3	0.7	0.9	1.0	1.0
Hg	kg	0.4	0.5	0.4	0.4	0.4	0.6	0.3	0.4	0.4	0.4
Pb	kg	337	426	337	401	377	506	282	334	373	373
Zn	kg	2.1	2.6	2.1	2.4	2.3	3.1	1.7	2.0	2.3	2.3
HCB	g	0.2	0.3	0.2	0.3	0.3	0.4	0.2	0.2	0.3	0.3
PCDD/F	mg	6.3	8.0	6.3	7.5	7.1	9.5	5.3	6.3	7.0	7.0
PCB	g	5.7	7.3	5.7	6.8	6.4	8.6	4.8	5.7	6.3	6.3

4.4.5 Red bronze production

The following SNAP code is covered:

- 04 03 06 Allied metal manufacturing (Red bronze production)

The following pollutants are relevant for the red bronze production process:

- Heavy metals: Cd, Cu, Pb, Zn

Methodology

Activity data

Activity data are available for the years 1990 and 1995-1997. Data for 1991-1994 was interpolated and 1998-2015 are kept constant on the same level as 1997.

Table 4.4.14 Activity data for red bronze production.

	Unit	1990	1995	1996	1997
Red bronze production	Mg	3895	4350	4400	4532

Emission factors

The applied emission factors are presented in Table 4.4.15 and are all referenced to Illerup et al. (1999).

Table 4.4.15 Emission factors for red bronze production.

Pollutant	Unit	Value
Cd	g/Mg	1
Cu	g/Mg	10
Pb	g/Mg	15
Zn	g/Mg	140

Emission trends

Emissions trends for Cd, Cu, Pb, and Zn from red bronze production are presented in Table 4.4.16.

Table 4.4.16 Emissions from red bronze production, kg.

	1990	1991	1992	1993	1994	1995	1996	1997-2015
Cd	3.9	4.0	4.1	4.2	4.3	4.4	4.4	4.5
Cu	39.0	39.9	40.8	41.7	42.6	43.5	44.0	45.3
Pb	58.4	59.8	61.2	62.5	63.9	65.3	66.0	68.0
Zn	545.3	558.0	570.8	583.5	596.3	609.0	616.0	634.5

4.4.6 Source specific recalculations and improvements

All particle emissions are reported back to 1990.

Iron and steel production

SO_2, NO_x, CO, Se and PAHs are new pollutants estimated from steel production in the electric arc furnace.

NMVOC emissions from the electro steelwork have been extrapolated back to 1985. By mistake, NMVOC was not included from the EAF for 2001, this has been corrected.

BC emissions from the rolling mills steel productions and the grey iron foundries are new in this year's inventory, as well as Hg from secondary lead production.

The correction of a factor 1000 error in the measured particle emissions from rolling mills in 2009-2010 results in drastic decreases in particle emissions for 2003-2010.

Secondary aluminium production

Data on raw material (aluminium scrap) for 2013-2014 has gathered by contacting the industry. Based on these new data the estimated production of secondary aluminium was updated, leading to decreases in emissions of -21.5 % (2013) and -22.7 % (2014).

Lead production

Hg is a new pollutant estimated from secondary lead production.

4.4.7 Source specific planned improvements

All emission factors for iron foundries will be reviewed and clear references provided.

It will be investigated whether activity data for red bronze production (Allied metal manufacturing) are available from Statistics Denmark.

4.5 Non-energy products from fuels and solvent use

4.5.1 NMVOCs used as solvents

Description of source category

Non-energy products from fuels and solvent use (NFR 2D) includes the following categories:

- Domestic solvent use including fungicides (NFR 2D3a, SNAP 060408 & 060411)
- Road paving with asphalt (NFR 2D3b, SNAP 040611)
- Asphalt roofing (NFR 2D3c, SNAP 040610)

- Coating applications (NFR 2D3d, SNAP 0601)
- Degreasing (NFR 2D3e, SNAP 0602)
- Dry cleaning (NFR 2D3f, SNAP 060202)
- Chemical products (NFR 2D3g, SNAP 0603)
- Printing (NFR 2D3h, SNAP 060403)
- Other solvent use (NFR 2D3i, SNAP 0604)
- Paraffin wax use (No NFR category – placed in NFR 2D3h in this year's reporting, SNAP 060606)

Methodologies, activity data, emission factors and pollutants for Road paving with asphalt (NFR 2D3b) and Asphalt roofing (NFR 2D3c) are described in their respective sections below. For all other categories in NFR 2D the methods for compiling activity data and emission factors, values of activity data and emission factors and calculated emissions are presented in this section.

Solvent use categories are aggregated according to the following four categories, which corresponds to the grouping in IPCC (2006):

- Coating applications (NFR 2D3d)
- Degreasing (NFR 2D3e) and Dry cleaning (NFR 2D3f)
- Chemical products (NFR 2D3g)
- Domestic solvent use including fungicides (NFR 2D3a), Printing (NFR 2D3h) and Other solvent use (NFR 2D3i)

Only NMVOCs used as solvents are relevant for these categories. 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 main components in solvents - and solvent use in industries and households is typically the dominant source of anthropogenic NMVOC emissions (UNFCCC, 2008; Pärt, 2005; Karjalainen, 2005). 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 sources.

Methodology

Until 2002 the Danish solvent emission inventory was based on questionnaires, which were sent to selected industries and sectors requiring information on solvent use. In 2003 it was decided to implement a method that is more complete, accurate and transparent with respect to including the total amount of used solvent, attributing emissions to industrial sectors and households and establishing a reliable model that is readily updated on a yearly basis.

The method is mainly based on the detailed approach and methodology described in EMEP/EEA (2013) and IPCC (2006), and emissions are calculated for industrial sectors, households for the stated NFR sectors, as well as for individual pollutants.

Emission modelling of solvents can basically be done in two ways: 1) By estimating the amount of (pure) solvents consumed, or 2) By estimating the amount of solvent containing products consumed, taking account of their solvent content (EMEP/EEA, 2013).

In 1) all relevant solvents must be estimated, or at least those together representing more than 90 % of the total pollutant emission, and in 2) all relevant source categories must be inventoried or at least those together contributing more than 90 % of the total pollutant emission. A simple approach is to use a per capita emission for each category, whereas a detailed approach is to get all relevant consumption data (EMEP/EEA, 2013; IPCC, 2006).

The detailed method 1) is used in the Danish emission inventory for solvent use, thus representing a chemicals approach, where each pollutant is estimated separately. The sum of emissions of all estimated pollutants used as solvents equals the pollutant emission from solvent use.

Pollutant list

The definitions of solvents and (NM)VOC that are used in the Danish emission inventory are as defined in the solvent directive (Directive 1999/13/EC) of the EU legislation: "Organic solvent shall mean any VOC which is used alone or in combination with other agents, and without undergoing a chemical change, to dissolve raw materials, products or waste materials, or is used as a cleaning agent to dissolve contaminants, or as a dissolver, or as a dispersion medium, or as a viscosity adjuster, or as a surface tension adjuster, or a plasticiser, or as a preservative". VOCs are defined as follows: "Volatile organic compound shall mean any organic compound having at 293.15 K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular condition of use".

This implies that some NMVOCs, e.g. ethylene glycol, that have vapour pressures just around 0.01 kPa at 20 °C, may only be defined as VOCs at use conditions with higher temperature. However, use conditions at elevated temperatures are typically found in industrial processes. Here the capture of solvent fumes is often efficient, thus resulting in small emissions (communication with industries).

The Danish list of NMVOCs comprises approx. 30 pollutants or pollutant groups representing more than 95 % of the total emission from solvent use, cf. Table 4.5.4.

Activity data

For each pollutant or product a mass balance is formulated:

$$\textit{Consumption} = (\textit{production} + \textit{import}) - (\textit{export} + \textit{destruction/disposal} + \textit{hold-up}) \qquad \text{(Eq. 1)}$$

Data on production, import and export amounts of solvents and solvent containing products are collected from Statistics Denmark (2016), which contains detailed statistical information on the Danish society. Manufacturing and trading industries are committed to reporting production and trade figures to the Danish Customs & Tax Authorities in accordance with the Combined Nomenclature. Import and export figures are available on a monthly basis from 1990 to present and contain trade information from 272 countries world-wide. Production figures are reported quarterly as "industrial commodity statistics by commodity group and unit" from 1990 to present. Prior to 1990 the figures are assumed constant on a 1990 level.

Destruction and disposal of solvents lower the pollutant emissions. In principle this amount must be estimated for each pollutant in all industrial activities and for all uses of pollutant containing products. At present the solvent inventory only considers destruction and disposal for a limited number of pollutants. For some pollutants it is inherent in the emission factor, and for others the reduction is specifically calculated from information obtained from the industry or literature.

Hold-up is the difference in the amount in stock in the beginning and at the end of the year of the inventory. No information on solvents in stock has been obtained from industries. Furthermore, the inventory spans over several years so there will be an offset in the use and production, import and export balance over time.

In some industries the solvents are consumed in the process, e.g. in the graphics and plastic industry, whereas in the production of paints and lacquers the solvents are still present in the final product. These products can either be exported or used in the country. In order not to double count consumption amounts of pollutants it is important to keep track of total solvent use, solvents not used in products and use of solvent containing products. Furthermore some pollutants may be represented as individual pollutants and also in chemical groups, e.g. "o-xylene", "mixture of xylenes" and "xylene". Some pollutants are better inventoried as a group rather than individual pollutants, due to missing information on use or emission for the individual pollutants. The Danish inventory considers single pollutants, with a few exceptions.

Activity data for pollutants are thus primarily calculated from Equation 1 with input from Statistics Denmark (2016). When Statistics Denmark holds no information on production, import and export or when more reliable information is available from industries, scientific reports or expert judgements the data can be adjusted or even replaced. The used amounts of products (activity data) in Table 4.5.1 are derived from used amounts of pollutants by assessing the amount of pollutants that is comprised within products belonging to each of the categories.

Table 4.5.1 Activity data (AD) in Gg per year. Complete time series can be seen in Annex 3C-28.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coating applications (NFR 2D3d)	83.2	82.2	91.1	104	74.2	45.8	42.8	42.3	46.3	40.3	42.9
Degreasing (NFR 2D3e) and Dry cleaning (NFR 2D3f)	1.41	1.41	1.53	0.59	0.37	0.25	0.22	0.055	0.097	0.19	0.15
Chemical products (NFR 2D3g)	406	406	504	567	740	641	640	516	517	485	500
Domestic solvent use - including fungicides (NFR 2D3a), Printing (NFR 2D3h) and Other solvent use (NFR 2D3i)	197	206	256	239	213	178	176	176	190	155	178

Emission factors

For each pollutant the emission is calculated by multiplying the consumption with the fraction emitted (emission factor), according to:

Emission = consumption * emission factor

The present Danish method uses emission factors that represent specific industrial activities, such as processing of polystyrene, dry cleaning etc. or that represent use categories, such as paints and detergents. Some pollutants have been assigned emission factors according to their water solubility. Higher hydrophobicity yields higher emission factors, since a lower amount ends in waste water, e.g. ethanol (hydrophilic) and turpentine (hydrophobic).

Emission factors for solvents are categorised in four groups in ascending order: (1) Lowest emission factors in the chemical industry, e.g. lacquer and paint manufacturing, due to emission reducing abatement techniques and destruction of solvent containing waste, (2) Other processes in industry, e.g. graphic industry, have higher emission factors, (3) Non-industrial use, e.g. auto repair and construction, have even higher emission factors, (4) Diffuse use of solvent containing products, e.g. painting, where practically all the pollutant present in the products will be released during or after use.

For a given pollutant the consumed amount can thus be attributed with two or more emission factors; one emission factor representing the emissions occurring at a production or processing plant and one emission factor representing the emissions during use of a solvent containing product. If the chemical is used in more processes and/or is present in several products more emission factors are assigned to the respective chemical amounts.

Emission factors can be defined from surveys of specific industrial activities or as aggregated factors from industrial branches or sectors. Furthermore, emission factors may be characteristic for the use pattern of certain products. The emission factors used in the Danish inventory also rely on the work done in a joint Nordic project (Fauser et al., 2009).

In Table 4.5.2 the emission factors are listed. They are based on the values in the Guidebook (EMEP/EEA, 2013) and adjusted on a country specific basis according to the assessment described above. See more details in the QA/QC section.

Table 4.5.2 Emission factors in Gg NMVOC per Gg AD. Complete time series can be seen in Annex 3C-29.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coating applications (NFR 2D3d)	0.0614	0.0603	0.0631	0.0600	0.0562	0.0580	0.0636	0.0641	0.0634	0.0629	0.0608
Degreasing (NFR 2D3e) and Dry cleaning (NFR 2D3f)	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05
Chemical products (NFR 2D3g)	0.0200	0.0200	0.0185	0.0123	0.00844	0.00787	0.00753	0.00945	0.00889	0.00893	0.00949
Domestic solvent use including fungicides (NFR 2D3a), Printing (NFR 2D3h) and Other solvent use (NFR 2D3i)	0.125	0.123	0.119	0.119	0.100	0.112	0.111	0.110	0.116	0.115	0.109

Source allocation

The Danish Working Environment Authority (WEA) is administrating the registrations of chemicals and products to the Danish product register. All manufacturers and importers of products for occupational and commercial use are obliged to register. The following products are comprised in the registration agreement:

- Chemicals and materials that are classified as dangerous according to the regulations set up by the Danish Environmental Protection Agency (EPA).
- Chemicals and materials that are listed with a limit value on the WEA “limit value list”.
- Materials, containing 1 % or more of a chemical, which is listed on the WEA “limit value list”.
- Materials, containing 1 % or more of a chemical, which are classified as hazardous to humans or the environment according to the EPA rules on classification.

There are the following important exceptions for products, which do not need to be registered:

- Products exclusively for private use.
- Pharmaceuticals ready for use.
- Cosmetic products.

The Danish product register does therefore not comprise a complete account of used pollutants. Source allocations of exceptions from the duty of declaration are done based on information from trade organisations, industries, scientific reports and information from the internet.

The data base Substances in Preparations in the Nordic Countries (SPIN) (www.spin2000.net) holds information on use of various pollutants in product and activities, i.e. Use Categories Nordic (UCN), and on use in industrial categories, i.e. according to the standard nomenclature for economic activities (NACE) system (http://ec.europa.eu/comm/competition/mergers/cases/index/nace_all.html). The use amount from DK Statistics is first distributed in SNAP categories according to UCN data, and second according to NACE industrial use in NFR categories.

Use of spray cans

Emissions from use of spray cans (CRF 3D3 Other-Solvent Use) include the propellant (propane and butane) and solvents. Propellants comprise, according to communication with “Aerosol Industriens Brancheforening” and FORCE (2009), approx. 33 vol-% (24 weight-%) of a can. According to Rambøll (2004) the remaining amount is solvents (VOCs), 71 weight-% for spray paint and 51 weight-% for cosmetics, and non-VOCs, 5 weight-% for spray paints and 25 weight-% for cosmetics. 3% of the Danish marked is spray paints. The rest is cosmetics, which comprises deodorants, hairspray and foam products. 90% of the use in Denmark is imported. It is assumed that approx. 5% remains in the can and is destroyed in waste handling. Based on these assumptions the total VOC emissions from use of spray cans in Denmark is 1788 tonnes per year. This amount is assigned to all years as no detailed consumption trend is available. The specific compounds are propane and butane as propellants and ethanol, tert-butanol, acetone, butanone, butylacetate, ethylacetate, propanol, toluene and xylene as solvents.

Emission trends

Table 4.5.3 and Figure 4.5.1 show the emissions of NMVOC from 1985 to 2015, where the used amounts of single pollutants have been assigned to specific products and NFR sectors. From 1985 to 1990 the emission level is set constantly equal to the 1990 emission level, due to missing reliable data.

A general increase is seen for all sectors from 1990 to 1996 followed by a decrease from 1997 to 2006 and stagnation in the period 2007 to 2015.

In Table 4.5.4 the emission for 2015 is split into individual pollutants. The most abundantly used solvents are ethanol and turpentine, or white spirit defined as a mixture of stoddard solvent and solvent naphtha and propylalcohol. Ethanol is used as solvent in the chemical industry and as windscreen washing agent. Turpentine is used as thinner for paints, lacquers and adhesives. Propylalcohol is used in cleaning agents in the manufacture of electrical equipment, flux agents for soldering, as solvent and thinner and as windscreen washing agent. Household emissions are dominated by propane and butane, which are used as aerosols in spray cans, primarily in cosmetics. For some pollutants the emission factors are precise but for others they are rough estimates. The division of emission factors into four categories implies that high emission factors are applicable for use of solvent containing products and lower emission factors are applicable for use in industrial processes.

Table 4.5.3 Emissions in Gg NMVOC per year. Complete time series can be seen in Annex 3C-30.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Coating applications (NFR 2D3d)	4.96	4.96	5.75	6.25	4.17	2.60	2.73	2.71	2.94	2.54	2.61
Degreasing (NFR 2D3e) and Dry cleaning (NFR 2D3f)	7E-05	7E-05	8E-05	3E-05	2E-05	1E-05	1E-05	3E-06	5E-06	1E-05	1E-05
Chemical products (NFR 2D3g)	8.14	8.14	9.32	6.96	6.25	5.04	4.81	4.87	4.60	4.33	4.74
Domestic solvent use including fungicides (NFR 2D3a), Printing (NFR 2D3h) and Other solvent use (NFR 2D3i)	25.3	25.3	30.6	28.4	21.4	20.0	19.5	19.3	22.0	17.8	19.4
Total NMVOC	38.0	38.4	45.6	41.6	31.8	27.7	27.0	26.9	29.5	24.7	26.8

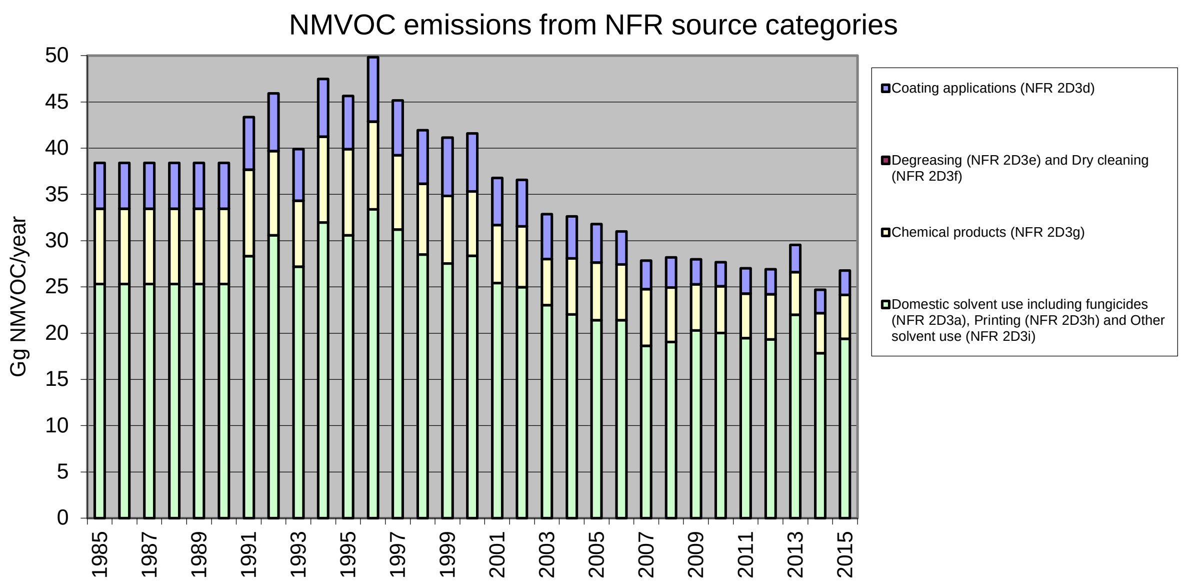

Figure 4.5.1 NMVOC emissions in Gg NMVOC per year. The methodological approach for finding emissions in the period 1985 – 2015 is described in the text. Figures can be seen in Table 4.5.3 and in Annex 3C-30.

Table 4.5.4 2015 NMVOC emissions of single pollutants or pollutant groups.

Pollutant	CAS no	Emissions 2015 (t)
ethanol	64-17-5	9157
turpentine (white spirit: stoddard solvent and solvent naphtha)	64742-88-7 8052-41-3	5271
propyl alcohol	67-63-0	3037
pentane	109-66-0	1858
propylene glycol	57-55-6	1472
cyanates	79-10-7	1320
methanol	67-56-1	1260
acetone	67-64-1	821
1-butanol	71-36-3	308
butanone	78-93-3	299
propane	74-98-6	282
butane	106-97-8	282
glycol ethers	110-80-5 107-98-2 108-65-6 34590-94-8 112-34-5 and others	276
xylenes	1330-20-7 95-47-6 108-38-3 106-42-3	226
ethylene glycol	107-21-1	199
butanoles	78-92-2 2517-43-3 and others	124
cyclohexanones	108-94-1	115
phenol	108-95-2	108
toluene	108-88-3	104
formaldehyde	50-00-0	93.8
styrene	100-42-5	44.8
ethyl acetate	141-78-6	43.9
acyclic aldehydes	78-84-2 111-30-8 and others	38.7
butyl acetate	123-86-4	22.2
tetrachloroethylene	127-18-4	1.3
Total		26,765

4.5.2 Road paving with asphalt

Description of source category

Road paving with asphalt is an activity that can be found all over the country and especially in relation to establishing new traffic facilities. The raw materials for construction of transport facilities are prepared on one of the plants located near the locality of application to limit the transport distance. The asphalt concrete is mixed and brought to the locality of application on a truck.

Transport facilities are constructed by a number of different layers:

- a load bearing layer (e.g. course gravel)
- an adhesive layer (liquefied asphalt e.g. “cutback” asphalt or asphalt emulsion)
- a wearing coarse (e.g. hot mix asphalt concrete)

Different qualities of “cutback” asphalt (e.g. asphalt dissolved in organic solvents/petroleum distillates) and asphalt emulsion contains different kinds and amounts of solvent. Cutback asphalt contains 25-45%v/v solvent e.g. heavy residual oil, kerosene-type solvent, naphtha or gasoline solvent. Approximately 500.000 litre solvent evaporates annually from the use of ”cutback” asphalt (Asfaltindustrien, 2003). This amount of solvent, which is added to the asphalt, is comprised in the solvent categories above with an emission factor of approximately unity. This means that NMVOC emissions from “cutback” asphalt in Road paving NFR 2D3b only include emissions from the asphalt fraction as quantified in Table 4.5.5.

Methodology

Emissions are calculated from Eq. 1 for the pollutants NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$ and BC.

Activity data

The use amounts of asphalt for road paving have been compiled from production, import and export statistics of asphalt products in Statistics Denmark (2016).

Table 4.5.5 Activity data for asphalt in road paving in Gg per year. Complete time series can be seen in Annex 3C-31.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Road paving with asphalt (NFR 2D3b)	2 370	2 370	3 144	2 933	3 879	3 005	3 896	3 233	3 339	3429	3440

Emission factors

Default emission and abatement factors are derived from EMEP/EEA (2013) and US EPA (2004).

Table 4.5.6 Emission factors for NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$ and BC from road paving with asphalt. Abatement factors (AF) are stated in brackets.

		Road paving with asphalt (incl. cutback)
NMVOC	g per tonnes	16
CO	g per tonnes	75
TSP	g per tonnes	50 (99.6%)
$PM_{2.5}$	g per tonnes	6,6 (98.4%)
PM_{10}	g per tonnes	49 (98.4%)
BC	g per tonnes	0.006 (98.4%)

Emission trends

Table 4.5.7 NMVOC CO, TSP, PM_{10}, $PM_{2.5}$ and BC emissions in Gg per year from road paving with asphalt. Complete time series can be seen in Annex 3C-32.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
NMVOC	0.0379	0.0379	0.0503	0.0469	0.0621	0.0481	0.0623	0.0517	0.0534	0.0549	0.0550
CO	0.178	0.178	0.236	0.220	0.291	0.225	0.292	0.242	0.250	0.257	0.258
TSP		0.119	0.158	0.148	0.195	0.151	0.196	0.163	0.168	0.173	0.173
$PM_{2.5}$		0.0155	0.0206	0.0192	0.0254	0.0197	0.0256	0.0212	0.0219	0.0225	0.0226
PM_{10}		0.117	0.155	0.144	0.191	0.148	0.192	0.159	0.164	0.169	0.169
BC		1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05

4.5.3 Asphalt roofing

Methodology

Emissions are calculated from Eq. 1 for the pollutants NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$ and BC.

Activity data

The use amounts of asphalt for roofing has been compiled from production, import and export statistics of asphalt products in Statistics Denmark (2016).

Table 4.5.8 Activity data for asphalt roofing in Gg per year. Complete time series can be seen in Annex 3C-33.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Asphalt roofing (NFR 2D3c)	120	120	123	204	187	105	134	131	125	152	137

Emission factors

Default emission and abatement factors are derived from EMEP/EEA (2013) and US EPA (2004).

Table 4.5.9 Emission factors for NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$ and BC from asphalt roofing. Abatement factors (AF) are stated in brackets.

		Asphalt roofing
NMVOC	g per tonnes	80
CO	g per tonnes	9.5
TSP	g per tonnes	41 (96.3%)
$PM_{2.5}$	g per tonnes	2.0 (96.3%)
PM_{10}	g per tonnes	10 (96.3%)
BC	g per tonnes	1E-05 (96.3%)

Emission trends

Table 4.5.10 NMVOC and CO emissions in Gg per year from asphalt roofing. Complete time series can be seen in Annex 3C-34.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
NMVOC	0.0096	0.0096	0.0099	0.0163	0.0150	0.0084	0.0108	0.0105	0.0100	0.0122	0.0109
CO	0.00114	0.00114	0.00117	0.00194	0.00178	0.00100	0.00128	0.00124	0.00119	0.00144	0.00130
TSP		0.00489	0.00502	0.00829	0.00761	0.00428	0.00547	0.00533	0.00511	0.00618	0.00556
$PM_{2.5}$		0.00024	0.00025	0.00042	0.00038	0.00021	0.00027	0.00027	0.00026	0.00031	0.00028
PM_{10}		0.00122	0.00126	0.00207	0.00190	0.00107	0.00137	0.00133	0.00128	0.00155	0.00139
BC		1E-09	1E-09	2E-09	2E-09	1E-09	1E-09	1E-09	1E-09	1E-09	1E-09

4.5.4 Paraffin wax use

Methodology

The category Paraffin wax use covers the following activity:

- Combustion of candles

Paraffin waxes are used in applications such as candles, corrugated boxes, paper coating, board sizing, adhesives, food production, packaging, wax polishes, surfactants (used in detergents or in wastewater treatment), and many others. Emissions from the use of paraffin waxes occur primarily when they are combusted during use, e.g. candles, or when incinerated or used in waste water treatment. The latter cases should be reported in the energy or waste sectors, respectively (IPCC, 2006).

In the Danish inventory emissions are calculated from Eq. 1 for the pollutants CO, TSP, PM_{10}, $PM_{2.5}$, PCDD/Fs, benzo[k]fluoranthene, benzo[a]pyrene and indeno[1,2,3-cd]pyrene only from the combustion of candles, which is considered to be the main emission source, are included.

Activity data

Activity data in Gg used candles are derived from import, export and production data from Statistics DK (2016).

Table 4.5.11 Activity data for paraffin wax use in Gg per year. Complete time series can be seen in Annex 3C-35.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Paraffin wax use (No NFR category)[1)]	7.44	7.44	9.09	16.9	34.4	35.3	30.2	27.9	29.1	30.3	24.9

[1)] Placed in NFR 2D3h in this year's reporting.

Emission factors

Default emission factors are compiled from the scientific literature.

Table 4.5.12 Emission factors for paraffin wax use. Complete time series can be seen in Annex 3C-36.

		Paraffin wax use
CO	kg per Mg	10
TSP	kg per Mg	1.34
PM_{10}	kg per Mg	1.34
$PM_{2.5}$	kg per Mg	1.34
PCDD/Fs	µg per Mg	0.027
Benzo[k]fluoranthene	mg per Mg	4.64
Benzo[a]pyrene	mg per Mg	3.71
Indeno[1,2,3-cd]pyrene	mg per Mg	0.93

Emission trends

Table 4.5.13 Emissions from paraffin wax use. Complete time series can be seen in Annex 3C-37.

		1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
CO	Mg per y	74,4	74,4	90,9	169	344	353	302	279	291	303	249
TSP	Mg per y	9,98	9,98	12,2	22,7	46,1	47,3	40,4	37,3	39.0	40,6	33,4
PM_{10}	Mg per y	9,98	9,98	12,2	22,7	46,1	47,3	40,4	37,3	39.0	40,6	33,4
$PM_{2.5}$	Mg per y	9,978	9,98	12,2	22,7	46,1	47,3	40,4	37,3	39.0	40,6	33,4
PCDD/Fs	mg per y	0,201	0,201	0,246	0,457	0,930	0,953	0,815	0,752	0,786	0,82	0,67
Benzo[k]fluoranthene	g per y	34,5	34,5	42,2	78,5	160	164	140	129	135	141	116
Benzo[a]pyrene	g per y	27,6	27,6	33,7	62,8	128	131	112	103	108	113	92,4
Indeno[1,2,3-cd]pyrene	g per y	6,92	6,92	8,46	15,7	32,0	32,8	28,1	25,9	27,1	28,2	23,2

4.5.5 Source specific recalculations and improvements

Emissions of TSP, PM10, PM2.5 and BC have be included for road paving and asphalt roofing, with emissions and abatement factors from EMEP/EEA (2013) and US EPA (2004).

4.5.6 Source specific planned improvements

None.

4.6 Other product use

Source category description

The sub-sector *Other product use* (NFR 2G) covers the following processes relevant for the Danish inventories:

- Use of fireworks (SNAP 060601)
- Use of tobacco (SNAP 060602)
- Use of charcoal for barbeques (SNAP 060605)

The time series for emission from *Other product use* is available in the NFR tables. Table 4.6.1 presents an overview of emissions from 2015.

Table 4.6.1 Overview of 2015 emissions from Other product use.

	Total emission from other product use		Fraction of IPPU, %	Largest contributor in Mineral industries	Emission from largest contributor		Fraction of Other product use, %
SO_2	0.07	Gg	5.3	Charcoal for barbeques	0.06	Gg	80.1
NO_x	0.07	Gg	74.9	Charcoal for barbeques	0.05	Gg	79.4
NMVOC	0.09	Gg	0.3	Charcoal for barbeques	0.05	Gg	61.7
CO	4.25	Gg	89.0	Charcoal for barbeques	3.83	Gg	90.0
NH_3	0.03	Gg	6.0	Use of tobacco	0.03	Gg	94.4
TSP	0.38	Gg	7.1	Use of fireworks	0.23	Gg	60.1
HMs	4.51	Mg	58.8	Cu from use of fireworks	2.57	Mg	57.0
POPs	129.5	kg	127.2	PAH from charcoal for barbeques	82.1	kg	100.0

4.6.1 Use of other products

As listed above Table 4.6.1, this category includes the use of fireworks, tobacco and charcoal for barbeques.

The following pollutants are relevant for the other product use:

- SO_2
- NO_x
- NMVOC
- CO
- NH_3
- Particulate matter: TSP, PM_{10}, $PM_{2.5}$, BC
- Heavy metals: As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn
- POPs: HCB, PCDD/F, PAHs (benzo(a)pyrene, benzo(b)flouranthene, benzo(k)flouranthene, indeno(1,2,3-c-d)pyrene), PCBs

Methodology

Data on the used amounts of product are obtained from Statistics Denmark (2016), emission factors are primarily from international literature and guidelines.

For more information on what is included and descriptions of the trends, please refer to Hjelgaard et al. (2015).

Activity data

Data on consumption of other products are presented in Table 4.6.2 and Annex 3C-38.

Table 4.6.2 Activity data for the use of other products, Mg.

	1980	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Fireworks	1000	1000	1279	2998	4855	3684	5422	4732	3484	4202	3609	5791
Tobacco	14137	14017	12991	11644	11365	10378	9152	8281	8198	8432	7128	7031
BBQ	1943	4429	7172	7895	13358	14925	7834	6761	14222	14150	11468	18224

Emission factors

The emission factor for fireworks for Pb was changed in 2000 and Hg and Pb, along with any compounds derived here from, were forbidden in 2003 and 2007, respectively. Emissions are therefore noted as not occurring for these years and forward.

Table 4.6.3 Emission factors for other product use.

Compound	Unit	Fireworks	Tobacco	BBQ
SO_2	kg/Mg	1.94 (a)	0.40(e)	3.10 (i)
NO_X	kg/Mg	0.26 (f)	1.80(f)	3.00 (j)[4]
NMVOC	kg/Mg	-	4.84 (f)	3.00 (j)[4]
CO	kg/Mg	6.90 (a)	55.10(f)	210.0 (j)[4]
NH_3	kg/Mg	-	4.15(f)	0.10 (e)
TSP	kg/Mg	39.66 (b)	13.67(g)	3.10 (i)
PM_{10}	kg/Mg	19.83 (b)	13.67(g)	3.10 (i)
$PM_{2.5}$	kg/Mg	13.88 (b)	13.67(g)	3.10 (i)
BC	% of $PM_{2.5}$	-	0.45 (f)	14.7 (e)
As	g/Mg	1.33 (f)	0.16 (h)	0.10 (i)
Cd	g/Mg	0.67 (c)	0.02(e)	0.04 (i)
Cr	g/Mg	15.56 (f)	0.35 (h)	0.04 (e)
Cu	g/Mg	444.4 (f)	0.15 (h)	0.15 (e)
Hg	g/Mg	0.06 (f)[1]	0.01(e)	0.07 (i)
Ni	g/Mg	30 (f)	0.03(e)	0.13 (i)
Pb	g/Mg	2200 (d)[2] 666.7 (c)[3]	0.64(e)	4.45 (i)
Se	g/Mg	-	0.01(e)	0.65 (i)
Zn	g/Mg	260 (f)	1.61(e)	1.90 (i)
HCB	mg/Mg	-	-	0.10 (e)
PCDD/Fs	ug/Mg	-	0.10 (f)	10.50 (k)
Benzo[b]fluoranthene	g/Mg	-	0.05 (f)	2.14 (e)
Benzo[k]fluoranthene	g/Mg	-	0.05 (f)	1.25 (e)
Benzo[a]pyrene	g/Mg	-	0.11 (f)	2.16 (e)
Indeno[1,2,3-cd]pyrene	g/Mg	-	0.05 (f)	1.46 (e)
PCB		-	-	0.13 (e)

[1] The emission of Hg from fireworks was banned in 2002, [2] 1980-1999, [3] 2000-2006, [4] Calculated from default uncontrolled combustion and a net calorific value of 30 MJ/kg, (a) Van der Maas et al. (2010), (b) Klimont et al. (2002), (c) Passant et al. (2003), (d) Miljöförvaltningen (1999), (e) Emission factors for wood (111A) combustion in residential plants (1A4b i), SNAP 020200, the energy content used in the calculation is the average of wood pills and wood waste (16.1 GJ/Mg), (f) EMEP/EEA (2013), (g) Martin et al. (1997), (h) Finstad & Rypdal (2003), (i) Environment Australia (1999), (j) IPCC (1996), (k) Hansen (2000).

Emission trends

An excerpt of the calculated emissions from other product use is shown in Table 4.6.4. The full time series for all pollutants is available in Annex 3B-39.

Table 4.6.4 Excerpt of the emissions from other product use.

		Unit	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
NO_x	Fireworks	Mg	0.3	0.3	0.8	1.3	1.0	1.4	1.2	0.9	1.1	0.9	1.5
	Tobacco	Mg	25.2	23.4	21.0	20.5	18.7	16.5	14.9	14.8	15.2	12.8	12.7
	BBQ	Mg	13.3	21.5	23.7	40.1	44.8	23.5	20.3	42.7	42.5	34.4	54.7
	Total	Mg	38.8	45.2	45.4	61.8	64.4	41.4	36.4	58.3	58.7	48.2	68.8
CO	Fireworks	Mg	6.9	8.8	20.7	33.5	25.4	37.4	32.6	24.0	29.0	24.9	40.0
	Tobacco	Mg	772.4	715.8	641.6	626.2	571.8	504.3	456.3	451.7	464.6	392.8	387.4
	BBQ	Mg	930.1	1506.2	1658.0	2805.1	3134.2	1645.2	1419.8	2986.6	2971.5	2408.2	3827.0
	Total	Mg	1709.4	2230.9	2320.2	3464.8	3731.5	2186.9	1908.7	3462.4	3465.1	2825.9	4254.4
$PM_{2.5}$	Fireworks	Mg	-	17.8	41.6	67.4	51.1	75.3	65.7	48.4	58.3	50.1	80.4
	Tobacco	Mg	-	177.6	159.2	155.4	141.9	125.1	113.2	112.1	115.3	97.5	96.1
	BBQ	Mg	-	22.2	24.5	41.4	46.3	24.3	21.0	44.1	43.9	35.5	56.5
	Total	Mg	-	217.6	225.3	264.2	239.3	224.7	199.9	204.5	217.5	183.1	233.0
Cu	Fireworks	kg	-	568.4	1332.3	2157.5	1637.1	2409.8	2102.8	1548.3	1867.3	1603.7	2573.3
	Tobacco	kg	-	2.0	1.8	1.7	1.6	1.4	1.3	1.2	1.3	1.1	1.1
	BBQ	kg	-	1.1	1.2	2.0	2.3	1.2	1.0	2.2	2.2	1.7	2.8
	Total	kg	-	571.5	1335.2	2161.2	1640.9	2412.3	2105.1	1551.7	1870.8	1606.5	2577.1
Hg	Fireworks	kg	-	0.1	0.2	0.3	-	-	-	-	-	-	-
	Tobacco	kg	-	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0
	BBQ	kg	-	0.5	0.5	0.9	1.0	0.5	0.4	0.9	0.9	0.7	1.2
	Total	kg	-	0.6	0.8	1.2	1.0	0.6	0.5	1.0	1.0	0.8	1.2
Pb	Fireworks	kg	-	2813.9	6595.4	3236.7	2456.0	-	-	-	-	-	-
	Tobacco	kg	-	8.4	7.5	7.3	6.7	5.9	5.3	5.3	5.4	4.6	4.5
	BBQ	kg	-	31.9	35.1	59.4	66.4	34.9	30.1	63.3	63.0	51.0	81.1
	Total	kg	-	2854.2	6638.0	3303.5	2529.1	40.8	35.4	68.6	68.4	55.6	85.6
Zn	Fireworks	kg	-	332.6	779.5	1262.3	957.8	1409.8	1230.2	905.9	1092.5	938.2	1505.5
	Tobacco	kg	-	20.9	18.7	18.3	16.7	14.7	13.3	13.2	13.6	11.5	11.3
	BBQ	kg	-	13.6	15.0	25.4	28.4	14.9	12.8	27.0	26.9	21.8	34.6
	Total	kg	-	367.1	813.2	1305.9	1002.9	1439.5	1256.4	946.1	1133.0	971.5	1551.5
POPs	Tobacco	kg	-	3.2	2.9	2.8	2.6	2.3	2.0	2.0	2.1	1.8	1.7
	BBQ	kg	-	50.3	55.3	93.6	104.6	54.9	47.4	99.7	99.2	80.4	127.8
	Total	kg	-	53.5	58.2	96.4	107.2	57.2	49.4	101.7	101.3	82.1	129.5

4.6.2 Source specific recalculations and improvements

All particle emissions are extrapolated back to 1990.

New pollutants included in this year's inventory include NOx from fireworks and BC from tobacco and barbeques.

4.7 Other industry production

4.7.1 Source category description

The sub-sector *Other production* (NFR 2H) covers the following process relevant for the Danish inventories: 2H2 Food and beverages industry

4.7.2 Food and beverages industry

The following SNAP-codes are covered:

- 04 06 05 Bread
- 04 06 06 Wine
- 04 06 07 Beer
- 04 06 08 Spirits
- 04 06 25 Sugar production
- 04 06 26 Flour production
- 04 06 27 Meat, fish etc. frying/curing
- 04 06 98 Margarine and solid cooking fats
- 04 06 99 Coffee roasting

The pollutant relevant for the food and beverages industry is NMVOC and particles from flour production.

Methodology

The emissions of NMVOC from production of foods and alcoholic beverages are estimated from production statistics (Statistics Denmark, 2016), standard emission factors from the EMEP/EEA (2013), a country specific emission factor for sugar refining.

Activity data and particle emissions from flour production are available for 2007-2014 (and partly for 2004-2006).

Activity data

The production statistics for the relevant processes have been aggregated based on data from Statistics Denmark and presented in Table 4.7.1 and Annex 3C-40. The activity data for white wine includes the production of apple and pear cider and red wine includes other fruit wines.

Table 4.7.1 Production of foods and beverages (Statistics Denmark, 2016).

		1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Bread (rye and wheat)	Gg	193	190	231	244	257	245	207	233	227	208	208
Biscuits, cakes and other bakery products	Gg	119	99	148	138	157	118	114	109	115	113	111
Red wine	M l	12	10	5	5	1	4	3	2	4	1	1
White wine	M l	NO	3.2	0.5	0.3	3.1	18	13	17	26	31	10
Beer	M l	836	930	990	746	868	651	669	608	614	612	612
Malt whisky	M l	0.24	0.02	NO	NO	0.001	NO	NO	NO	NO	NO	NO
Other spirits	M l	39	33	27	24	26	17	21	16	15	7	4
Sugar production	Gg	533	506	444	443	503	262	218	262	493	506	468
Flour production	Gg	-	164	164	164	168	140	183	198	207	224	224
Poultry curing	Gg	4	11	14	24	35	54	57	63	65	65	64
Fish and shellfish curing	Gg	35	52	31	44	41	73	63	62	67	69	69
Other meat curing	Gg	531	448	464	393	361	303	307	249	241	227	211
Margarine and solid cooking fats	Gg	222	161	144	123	109	105	114	106	98	104	100
Coffee roasting	Gg	53	52	49	56	37	37	23	19	17	17	17

NO: not occuring

Emission factors

The emission factors used to calculate the NMVOC emissions from food and beverage production are shown in Table 4.7.2. Regarding refining of sugar, the default emission factor has been revised based on company specific measurements obtained from Nielsen (2011). TOC has been measured in order to solve odour issues. The emission of TOC has been used as indicator for NMVOC assuming a conversion factor at: 0.6 kg C/kg NMVOC.

The emission factor for particles from flour production is the calculated IEF for 2004-2014 of 0.10-0.13 Mg PM_{10} per Gg flour produced.

Table 4.7.2 Emission factors for NMVOC and particles for production of food and alcoholic beverages.

Production	Unit	Value	Reference
Bread (rye and wheat)	kg/Mg bread	4.5	EMEP/EEA (2013)
Biscuits, cakes and other bakery products	kg/Mg product	1	EMEP/EEA (2013)
Red wine	kg/m^3 wine	0.8	EMEP/EEA (2013)
White wine	kg/m^3 wine	0.35	EMEP/EEA (2013)
Beer	kg/m^3 beer	0.35	EMEP/EEA (2013)
Malt whisky	kg/m^3 alcohol	150	EMEP/EEA (2013)
Other spirits	kg/m^3 alcohol	4	EMEP/EEA (2013)
Sugar production	kg/Mg sugar	0.2	Nielsen (2011)
Meat, fish and poultry	kg/Mg product	0.3	EMEP/EEA (2013)
Margarine and solid cooking fats	kg/Mg product	10	EMEP/EEA (2013)
Coffee roasting	kg/Mg beans	0.55	EMEP/EEA (2013)

Emission trends

The emission trend for emission of NMVOC from production of food and beverage is presented in Figure 4.7.1 and Annex 3C-41.

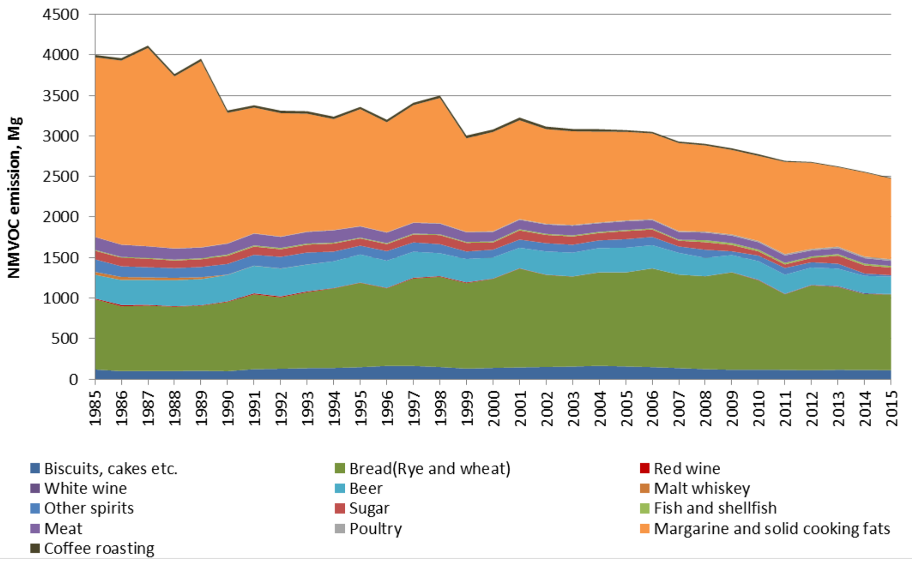

Figure 4.7.1 NMVOC emissions from the production of food and beverages, Mg.

The emission of NMVOC from production of food and beverage follows the activity as the same emission factors have been used for the entire period.

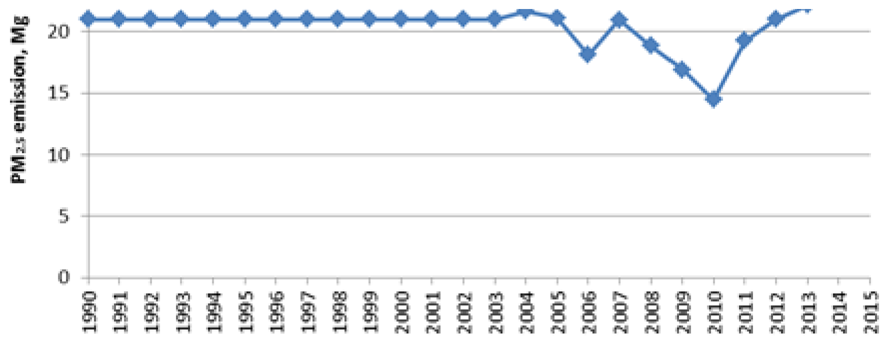

Figure 4.7.2 $PM_{2.5}$ emissions from the production of flour, Mg.

4.7.3 Source specific recalculations and improvements

Particle emissions from flour production are new in this year's submission.

An update of the activity data from Statistics Denmark has led to recalculations in the NMVOC emissions of 2000, 2003 and 2010-2014 of -0.1 % (2014) to 0.4 % (2010).

4.7.4 Source specific planned improvements

Other activities not currently included, such as grain drying and fish meal processing will be investigated further.

4.8 Wood processing

4.8.1 Source category description

The sub-sector *Wood processing* (NFR 2I) covers the production of wood products.

4.8.2 Wood processing

The following SNAP-code is covered:

- 04 06 20 Wood processing

The following pollutants are relevant for the wood processing industry:

- Particulate matter: TSP, PM_{10}, $PM_{2.5}$

Methodology

The emission of particles from production of wood products is estimated from production statistics (Statistics Denmark, 2016), standard emission factors from the EMEP/EEA (2013) and an assumption for the particle distribution TSP/PM_{10}/$PM_{2.5}$.

In addition to this, activity data from Statistics Denmark (m^3) are multiplied by a country specific density to gain the unit of Gg wood product.

Activity data

The production data from Statistics Denmark (2016) are multiplied with the density 0.522 Mg per m^3. The density is calculated from the carbon content of 0.261 Mg C per m^3 (Schou et al., 2015) and the carbon fraction of 0.5 (KP Sup., 2013, Table 2.8.1). The resulting activity data are presented in Table 4.8.1 and Annex 3C-42.

Table 4.8.1 Activity data wood processing, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Wood processing	359.3	464.8	481.3	368.3	436.6	405.0	386.9	392.5	435.0	453.4

Emission factors

The emission factors used to calculate the particle emissions from wood processing are shown in Table 4.8.2.

Table 4.8.2 Emissions factors for wood processing.

Pollutant	Unit	Value	Reference
TSP	Mg/Gg	1	EMEP/EEA (2013)
PM_{10}	% of TSP	40	Expert judgement
$PM_{2.5}$	% of TSP	20	Expert judgement

Emission trends

The emission trends for particles are available in Table 4.8.3 and Annex 3C-43.

Table 4.8.3 Particle emissions from wood processing, Mg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
TSP	359.3	464.8	481.3	368.3	436.6	405.0	386.9	392.5	435.0	453.4
PM_{10}	143.7	185.9	192.5	147.3	174.6	162.0	154.8	157.0	174.0	181.4
$PM_{2.5}$	71.9	93.0	96.3	73.7	87.3	81.0	77.4	78.5	87.0	90.7

4.8.3 Source specific recalculations and improvements

Particle emissions are extrapolated back to 1990.

The TSP emission for 2014 was estimated based on historical data due to lack of actual data. 2014 data have now been collected and reported along with PM_{10} and $PM_{2.5}$ data; these were mistakenly not reported for 2014 in last submission. The recalculation for TSP in 2014 is an increase of 10 %.

4.9 Other production, consumption, storage, transportation or handling of bulk products

4.9.1 Source category description

The sub-sector *Other production, consumption, storage, transportation or handling of bulk products* (NFR 2L) covers the treatment of slaughterhouse waste (NFR 2L3).

4.9.2 Slaughterhouse waste

One company treats slaughterhouse waste: Daka with five departments located in Løsning, Randers, Lunderskov, Ortved, and Nyker. The following SNAP-code is covered:

- 04 06 17 Slaughterhouse waste

The following pollutant is relevant for the treatment of slaughterhouse waste:

- NH_3

Methodology

The raw materials for the processes are by-products from the slaughterhouse, animals dead from accident or disease, and blood. The outputs from the processes are protein and fat products as well as animal fat, meat and bone meal.

The emissions from the processes are related to the consumption of energy and emissions of e.g. NH_3 and odour. The last-mentioned emissions are related to storage of the raw materials as well as to the drying process.

The emission of NH_3 from treatment of slaughterhouse waste has been calculated from an average emission factor based on measurements from Danish plants (Daka, 2002; 2004) and activity data from Statistics Denmark (2016).

Activity data

The activity data for treatment of slaughterhouse waste are compiled from different sources. Due to changes in the company structure environmental reports are only available for some years (1997-2006). Therefore, data from Statistics Denmark are used in combination with blood meal data (partly estimated based on data from the environmental reports). The activity data are presented in Table 4.9.1 and Annex 3C-44.

Table 4.9.1 Activity data for treatment of slaughterhouse waste, Gg.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Meat/bone meal[1]	134.4	128.8	197.0	198.6	177.4	104.6	96.3	73.7	78.5	88.3	98.5
Animal fat[1]	11.1	72.1	54.2	73.4	90.2	75.3	77.7	76.2	48.2	37.6	54.0
Blood meal[2]	11.0	11.0	11.0	11.4	10.2	7.5	7.5	7.5	7.5	7.5	7.5
Total	156.5	211.9	262.2	283.4	277.9	187.4	181.5	157.4	134.3	133.4	160.0

[1] Statistics Denmark (2016).

[2] Based on environmental reports from Daka for the years 1998 – 2009 and assumed for the other years.

Emission factors

The emission of NH_3 from treatment of slaughterhouse waste has been calculated from an average emission factor based on measurements from Danish plants (Daka, 2004). Measurements of NH_3 during the years 2002/3 from three locations (Lunderskov, Løsning and Randers) with different product mix have been included in the determination of an emission factor.

Weighted emission factors covering all the products within the sector have been estimated for 2002 and 2003 as well as a weighted emission factor covering 1985-2001. The estimated emission factors are presented in Table 4.9.2.

Table 4.9.2 Emission factors for treatment of slaughterhouse waste.

	EF	1985-2001	2002	2003-2015
NH_3	g/Mg	120	151	475

Emission trends

Emissions from the treatment of slaughterhouse waste are available in Table 4.9.3 and Annex 3C-45.

Table 4.9.3 Emissions from the treatment of slaughterhouse waste, Mg.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
NH_3	18.8	25.4	31.5	34.0	132.0	89.0	86.2	74.8	63.8	63.4	76.0

4.9.3 Source specific recalculations and improvements

Emissions of NH_3 from slaughterhouse waste have been extrapolated back to 1985.

4.10 QA/QC and verification

Please refer to the Danish National Inventory Report reported to the UNFCCC (Nielsen et al., 2016).

4.11 Uncertainty estimates

The Danish uncertainty estimates are based on the simple "Approach 1".

The uncertainty estimates are based on emission data for the base year (1990) and year 2015 as well as on uncertainties for activity data and emission factors for each of the NFR source categories.

Table 4.11.1 presents the calculated Approach 1 uncertainties for the IPPU sector.

Table 4.11.1 Approach 1 uncertainties for Industrial processes and product use (NFR 2).

Pollutant	Uncertainty total emission %	Trend 1990-2015 %	Uncertainty trend %-age points
SO_2	169.63	-67.2	18.0
NO_x	69.68	-90.5	8.1
NMVOC	15.87	-30.5	7.6
CO	76.58	-67.0	58.1
NH_3	179.83	-23.9	132.4
TSP	259.81	-2.5	78.7
PM_{10}	150.11	-11.5	71.6
$PM_{2.5}$	110.16	-37.4	44.4
BC	123.04	-24.7	65.2
As	620.03	-50.7	112.6
Cd	565.50	-68.3	61.6
Cr	534.78	-21.8	168.4
Cu	295.49	321.1	230.7
Hg	249.82	-99.0	10.4
Ni	474.49	-68.3	171.7
Pb	625.50	-83.0	48.8
Se	920.88	-33.5	179.0
Zn	377.86	-79.4	164.1
HCB	479.18	-94.3	45.8
PCDD/F	159.85	-96.2	34.3
benzo(b)flouranthene	200.25	-56.1	365.1
benzo(k)flouranthene	199.27	-72.1	249.5

benzo(a)pyrene	199.79	-55.6	365.2
indeno(1,2,3-c,d)pyrene	200.08	-68.2	279.7
PCB	555.82	-94.7	21.4

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5 Agriculture (NFR sector 3)

5.1 Overview of the sector

The emission from the agricultural activities covers a range of pollutants. In Table 5.1 are given an overview of sources and pollutants.

Table 5.1 Overview of sources and pollutants.

NFR codes		Longname	Main pollutants (from 1990)				Particulate matter (from 1990)			
			NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC
3B		Manure management	x	x		x	x	x	x	
3D	3Da	Agricultural soils	x			x				
	3Dc	Farm-level agricultural operations					x	x	x	
	3De	Cultivated crops		x		x				
	3Df	Use of pesticides								
3F		Field burning of agricultural residues	x	x	x	x	x	x	x	x

NFR codes		Longname	Other (from 2000)				
			CO	HM[a]	POP[b]	HCB	PCB
3B		Manure management					
3D	3Da	Agricultural soils					
	3Dc	Farm-level agricultural operations					
	3De	Cultivated crops					
	3Df	Use of pesticides				x	
3F		Field burning of agricultural residues	x	x	x	x	x

[a] As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn

[b] dioxins and furanes (PCDD/F) and polycyclic aromatic hydrocarbons (PAH – benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoran-thene and indeno(1,2,3-cd)pyrene)

Buffalos, camels, lamas, mules and donkeys are not farmed in Denmark therefore no emission estimates from these animal categories.

Table 5.2 shows the agricultural contribution of total national emissions in 2015. The main part of the NH_3 emission (95 %) is related to the agricultural sector, while the agricultural contribution of TSP, PM_{10} and $PM_{2.5}$ are 70 %, 27 % and 6 %, respectively. Due to implementation of NMVOC emission from manure management, the agricultural share now accounts for 35 % of the total. The inventory also includes the NO_x emission from application of inorganic fertilisers and animal manure, which result in an agricultural part on 15 % of the total. The agricultural part of the total SO_x emission is lower than 1 %.

Table 5.2 Emission 2015, Agricultural share of the Danish total emission.

	NH_3	TSP	PM_{10}	$PM_{2.5}$	NMVOC	SO_X	NO_X
National total, kt	73	89	30	20	109	11	114
Agricultural total, Kt	69	62	8	1	38	<1	17
Agricultural part, %	95	70	27	6	35	<1	15

5.1.1 Ammonia

The majority of the Danish NH_3 emission, corresponding to 95 %, originates from the agricultural sector. The remaining 5 % is mainly related to emission from transport. Figure 5.1 shows the distribution of sources of NH_3 emission from the agricultural sector for 2015. The main part of the agricultural emission is directly related to the livestock production by 52 % from manure management, 28 % from manure applied to soils and 3 % from grazing animals. Emissions from use of inorganic fertiliser and cultivated crops contribute with 9 % and 8 %, respectively. Emissions from NH_3-treated straw, field burning of agricultural residues and sewage sludge used as fertiliser amount to less than 1 %.

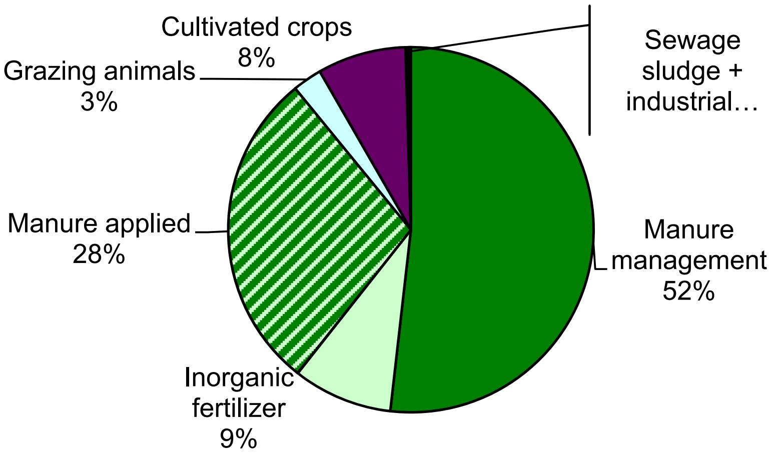

Figure 5.1 NH_3 emissions from the agricultural sector, 2015.

The NH_3 emission from the agricultural sector has decreased between 1985 and 2015 from 128.78 kt NH_3 to 68.98 kt NH_3, corresponding to a 46 % reduction (Table 5.3). This significant drop in NH_3 emissions should be read in a conjunction of a very active national environmental policy designed to reduce the loss of nitrogen to the aquatic environment. A string of measures have been introduced by action plans, for example the NPO (Nitrogen, phosphor, organic matter) Action Plan (1986), Action Plans for the Aquatic Environment (1987, 1998, 2004), the Action Plan for Sustainable Agriculture (1991), the Ammonia Action Plan (2001) and latest the action plan the Agreement on Green Growth (2009 and 2010). Based on these action plans have legislative changes and actions led to an optimization of manure as a resource.

Requirements to capacity of slurry storage and requirements to handling of manure during spreading has led to a decrease in animal nitrogen excretion, improvement in use of nitrogen in manure and a fall in the use of inorganic fertiliser. A Danish environmental approval act for livestock holdings was acted in January 2007 and according to the act, farmers are required to apply for an environmental approval if the farmer wants to change or expand the livestock production facilities. In order to get environmental approval farmers has to fulfil requirements concerning Best Available Technique (BAT) and specific environmental requirements as for example emission of ammonia. The action plans have helped to reduce the overall NH_3 emission significantly and the Danish environmental approval act for livestock will contribute to a further reduction in emissions in future.

Table 5.3 Total NH_3 emissions from the agricultural sector 1985 to 2015, kt NH_3.

		1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
3B	Manure management, total	53.45	51.00	46.81	46.74	47.22	39.75	39.60	38.49	35.63	35.77	35.73
	Cattle	*13.80*	*12.62*	*11.48*	*11.69*	*10.45*	*10.70*	*11.01*	*11.03*	*11.02*	*10.74*	*10.66*
	Swine	*31.67*	*28.92*	*26.20*	*25.03*	*24.80*	*17.66*	*17.48*	*16.31*	*15.79*	*15.97*	*15.69*
	Other animals	*7.98*	*9.47*	*9.14*	*10.02*	*11.97*	*11.39*	*11.11*	*11.15*	*8.83*	*9.07*	*9.38*
3Da1	Inorganic N-fertiliser	18.32	16.21	11.79	8.06	6.52	5.51	5.56	5.28	5.59	5.64	6.10
3Da2a	Manure applied to soil	39.80	36.74	29.66	25.55	20.91	20.75	19.71	19.50	19.47	19.55	19.63
3Da2b	Sewage slugde applied to soil	0.05	0.07	0.11	0.08	0.05	0.06	0.06	0.06	0.06	0.06	0.06
3Da3	Urine and dung deposite by grazing animals	3.12	2.91	3.02	2.92	2.21	1.87	1.81	1.84	1.86	1.85	1.79
3De	Cultivated crops	5.97	5.92	5.28	5.21	5.34	5.41	5.42	5.40	5.37	5.45	5.40
3F	Field burning of agricultural residue	1.53	0.08	0.09	0.11	0.13	0.09	0.09	0.10	0.11	0.11	0.11
3I	NH_3 treated straw	6.54	10.19	6.63	2.47	0.26	0.16	0.16	0.16	0.16	0.16	0.16
3.	Agricultural sector - total	128.78	123.12	103.40	91.15	82.63	73.59	72.41	70.82	68.25	68.58	68.98

The management of manure has to be considered as the most important emission source. Most of the emission originates from the production of swine and cattle, which contributed, respectively with 44 % and 30 %.

It is noteworthy that the overall emission from swine has decreased by 50 % from 1985 to 2015 despite a considerable increase in swine production from 14.8 million produced fattening pigs in 1985 to 19.9 million in 2015. The most important reason for this is the improvement in feed efficiency. In 1985, the nitrogen excretion for a fattening pig was estimated to 5.09 kg N (Poulsen & Kristensen, 1998). In 2015, that figures were considerably lower at 2.90 kg N per fattening pig produced (Poulsen, 2016). Due to the large contribution from the swine production, the lower level of N-excretion has a significant influence on total agricultural emissions.

Since 1985, changes in practice of manure application to the fields have taken place, which has reduced the emission from manure applied to soils. From the beginning of the 1990s slurry has increasingly been spread using trailing hoses. From the late 1990s the practice of slurry injection or mechanical incorporation into the soil has increased. This development is a consequence of a ban on broad spreading but it is also a consequence of the general requirement to improve the utilisation of nitrogen in the manure - e.g. requirements that a larger part of the nitrogen in manure has to be included in the farmer's nitrogen accounting. This has forced farmers to consider the manure as a fertiliser resource instead of a waste product.

5.1.2 Particulate matter

In NFR, the emission of particulate matter (PM) is reported for the years 1990 to 2015. The emission from the agricultural sector includes the emission of dust from animal housing systems, field operations and field burning of agricultural residues.

TSP (total suspended particulate) emission from the agricultural sector contributes with 70 % to the national TSP emission in 2015 and the emission shares for PM_{10} and $PM_{2.5}$ are 27 % and 6 % respectively. The majority of the TSP emission originates from the field operations 89 % while the emission from animal housings contributes with 11 % and field burning of agricultural residues, contributes with less than 1 % to the agricultural emission in 2015.

The PM emission from agricultural activities, given in TSP, is decreased 17 % during the period from 1990 to 2015 (Figure 5.2) mainly to decrease in the emission from field operations.

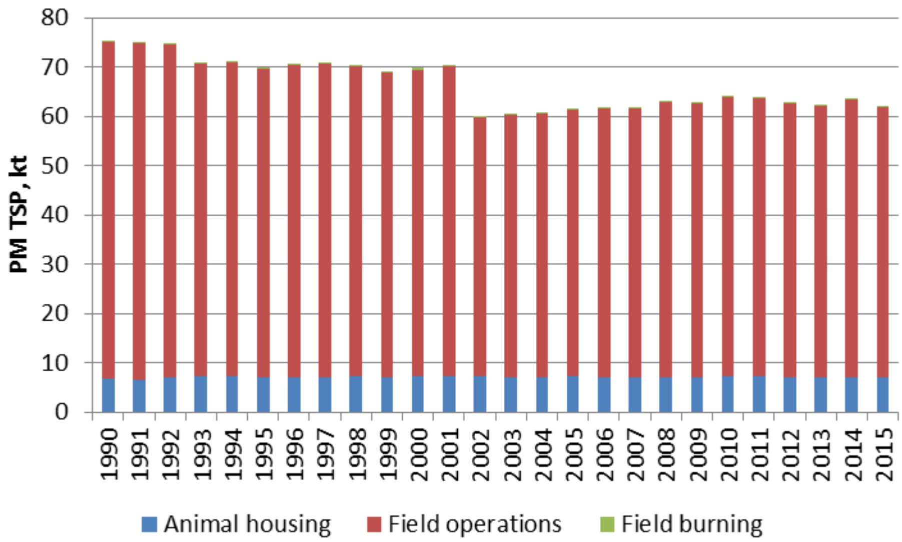

Figure 5.2 Emission of particulate matter (TSP) from the agricultural sector 1990 to 2015.

5.2 References – sources of information

DCE – the Danish Centre for Environment and Energy, Aarhus University, which is responsible for the emission inventory, has established data agreements with the institutes and organisations to assure that the necessary data are available for timely completion of the emission inventory. The main part of the emission is related to livestock production and most of the data are based on Danish standards.

Activity data, emissions factors (EF) and additional values are collected, evaluated and discussed in cooperation with Statistics Denmark, DCA - Danish Centre for Food and Agriculture, Aarhus University, SEGES, Danish Environmental Protection Agency and the Danish AgriFish Agency. It means that both the data and the methods used are evaluated continuously according to latest knowledge and information. Table 5.4 shows the source of data input from the different institutes.

Table 5.4 List of institutes involved in the emission inventory.

References	Abbreviation	Data / information
Statistics Denmark - Agricultural Statistics (http://www.dst.dk/en.aspx)	DSt	-livestock production -milk yield -slaughtering data -land use -crop production -crop yield
Danish Centre for Food and Agriculture, Aarhus University	DCA	-N-excretion -feeding situation -NH_3 emissions factor -PM emissions factor
SEGES (https://www.seges.dk/)	SEGES	-housing type (until 2004) -grazing situation -manure application time and methods -field burning of agricultural residue -acidification of slurry
Danish Environmental Protection Agency (http://www.mst.dk)	EPA	-sewage sludge used as fertiliser (until 2004)
The Danish AgriFish Agency (http://naturerhverv.fvm.dk)	DAFA	-inorganic fertiliser -number of animals from CHR -housing type (from 2005) -sewage sludge used as fertiliser(from 2005)

5.2.1 Methods

The emission calculation is based on the methodologies provided in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2016).

The agricultural sector includes emission from manure management (NFR 3A), agricultural soils (NFR 3D) and field burning of agricultural residue, (NFR 3F). The field burning of agricultural residue has been prohibited since 1989. However, burning of straw may take place in connection with fields continuously cultivating seed grass or in cases where weather conditions result in surplus of straw in form of wet or broken bales.

The emissions from the agricultural sector are calculated in a comprehensive agricultural model complex called IDA (Integrated Database model for Agricultural emissions). The model complex is designed in a relational database system (MS Access). Input data are stored in tables in one database called IDA_Backend and the calculations are carried out as queries in another linked database called IDA. The model, as shown in Figure 5.3, is implemented and used to calculate emissions of air pollutants NH_3, PM, NO_x, CO, NMVOC, SO_2, heavy metals, dioxin, PAH, HCB, PCB and greenhouse gases (N_2O, CH_4 and CO_2). Thus, the same activity data is used for both the air pollutants and the greenhouse gases and there is direct link between the NH_3 emission and the emission estimation of N_2O.

DCA, Danish Centre for Food and Agriculture, Aarhus University delivers Danish standards relating to feeding consumption, manure type in different housing types, nitrogen content in manure, etc. Previously, the standards were updated and published every third or fourth year – the last one is Poulsen et al. from 2001. From year 2001, DCE receives updated data annually directly from DCA in the form of spread sheets. These standards have been described and published in English in Poulsen & Kristensen (1998). From 2004 the standards are uploaded every year at http://anis.au.dk/forskning/sektioner/husdyrernaering-og-fysiologi/normtal/.

IDA - Integrated Database model for Agricultural emissions

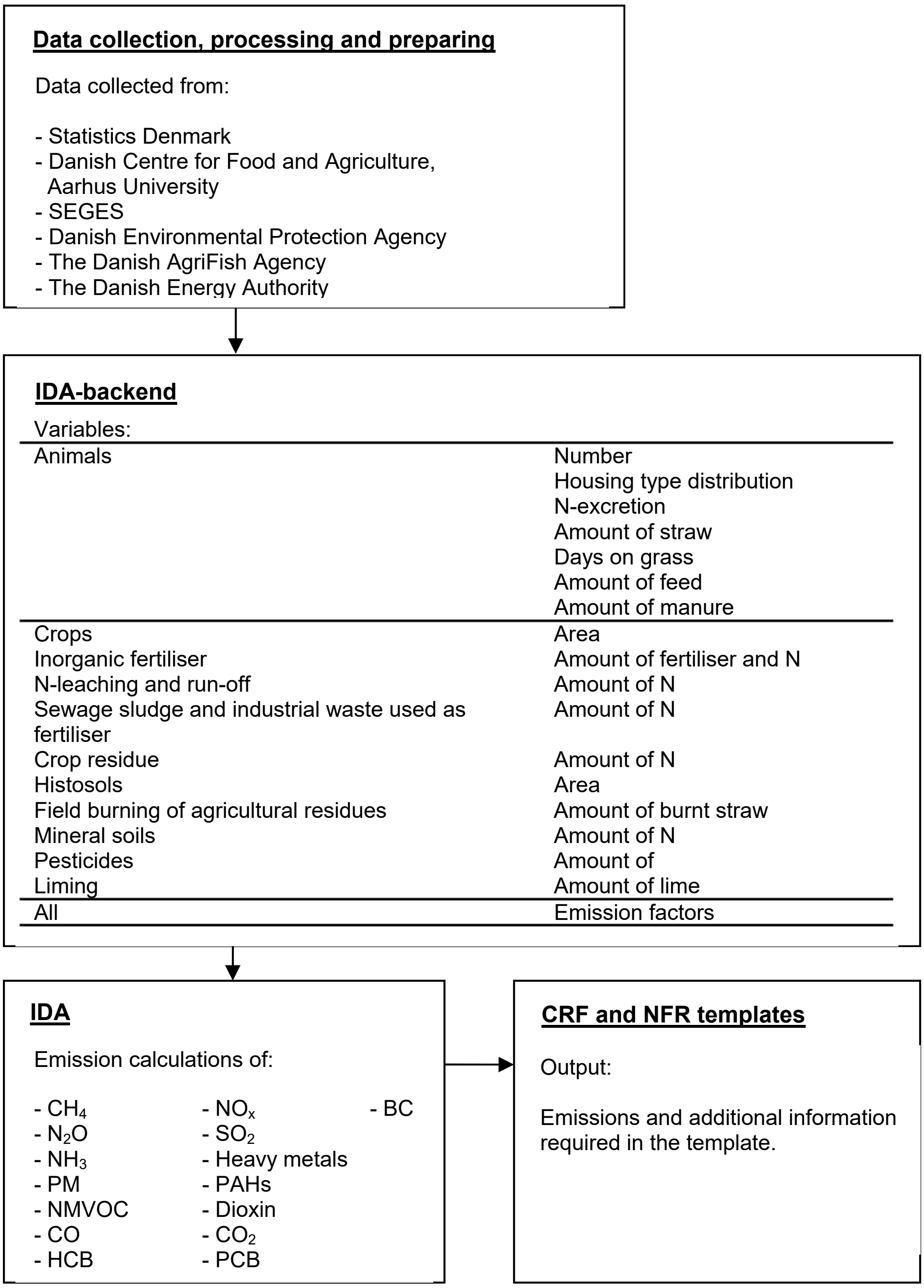

Figure 5.3 Overview of the data process for calculation of agricultural emissions.

IDA includes 39 different livestock categories, divided on weight class and age. Each of these subcategories is subdivided according to housing system and manure type, which results in 269 different combinations of subcategories and housing type (Table 5.5). The emissions are calculated from each of these subcategories and then aggregated in accordance with the livestock categories given in the NFR. It is important to point out that changes in the emission and the implied emission factor over the years are not only a result of changes in the number of animals, but also depend on changes in the allocation of subcategories, changes in feed consumption, changes in housing type and changed practices with regard to the handling of livestock manure in relation to storage and application.

Table 5.5 Livestock categories and subcategories.

NFR 3B	Animal categories	Includes	No. of sub-categories in IDA, animal type/housing system/manure type
3B 1a	Dairy Cattle[1]	Dairy Cattle	35
3B 1b	Non-dairy Cattle[1]	Calves (<½ year), heifers, bulls, suckling cattle	129
3B 2	Sheep	Sheep and lambs	2
3B 3	Swine	Sows, weaners, fattening pigs	37
3B 4d	Goats	Including kids (meet, dairy and mohair)	3
3B 4e	Horses	<300 kg, 300 - 499 kg, 500 - 700 kg, >700 kg	4
3B 4gI-gIV	Poultry	Hens, pullet, broilers, turkey, geese, ducks, ostrich, pheasant	50
3B 4h	Other	Fur bearing animals, deer	9

1) For all cattle categories, large breed and jersey cattle are distinguished from each other.

5.3 Manure management

For the sector manure management is the emissions of NH_3, PM, NMVOC and NO_x estimated.

5.3.1 Activity data

Animals

Table 5.6 shows the development in livestock production from 1985 to 2015 based on the Agricultural Statistics (Statistics Denmark). The number of animal corresponds to average annual production (AAP), which means the number of animals that are present on average within the year (EMEP/EEA, 2016). For many animal categories the number given in the annual Agricultural Statistics can be used directly. However, for weaners, fattening pigs, bulls and poultry the number is based on slaughter data also collected from the Agricultural Statistics, because the total production cycle for these animals is less than one year and because the normative figures are based on one produced animal. See Annex 3D Table 3D-1 for number of animals allocated on subcategories.

Only farms larger than five hectares are included in the annual census. Especially horses, goats and sheep are placed on small farms, which mean that the number of animals given in the Agricultural Statistics is not representative. Therefore, the number of sheep and goats is based on the Central Husbandry Register (CHR) which is the central register of farms and animals managed by the Ministry of Food, Agriculture and Fisheries. The number of deer and ostriches is also based on CHR because these are not included in the Agricultural Statistics published by Statistics Denmark. The number of horses is based on data from SEGES. The number of pheasants is based on expert judgement from Department of Bioscience, Aarhus University and the Danish pheasant breeding association.

Since 1985, the production of swine, poultry and fur has increased significantly. This is contrary to the production of cattle, which has decreased as a result of increasing milk yields. The production of non-dairy cattle follows same trend as dairy cattle, the production of beef cattle is negligible in the Danish agricultural production.

Table 5.6 Livestock production 1985 to 2015 given in AAP, 1000 head - NFR category 3B.

NFR	Animal category	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
3B 1a	Dairy Cattle	896	753	702	636	564	568	565	587	582	563	561
3B 1b	Non-dairy cattle	1 721	1 486	1 388	1 232	1 006	1 003	1 003	1 020	1 032	1 052	991
3B 2	Sheep*	99	230	202	279	316	278	234	226	221	220	210
3B 3	Swine	9 089	9 497	11 084	11 922	13 534	13 173	12 932	12 331	12 076	12 332	12 538
3B 4d	Goats*	8	7	7	8	11	16	13	13	13	12	11
3B 4e	Horses*	140	135	143	150	175	165	155	155	150	150	155
3B 4gI	Laying hens	5 577	5 696	6 088	4 935	5 168	5 248	5 679	5 597	5 766	5 585	5 765
3B 4gII	Broilers	8 490	9 802	12 585	16 047	11 905	12 836	12 528	12 576	13 215	12 318	11 122
3B 4gIII	Turkeys	308	238	456	456	516	494	400	460	289	248	249
3B 4gIV	Other poultry	1 822	1 600	1 563	1 374	1 509	1 510	1 963	1 444	1 263	1 253	1 447
3B 4h	Other											
3B 4h	Fur bearing animals	1 906	2 264	1 850	2 199	2 552	2 699	2 757	2 948	3 143	3 315	3 400
3B 4h	Deer	9	10	10	10	10	10	8	7	8	7	8

*Includes animals on small farms (less than 5 ha), which are not included in the Agricultural Statistics published by Statistics Denmark.

See Annex 3D Table 3D-1 for number of animals allocated on subcategories.

N-excretion

The normative figures for both total nitrogen excretion and the content of Total Ammoniacal Nitrogen (TAN) are provided by DCA, Aarhus University.

The emission of NH_3 from manure management is calculated on the basis on nitrogen excreted from livestock. Most of the N excreted that is readily degradable and broken down to NH_4-N is found in the urine. The relationship between NH_4-N and total N will not remain constant over time due to changes in feed composition and feed use efficiency. In order to be able to implement the effect of NH_3 reducing measures as improvements in feed intake and composition in the emission inventory, it is necessary to calculate the emission based on the TAN content. Since 2007, DCA has established Danish standards based on TAN for liquid manure, which is incorporated in the inventory. The emission for solid manure and deep litter is based on the total N excreted because DCA's estimate of TAN follows urine-N.

In Annex 3D Table 3D.2 is given the average N-excretion based on Total-N for each NFR livestock category from 1985 to 2015 (Table 3D.2a) and N-excretion based on TAN for 2007-2015 (Table 3D.2b). These values include N excretion from grazing animals. Notice that each livestock category is an aggregated average of different subcategories (see Table 5.5).

Housing system

A systematic registration of the housing of husbandry for all farms does not exist from 1985 to 2004 and the housing type distribution is therefore based on estimates from Danish Agricultural Advisory Centre (now SEGES) (Rasmussen, 2006) and Lundgaard (2006). From 2005 the distribution of housing system is based on information from the Danish AgriFish Agency, which is based on information from the farmers.

The structural development in the agricultural sector has an influence on the changes in housing type distribution. The trend in housing system for dairy cattle goes from older tied-up housings, which is replaced by bigger housings with loose-holding. In 1985, 85 % of the dairy cattle were kept in tied-up housings and in 2015 the share is reduced to 7 %. In loose-holding systems the cattle have more space and more straw bedding and this will in general increase the NH_3 emission per animal compared to the tied-up housings. In Annex 3D Table 3D.3 the distribution of housing type for all animals for 1985-2015 is listed.

5.3.2 NH_3

Description

The main part of the NH_3 emission (52 %) is related to manure management – mainly from the cattle and swine production (Figure 5.4). The reduced emission from swine over time is due to an active environmental policy in combination with improvements within the genetic development and improvements of feed intake efficiency. The emission from cattle has decrease as a consequence of less number of cattle. The emission has increased slightly from "other", which is mainly due to an increase in number of produced mink.

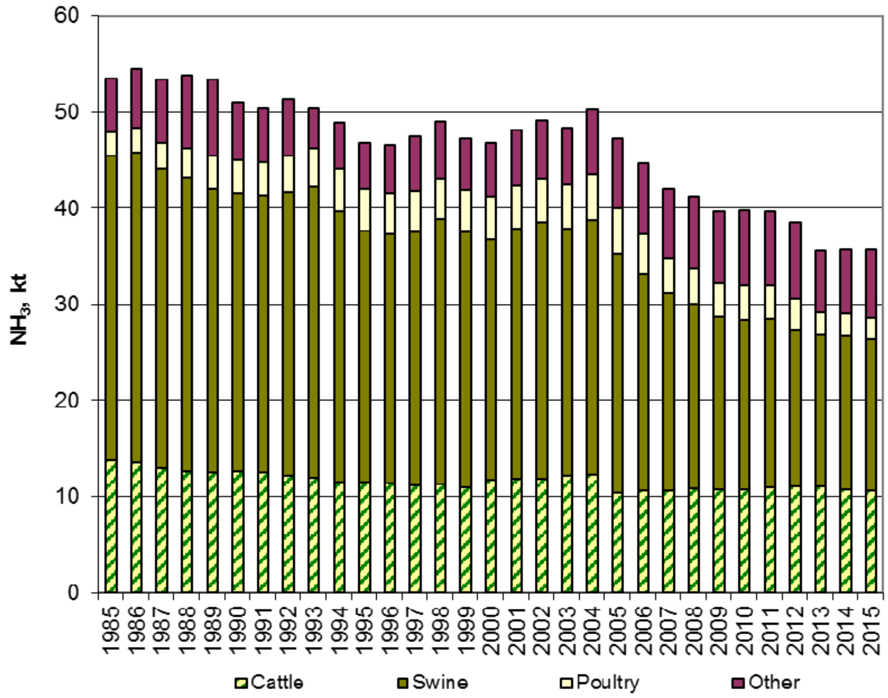

Figure 5.4 NH_3 emission from manure management 1985 to 2015.

Methodological issues

NH_3 emission from manure management covers emission from housings and storage and is based on N excreted and emission factors given in the normative figures (Poulsen et al., 2001; Poulsen 2016).

Activity data

See Chapter 5.2.1

Emission factor

Emission factors - Housing

The emission from housings is thus determined by a number of different conditions that depends on housing type and the different kinds of manure disposal systems placed in these housings. Danish Centre for Food and Agriculture, Aarhus University has carried out a number of emission surveys and estimated emission coefficients for each type of housings (Poulsen et al., 2001 and Poulsen, 2016). In Table 5.7 is shown the emission factors for the most important animal categories; dairy cattle and fattening pigs in different housing systems. For the slurry and liquid manure is given TAN emission factors (TAN ex animal) and for solid and deep litter manure is given N ex animal.

Table 5.7 NH_3 emission factors in different housing systems 2015 – dairy cattle and fattening pigs.

Manure system	Manure type	NH_3 emission	NH_3 emission
		Pct. NH_3-N of N ex Animal	Pct. NH_3-N of TAN ex Animal
Dairy cattle			
Tied-up	Solid manure	6.0	
	+ Liquid		10.0
Tied-up	Slurry		6.0
Loose-holding with beds, slatted floor	Slurry		16.0
Loose-holding with beds, slatted floor, scrapes	Slurry		12.0
Loose-holding with beds, solid floor	Slurry		20.0
Loose-holding with beds, drained floor	Slurry		8.0
Deep litter (all)	Deep litter	6.0	
Deep litter, slatted floor	Deep litter	6.0	
	+ Slurry		16.0
Deep litter, slatted floor, scrapes	Deep litter	6.0	
	+ Slurry		12.0
Deep litter, solid floor, scrapes	Deep litter	6.0	
	+ Slurry		20.0
Fattening pigs			
Full slatted floor	Slurry		24.0
Partly slatted floor (50-75% solid floor)	Slurry		13.0
Partly slatted floor (25-49% solid floor)	Slurry		17.0
Solid floor	Solid manure	15.0	
	+ Liquid		27.0
Deep litter	Deep litter	15.0	
Partly slatted floor and partly deep litter	Deep litter	15.0	
	+ Slurry		18.0

Emission factors - Storage

Livestock manure is collected either as solid manure or as slurry depending on housing type. In Table 5.8 are shown the emission factors used for storage. It is assumed that the part of solid manure taken directly from the housing into the field is 65 % from cattle, 25 % from pigs, 50 % from sows, 15 % from poultry and 5 % from hens (Poulsen, 2008). The remaining part of the solid manure is deposited in stock piles in the field before field application.

By law all slurry tanks have to be covered by a fixed cover or a full floating cover in order to reduce NH_3 emission. However, it can be difficult to establish a natural full floating cover every day all year especially for tank with pig slurry. In 2015 it is assumed that 5 % of the tanks with swine slurry and 2 % of tanks with cattle slurry are incompletely covered (Annex 3D Table 3D-4).

Table 5.8 NH_3 emission factors for storage 2015.

		Liquid manure	Slurry	Solid manure	Deep litter
		Loss of NH_3-N in %			
Animal category		of TAN ex housing	of TAN ex housing	of N ex housing	of N ex housing
Cattle		2.2	3.5	4.0	1.05
Swine	Fattening pigs	2.2	2.9	19.0	9.75
	Sows		2.9	19.0	6.50
Poultry	Hens and pullet		2.0[a]	7.5	4.75
	Broilers, geese and ducks			7.5	6.80
	Turkeys			7.5	8.00
Fur bearing animals			3.1	11.5	
Sheep/goats					3.0
Horses					3.0

[a] Loss of NH_3-N in % of N ex housing.

Reduction factors

Acidification of slurry in the housings and storage is an increasing used technique in Denmark. The acidification of the manure lowers the emission of NH_3 and this effect is included in the emission inventory. Use of acidification of slurry is a result of environmental requirements.

If farmers plan to expand the livestock production and build new housing or modified existing housing, the ammonia emissions from animal housing and stores must be reduced by 30 percent in accordance with the reference animal housing system. The requirement may be met by reducing ammonia loss in both existing and new facilities.

The amount of slurry acidified is estimated by SEGES (Vestergaard, 2015). The reduction of the emission from storage and application are described in Chapter 5.4.2. Amount of slurry acidified in housings and storage is estimated for the years 2012, 2013 and 2014. In 2014, approximately 3 % of total amount of slurry is acid treated in housing and storage. For 2015 no information about acidification were available, so same estimation as for 2014 are used.

Table 5.9 Amount of slurry acidified in housing.

Amount of slurry, tonnes	2012	2013	2014	2015
Total	38 401 894	37 365 664	38 210 485	38 210 485
Acidified in housing	874 000	1 100 000	1 200 000	1 200 000
Share, %	2	3	3	3

The estimation of reduced emission due to acidified slurry is based on the Environmental Technologies List (MST, 2016). The list contains technologies which through tests have been documented to be environmentally efficient and are continuously adjusted to knowledge on new technology. Due to the list the acidified slurry in housing the emission expected to be reduced by 50 % for cattle slurry and 65 % for swine slurry. Same reducing effect is assumed for acidification in storage. No information on the distribution of cattle- and swine slurry is available, thus it is assumed that 50 % of the slurry acidified is cattle slurry and 50 % are swine slurry.

Implied emission factor

Table 5.10 shows the implied emission factors for each NFR livestock category from 1985 to 2015. The implied emission factors express the average emission of NH_3 from housing and storage per AAP (annual average population) per year. The implied emission factors are changing from year to year depending on a combination of several factors, such as:

- change in number of animals or change in the share of different subcategories,
- change in feed intake and N-excretion,
- change in housing type
- acidification of slurry

It should be mentioned that the emission from urine and dung deposited by grazing animals is included in the emission from agricultural soils (NFR – 3Da3).

For most of the animal categories are the implied emission factor decreased from 1985 to 2015, which is mainly the result of measures in relation to the environmental Action Plans. Strict requirements to obtain improvements in utilisation of nitrogen in manure have resulted in reduction of N-excretion and especially for fattening pigs. For dairy cattle the implied emission factor has increased and this is due to increase in feed intake and milk production per cow.

Table 5.10 Implied emission factor, manure management 1985 to 2015, kg NH_3 per AAP per year.

NFR	Animal category	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
3B 1a	Dairy cattle	9.64	10.50	10.37	11.49	13.50	12.86	13.32	12.88	12.82	12.93	12.91
3B 1b	Non-dairy cattle	3.00	3.17	3.02	3.56	2.81	3.38	3.47	3.40	3.44	3.30	3.45
3B 2	Sheep	0.44	0.44	0.44	0.44	0.44	0.40	0.40	0.40	0.40	0.40	0.40
3B 3	Swine	3.48	3.04	2.36	2.10	1.83	1.34	1.35	1.32	1.31	1.29	1.25
3B 4d	Goats	1.09	1.09	1.09	1.09	1.05	0.98	0.98	0.99	0.99	0.99	0.99
3B 4e	Horses	5.44	5.34	4.80	4.84	4.84	4.34	4.34	4.34	4.34	4.34	4.34
3B 4gI	Laying hens	0.15	0.20	0.25	0.27	0.34	0.27	0.27	0.24	0.23	0.23	0.22
3B 4gII	Broilers	0.15	0.20	0.18	0.17	0.21	0.15	0.14	0.13	0.07	0.07	0.08
3B 4gIII	Turkeys	0.49	0.51	0.65	0.63	0.63	0.52	0.52	0.52	0.52	0.52	0.52
3B 4gIV	Other poultry	0.10	0.10	0.14	0.10	0.08	0.03	0.02	0.03	0.02	0.02	0.02
3B 4h	Other	2.46	2.28	2.15	2.13	2.44	2.55	2.47	2.39	1.80	1.81	1.87

Emissions

The NH_3 emission from manure management is estimated to 35.73 kt NH_3 in 2015 (Table 5.11). From 1985 to 2015, the emission is reduced by 33 %. As mentioned in Chapter 5.1.1 this development is mainly due to implementation of a number of action plans to reduce nitrogen losses from the agricultural production.

In 2015, cattle production contributes with 30 % of the total emission from manure management. The swine production contributes in 2015 with 44 % of the total emission from manure management. The number of cattle has decreased as a result of a growth in milk yield. The production of fattening pigs has increased by more than 50 % compared with 1985. However, despite this development the emission from swine is still decreasing. This is due to a breeding of pigs with focus on a biological development and improvement in fodder efficiency. Thus the N-excretion for fattening pigs has decreased from 5.09 kg per pig per year in 1985 to 2.90 in 2015.

Table 5.11 Emission of NH_3 from manure management 1985 to 2015, kt NH_3.

NFR	Animal category	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
3B 1a	Dairy cattle	8.64	7.90	7.29	7.30	7.62	7.31	7.53	7.56	7.47	7.27	7.24
3B 1b	Non-dairy cattle	5.17	4.72	4.19	4.39	2.83	3.39	3.48	3.47	3.55	3.47	3.42
3B 2	Sheep	0.04	0.10	0.09	0.12	0.14	0.11	0.09	0.09	0.09	0.09	0.08
3B 3	Swine	31.67	28.92	26.20	25.03	24.80	17.66	17.48	16.31	15.79	15.97	15.69
3B 4d	Goats	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
3B 4e	Horses	0.76	0.72	0.68	0.73	0.85	0.72	0.67	0.67	0.65	0.65	0.67
3B 4gI	Laying hens	0.86	1.17	1.51	1.35	1.76	1.44	1.53	1.34	1.35	1.31	1.24
3B 4gII	Broilers	1.24	1.99	2.31	2.68	2.52	1.89	1.71	1.68	0.87	0.84	0.84
3B 4gIII	Turkeys	0.15	0.12	0.29	0.29	0.33	0.26	0.21	0.24	0.15	0.13	0.13
3B 4gIV	Other poultry	0.18	0.16	0.22	0.14	0.12	0.04	0.04	0.04	0.03	0.02	0.02
3B 4h	Other	4.72	5.18	4.01	4.70	6.25	6.92	6.84	7.07	5.69	6.02	6.38
3B	Total	53.44	50.98	46.79	46.74	47.22	39.75	39.60	38.49	35.63	35.77	35.73

Figure 5.5 shows the percentage distribution of the NH_3 emission from housing, storage and application of manure. The main part of the reduction in NH_3 emission has taken place in connection with the application of manure in fields, due to changes in manure application practice, see Chapter 5.4.2. There has been a reduction in emissions associated with storage of manure, which is a result of improvement in coverage of slurry tanks. As a consequence of this development, the percentage of emission from housing is increased from 38 % in 1985 to 54 % in 2015.

The possibilities for NH_3 reduction will likely be focused on measures in housings by various technological solutions. Some ammonia reducing technology is already implemented in housing e.g. air cleaning systems and slurry acidification. The reduced effect of air cleaning systems is not taken into account in the Danish inventory because improvement in documentation is needed. The slurry acidification of slurry both in the housings, storage and application is taken in to account.

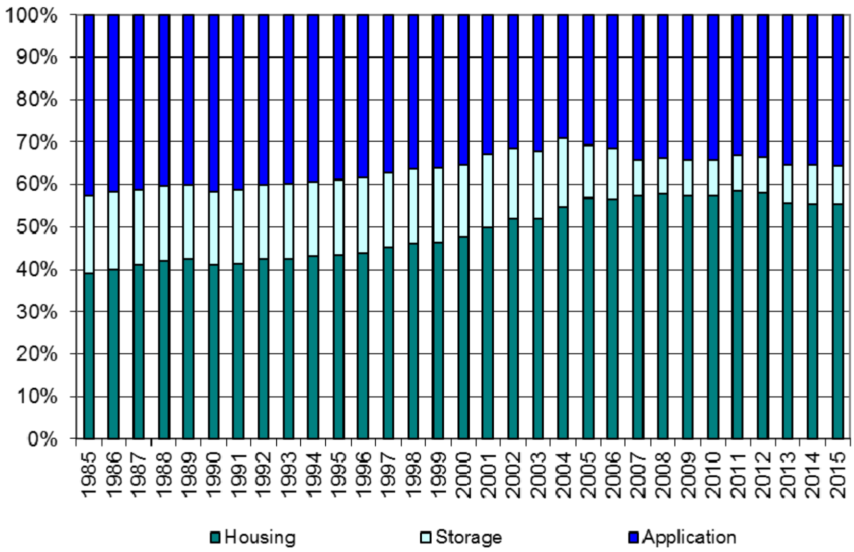

Figure 5.5 The percentage distribution of the NH_3 emission in manure management 1985-2015.

5.3.3 PM

Description

Investigations have shown that farmers, as well as livestock, are subject to an increased risk of developing lung and respiratory related diseases due to the particulate emissions (Hartung and Seedorf, 1999). This is because the particles are able to carry bacteria, viruses and other organic compounds.

In 2015 the PM emission from housings, given as TSP, is estimated to 6.92 kt, which correspond to 11 % of the emission of TSP from the agricultural sector. Of the 6.92 kt TSP, 56 % relates to swine production. The emission from cattle and poultry contributes with 20 % and 23 %, respectively and the remainder animals contribute with 1 %.

Methodological issues

The estimation of PM emission is based on the EMEP/EEA guidebook (2016) and includes primary particles in the form of dust from housings. The inventory includes PM emission from cattle, swine, poultry, horses, sheep, goats and fur bearing animals (Table 5.12). The number of grazing days is taken into account. Some animal categories are divided into subcategories and for some categories (if applicable) distinction is made between solid and slurry based housing systems.

The PM emission is related to the annual average population (AAP) and to the time the animal is housed. The PM emission from grazing animals is considered as negligible.

Table 5.12 Livestock categories used in the PM emission inventory.

Livestock categories as given in NFR	Subcategories as given in the EMEP/EEA guidebook	Danish inventory	Grazing days
Dairy Cattle	Dairy cattle	Dairy cattle	18
Non-Dairy Cattle	Calves	Calves < ½ yr	0
	Beef cattle	Bulls	0
		Heifers	132
		Suckling cattle	224
Swine	Sows	Sows (incl. weaners until 7 kg)	0
	Weaners	Weaners (7-32 kg)	0
	Fattening pigs	Fattening pigs (32-107 kg)	0
Poultry	Laying hens	Laying hens	0
	Broilers	Broilers	0
	Turkeys	Turkeys	0
	Other poultry	Ducks	0
		Geese	365
Horses	Horses	Horses	183
Sheep	Sheep	Sheep	265
Goats	Goats	Goats	265

Activity data

See Chapter 5.2.1

Emission factor

Emission factors for TSP, PM_{10} and $PM_{2.5}$ are based on the EMEP/EEA guidebook (EMEP/EEA, 2016). The same emissions factors are used for all years. Estimation of TSP is based on the transformation factors between TSP and PM_{10} as given in the EMEP/EEA emission inventory guidebook (2016).

Table 5.13 Emission factors for particle emission from animal housing system.

Livestock category	Housing system	Emission factor PM_{10}	$PM_{2.5}$	TSP	Transformation factor PM_{10} to TSP
		kg per AAP per year			
Cattle:					
Dairy cattle	Slurry	0.83	0.54	1.81	0.46
	Solid	0.43	0.28	0.94	0.46
Calves < ½ yr	Slurry	0.15	0.10	0.34	0.46
	Solid	0.16	0.10	0.35	0.46
Beef cattle	Slurry	0.32	0.21	0.69	0.46
	Solid	0.24	0.16	0.52	0.46
Heifer[1)]	Slurry	0.49	0.32	1.07	0.46
	Solid	0.30	0.19	0.64	0.46
Suckling cattle[2)]	Slurry	0.32	0.21	0.69	0.46
	Solid	0.24	0.16	0.52	0.46
Swine:					
Sows	Slurry	0.17	0.01	0.62	0.27
	Solid	0.17	0.01	0.62	0.27
Weaners	Slurry	0.05	0.00	0.27	0.19
	Solid[3]	0.05	0.00	0.27	0.19
Fattening pigs	Slurry	0.14	0.01	1.05	0.13
	Solid	0.14	0.01	1.05	0.13
Poultry:					
Laying hens	Solid	0.04	0.003	0.19	0.21
Broilers	Solid	0.02	0.002	0.04	0.50
Ducks	Solid	0.14	0.02	0.14	1.00
Geese	Solid	0.24	0.03	0.24	1.00
Turkeys	Solid	0.11	0.02	0.11	1.00
Horses	Solid	0.22	0.14	0.48	0.46
Sheep	Solid	0.06	0.02	0.14	0.40
Goats	Solid	0.06	0.02	0.14	0.40
Fur bearing animals	Solid	0.008	0.004	0.02	0.45

1) Average of "calves" and "dairy cattle".
2) Assumed the same value as for "Beef cattle".
3) Same as slurry based systems.

Emissions

Figure 5.6 shows the PM emission, given in TSP for each animal category in the period 1990 to 2015. It is seen that the main part of the emission originates from swine housings. See Annex 3D Table 3D-5 for the PM emission, given in TSP, PM_{10} and $PM_{2.5}$. In the period 1990 to 2015, the total agricultural emission of TSP from housings is increased by 5 %. The increase is mainly due to increase in the number of swine.

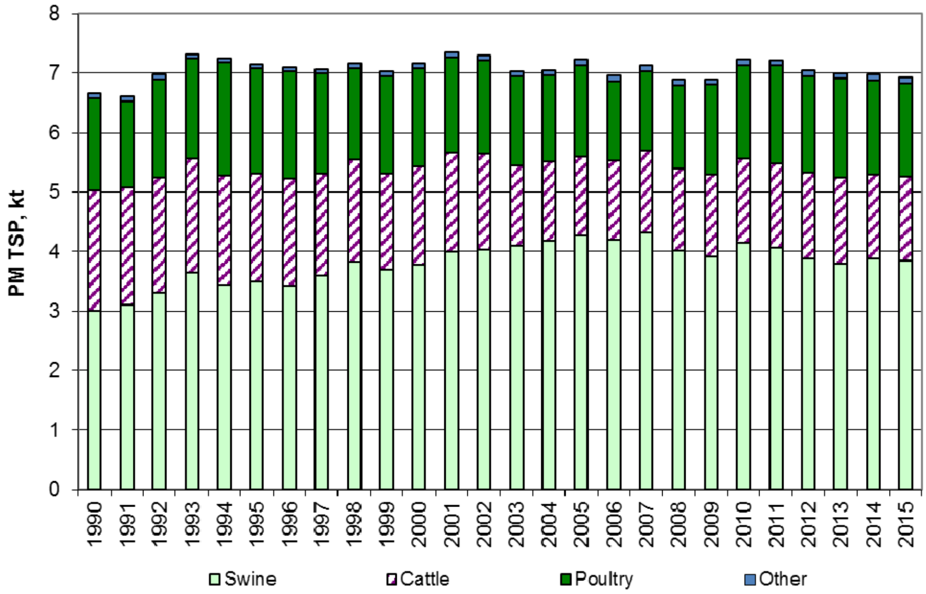

Figure 5.6 PM emission from housings 1990 – 2015, kt TSP.

5.3.4 NMVOC

Description

An estimate of NMVOC from manure has been calculated and shows that 94 % of the total Danish NMVOC emission is related to animal husbandry and mainly to the cattle production.

Methodological issues

The estimation of NMVOC emission is based on the EMEP/EEA guidebook (2016). NMVOC emissions from animal husbandry comes from feed, degradation of feed in the rumen and from undigested fat, carbohydrate and protein decomposition in the rumen and in the manure**.** Silage is a major source of NMVOC emissions and therefore two sets of emission factor are introduced in the Guidebook; a high emission factor based on feeding with silage and a low emission factor based on feeding without silage.

The calculation of NMVOC emissions is based on Tier1 approach.

Activity data

The NMVOC emission is estimated on the number of animal multiplied with the NMVOC emission factor for each animal category. The number of animal is given as the average annual population (AAP) – see Table 5.6.

Emission factor

NMVOC emission factors recommended in EMEP/EEA Guidebook 2016 Table 3-4 is used (Table 5.14). For days on grass, the emission factor for feeding without silage is used for cattle, sheep, goats and horses (Table 5.12). However, all emissions are entered in NFR category 3B, while the notation key NE is used for NFR category 3Da3.

Same emissions factors are used during all years, which mean that changes of the emission over time depends on change in animal production or change in grazing days.

Table 5.14 NMVOC emission factors (EMEP/EEA Guidebook 2016, Tier1).

	EF NMVOC with silage	EF NMVOC without silage[1]
Dairy Cattle	17.937	8.047
Non-Dairy Cattle	8.902	3.602
Sheep	0.279	0.169
Swine – sows		1.704
Swine – other		0.551
Goats	0.624	0.542
Horses	7.781	4.275
Laying hens		0.165
Broilers		0.108
Turkeys		0.489
Other poultry		0.489
Fur bearing animals		1.941

[1] Emission factor is also used for time on grass.

Emissions

The development of NMVOC emission from 1990 to 2015 shows a decrease from 38 kt to 36 kt with the highest fall in the beginning of the period (Figure 5.7). Back in 1990 two third of the emission originates from the cattle production, which is fallen to half the emission in 2015. A decrease of emission from cattle is a consequence of less number of animals due to higher milk yield. An increase of the production of swine and fur bearing animals has resulted in an increase of the emission from 1990 to 2015.

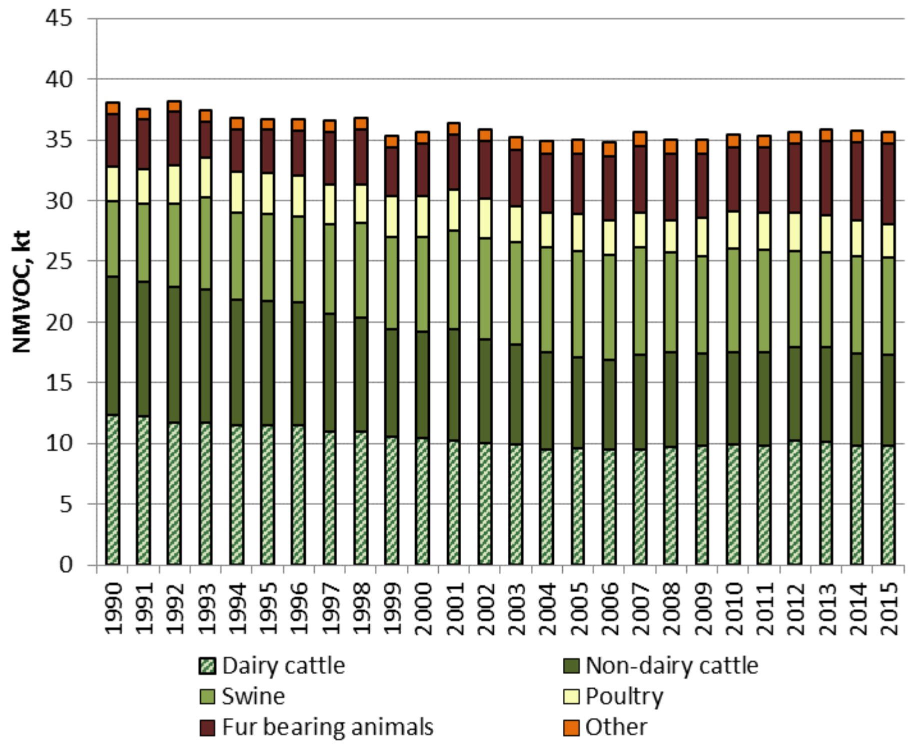

Figure 5.7 Emission of NMVOC from manure management, 1990-2015.

5.3.5 NO_x

Description

An estimate of NO_x from manure management has been calculated and shows that 1 % of the total Danish NO_x emission in 2015 is related to animal husbandry.

Methodological issues

The estimation of NO_x emission is based on the EMEP/EEA guidebook (2016) Tier1 approach.

Activity data

The Tier 1 approach is based on number of animal given as the average annual population (AAP). The Number is showed in Table 5.6.

Emission factor

Emission factor for estimation of NO emission from manure management is listed in Table 5.15. Some of the manure from the mink production is handled as slurry, but no EF for slurry is mentioned in the Guidebook. Therefore, the same emissions factor is used for both slurry and solid systems.

Table 5.15 NO emission factors (EMEP/EEA Guidebook 2016), kg NO_2 per AAP.

NFR code	Livestock	slurry	solid
3B 1a	Dairy cows	0.011	0.236
3B 1b	Other cattle	0.003	0.144
3B 2	Sheep		0.008
3B 3	Sows	0.006	0.202
3B 3	Fattening pigs	0.002	0.069
3B 4d	Goats		0.008
3B 4e	Horses		0.201
3B 4gi	Laying hens	0.005	0.0002
3B 4gii	Broilers		0.002
3B 4giii	Turkeys		0.008
3B 4giv	Ducks		0.006
3B 4giv	Geese		0.002
3B 4h	Fur bearing animals	0.0003[1]	0.0003

[1] Used the same EF as given for solid manure.

Emissions

The NO_x emission from 1990 to 2015 has decreased significantly from 0.48 kt NO_x to 0.20 kt NO_x corresponding to a 58 % reduction. The emission depends on number of animal and manure type and the decrease is mainly related to changes from solid based system to slurry based system for both the dairy cattle and the swine production. Thus, the allocation of solid manure was 23 % in 1990 and dropped to the half 10 % in 2015.

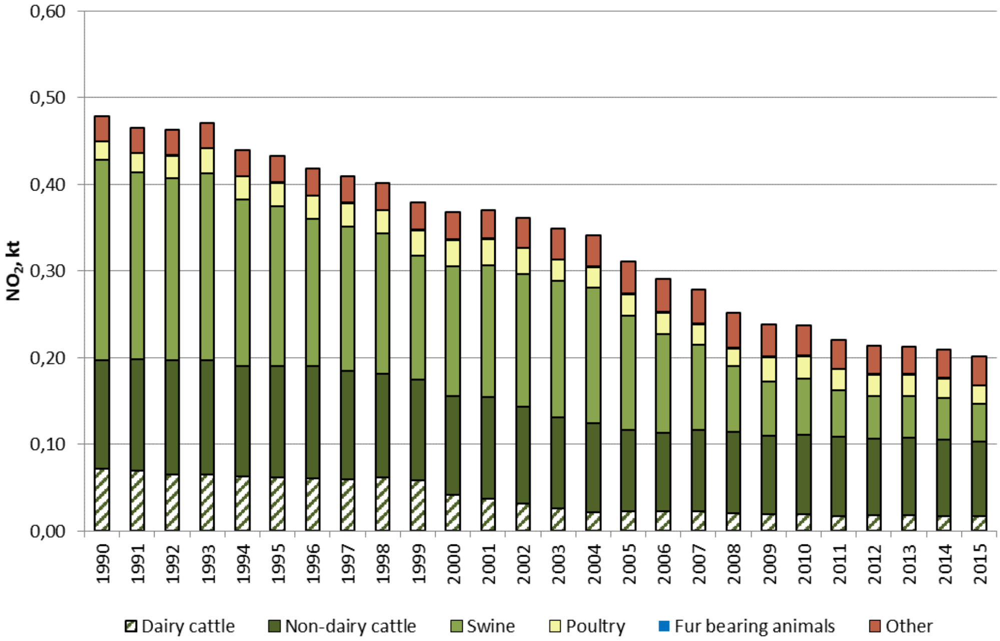

Figure 5.8 NO_x emission from manure management 1990–2015.

5.4 Soils

At present, farmed area covers about 60 % of the total land area in Denmark. In recent decades, farmed area has decreased, being replaced by built-up areas, roads, forest and nature habitats.

5.4.1 Inorganic N-fertilisers

Description

For the sector inorganic N-fertiliser the emission of NH_3 and NO_x are estimated.

The emission of NH_3 from inorganic fertiliser contributes in 2015 with 9 % of the emission from the agricultural sector. The emission of NO_x contributes in 2015 with 55 % of the emission from the agricultural sector.

Methodological issues

Emission of NH_3 from inorganic fertiliser is based on the consumption of fertiliser of different types and emission factors. In Table 5.16 are shown emission factors and consumption for 2015. See Annex 3D Table 3D-6 for assumptions for fertiliser type.

Emission of NO_x is based on the total consumption of N in inorganic N-fertiliser and emission factor.

Table 5.16 Inorganic N-fertiliser consumption 2015 and emission factors.

	NH_3 Emission factor[1], Kg NH_3-N pr kg N	Consumption[2], t N
Fertiliser type		
Calcium and boron calcium nitrate	0.05	0.2
Ammonium sulphate	0.09	7.0
Calcium ammonium nitrate and other nitrate types	0.008	98.7
Ammonium nitrate	0.015	3.7
Liquid ammonia	0.019	5.9
Urea	0.155	0.9
Other nitrogen fertiliser	0.01	24.4
Magnesium fertiliser	0.05	0.0
NPK-fertiliser	0.05	54.4
Diammonphosphate	0.05	0.3
Other NP fertiliser types	0.05	5.6
NK fertiliser	0.015	2.5
Total consumption of N in inorganic N-fertiliser		203.5

[1] EMEP/EEA (2016), see Annex 3D Table 3D-6 for assumptions for fertiliser type.

[2] The Danish AgriFish Agency.

Activity data

Data on the use of inorganic fertiliser is based on the annual sale estimations collected by the Danish AgriFish Agency (2015). The use of inorganic fertiliser includes fertiliser used in parks, golf courses and private gardens. Approximately 1 % of the inorganic fertiliser can be related to use outside the agricultural area.

Emission factor

Emission factors for both NH_3 and NO_x are based on the values given in EMEP/EEA guidebook (EMEP/EEA, 2016) and the same emission factors are used for all years 1985-2015. The implied emission factor for NH_3 is shown in Table 5.17 and it depends on consumption and type of fertiliser.

Table 5.17 Implied emission factor NH_3 for inorganic N-fertiliser, 1985-2015.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Implied emission factor NH_3, % of total N	3.79	3.33	3.07	2.64	2.60	2.39	2.33	2.32	2.38	2.49	2.47

Emissions

Since 1985 there has been a significant decrease in use of inorganic N-fertiliser. This is due to requirements to utilising of nitrogen in manure as outlined in various environmental action plans. Another explanation for a reduction of emission is a decrease in use of urea as currently accounting for less than 1 % of the total nitrogen (Table 5.16). In Figure 5.9 are shown emission of NH_3 and NO_x.

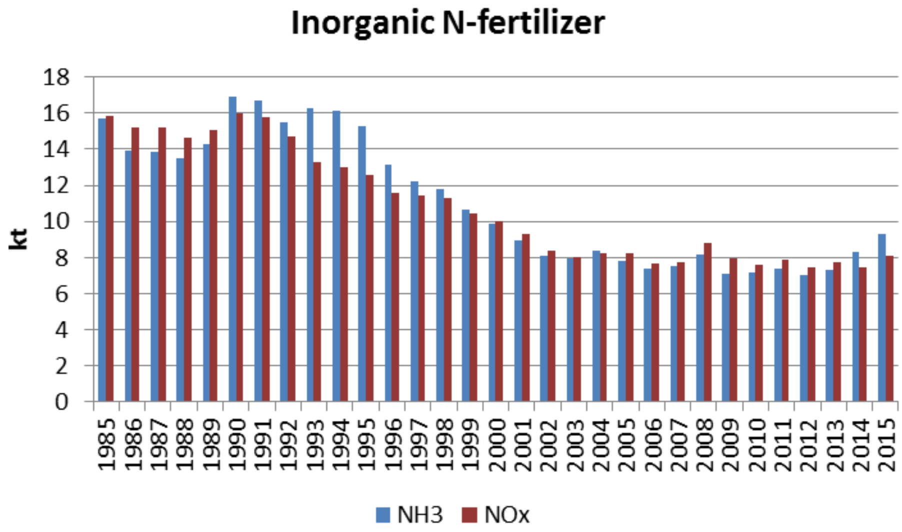

Figure 5.9 Emission of NH_3 and NO_x for 1985-2015, kt.

5.4.2 Animal manure applied to soils

Description

For the sector animal manure applied to soils the emission of NH_3 and NO_x are estimated.

Emission of NH_3 from animal manure applied to soils contributes in 2015 with 28 % of the NH_3 emission from the agricultural sector. Emission of NO_x from animal manure applied to soils contributes in 2015 with 49 % of the NO_x emission from the agricultural sector.

Methodological issues

To calculate emissions of NH_3 from animal manure applied to soils an emission factor are estimated and multiplied with TAN ex storage for liquid manure and N ex storage for solid manure for each animal type.

The NO_x emission is calculated as emission factor multiplied with N ex storage for each animal type.

Activity data

Based on the normative figures (Poulsen, 2016) the amount of TAN ex storage for liquid manure and the amount of N ex storage all manure are estimated.

Emission factor NH_3

The emission factor are based on background estimates of time of application, application methods, application in growing crops or on bare soil and the time from application to ploughing in soil. The amount of manure there are acidified is also taken into account. The emission factor differs between solid manure and liquid manure and also between manure from cattle and swine. For all other animals same emission factor as for cattle is used.

The emission factors will vary from year to year depending on changes in the practice of application. In Table 5.18 background information for 2015 are given. This estimate is based on information from SEGES.

Table 5.18 Estimate for application method, time of application and time before the manure is incorporated in the soil for 2015.

Liquid manure				Length of time before incorporation into soil, hours							
Application methods	Application time	Percentage distribution of manure		0		4, and then harrowed		4, and then Ploughed		Not incorporated	
		Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs
Incorporated	winter-spring	59	27	59	27	-	-	-	-	-	-
Incorporated	summer-autumn	18	10	18	10	-	-	-	-	-	-
Trailing hoses	winter-spring	19	60	-	-	-	-	-	-	19	60
Trailing hoses	spring-summer	2	1	-	-	-	-	-	-	2	1
Trailing hoses	late summer-autumn	2	2	-	-	-	-	-	-	2	2
Total		100	100	77	37	-	-	-	-	23	63
Solid manure				Length of time before incorporation into soil, hours							
Application methods	Application time	Percentage distribution of manure		0		4		6		Not incorporated	
		Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs	Cattle	Pigs
Broad spreading	winter-spring	90	76	-	-	70	60	20	16	-	-
Broad spreading	spring-summer	5	5	5	5	-	-	-	-	-	-
Broad spreading	late summer-autumn	5	19	-	-	5	19		-	-	-
Total		100	100	5	5	75	79	20	16	-	-

Acidification of slurry just before application on fields is an increasing used technique in Denmark and a result of environmental requirements. If slurry is applied on grass fields or on soil without vegetation, the slurry has to be injected or treated with acid to lower the ammonia emission.

The acidification of the manure lowers the emission of NH_3 from the treated manure by 49 % for cattle manure and 40 % for swine manure (VERA, 2010). The amount of manure acidified is estimated by SEGES for the years 2011, 2012, 2013 and 2014 (Vestergaard, 2015). It has not been possible to get data for 2015, but it is estimated to be on the same level as in 2014. It is mainly cattle manure, which is acidified in storage and just before application.

Table 5.19 Share of liquid manure acidified in storage and just before application, 2011-2015.

	2011	2012	2013	2014	2015
Share of cattle manure, %	3	6	10	13	13
Share of swine manure, %	1	1	1	1	1

In 2015, the emission factor for cattle is for solid manure estimated to 7 % of N ex storage and for liquid manure estimated to 13 % TAN ex storage, for swine the emission factors are 6 % and 11 %, respectively.

Emissions factor NO_x

The emission factor for NO_x is based on EMEP/EEA guidebook (2016). Only one emission factor regarding the NO_x emission for 3D is mentioned in the EMEP/EEA Guidebook (refer to Table 3-1). The background reference for the Tier 1 emission factor is based on a literature study, which do not distinguish between different kinds of fertiliser types. This indicate that the same emission factor can be used independent of the crops are fertilized with mineral fertiliser or manure. The NO_x emission is estimated based on the Tier 1 emission factor at 0.04 kg NO_2 per kg N fertilized.

Emissions

The emission of NH_3 from manure applied to soils has decreased by 51 % from 1985 to 2015, this is due to decrease of N excreted by animals and by changes in the way manure is handled during application. Based on the action plans various initiatives has been implemented and include for example requirement for a minimum 9-month manure storage capacity, requirement that manure applied to soil be ploughed down within six hours, a ban on the application of manure in winter and broad spreading is no longer allowed. An increasing share of the slurry is injected to soil which result in a lower emission.

Emission of NO_x from manure applied to soils has decreased by 8 % from 1985 to 2015 this is mainly due to decrease of N excreted.

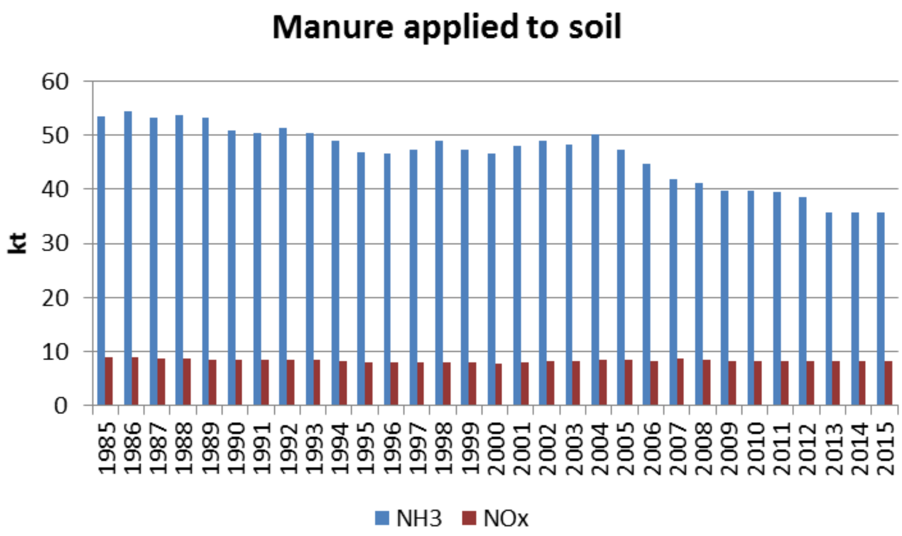

Figure 5.10 Emission of NH_3 and NO_x from manure applied to soils, 1895-2015, kt NH_3 and NO_x.

5.4.3 Sewage sludge applied to soils

Description

For the sector sewage sludge applied to soils the emission of NH_3 and NO_x are estimated.

Emission of NH_3 and NO_x from sewage sludge applied to soils contributes in 2015 with less than 1 % and 2 % from the agricultural sector, respectively.

Methodological issues

Amount of N applied are multiplied with the emission factor.

Activity data

Information on amount of sewage sludge, N-content and NH_3 emission factor is obtained from reports prepared by the Danish Environmental Protection Agency and based on data from the fertiliser accounts controlled by The Danish AgriFish Agency. Farmers with more than 10 animal units have to be registered and keep accounts of the use of N content in manure, received manure or other organic fertiliser.

Table 5.20 Activity data used to estimate NH_3 and NO_x from sewage sludge, 1985-2015.

		1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Amount of sludge applied on soil	Tonnes of dry matter	50 000	77 883	112 235	83 727	45 739	56 665	54 564	52 002	51 731	53 766	58 273
N-content	%	4.00	4.00	4.13	4.33	4.75	4.75	4.75	4.75	4.75	4 75	4.75
N applied on soil	Tonnes N	2 000	3 115	4 635	3 625	2 173	2 692	2 592	2 470	2 457	2 554	2 768

Emission factor NH_3

The emission factor for NH_3 emission from sewage sludge applied to soil is based on information from the Danish Environmental Protection Agency. It is estimated to 0.019 kg NH_3-N per kg N and the same for all years 1985-2015.

Emission factor NO_x

The emission factor for NO_x is based on Stehfest and Bouwman (2006) 0.04 kg NO_2 per N applied.

Emissions

Emission of NH_3 and NO_x from sewage sludge is shown in Figure 5.11. The emission follow the amount of N applied.

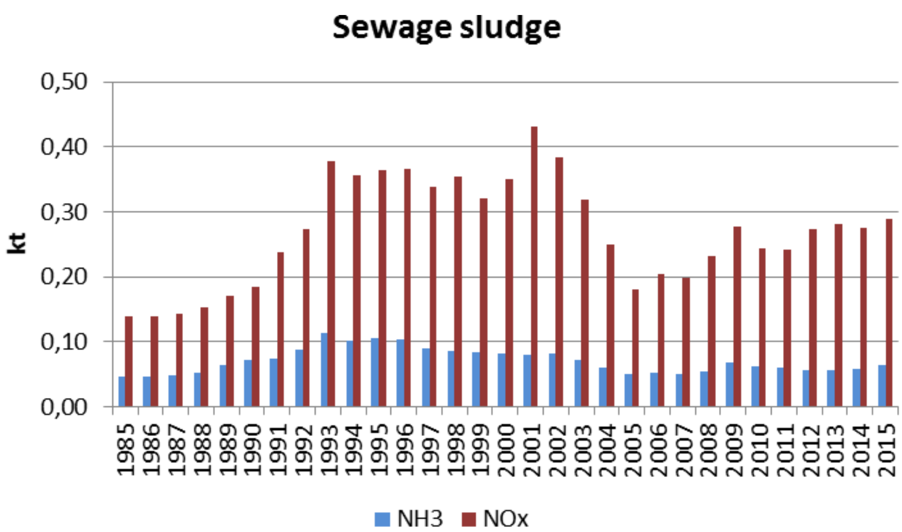

Figure 5.11 Emission of NH_3 and NO_x from sewage sludge, 1985-2015, kt.

5.4.4 Urine and dung deposited by grazing animals

Description

It is assumed that 5 % of the manure from dairy cattle is deposited in the field, which corresponding to 18 days per year (Aaes, 2008). For heifers 36 % of the nitrogen in the manure is estimated deposited during grazing (Aaes, 2008), 61 % for suckling cows (Poulsen et al, 2001), 50 % for horses (Clausen, 2008) and 73 % for sheep and goats (Poulsen et al, 2001).

Emission of NH_3 from urine and dung deposit by grazing animals contributes in 2015 with 3 % of the emission from the agricultural sector.

Methodological issues

Emission of urine and dung deposited by grazing animals is based on N excreted ab animal, number of days the animals are on grass and the emission factor.

Activity data

The activity data are number of animals (see Chapter 5.2.1), N excreted ab animal and number of days on grass (see Table 5.12) which combined gives the N deposit on grass, see Table 5.21.

Table 5.21 N deposit on grass, 1985-2015, M kg N.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
N deposited on grass	37	34	36	34	26	22	21	22	22	22	21

Emission factor

Study of grazing cattle indicates that 7 % of the total nitrogen content is assumed to evaporate as NH_3 (Jarvis *et al*. 1989a, Jarvis *et al*. 1989b and Bussink 1994). This emission factor is used for all animal categories.

Emissions

The emission of NH_3 from urine and dung deposit by grazing animals has decreased by 43 % from 1985 to 2015 and this is mainly due to decrease in number of dairy cattle and decrease in number days on grass for dairy cattle.

Table 5.22 Emission of NH_3 from urine and dung deposit by grazing animals, 1985-2015, kt NH_3.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Grazing animals	3.12	2.91	3.02	2.92	2.21	1.87	1.81	1.84	1.86	1.85	1.79

5.4.5 Farm-level agricultural operations including storage, handling and transport of agricultural products

Description

During agricultural operations such as soil cultivation, harvesting, cleaning, drying and transport an emission PM occur. In the EMEP/EEA guidebook are only method and emission factors for the operations done in the field that is soil cultivation, harvesting, cleaning and drying.

The emission of PM TSP from field operations contributes with 88 % of the total emission of TSP in 2015.

Methodological issues

The emission of PM from field operations is calculated by area of cultivated crops multiplied with number of operations and emission factor, for each crop type and type of operation.

Activity data

For activity data are used area of cultivated crops and number of operations for each crop. The area of crops is estimated by Statistic Denmark (DSt, 2015) and number of operations are based on budget estimates made by Knowledge Centre for Agriculture. See Annex 3D Table 3D-7 for area of cultivated crops and Annex 3D Table 3D-8a-8d for number of operations divided in soil cultivation, harvesting, cleaning and drying.

Emission factor

The emission factors used are given in Table 5.23 and they are based on EMEP/EEA guidebook (EMEP/EEA, 2016) and van der Hoek (2007).

Table 5.23 Emission factors for field operations, kg per ha.

PM_{10}	Soil cultivation	Harvesting	Cleaning	Drying
Wheat	0.25[a]	0.27[b]	0.19[a]	0.56[a]
Rye	0.25[a]	0.2[b]	0.16[a]	0.37[a]
Barley	0.25[a]	0.23[b]	0.16[a]	0.43[a]
Oat	0.25[a]	0.34[b]	0.25[a]	0.66[a]
Other arable	0.25[a]	0.26[c]	0.19[c]	0.51[c]
Grass	0.25[a]	0.25[a]	0[a]	0[a]
$PM_{2.5}$				
Wheat	0.015[a]	0.011[b]	0.009[a]	0.168[a]
Rye	0.015[a]	0.008[b]	0.008[a]	0.111[a]
Barley	0.015[a]	0.009[b]	0.008[a]	0.129[a]
Oat	0.015[a]	0.014[b]	0.0125[a]	0.198[a]
Other arable	0.015[a]	0.010[c]	0.009[c]	0.152[c]
Grass	0.015[a]	0.01[a]	0[a]	0[a]
TSP[d]				
Wheat	2.5	2.7	1.9	5.6
Rye	2.5	2	1.6	3.7
Barley	2.5	2.3	1.6	4.3
Oat	2.5	3.4	2.5	6.6
Other arable	2.5	2.6	1.9	5.1
Grass	2.5	2.5	0	0

[a] EMEP/EEA (2013).

[b] van der Hoek (2007).

[c] average of wheat, rye, barley and oat.

[d] PM_{10} multiplied by 10 (van der Hoek, 2007).

Emissions

The emission of PM_{10}, $PM_{2.5}$ and TSP are shown in Table 5.24. The emission of TSP has decreased 21 % from 1990 to 2015 due to decrease in the area of cultivated crops and number of treatments of the fields.

Table 5.24 Emissions of PM_{10}, $PM_{2.5}$ and TSP from field operations, 1990-2015, tonnes.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
PM_{10}	6 839	6 250	6 238	5 415	5 665	5 654	5 559	5 522	5 637	5 504
$PM_{2.5}$	527	485	479	436	468	457	445	448	466	458
TSP	68 392	62 496	62 382	54 146	56 655	56 541	55 587	55 218	56 365	55 040

5.4.6 Cultivated crops

Description

For the sector cultivated crops the emission of NH_3 and NMVOC are estimated.

The Danish emission inventory includes NH_3 emission from crops, despite the uncertainties related to this emission source. Literature research shows that the volatilisation from crop types differs considerably. However, as for the emission ceiling given in the Gothenburg-Protocol and the EU NEC Directive the emission from crops is not taken into account.

Methodological issues

The emission is calculated based on area of agricultural land and emission factors.

Activity data

Activity data are obtained from Statistics Denmark, see Annex 3.D Table 3D-7.

Emission factor NH_3

EF´s for crops are estimated to 2 % for crops and 0.5 % for grass based on a literary survey (Gyldenkærne and Albrektsen, 2009).

Table 5.25 EF used to estimate the emission of NH_3 from crops.

Crops	kg NH_3-N per ha
Cash crops, beets and silage maize	2
Grass/clover in rotation	0.5
Permanent grass	0.5
Set-a side	0

Emission factor NMVOC

The calculation of the NMVOC emission is based on emission factors recommended in EMEP/EEA Guidebook 2016 Table 3-3 for cultivation of wheat, rye, rape and grass land. A Tier 2 IEF is estimated corresponding to Danish yield level dry matter content (DM) for these crop types. The emission from other crop types is not available in the Guidebook. However, the total NMVOC emission is estimated as the Tier 2 IEF multiplied with the total cultivated area.

The NMVOC emission from cultivated crops is estimated to 2.11 kt in 2015 based on an IEF at 0.80 and a cultivated area of 2 633 thousand hectare. The IEF varies annually from 0.51 -0.80 kg NMVOC per hectare depending on the allocation of the four mentioned crop types. Higher allocation of rape and rye result in higher IEF due to a higher emission factor for these two crop types.

Table 5.26 Estimation of a Tier 2 NMVOC emission factor, 2015.

	EEA/EMEP, Emission factor	Fraction of year emitting	Total	Mean dry matter of crop	NMVOC EF	Cultivated area	NMVOC emission	Tier 2 DK
Crop	Kg NMVOC /kg DM/yr		Kg/kg DM//yr	kg DM/ha	Kg/ha/yr	ha	Kg/ha/yr	IEF, kg NMVOC/ha
Wheat	2.60E-08	0.3	6.82E-05	6 826	0.47	608 733	283 851	
Rye	1.41E-07	0.3	3.70E-04	5 389	1.99	125 540	250 422	
Rape	2.02E-07	0.3	5.30E-04	3 945	2.09	193 234	403 842	
Grass land*	1.03E-08	0.5	4.51E-05	9 230	0.42	510 393	212 528	
Total						1 437 900	1 150 142	0.80

*Grass land 15 C.

Emissions

Emission of NH3 and NMVOC are shown in Figure 5.12. The emission of NH3 has decreased by 10 % from 1985 to 2015 and the emission of NMVOC has increased by 12 %.

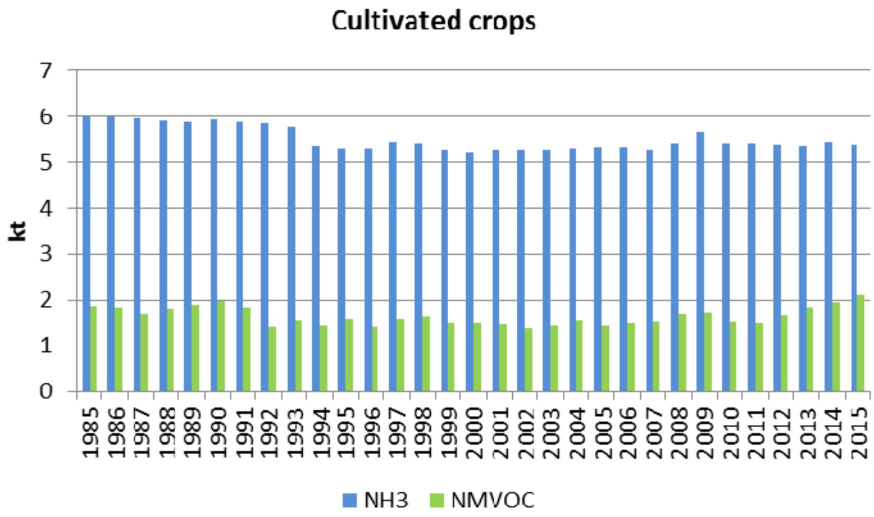

Figure 5.12 Emission of NH_3 and NMVOC from cultivated crops, 1985-2015, kt.

5.4.7 Use of pesticides

Description

A range of pesticides are use in the Danish agricultural sector and some of them contain Hexachlorobenzene (HCB), but pure HCB used as pesticide is banned. HCB is a poisonous substance, which is dangerous to human and animal health but is used as agent in pesticides.

The emission of HCB from use of pesticides contributes with less than 1 % of the Danish total HCB emission.

Methodological issues

Emission of HCB from use of pesticides is based on amount of effectual substance used and emission factors for each type of pesticides.

Activity data

A range of pesticides are used in Denmark. In the period from 1990 to 2015 six types of pesticides containing HCB have been identified as used in Denmark. These are atrazine, chlorothalonil, clopyralid, lindane, pichloram and simazine. Data of amounts of effectual substance used in Denmark are collected from Environmental Protection Agency (EPA), see Table 5.27. The use of atrazine and lindane stopped in 1994 and the use of chlorothalonil and simazine ceased in 2000 and 2004, respectively.

Table 5.27 Amounts of effectual substance used in Denmark, 1990-2015, kg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015*
Atrazine	91 294	-	-	-	-	-	-	-	-	-
Chlorothalonil	10 512	10 980	7 340	-	-	-	-	-	-	-
Clopyralid	16 461	22 587	7 446	5 874	9 122	11 840	8 170	14 258	13 525	13 525
Lindane	8 356	-	-	-	-	-	-	-	-	-
Pichloram	-	-	-	-	723	1 349	206	256	258	-
Simazine	30 234	19 865	23 620	-	-	-	-	-	-	-

*Same as 2014 due to lack of data.

Emission factor

No default emission factors are given in EMEP/EEA Guidebook. Emission factors given in Yang (2006) are used in the calculation of the emissions, see Table 5.28.

Table 5.28 Emission factors for HCB from pesticides, 1990-2015, g per tonnes.

	1990	1995	2000	2001-2015
Atrazine	100	1	1	1
Chlorothalonil	500	40	40	10
Clopyralid	2.5	2.5	2.5	2.5
Lindane	100	50	50	1
Pichloram	100	50	50	8
Simazine	100	1	1	1

Emissions

Table 5.29 shows the emission of HCB from the use of pesticides for the years 1990-2015. The emission has decreased significantly from 1990 to 2015 due to decrease in use of pesticides containing HCB.

Table 5.29 Emission of HBC, 1990-2015, kg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pesticides	18.28	0.50	0.33	0.01	0.02	0.03	0.02	0.03	0.03	0.03

5.5 Field burning of agricultural residues

Description

Field burning of agricultural residues has been prohibited in Denmark since 1990 and may only take place in connection with production of grass seeds on fields with repeated production and in cases of wet or broken bales of straw.

Emissions of NH_3, NO_x, CO, NMVOC, SO_2, PM, BC, heavy metals, dioxin, PAHs, HCB and PCB are included under the NFR category 3F. The emission of NH_3 from field burning contributes in 2015 with less than 1 % of the agricultural emission. Emissions of PM and NMVOC from field burning contributes with less than 1 % TSP, 1 % PM_{10}, 2 % $PM_{2.5}$ and less than 1 % NMVOC of the agricultural emission. The emission of NO_x, BC, CO, SO_2, heavy metals, dioxin and PCB from field burning contribute with less than or around 1 % of the total national emission, while the emission of PAHs and HCB contribute with around 4-6 % of the national emission. From 1989 to 1990 all emissions decrease significantly due to the ban on field burning.

Methodological issues

Emissions from field burning of agricultural residues are calculated based on the amount of burnt straw given in tons dry matter and emission factors given in the EMEP/EEA guidebook (EMEP/EEA, 2016).

Activity data

The amount of burnt straw from the grass seed production is estimated as 15-20 % of the total amount produced. The amount of burnt bales of wet straw is estimated as 0.1 % of total amount of straw. Both estimates are based on expert judgement by SEGES. The total amounts are based on data from Statistics Denmark. See Annex 3D Table 3D-9 for activity data.

Emission factor

The EMEP/EEA guidebook (EMEP/EEA, 2016) default values for the emission factors for field burning of agricultural residues are used (Table 5.30).

Table 5.30 EF for field burning of agricultural residues.

Pollutant	EF	Unit
NO_x[1]	2.4	g/kg DM
CO[1]	58.9	g/kg DM
NMVOC[1]	6.3	g/kg DM
SO_x[1]	0.3	g/kg DM
NH_3[1]	2.4	g/kg DM
TSP[1]	5.8	g/kg DM
PM_{10}[1]	5.8	g/kg DM
$PM_{2.5}$[1]	5.5	g/kg DM
BC[1]	0.5	g/kg DM
PCDD/F[1]	500	ng TEQ/t
Pb[1]	0.865	mg/kg DM
Cd[1]	0.049	mg/kg DM
Hg[1]	0.008	mg/kg DM
As[1]	0.058	mg/kg DM
Cr[1]	0.22	mg/kg DM
Ni[1]	0.177	mg/kg DM
Se[1]	0.036	mg/kg DM
Zn[1]	0.028	mg/kg DM
Cu[2]	0.0003	mg/kg DM
Benzo(a)pyrene[2]	2 787	mg/kg DM
benzo(b)fluoranthene[2]	2 735	mg/kg DM
benzo(k)fluoranthene[2]	1 073	mg/kg DM
Indeno(1,2,3-cd)pyrene[2]	1 017	mg/kg DM
HCB (broken bales)[3]	0.003	g/tonnes
HCB (seed production)[3]	0.002	g/tonnes
PCB (broken bales)[4]	3	ng TEQ/t
PCB (seed production)[4]	0.05	ng TEQ/t

[1] EMEP/EEA, 2013.
[2] Jenkins, 1996.
[3] Yang (2006).
[4] Black et al. (2012).

Emissions

See Annex 3D Table 3D-10 for emissions of all pollutants 1985 to 2015.

5.6 Agriculture other

5.6.1 NH_3 treated straw

Description

NH_3 is used for conservation of straw for feeding. As for the emission ceiling given in the Gothenburg-Protocol and the EU NEC Directive the emission from NH_3 treated straw is not taken into account.

Methodological issues

Emissions are calculated as NH_3 used for treatment of straw multiplied the emission factor.

Activity data

Information on NH_3 used for treatment of straw is collected from the suppliers. NH_3 treated straw has been prohibited from 2006, but in some areas exemption are given due to wet weather.

Table 5.31 Activity data for NH_3 treated straw 1985 to 2015.

	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Tonnes NH_3-N	8 300	12 936	8 421	3 131	329	300	200	200	200	200	200

Emission factor

Investigations show that up to 80-90% of the supplied NH_3 (given in NH_3-N) can emit (Andersen et al., 1999). However, the emissions can be reduced particularly if the right dose is used. It is assumed that the emission factor is 65 % of the applied NH_3-N.

Emissions

Emission of NH_3 from NH_3-treated straw is shown in Figure 5.13.

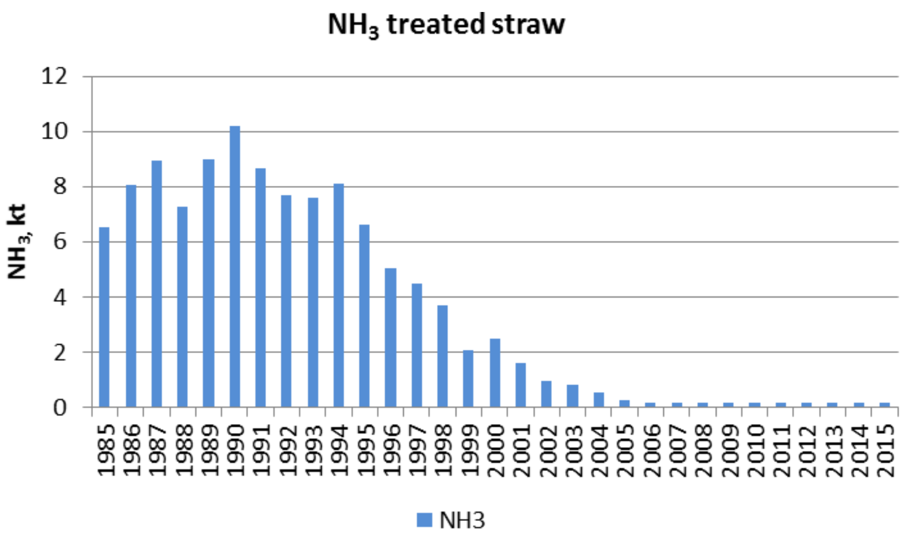

Figure 5.13 Emission of NH_3 from NH_3-treated straw, 1985-2015.

5.7 Uncertainties

Table 5.32 shows the estimated uncertainties for activity data and emissions factor for each pollutant.

NH_3

3B Manure management

It is defined that activity for manure management covers both the number of animals and housing type. The allocation of animal on different housing types determines if the manure is handled as slurry or solid manure.

The number of animals for the most important animal categories is estimated by Statistic Denmark. The uncertainties for the most important livestock categories are relatively low e.g. for swine and cattle the uncertainties is estimated to 1.3 % and 0.9 %, respectively. The uncertainty is higher for less important animal groups, e.g. fur bearing animals (3.4 %), poultry, horses, sheep (10.4 %). The uncertainty for number of animals overall is estimated to 2 %. The allocation of housing system is based on information from the farm nitrogen budgets handled and controlled by the Danish AgriFish Agency. All farmers have to submit the information regarding the housing type annually and the uncertainty is assumed as relatively low.

The uncertainties for the activity data is thus a combination of low uncertainty in animal numbers, a relatively low uncertainty for housing type, which assumed to result in an overall uncertainty by 5 %.

The uncertainty for the emission factor covers nitrogen excretion, grazing days and NH_3 emission factors from housing and during storage of the manure. The Danish Normative System for animal excretions is based on data from SEGES, which is the central office for all Danish agricultural advisory services. SEGES engages in a great deal of research as well as the collection of efficacy reports from Danish farmers for dairy production, meat production, pig production, etc., to optimise productivity in Danish agriculture. Feeding plans from 15-18 % of the Danish dairy productions, 25-30 % of swine productions, 80-90 % of poultry productions and approximately 100 % of fur productions are collected annually. These basic feeding plans are used to develop the standard values of the "Danish Normative System". However, due to the large number of farms included in the norm figures, the arithmetic mean can be assumed as a very good estimate with a low uncertainty.

Regarding the uncertainties for the emission factor, it has to be included that the emission comes from three different places in the livestock production; from manure in housing, from stored manure and from application of manure. The uncertainties for emission measurements in housing, which are the basement for the normative standards varies from 15 -25 % (Poulsen et al., 2001). But there is no specified uncertainty estimates for emission factors for storage and application of manure. The overall uncertainty value for NH_3 emission factor for manure management is assumed to be around 25 %.

3Da1 Inorganic fertilisers

The activity data for the emission from inorganic N-fertiliser depends on the amount of sold fertiliser and the N-content for each fertiliser type, which is based on annually information given by the Danish AgriFish Agency. Uncertainty is considered to be low; 3 % based on expert judgement.

No uncertainty values for the emission factor are given in the EMEP/EEA guidebook. The Danish inventory assume an uncertainty value at 25 %, which indicated a uncertainty in the translation of the Danish fertiliser types to types specified in the guidebook but also indicate an uncertainty of the emission factors specified in the guidebook.

3Da2a Animal manure applied to soils

Besides the number of animals, the uncertainty for activity data covers N-excretion, grazing days and the NH_3 emission from housing and storage. It is assumed that the most important variables are the number of animals which has a low uncertainty 2 %. However, the uncertainty is also affected by the other variables, which have a higher uncertainty estimate. Thus, the uncertainty for the activity data is assumed to be around 15 %.

The emission factor depends on the uncertainty regarding the information on application time, application technics and plant cover. The uncertainty is estimated to 25 %.

3Da2b Sewage sludge applied to soils

From 2005 and onwards the amount of N applied from wastewater treatment is based on the fertiliser accounts controlled by the Danish AgriFish Agency. Farmers with more than 10 animal units have to be registered and have to keep accounts of the N content in manure, received manure or other organic fertiliser. The uncertainty for the activity data is assumed to be 15 %.

The emission factor depends on the application of time, application technic and the climate conditions and the uncertainty is assumed to be relatively high – around 50 %.

3Da3 Urine and dung deposited by grazing animals

The overall uncertainty for the activity is estimated to 5 %. Besides the number of animals, the uncertainty depends on number of grassing days.

Regarding the uncertainty for the emissions factor, this depends on the N excretion and the climate conditions as temperature, wind and precipitation. The uncertainty value is estimated to 25 %.

3De Cultivated crops

The activity data covers the cultivated area which is based on Statistics Denmark. For the major crops, the uncertainty is relatively low – e.g. winter wheat it is 1.1 % in 2015. The overall uncertainty for the activity is estimated to 2 %. Knowledge concerning the emission is relatively limited and therefore the uncertainty is assumed to be 50 %.

3F Field burning of agricultural residues

An uncertainty of 25 % for the activity for field burning of agricultural residues is used. The uncertainty is a combination of the uncertainty for area of grass for seed production, which has a low uncertainty, amount of burned straw and yield, which have a high uncertainty. The uncertainties for the emission factor are based on the EMEP/EEA Guidebook (EMEP/EEA, 2016) and Jenkins et al. (1996).

3I Agriculture other

Under NFR category 3I emissions from NH_3 treated straw is entered. NH_3 treated straw was until 2006 used as cattle feed. By law in 2006 the NH_3 treatment of straw was banned. However, due to wet weather conditions exemption are given in some areas. The activity depends on the amount of ammonia used in the second half of the year and is based on information from the AgriFish Agency. The uncertainty value is assumed to be 20 %. The uncertainty level for the emission factor is assumed to be 50 %.

PM

Uncertainty estimates due to the activity data is estimated to 7 %. Besides number of animal and housing type, also uncertainty related to the production cycles plays a role.

The activity data covers the cultivated crops and number of operations for each crop type. The area of crops is estimated by Statistic Denmark and number of operations is based on budget estimates made by Knowledge Centre for Agriculture. The uncertainty is assumed to be 10 %.

The uncertainties for the PM emission factors have been considered to be very high and especially for animal husbandry and manure management. The uncertainty estimates regarding the PM emission factors for manure management and farm level agricultural operations are based on the EMEP/EEA guidebook.

Other pollutants

For both the NO_x and NMVOC emission the activity data is based on the same conditions as mentioned in NH_3 chapter and therefore the same uncertainty estimates is used.

The uncertainty for the NO_x and NMVOC emission factor is based on expert judgment and is considered to be very high; 100 - 500 % based on the on the EMEP/EEA guidebook.

Emission of BC, CO, SO_2, heavy metals, dioxin, PAHs, HCB and PCB from the agricultural sector originates from field burning of agricultural residues. The uncertainty for activity data for these emissions is a combination of the uncertainty for crop production which is low and the uncertainty of the amount of burned straw which is high. The uncertainties for the emission factors are based on EMEP/EEA guidebook. All uncertainties for field burning are relatively high. The uncertainty for activity data for the emission of HCB from pesticides are estimated to 5 % and the uncertainty for the emission factor are relatively high.

Table 5.32 Estimated uncertainty associated with activities and emission factors for the agricultural sector.

Compound	NFR sector	Emission	Activity data, %	Emission factor, %	Combined Uncertainty, %	Total Uncertainty, %
NH_3, kt	3.B Manure management	35.73	5	25	25	16
	3.Da1 Inorganic fertilisers	6.10	3	25	25	
	3.Da2a Animal manure applied	19.63	15	25	29	
	3.Da2b Sewage sludge applied	0.06	15	50	52	
	3.Da3 Deposited by grazing	1.79	5	25	25	
	3.De Cultivated crops	5.40	2	50	50	
	3.F Field burning	0.11	25	50	56	
	3.I Agriculture other	0.16	20	50	54	
TSP, kt	3.B Manure management	6.92	7	300	300	268
	3.Dc Farm-level agri. operations	55.04	10	300	300	
	3.F Field burning	0.26	25	50	56	
PM_{10}, kt	3.B Manure management	2.37	7	300	300	221
	3Dc Farm-level agri. operations	5.50	10	300	300	
	3.F Field burning	0.26	25	50	56	
$PM_{2.5}$, kt	3.B Manure management	0.54	7	300	300	172
	3Dc Farm-level agri. operations	0.46	10	300	300	
	3.F Field burning	0.24	25	50	56	
NMVOC, kt	3 B Manure management	35.68	2	300	300	283
	3.De Cultivated crops	2.11	5	500	500	
	3.F Field burning	0.28	25	100	103	
NO_x, kt	3.B Manure management	0.20	5	100	100	191
	3.Da1 Inorganic fertilisers	8.11	3	400	400	
	3.Da2a Animal manure applied	8.33	15	400	400	
	3.Da2b Sewage sludge applied	0.29	15	400	400	
	3.F Field burning	0.11	25	25	35	
HCB, kg	3.F Field burning	0.03	5	500	500	409
HCB, kg	3 G Agriculture other	0.11	25	500	501	
PCB, kg	3.F Field burning	< 0.01	25	500	501	501
SO_2, kt	3.F Field burning	0.01	25	100	103	103
BC, kt	3.F Field burning	0.02	25	100	103	103
CO, kt	3.F Field burning	2.61	25	100	103	103
Pb, Mg	3.F Field burning	0.04	25	50	56	56
Cd, Mg	3.F Field burning	<0.01	25	100	103	103
Hg, Mg	3.F Field burning	<0.01	25	200	202	202
As, Mg	3.F Field burning	<0.01	25	100	103	103
Cr, Mg	3.F Field burning	0.01	25	200	202	202
Cu, Mg	3.F Field burning	<0.01	25	200	202	202
Ni, Mg	3.F Field burning	0.01	25	200	202	202
Se, Mg	3.F Field burning	<0.01	25	100	103	103
Zn, Mg	3.F Field burning	<0.01	25	200	202	202
Dioxin, g I-Teq	3.F Field burning	0.03	25	500	501	501
Benzo(a)pyrene, Mg	3.F Field burning	0.12	25	500	501	501
Benzo(b)fluoranthen, Mg	3.F Field burning	0.12	25	500	501	501
Benzo(k)fluoranthen, Mg	3.F Field burning	0.05	25	500	501	501
Indeno(1,2,3 cd)pyrene, Mg	3.F Field burning	0.05	25	500	501	501

5.8 Quality assurance and quality control (QA/QC)

A general QA/QC and verification plan for the agricultural sector is continuously under development and will be improved and developed in line with the deficiencies are identified and corrected. The objectives for the quality planning, as given in the CLRTAP Emission Inventory Guidebook, which is closely related to the IPCC Good Practice Guidance, are to improve the transparency, consistency, comparability, completeness and confidence.

To ensure consistency a procedure for internal quality check are provided. Input of external data is checked and certain time series have been prepared for both the activity data, the emission factors and implied emission factors, 1985 - 2015. The annual change for each emission source on activity will be checked for significant differences and if necessary explained. Considerable variation between years can reveal miscalculations or changes in methods. All checks of all activity data, emission factor, implied emission factor and other important key parameters are provided and achieved in excel spread sheet.

Activity data and emission factors are collected and discussed in cooperation with specialists and researchers at different institutes and research departments. As a consequence, both data and methods are evaluated continuously according to latest knowledge and information. A more detailed description of quality assurance and quality control is given in the Denmark´s National Inventory Report 2015 and 2016 - submitted under the United Nations Framework Convention on Climate Change (http://dce2.au.dk/pub/SR189.pdf).

5.9 Recalculations

Compared with the previous NH_3, NMVOC and PM emissions inventory (submission 2016), some changes and updates have been made, see Table 5.33. These changes cause a decrease/increase in the total NH_3, NMVOC and PM emission for all years (1985–2014).

Table 5.33 Changes in NH_3, NMVOC and PM emission in the agricultural sector compared to NFR reported last year.

NH_3 emission, kt NH_3	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
2015 submission	126.13	123.78	106.87	92.99	83.93	75.27	74.30	72.85	70.28	70.36
2016 submission	128.78	123.12	103.40	91.15	82.63	73.59	72.41	70.82	68.25	68.58
Difference, %	2.10	-0.54	-3.25	-1.98	-1.54	-2.24	-2.55	-2.79	-2.89	-2.52

NMVOC emission, kt	1990	1995	2000	2005	2010	2011	2012	2013	2014
2015 submission	40.20	38.55	37.40	36.75	37.18	37.04	37.59	37.99	37.96
2016 submission	40.20	38.55	37.40	36.75	37.18	37.04	37.59	37.99	37.97
Difference, %	0.00	0.00	0.00	0.00	0.00	-0.002	-0.001	0.001	0.02

PM emission, kt TSP	1990	1995	2000	2005	2010	2011	2012	2013	2014
2015 submission	91.60	87.05	88.08	79.40	81.58	81.18	79.71	78.99	80.14
2016 submission	86.04	80.24	80.31	71.22	73.75	73.57	72.40	71.98	73.17
Difference, %	-6.07	-7.83	-8.82	-10.31	-9.60	-9.37	-9.17	-8.88	-8.70

For the emission of NH_3 is seen change in the emission from manure management, animal manure applied to soil, inorganic N-fertiliser and NH_3-straw. Change in the emission from manure management is due to change in normative figures for sheep and goats (1985-1999), change in number of weaners and fattening pigs (2011-2014) due to change in the statistics and change in normative figures and emission factors for hens (2012-2014) due to errors. Emission from animal manure applied to soil are also changed due to the changes mentioned for manure management, but also by change in emission factor for acidification of slurry applied (2006-2014).

Change in NH_3 emission from inorganic N-fertiliser is due to change in emission factors. The emission factors have been updated to emission factors given in EMEP/EEA guidebook 2016. The change in emission factors increases the emission in 1985-1989 and decreases the emission in 1990-2014. This is due to the combination of fertiliser types and increase and decrease in the emission factors.

The amount of NH_3 used for NH_3-treated straw has been change for the years 2006-2014, due to updated estimates.

Change in the emission of NMVOC in 2011-2014 is due to change in the number of animals.

Emission of PM TSP is changed for emission from manure management due to change in emission factors. The emission factors have been updated to emission factors given in EMEP/EEA guidebook 2016. The updated emission factors decreases the emission from swine and poultry.

5.10 Planned improvements

In recent years, there has been focus on reduction of the NH_3 emission and especially the possibilities for emission reduction in housings. Data regarding acidification of slurry received from SEGES is included in the inventory, but no other technologies are included. Until now, still relatively few housing has implemented NH_3 reduction technologies. There is no doubt, that the ammonia reducing technology will play an important role in the future. Information on use of different reducing technologies is not yet available in a form which can be included in the inventory. However, DCE are in contact and dialog with the ministry and the agricultural sector and when data is available other reducing technologies can be implemented in the emission inventory.

The QA/QC plan for the agricultural sector is continually under development. Until now, the main focus has been on the internal procedure check. There is still a need to provide the procedure for control of the inventory data calculations. This means to identify the possibility to compare the calculations made by other institutions or organisations e.g. calculation of total N-excretion made by the DCA-Danish Centre for Food and Agriculture, Aarhus University. Furthermore, it is a need to consider how to ensure a quality assurance procedure for the entire inventory.

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6 Waste

The waste sector consists of the four main NFR categories 5A Solid waste disposal, 5B Biological treatment of solid waste, 5C Incineration and open burning of waste, 5D Wastewater treatment and discharge and 5E Other waste. Table 6.1 below shows the relevant SNAP codes for the waste sector.

Table 6.1 Link between SNAP codes and NFR sectors.

SNAP code	SNAP name	NFR code
090401	Managed Waste Disposal on Land	5A
090402	Unmanaged Waste Disposal Sites	5A
090403	Other	5A
091001	Wastewater treatment in industry	5D
091007	Latrines	5D
091002	Wastewater treatment in residential/commercial sector	5D
090201	Incineration of domestic or municipal wastes	5C
090202	Incineration of industrial wastes (except flaring)	5C
090204	Flaring in chemical industries	5C
090205	Incineration of sludge from waste water treatment	5C
090207	Incineration of hospital wastes	5C
090208	Incineration of waste oil	5C
090901	Incineration of corpses	5C
090902	Incineration of carcasses	5C
090700	Open burning of agricultural wastes	5C
091003	Sludge spreading	5E
091005	Compost production	5B
091006	Biogas production	5B
091008	Other production of fuel (refuse derived fuel)	5E
091009	Accidental fires	5E

Incineration of waste (municipal, industrial, clinical and hazardous) in Denmark is done with energy recovery and therefore the emissions are included under the relevant sectors under NFR sector 1A. The documentation for waste incineration is included in Chapter 3.2.

6.1 Solid waste disposal

Major emissions from landfilling are emissions of greenhouse gases, i.e. CH_4. It is assumed that landfilling also leads to emission of small quantities of NMVOC, CO, NH_3 and NO_x. PM emissions are emitted from waste handling as well, but these have not been included in the current submission.

Currently, Denmark has not estimated emissions of air pollutants from solid waste disposal. The EMEP/EEA Guidebook contains default NMVOC and particle emission factor. However, due to a limited amount of resources, it has not been possible to estimate such emissions.

6.2 Biological treatment of solid waste

This sector covers two activities: composting and anaerobic digestion at biogas facilities. These are described in more detail below.

6.2.1 Compost production

This section covers the biological treatment of solid organic waste called composting. Pollutants that are emitted during composting are CO and NH_3.

Methodology

Emissions from composting have been calculated according to a country specific Tier 1 method.

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.

In 2001, 123 composting facilities treated only garden and park waste (type 2 facilities), nine facilities treated organic waste mixed with GPW or other organic waste (type 1 facilities) and 10 facilities treated GPW mixed with sludge and/or "other organic waste" (type 3 facilities). 92 % of these facilities consisted entirely of windrow composting, which is a simple technology composting method with access to only natural air. It is assumed that all facilities can be considered as using windrow composting (Petersen & Hansen, 2003).

Composting is performed with simple technology in Denmark; this implies that temperature, moisture and aeration are not consistently controlled or regulated. Temperature is measured but not controlled, moisture is regulated by watering the windrows in respect to weather conditions and aeration is assisted by turning the windrows (Petersen & Hansen, 2003).

During composting a fraction of the degradable organic carbon (DOC) in the waste material is converted into CO. Even though the windrows are occasionally turned to support aeration, anaerobic sections are inevitable and will cause a small emission of CH_4. In the same manner, aerobic biological digestion of N leads to an emission of NO_X, while the anaerobic decomposition leads to the emission of NH_3 (IPCC, 2006).

Activity data

All Danish waste treatment plants are obligated to statutory registration and reporting of all waste entering and leaving the plants. All waste streams are weighed, categorised with a waste type and a type of treatment and registered to the ISAG waste information system, which contain data for 1995-2009 (ISAG, 2010). For 2010 to 2013 data was from the new waste data system was obtained from the Danish EPA. For 2013, the total amount of composted waste was allocated according to the fractional distribution between the four waste types in 2009. The new waste data system (WDS) replaces ISAG from 2010 and forward. Activity data for 2010-2014 are provided in table 6.3. Based on the approach of allocation the total amount of waste composted in 2010 to 2015, no visible data break are observed in the time series as visualised in Figure 6.1. It should however be mentioned that work is ongoing in regard to reallocating composted amounts according to EWC level 3 description, why adjustments in data and methodology may occur in the reporting year 2016.

Figure 6.1 illustrates the composted amount of waste divided in the four categories mentioned earlier.

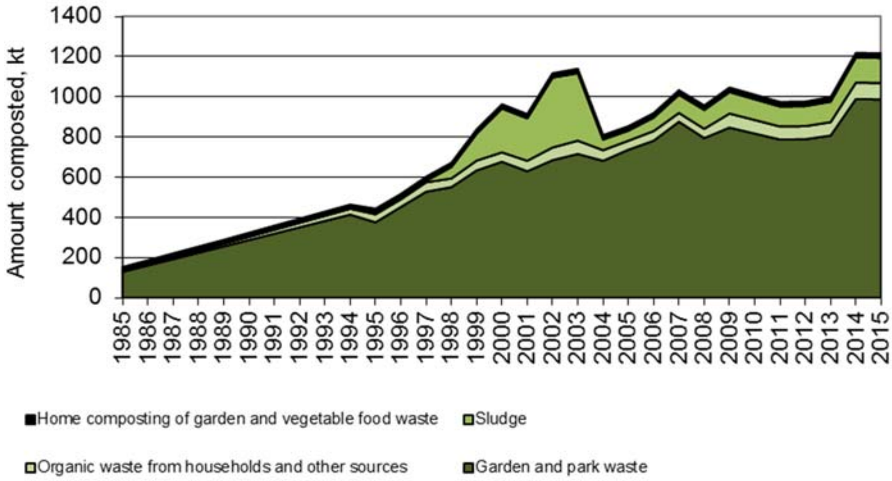

Figure 6.1 Amount of composted waste divided in garden and park waste (GPW), organic municipal solid waste (MSW), sludge and home composting of garden and food waste, these data are also shown in Table 6.3.

Activity data for the years 1995-2009 are collected from the ISAG database for the categories: "sludge", "organic waste from households and other sources" and "garden and park waste". Activities for 2010-2014 are collected from the new WDS.

The Danish legislation on sludge (DEPA, 2006) was implemented in the summer of 2003. This stated that composted sludge may only be used as a fertilizer on areas not intended for growing foods of any kind for at least 2-3 years. This restriction caused the amount of composted sludge to drop drastically from 2003 to 2004.

The trend in composting of sludge does not demonstrate a convincing trend that can be used for estimation of activity data for previous years. Since this activity is insignificant for 1995-1997 (1-2 %) it is assumed to be "not occurring" for 1985-1994.

The amount of organic waste from households composted in the years 1985-1994 is estimated by multiplying the number of facilities treating this type of waste with the average amount composted per facility in the years 1995-2001 (2.6-3.8 Gg per facility per year). Table 6.2 shows the number of composting plants grouped into plant types composting organic waste mixed with GPW (type1), GPW only (type 2) and GPW mixed with sludge and/or "other organic waste" (Type 3) described in the methodology section above.

Table 6.2 Number of composting facilities in the years 1985-2001.

Plant type*	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Type 1	2	2	3	3	4	5	6	7	8	9
Type 2	6	10	14	18	22	38	54	70	86	102
Type 3	0	0	0	0	0	1	2	2	3	4
Total	8	12	17	21	26	44	62	79	97	115

Continued

Facility type	1995	1996	1997	1998	1999	2000	2001
Type 1	13	14	13	14	13	11	9
Type 2	113	108	99	102	111	115	123
Type 3	9	9	11	10	10	7	10
Total	136	133	126	130	139	138	149

Type 1 waste treatment sites normally includes biogas producing facilities, but these are not included in this table.

*Petersen, 2001 and Petersen & Hansen, 2003

The ISAG activity data for composting of GPW include wood chipping. Compost data for GPW provided by Petersen (2001) and Petersen & Hansen (2003) show that for 1997-2001, wood chipping accounts for about 3 % of the total chosen ISAG activity data for GPW. Activity data for GPW for the years 1985-1994 and 2010-2013 are estimated by extrapolating the trend.

The last waste type involved in composting is home composting of garden waste and vegetable waste. The activity data for this category are known from Petersen & Kielland (2003) to be 21.4 Gg in 2001. It is assumed that the following estimates made by Petersen & Kielland (2003) are valid for all years 1985-2014:

- 28 % of all residential buildings with private gardens (including summer cottages) are actively contributing to home composting.
- 14 % of all multi-dwelling houses are actively contributing to home composting.
- 50 kg waste per year will on average be composted at every contributing residential building.
- 10 kg waste per year will on average be composted at every contributing multi-dwelling house.

Multi-dwelling houses include apartment buildings and it is very uncommon for people in these types of buildings to compost their bio-waste and the average amount of composted waste is therefore lower in spite of the higher number of residents. Statistics on the total number of occupied residential buildings, summer cottages and multi-dwelling houses are available at the Statistics Denmark's website.

The calculated activity data for home composting of garden and vegetable waste are shown in Table 6.3 and Annex 3E-5.

Table 6.3 Activity data composting, kt.

	1985	1990	1995	2000	2005	2010	2013	2014	2015
Composting of garden and park waste	130	288	376	677	737	817	808	989	987
Composting of organic waste from households and other sources	5	16	40	47	45	68	67	82	82
Composting of sludge	NO	NO	7	218	50	103	102	125	125
Home composting of garden and vegetable food waste	19	20	21	21	22	23	23	23	23
Total	154	324	444	963	854	1011	999	1219	1216

NO = Not occurring.

Emission factors

The emissions from composting strongly depend on both the composition of the treated waste and on process conditions such as aeration, mechanical agitation, moisture control and temperature pattern (Amlinger et al., 2008).

The emission factors provided in Table 6.4 are considered the best available for the calculation of Danish national emissions from composting.

Table 6.4 Composting emission factors, per Mg.

	Composting of garden and park waste (GPW)	Composting of organic waste	Composting of sludge	Home composting of garden and vegetable food waste
Unit	Kg	Kg	kg	kg
NO_x	NAV	NAV	NAV	NAV
CO	0.56	NAV	NAV	0.08
NH_3	0.66	0.24	0.31	0.63
Source	Boldrin et al., 2009	EEA, 2009	MST, 2013	Boldrin et al., 2009

Emissions from Boldrin et al. (2009) are given in percentage of total degraded carbon or nitrogen respectively. The factors shown in Table 6.4 are calculated by assuming 37.5 % DOC in dry matter, 2 % N in dry matter and 50 % moisture in the waste (Boldrin et al., 2009).

Boldrin et al. (2009) and MST (2013) do not directly provide any emission factors, the following assumptions were made to derive the factors shown in Table 6.4:

- 0.5 % N per dry matter waste water sludge
- 25 % moisture in waste water sludge.
- 2 % N per dry matter garden waste (incl. home composting)
- DOC is 25-50 % in garden waste (incl. home composting)
- 50 % moisture in garden waste (incl. home composting)

Emissions

Table 6.5 show the total national emissions from composting. The full time series is shown in Annex 3E-6.

Table 6.5 National emissions from composting, Mg.

	1985	1990	1995	2000	2005	2010	2013	2014	2015
CO	74.6	163.5	213.1	382.4	416.2	461.4	455.9	558.2	557.0
NH_3	99.0	206.5	273.2	538.8	526.5	601.8	594.8	725.5	724.0

6.2.2 Biogas production

Emissions from biogas production are divided and reported in different sectors according to waste type and method.

Methodology

Emissions from the combustion of biogas regardless of the origin are included in the energy sector and are allocated to the appropriate subsector in the Danish energy statistics. See this IIR Chapter 3, Energy.

The reduced emissions from biogasified versus raw manure spread on agricultural soils are described in the agricultural sector in Chapter 5.

Fugitive emissions of NMVOC and NH_3 from anaerobic digestion of sludge from wastewater treatment should be included in the NFR source category 5D Wastewater treatment and discharge. However, NMVOC and NH_3 emission from anaerobic digestion of sludge from wastewater treatment are not presently included in the submission but should be investigated and possibly added to this chapter to the extent that emissions originates from the digester tank, while the emissions originating from wastewater treatment processes should be described and included in Chapter 6.4.

Emissions that may be presented in this section in the future include fugitive emissions from the digester tank at the wastewater treatment plants treating the sludge by anaerobic digestion and emissions from combustion of biogas at the biogas production plants (own production and use).

Fugitive emissions from anaerobic digestion of bio-waste is to be included in this chapter, but fugitive emissions from storage, pre- and post-treatment of the digestate should be included in the relevant chapters as appropriate.

6.3 Waste incineration

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 3.2. Flaring off-shore and in refineries are included under NFR sector 1B2c, for documentation please refer to Chapter 3.4. No flaring in chemical industry occurs in Denmark.

6.3.1 Human cremation

The incineration of human corpses is a common practice that is performed on an increasing percentage of the deceased. All Danish crematoria use optimised and controlled cremation facilities, with temperatures reaching 800-850 °C, secondary combustion chambers, controlled combustion air flow and regulations for coffin materials.

However, the emissions of especially Hg caused by cremations can still contribute to a considerable part of the total national emissions. In addition to the most frequently discussed emissions of Hg and PCDD/Fs (dioxins and furans), are the emissions of compounds like SO_2, NO_x, NMVOC, CO, other heavy metals (As, Cd, Cr, Cu, Ni, Pb, Se, Zn), particulate matter, HCB, PAHs and PCBs.

Crematoria are usually located within cities, close to residential areas and normally, their stacks are relatively low. Therefore environmental and human exposure is likely to occur as a result of emissions from cremation facilities.

Methodology

During the 1990es all Danish crematoria were rebuilt to meet new standards. This included installation of secondary combustion chambers and in most cases, replacement of old primary combustion chambers (Schleicher et al., 2001). All Danish crematoria are therefore performing controlled incinerations with a good burn-out of the gases, and a low emission of pollutants.

Following the development of new technology, the emission limit values for crematoria were lowered again in January 2011. These new standards were originally expected from January 2009 but were postponed two years for existing crematoria.

Table 6.9 shows a comparison of the emission limit values from February 1993 and the new standard limits.

Table 6.9 Emission limit values mg per Nm^3 at 11 % O_2.

Component	1993 standard*	2011 standard**
Total dust	80	10
CO	50	50
Hg	No demands	0.1
Other demands:		
Stack height	3 m above rooftop	3 m above rooftop
Temperature in stack	Minimum 150 °C	Minimum 110 °C
Flue gas flow in stack	8 – 20 m/s	No demands
Temperature in after burner	850 °C	800 °C
Residence time in after burner	2 seconds	2 seconds
Odour	The crematory must not cause noticeable odour in the surroundings	The crematory must not cause odour nuisance outside the crematory perimeter, that is significant according to the supervisory authority

* Schleicher et al., 2001;**Schleicher & Gram, 2008.

To meet the new standards, some crematoria have been rebuilt to larger capacity while others are closed (MILIKI, 2006). In 2011, there were 26 operating crematoria in Denmark, some with multiple furnaces (DKL, 2015).

Crematoria that are not closed are equipped with flue gas cleaning (bag filters with activated carbon). The use of air pollution control devices, and activated carbon, for the removal of Hg will also reduce the flue gas concentration of dioxins, PAHs and odour. Existing knowledge on the reduction efficiencies justifies are presented in Schleicher & Gram (2008).

Around half of the Danish crematoria are currently connected to the district heating system and in addition, a few crematoria produce heat for use in their own buildings. The bag filter cleaning system requires that the flue gas is cooled down to 125-150 °C, and the cheapest way to do so is to use the surplus heat in the district heating system (DKL, 2009). The heat contribution from crematoria is negligible compared to the total district heat production and is not part of the Danish energy statistics.

Activity data

Table 6.10 shows the time series of total number of deceased persons (Statistics Denmark, 2016), number of cremations and the fraction of cremations in relation to the total number of deceased (DKL, 2016). Annex 3E-1 presents data for the entire time series.

Table 6.10 Data human cremations (DKL 2016, Statistics Denmark 2016).

	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
Nationally deceased	55 939	58 378	60 926	63 127	57 998	54 962	54 368	52 471	51 340	52 555
Cremations	33 986	36 705	40 991	43 847	41 651	40 758	42 050	42 349	41 532	43 238
Cremation fraction, %	60.8	62.8	67.3	69.5	71.8	74.2	77.3	80.7	80.9	82.3

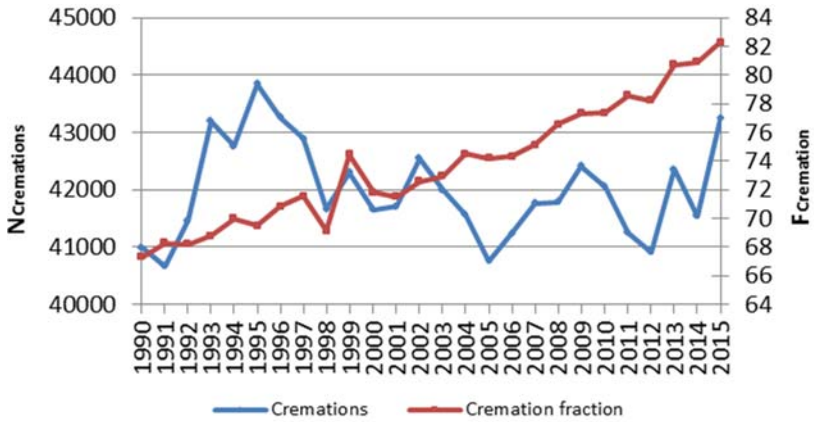

Figure 6.3 Illustration of the development in cremations (DKL 2016), where the number of cremations, $N_{cremations}$, is shown at the left Y-axis. The cremation percentage, $F_{cremations}$, shows the percentage of cremated deceased of the total number of deceased for the years 1984 to 2015. Data for 1980-1983 are estimated values, for details on the estimation, see Annex 3E-1.

Even though the total number of annual cremations is fluctuating, the cremation percentage has been steadily increasing since 1984, and is likely to continue to increase.

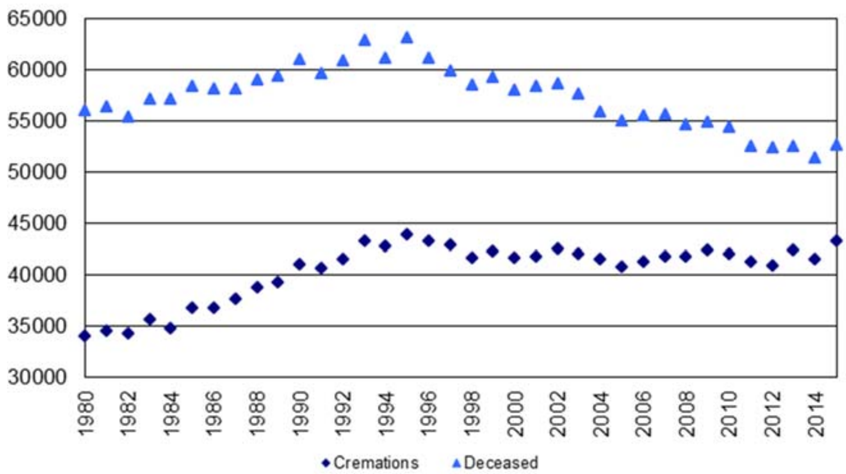

Figure 6.4 Trends of the activity data for cremation of human corpses and the number of deceased persons.

Figure 6.4 presents the trend of the number of deceased persons together with the activity data for human cremation. The figure shows a direct connection between the number of deceased and the activity of human cremation as the two trends are quite similar. Figure 6.4 also shows the effect of the increasing fraction of cremations per deceased, as the number of cremations is not decreasing along with the number of deceased. The percentage of the deceased being cremated has increased from 67 % in 1990 to 82 % in 2015 as shown in Figure 6.3, Table 6.10 and Annex 3E-1.

Emission factors

For crematoria, emissions are calculated by multiplying the total number of cremations by the emission factors. The emission factors are gathered from literature and are based on the measurements performed in countries that are comparable with Denmark. By comparable is meant countries that use similar incineration processes, similar cremation techniques including support fuel and have a similar composition of sources to lifetime exposure, lifetimes and coffins.

Table 6.11 lists the emission factors in the time period 1980-2010 and their respective references. As mentioned earlier, 2011 is year one after installation of bag filters with activated carbon at all Danish crematoria, causing the emission factors for particles, heavy metals, PAhs and PCDD/Fs to decrease quite drastically (Schleicher & Gram, 2008).

Table 6.11 Emission factors for human cremation with references.

Pollutant name	Unit	Emission factor*	Reference
SO_2	kg/body	0.113	Santarsiero et al., 2005
NO_X	kg/body	0.825	Santarsiero et al., 2005
NMVOC	kg/body	0.013	EEA, 1996
CO	kg/body	0.010	Schleicher et al., 2001
NH_3		NA	
TSP	kg/body	0.039	Webfire, 2012
PM_{10}	kg/body	0.035	Webfire, 2012
$PM_{2.5}$	kg/body	0.031	Webfire, 2012
As	g/body	0.014	Webfire, 2012
Cd	g/body	0.005	Webfire, 2012
Cr	g/body	0.014	Webfire, 2012
Cu	g/body	0.012	Webfire, 2012
Hg	g/body	1.12	Kriegbaum et al., 2005
Ni	g/body	0.017	Webfire, 2012
Pb	g/body	0.030	Webfire, 2012
Se	g/body	0.020	Webfire, 2012
Zn	g/body	0.160	Webfire, 2012
HCB	mg/body	0.152	Toda, 2006
PCDD/F	µg I-TEQ/body**	0.350	Schleicher et al., 2001
Benzo(b)flouranthene	µg/body	7.21	Webfire, 2012
Benzo(k)flouranthene	µg/body	6.44	Webfire, 2012
Benzo(a)pyrene	µg/body	13.20	Webfire, 2012
Indeno(1,2,3-c-d)pyrene	µg/body	6.99	Webfire, 2012
PCBs	mg/body	0.414	Toda, 2006

*NA = not applicable. ** I-TEQ: International Toxicity Equivalents.

The average body weight of cremated corpses is assumed to be 65 kg.

Flue gas cleaning efficiencies are based on measurements performed at Danish crematoria and expert judgements, and set equal to 99 % for PCDD/Fs, particles, PAHs and heavy metals. These abatement efficiencies are implemented from 2011. For all other pollutants the emission factors are as listed in Table 6.11.

It has not been possible to find data for ammonia. Ammonia might appear in lesser amounts, but will most likely be converted to NO_X at the high incineration temperatures.

There might for some emission factors be included a small part of the support fuel (natural gas) if the measurements were taken early in the burning process. This would then be a double counting since fuel for cremation is reported under NFR code 1A4a, commercial and institutional. However, this double counting is considered miniscule.

Emissions

Table 6.12 shows the total emissions from selected years. To view the entire time series 1980-2015, see Annex 3E-3. The dioxin emission is given in I-TEQ;

i.e. International Toxicity Equivalents which is a weighted addition of congener toxicity with reference to 2,3,7,8-TCDD (Seveso-dioxin).

Emissions from human cremations have been steady over the last two decades but have decreased strongly for the pollutants TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/Fs and PAHs from 2010 to 2011 because of the installation of bag filters with activated carbon.

Table 6.12 Total national emissions from human cremations.

	Unit	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
SO_2	Mg	3.83	4.14	4.62	4.94	4.70	4.60	4.74	4.77	4.68	4.88
NO_X	Mg	28.04	30.28	33.82	36.17	34.36	33.63	34.69	34.94	34.26	35.67
NMVOC	Mg	0.442	0.477	0.533	0.570	0.541	0.530	0.55	0.55	0.54	0.56
CO	Mg	0.340	0.367	0.410	0.438	0.417	0.408	0.42	0.42	0.42	0.43
TSP	Mg	1.31	1.42	1.58	1.69	1.61	1.57	1.62	0.02	0.02	0.02
PM_{10}	Mg	1.18	1.27	1.42	1.52	1.45	1.41	1.46	0.01	0.01	0.02
$PM_{2.5}$	Mg	1.18	1.27	1.42	1.52	1.45	1.41	1.30	0.01	0.01	0.01
As	kg	0.46	0.50	0.56	0.60	0.57	0.55	0.57	0.01	0.01	0.01
Cd	kg	0.17	0.18	0.21	0.22	0.21	0.21	0.21	0.00	0.00	0.00
Cr	kg	0.46	0.50	0.56	0.59	0.56	0.55	0.57	0.01	0.01	0.01
Cu	kg	0.42	0.46	0.51	0.55	0.52	0.51	0.52	0.01	0.01	0.01
Hg	kg	38.03	41.07	45.87	49.06	46.61	45.61	47.05	0.47	0.46	0.48
Ni	kg	0.59	0.64	0.71	0.76	0.72	0.71	0.73	0.01	0.01	0.01
Pb	kg	1.02	1.10	1.23	1.32	1.25	1.22	1.26	0.01	0.01	0.01
Se	kg	0.67	0.73	0.81	0.87	0.82	0.81	0.83	0.01	0.01	0.01
Zn	kg	5.44	5.88	6.56	7.02	6.67	6.53	6.73	0.07	0.07	0.07
HCB	g	5.15	5.56	6.21	6.65	6.31	6.18	6.37	6.42	6.30	6.55
PCDD/F	mg	11.90	12.85	14.35	15.35	14.58	14.27	14.72	0.15	0.15	0.15
benzo(b)flouranthene	g	0.25	0.26	0.30	0.32	0.30	0.29	0.30	0.00	0.00	0.00
benzo(k)flouranthene	g	0.22	0.24	0.26	0.28	0.27	0.26	0.27	0.00	0.00	0.00
benzo(a)pyrene	g	0.45	0.48	0.54	0.58	0.55	0.54	0.56	0.01	0.01	0.01
indeno(1,2,3-c-d)pyrene	g	0.24	0.26	0.29	0.31	0.29	0.28	0.29	0.00	0.00	0.00
PCB	g	14.05	15.18	16.95	18.13	17.22	16.86	17.39	17.51	17.18	17.88

6.3.2 Animal cremation

The incineration of animal carcasses in animal crematoria follows much the same procedure as human cremation. Animal crematoria use similar two chambered furnaces and controlled incineration. However, animal carcasses are burned in special designed plastic (PE) bags rather than coffins. Emissions from animal cremation are similar to those from human cremation, with the exception of Hg which mainly stems from amalgam tooth fillings.

Animal cremations are performed in two ways, individually where the owner often pays for receiving the ashes in an urn or collectively which is most often the case with animal carcasses that are left at the veterinarian.

Methodology

Open burning of animal carcasses is illegal in Denmark and is not occurring and small-scale incinerators are not known to be used at Danish farms. Livestock that is diseased or in other ways unfit for consumption is disposed of through rendering plants, incineration of livestock carcasses is illegal and these carcasses are therefore commonly used in the production of fat and soap at Daka Bio-industries.

The only animal carcasses that are approved for cremation in Denmark are deceased pets and animals used for experimental purposes, where the incineration must take place at a specialised animal crematorium. There are four animal crematoria in Denmark but one of these is situated at a waste incineration company in northern Jutland called AVV. The specially designed cremation furnaces are at this location connected to the flue gas cleaning equipment of the municipal waste incineration plant with energy recovery and the emission from the cremations are therefore included in the annual inventory from AVV. Consequently, this crematorium is included in Chapter 3.2 Stationary combustion. Therefore only three animal crematoria are included in this sector.

Animal by-products are regulated under the EU commission regulation no. 142/2011. This states that animal crematoria must be approved by the authority and comply either with the EU directive (2000/76/EC) on waste incineration or with Regulation (EC) No. 1069/2009 (EC, 2011).

The incineration of animal carcasses is, as the incineration of human corpses, performed in special incineration chambers. All Danish animal crematoria have primary combustion chambers with temperatures around 850 ºC and secondary combustion chambers with temperatures around 1100 ºC. The support fuel used at the Danish facilities is natural gas.

Emissions from pet cremations are calculated for SO_2, NO_x, NMVOC, CO, NH_3, particles, heavy metals (As, Cd, Cr, Cu, Ni, Pb, Se, Zn), HCB, dioxins/furans, PAHs and PCBs. For the pollutants SO_2, NO_x, CO, As, Se, HCB, PAHs and PCBs, emissions are estimated by using the same emission factors as for human cremation.

Activity data

Activity data for animal cremation are gathered directly from the animal crematoria. There is no national statistics available on the activity from these facilities. The precision of activity data therefore depends on the information provided by the crematoria.

The following Table 6.13 lists the four Danish pet crematoria, their foundation year and provides each crematorium with an id letter.

Table 6.13 Animal crematoria in Denmark.

Id	Name of crematorium	Founded in
A	Dansk Dyrekremering ApS	May 2006
B	Ada's Kæledyrskrematorium ApS	Unknown, existed in more than 30 years, assumed 1980
C	Kæledyrskrematoriet	2006
D	Kæledyrskrematoriet v. Modtagestation Vendsyssel I/S	-

Crematoria D is situated at the AVV municipal waste incineration site and the emissions from this site are, as previously mentioned, included in the annual emission reporting from AVV and consequently included in the energy sector as waste incineration with energy recovery. Therefore, only crematoria A-C are considered in this chapter.

Table 6.14 lists the activity data for crematoria A-C. The entire dataset for 1980-2014 is available in Annex 3E-2.

Table 6.14 Activity data. Source: direct contact with all Danish crematoria.

	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
Total, Mg	50	100	150	200	443	762	1449	1146	1161	1119

Crematorium B delivered exact annual activity data for the years 1998-2015. They were not certain about the founding year but believe to have existed since the early 1980es. It is assumed that crematorium B was founded at January 1st 1980 and activity data for 1980-1997 must therefore be estimated.

Statistical data describing the national consumption for pets including food and equipment for pets were evaluated as surrogate data. These statistical data show an increase of consumption of 6 % from 1998 to 2000, in the same period the amount of cremated animal carcasses increased with 89 % and no correlation seems to be present. Since there are no other available data on the subject of pets, it is concluded that there are no surrogate data available.

It is not possible to extrapolate data linearly back to 1980 because the activity, due to the steep increase, in this case would become negative from 1993 and back in time.

The activity data for animal cremation for the period of 1980-1997 are estimated by expert judgement. The estimated data are shown in Table 6.14, Figure 6.5 and Annex 3E-2.

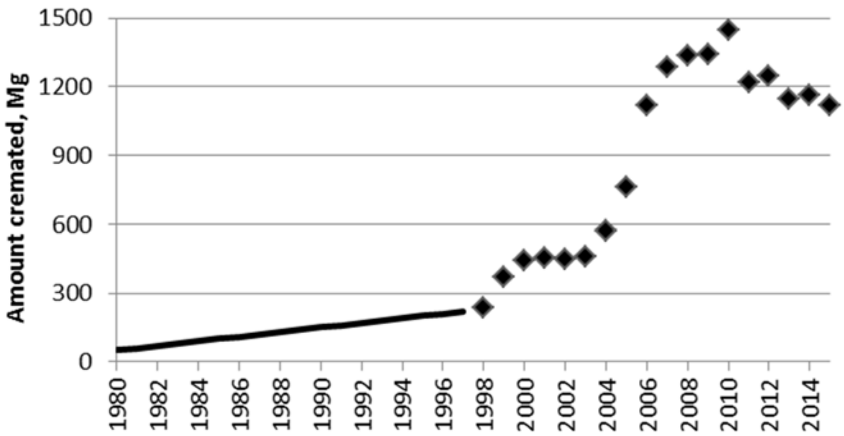

Figure 6.5 The amount of animal carcasses cremated, in Mg. Data from 1998-2015 are delivered by the crematoria and is considered to be exact; these data are marked as points. Data from 1980-1997 are estimated and are shown as the thick line in the figure.

Emission factors

Concerning the incineration of animal carcasses in animal crematoria there is not much literature to be found. The EMEP/EEA Guidebook (EEA, 2009) is the only available source to emission factors for NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$ and PCDD/F.

Chen et al. (2004) is the only available source to emission factors for the heavy metals Cd, Cr, Cu, Ni, Pb and Zn.

There is a good agreement between the emission factors for animal and human cremation for PCDD/F and a relatively good agreement for NMVOC, TSP, PM_{10}, $PM_{2.5}$ and heavy metals.

The emission factors of the remaining pollutants SO_2, NO_x, CO, As, Se, HCB, PAHs and PCBs are collected from the literature search on human cremation, and it is assumed that humans and animals are similar in composition for this purpose. Emission factors from human cremation are recalculated to match the activity data for animal cremation, emission per Mg.

No data were available for the emission of Hg in animal cremations. The Hg emission factor for human cremation is not transferable to animal cremations, because the Hg emission from human cremations primarily stems from tooth fillings.

Table 6.15 lists the emission factors and their respective references.

Table 6.15 Emission factors for animal cremation with references, per Mg.

Pollutant	Unit	Emission factor	Source
SO_2	kg	1.73*	Santarsiero et al, 2005
NO_X	kg	12.69*	Santarsiero et al, 2005
NMVOC	kg	2 00	EEA, 2009
CO	kg	0.15*	Schleicher et al., 2001
NH_3	kg	1.90	EEA, 2009
TSP	kg	2.18	EEA, 2009
PM_{10}	kg	1.53	EEA, 2009
$PM_{2.5}$	kg	1.31	EEA, 2009
As	g	0.21*	Webfire, 2012
Cd	g	0.01	Chen et al., 2004
Cr	g	0.07	Chen et al., 2004
Cu	g	0.02	Chen et al., 2004
Hg	-	NAV	-
Ni	g	0.06	Chen et al., 2004
Pb	g	0.18	Chen et al., 2004
Se	g	0.30*	Webfire, 2012
Zn	g	0.19	Chen et al., 2004
HCB	mg	2.33*	Toda, 2006
PCDD/F	µg I-TEQ	10.00	EEA, 2009
Benzo(b)flouranthene	mg	0.11*	Webfire, 2012
Benzo(k)flouranthene	mg	0.10*	Webfire, 2012
Benzo(a)pyrene	mg	0.20*	Webfire, 2012
Indeno(1,2,3-c-d)pyrene	mg	0.11*	Webfire, 2012
PCB	mg	6.36*	Toda, 2006

* Emission factors from human cremations.

Emissions

For the incineration of animal carcasses, emissions are calculated by multiplying the amount of incinerated animals by the emission factors.

Emissions are summarised in Table 6.16, while emissions for the full time series are shown in Annex 3E-4.

Table 6.16 Emissions from animal cremation.

	unit	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
SO_2	Mg	0.09	0.17	0.26	0.35	0.77	1.32	2.51	1.99	2.01	1.94
NO_X	Mg	0.63	1.27	1.90	2.54	5.63	9.68	18.39	14.57	14.74	14.20
NMVOC	Mg	0.10	0.20	0.30	0.40	0.89	1.52	2.90	2.30	2.32	2.24
CO	Mg	0.01	0.02	0.02	0.03	0.07	0.12	0.22	0.18	0.18	0.17
NH_3	Mg	0.10	0.19	0.29	0.38	0.84	1.45	2.75	2.18	2.21	2.13
TSP	Mg	0.11	0.22	0.33	0.44	0.97	1.66	3.16	2.50	2.53	2.44
PM_{10}	Mg	0.08	0.15	0.23	0.31	0.68	1.17	2.22	1.76	1.78	1.71
$PM_{2.5}$	Mg	0.07	0.13	0.20	0.26	0.58	1.00	1.90	1.50	1.52	1.47
As	kg	0.01	0.02	0.03	0.04	0.09	0.16	0.30	0.24	0.24	0.23
Cd	kg	0.001	0.001	0.002	0.002	0.004	0.01	0.01	0.01	0.01	0.01
Cr	kg	0.004	0.01	0.01	0.01	0.03	0.05	0.10	0.08	0.08	0.08
Cu	kg	0.001	0.002	0.003	0.004	0.01	0.02	0.03	0.02	0.02	0.02
Ni	kg	0.003	0.01	0.01	0.01	0.03	0.05	0.09	0.07	0.07	0.07
Pb	kg	0.01	0.02	0.03	0.04	0.08	0.14	0.26	0.21	0.21	0.20
Se	kg	0.02	0.03	0.05	0.06	0.13	0.23	0.44	0.35	0.35	0.34
Zn	kg	0.01	0.02	0.03	0.04	0.08	0.14	0.28	0.22	0.22	0.21
HCB	g	0.12	0.23	0.35	0.47	1.03	1.78	3.38	2.68	2.71	2.61
PCDD/F	mg	0.50	1.00	1.50	2.00	4.43	7.62	14.49	11.48	11.61	11.19
benzo(b)flouranthene	g	0.01	0.01	0.02	0.02	0.05	0.08	0.16	0.13	0.13	0.12
benzo(k)flouranthene	g	0.005	0.01	0.01	0.02	0.04	0.08	0.14	0.11	0.11	0.11
benzo(a)pyrene	g	0.01	0.02	0.03	0.04	0.09	0.15	0.29	0.23	0.24	0.23
indeno(1,2,3-c-d)pyrene	g	0.01	0.01	0.02	0.02	0.05	0.08	0.16	0.12	0.12	0.12
PCB	g	0.32	0.64	0.95	1.27	2.82	4.85	9.22	7.30	7.39	7.12

6.4 Wastewater handling

According to the EMEP/EEA Guidebook wastewater handling can be a source for emissions of POPs, NMVOC, NH_3 and CO. Of these pollutants, only NMVOC is thought to be significant.

For the current submission Denmark has not estimated emissions of air pollutants from wastewater handling. The EMEP/EEA Guidebook contains a default NMVOC emission factor for latrines and wastewater handling, however due to limited resources it has not been possible to estimate such emissions.

6.5 Other waste

This category is a catch all for the waste sector. Emissions in this category could stem from e.g. sludge spreading, accidental fires and other combustion without energy recovery.

6.5.1 Sludge spreading

Sludge from wastewater treatment plants is only spread out in the open with the purpose of fertilising agricultural land. Emissions that derive from this activity are included in Chapter 5.

6.5.2 Accidental building fires

Emissions from accidental fires are categorised under the NFR category 5E Other waste. Pollutants that are emitted from building fires include SO_2, NO_x, NMVOC, CO, heavy metals (As, Cd, Cr, Cu, Hg, Pb), particles, PCDD/F and PAHs.

Methodology

Emissions from building fires are calculated by multiplying the number of building fires with selected emission factors. Six types of buildings are distinguished with different emission factors: detached houses, undetached houses, apartment buildings, industrial buildings, additional buildings and containers.

Activity data

In January 2005 it became mandatory for the local authorities to register every rescue assignment in the *online data registration- and reporting system called ODIN, ODIN is developed and run by* the Danish Emergency Management Agency (DEMA, 2007).

Activity data for accidental building fires are given by ODIN (DEMA, 2012). Fires are classified in four categories: full, large, medium and small. The emission factors comply for full scale fires and the activity data are therefore recalculated as a full scale equivalent where it is assumed that a full, large, medium and a small scale fire leads to 100 %, 75 %, 30 % and 5 % of a full scale fire respectively.

In practice, a full scale fire is defined as a fire where more than three fire hoses were needed for extinguishing the fire, a full scale fire is considered as a complete burnout. A large fire is in this context defined as a fire that involves the use of two or three fire hoses for fire extinguishing and is assumed to typically involve the majority of a house, an apartment, or at least part of an industrial complex. A medium size fire is in this context defined as a fire involving the use of only one fire hose for fire-fighting and will typically involve a part of a single room in an apartment or house. And a small size fire is in this context defined as a fire that was extinguished before the arrival of the fire service, extinguished by small tools or a chimney fire.

The total number of registered fires is known for the years 1989-2014. For the years 2007-2014 the total number of registered building fires is known with a very high degree of detail. Data for 2015 have been kept constant at 2014 levels.

Table 6.17 shows the occurrence of all types of fires (registered for 1989-2012) and the occurrence of building fires (2007-2014) registered at DEMA. The 1980-1988 data for all fires are estimated to be the average of 1989-2010 data. In 2007-2015 the average per cent of building fires, in relation to all fires, was 60 %. The total numbers of building fires 1980-2006 are calculated using this percentage. The full time series is presented in Annex 3E-7.

Table 6.17 Occurrence of all fires and building fires.

	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
All fires	17 751	17 751	17 025	19 543	17 174	16 551	16 728	12 734	12 454	12 454
Building fires	10 621	10 621	10 187	11 694	10 276	9903	9325	9893	9473	9473

The building fires that occurred in the years 2007-2015 are subcategorised into six building types; detached houses, undetached houses, apartment buildings, industrial buildings, additional buildings and container fires.

Table 6.18 states the average registered activity data for building fires for the years 2007-2010, divided in both damage size and building type. This describes the average share of building fires from 2007-2010 of a certain type and size, in relation to all building fires in the same four years period.

Table 6.18 Registered occurrence of building fires, average of 2007-2010 fires, %. (DEMA).

Size	Detached	Undetached	Apartment	Industry	Additional	Container	All building fires
Full	2.46	0.50	0.31	0.73	0.44	0.17	4.61
Large	4.01	1.14	1.09	1.69	3.08	1.92	12.93
Medium	5.24	2.33	6.15	2.92	4.30	18.46	39.40
Small	11.77	4.24	12.64	5.36	4.79	4.27	43.06
All	23.47	8.21	20.19	10.70	12.61	24.82	100.00

It is assumed that the average percentages provided by the years 2007-2010 shown in Table 6.18 are compliable for the years 1980-2006. Hereby, similar activity data for building fires can be estimated back to 1980.

By applying the damage rates of 100 %, 75 %, 30 % and 5 % corresponding to the damage sizes full, large, medium and small, a full scale equivalent can be determined. Table 6.19 shows the calculated full scale equivalents (FSE). The full time-series is presented in Annex 3E-8.

Table 6.19 Accidental building fires full scale equivalent activity data.

	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
Container fires	782	782	750	861	756	729	594	584	584	584
Detached house fires	810	810	777	892	784	755	833	761	660	660
Undetached house fires	240	240	231	265	233	224	194	162	318	318
Apartment building fires	383	383	367	421	370	357	348	316	299	299
Industry building fire	334	334	320	368	323	311	281	275	751	751
Additional building fires	455	455	437	501	440	424	429	619	577	577

Emission factors

For building fires, emissions are calculated by multiplying the number of full scale equivalent fires with the emission factors. The emission factors are produced from different measurements and assumptions from literature and expert judgements. When possible, emission factors are chosen that represent conditions that are comparable to Denmark. By comparable is meant countries that have similar building traditions, with respect to the materials used in building structure and interior.

In the process of selecting the best available emission factors for the calculation of the emissions from Danish accidental building fires, a range of different sources has been studied. Unfortunately it is difficult to do an interrelated comparison of the different sources because they all establish emission factors on different assumptions and many of these assumptions are not fully accounted for.

Table 6.20 lists the emission factors that are used for the year 2015 and their respective references.

Table 6.20 Emission factors building fires.

Compound	Unit /fire	Detached house	Undetached house	Apartment building	Industrial building	Additional building	Container	Reference
SO_2	kg	266.6	214.4	124.5	802.9	32.1	2.4	Blomqvist et.al. 2002
NO_x	kg	19.9	16.0	9.3	24.0	1.0	3.0	NAEI, 2009
NMVOC*	kg	99.6	80.1	46.5	120.0	4.8	0.7	NAEI, 2009
CO	kg	278.9	224.3	130.3	336.0	13.4	42.0	NAEI, 2009
TSP	kg	143.8	61.6	43.8	27.2	1.1	23.2	Aasestad, 2008**
PM_{10}	kg	143.8	61.6	43.8	27.2	1.1	23.2	Aasestad, 2008**
$PM_{2.5}$	kg	143.8	61.6	43.8	27.2	1.1	23.2	Aasestad, 2008**
As	g	1.35	0.58	0.41	0.25	0.01	0.22	Aasestad, 2008**
Cd	g	0.85	0.36	0.26	0.16	0.01	0.14	Aasestad, 2008**
Cr	g	1.29	0.55	0.39	0.24	0.01	0.21	Aasestad, 2008**
Cu	g	2.99	1.28	0.91	0.57	0.02	0.48	Aasestad, 2008**
Hg	g	0.85	0.36	0.26	0.16	0.01	0.14	Aasestad, 2008**
Pb	g	0.42	0.18	0.13	0.08	0.003	0.07	Aasestad, 2008**
PCDD/F*	mg	3.5	2.8	1.6	4.2	0.2	1.1	Hansen, 2000
Benzo[b]fluoranthene	g	12.6	10.1	5.9	15.2	0.6	1.9	NAEI, 2009
Benzo[k]fluoranthene	g	4.4	3.6	2.1	5.4	0.2	0.7	NAEI, 2009
Benzo[a]pyrene	g	8.0	6.4	3.7	9.6	0.4	1.2	NAEI, 2009
Indeno[1,2,3-cd]pyrene	g	8.6	6.9	4.0	10.4	0.4	1.3	NAEI, 2009

*Container fires have a different source than the other five categories; Blomqvist et.al. 2002, ** Personal contact with Kristin Aasestad has provided a correction of the units which are inaccurate in the text of Aasestad (2008)

Emission factors for detached, undetached and apartment fires depend on the annual average floor space; see Table 6.21. Industrial, additional and container fires on the other hand are assumed to have a constant size/volume throughout the time series. Emission factors for all building fires for 1980-2015 are shown in Annex 3E-9.

Emission factors from Aasestad (2008) are already specified for four of the six building types; detached houses, undetached houses, apartment buildings and industrial buildings. Aasestad (2008) and all other sources considered were altered to match the six building types. This alternation was performed simply by adjusting the average floor space for each of the building types respectively, whereas factors like loss rate and mass of combustible contents per area are not altered.

The average floor space in Danish buildings is stated in Table 6.21. The data are collected from Statistics Denmark and takes into account possible multiple building floors but not attics and basements. For the full time series see Annex 3E-10. The average floor space in industrial buildings, schools etc. is estimated to 500 square meters for all years and the average floor space for additional buildings, sheds etc. is estimated to 20 square meters for all years.

Table 6.21 Average floor space in building types (Statistics Denmark, 2016).

	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
Detached houses	154	154	156	155	156	162	163	166	167	167
Undetached houses	130	130	129	129	131	131	134	133	132	132
Apartment buildings	74	75	75	75	75	76	77	78	78	78

Emission factors from literature are given in mass emission per mass burned. For the calculation of these emission factors to a unit that matches, the activity data, the building masses are estimated using the same methodology as in Hansen (2000).

The total building masses are calculated using an average weight loss rate of 12.4 % (Persson et al., 1998) and data for the amount of combustible material in the building structure itself (Blomqvist et al., 2002) and the amount of combustible interior (Persson et al., 1998).

Emission factors for container fires cannot be calculated based on an average floor space but on an average mass. The average mass of a container is set to 1 Mg and covers all types of containers, from small residential garbage containers to large shipping containers and waste/goods in storage piles.

Building masses for 2015 are presented in Table 6.22.

Table 6.22 Building mass per building type.

	Unit	Detached house	Undetached house	Apartment building	Industry building	Additional building	Container
Average floor area	m^2	167	132	78	500	20	-
Building mass per floor area	kg/m^2	40	40	35	30	30	-
Total building mass*	Mg/fire	6.7	5.4	2.7	15.0	0.6	1

For further detail on the emission factors and calculations, please refer to Hjelgaard (2013).

Emissions

Table 6.23 shows the total emissions from building fires. The entire time series 1980-2015 is shown in Annex 3E-9.

Table 6.23 Emissions from building fires.

	unit	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
SO_2	Mg	580.4	581.3	559.3	640.2	565.2	552.4	542.98	519.33	904.50	904.50
NO_x	Mg	32.9	33.0	31.8	36.3	32.1	31.5	31.52	29.65	41.36	41.36
NMVOC	Mg	153.3	153.7	148.0	169.3	149.7	147.2	149.11	139.90	198.46	198.46
CO	Mg	460.7	461.6	444.5	508.4	449.5	441.2	64.61	60.62	86.00	86.00
TSP	Mg	175.8	175.8	168.6	193.5	170.1	163.9	168.78	154.98	162.27	162.27
PM_{10}	Mg	175.8	175.8	168.6	193.5	170.1	163.9	168.78	154.98	162.27	162.27
$PM_{2.5}$	Mg	175.8	175.8	168.6	193.5	170.1	163.9	168.78	154.98	162.27	162.27
As	kg	1.6	1.6	1.6	1.8	1.6	1.5	0.00	0.00	0.00	0.00
Cd	kg	1.0	1.0	1.0	1.1	1.0	1.0	0.00	0.00	0.00	0.00
Cr	kg	1.6	1.6	1.5	1.7	1.5	1.5	0.00	0.00	0.00	0.00
Cu	kg	3.7	3.7	3.5	4.0	3.5	3.4	0.00	0.00	0.00	0.00
Hg	kg	1.0	1.0	1.0	1.1	1.0	1.0	0.00	0.00	0.00	0.00
Pb	kg	0.5	0.5	0.5	0.6	0.5	0.5	0.00	0.00	0.00	0.00
PCDD/F	g I-TEQ	6.2	6.2	6.0	6.9	6.1	5.9	5.86	5.52	7.57	7.57
Benzo(b)fluoranthene	kg	20.8	20.9	20.1	23.0	20.3	20.0	19.96	18.78	26.20	26.20
Benzo(k)fluoranthene	kg	7.3	7.4	7.1	8.1	7.2	7.0	7.04	6.62	9.24	9.24
Benzo(a)pyrene	kg	13.2	13.2	12.7	14.5	12.8	12.6	12.61	11.86	16.54	16.54
Indeno(1,2,3-cd)pyrene	kg	14.3	14.3	13.8	15.7	13.9	13.7	13.66	12.85	17.92	17.92

6.5.3 Accidental vehicle fires

Pollutants that are emitted from accidental vehicle fires include SO_2, NO_x, NMVOC, CO, particulate matter, heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn), PCDD/F and PAHs.

Methodology

Emissions from vehicle fires are calculated by multiplying the mass of vehicle fires with selected emission factors. Emission factors are not available for different vehicle types, whereas it is assumed that all the different vehicle types leads to similar emissions. The activity data are calculated as an annual combusted mass by multiplying the number of different full scale vehicle fires with the Danish registered average weight of the given vehicle type.

Activity data

As with accidental building fires, data for accidental vehicle fires are available through the Danish Emergency Management Agency (DEMA). DEMA provides very detailed data for 2007-2014; the remaining years back to 1980 are estimated by using surrogate data.

Table 6.24 shows the occurrence of fires in general and vehicle fires registered at DEMA. In 2007-2010 the average per cent of vehicle fires, in relation to all fires, was 20 %. The total numbers of vehicle fires in 1980-2006 are calculated using this percentage. The full time series is presented in Annex 3E-7.

Table 6.24 Occurrence of all fires and vehicle fires.

Year	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
All fires	17751	17751	17025	19543	17174	16551	16728	12734	12454	12454
Vehicle fires	3497	3497	3354	3850	3383	3260	3459	2841	2981	2981

There are fourteen different vehicle categories. The activity data are categorised in passenger cars (lighter than 3500 kg), buses, light duty vehicles (vans and motor homes), heavy duty vehicles (trucks and tankers), motorcycles/mopeds, other transport, caravans, trains, boats, airplanes, bicycles, tractors, combine harvesters and machines.

In the same manner as accidental building fires, the 2007-2015 data from DEMA can be divided in four categories according to damage size. It is assumed that a full scale fire is a complete burnout of the given vehicle, and that a large, medium and small scale fire corresponds to 75 %, 30 % and 5 % of a full scale fire respectively. The total number of full scale equivalent (FSE) fires can be calculated for each of the fourteen vehicle categories for 2007-2015.

The total number of registered vehicles is known from Jensen et al. (2012) and Statistics Denmark (2015). By assuming that the share of vehicle fires in relation to the total number of registered vehicles, of every category respectively, can be counted as constant, the number of vehicle fires is estimated for the years 1980-2006. The numbers of registered vehicles from 1980 to 1984 are extrapolated based on the years 1985 to 1989, where a clear trend has been visible this trend has been extrapolated (e.g. passenger cars), otherwise the average value of 1985 to 1989 has been used (e.g. buses).

Table 6.25 states the total number of national registered vehicles and the number of full scale equivalent vehicle fires. The full time series 1980-2015 is shown in Annex 3E-14.

Table 6.25 Number of nationally registered vehicles and full scale equivalent vehicle fires.

	Passenger Cars		Buses		Light Duty Vehicles		Heavy Duty Vehicles	
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires
1980	1475109	429	8070	12	99168	10	47428	60
1985	1564319	455	8010	11	147874	14	46962	60
1990	1645454	479	8109	12	192317	19	45664	58
1995	1733242	504	14371	21	228074	22	48077	61
2000	1916364	557	15051	22	272386	27	50227	64
2005	2012216	585	15131	22	372674	36	49311	63
2010	2246675	646	14577	23	362385	38	44813	60
2013	2373251	514	12829	11	306421	32	41999	53
2014	2390554	514	12846	11	310417	32	43568	53
2015	2390554	514	12846	11	310417	32	43568	53

Continued

	Motorcycles/Mopeds		Caravans		Train		Boat	
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires
1980	220273	78			7284	9	2222	25
1985	191478	68			7284	9	2222	25
1990	163133	58	86257	24	7156	9	2324	26
1995	165272	58	95831	26	6854	8	1911	21
2000	233309	82	106935	29	4907	6	1759	19
2005	273904	97	121350	33	3195	4	1792	20
2010	301562	83	142354	37	2740	2	1773	16
2013	296522	82	142667	33	3048	2	1781	14
2014	295948	82	141418	33	3085	2	1722	14
2015	295948	82	141418	33	3085	2	1722	14

Continued

	Airplane		Tractor		Combined Harvester		Bicycle	Other Transport	Machine
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	FSE fires	FSE fires	FSE fires
1980	1060	1	139600	87	38781	64			
1985	1060	1	128700	80	35708	59			
1990	1055	1	131880	82	33594	56			
1995	1058	1	130028	81	27986	46			
2000	1070	1	111736	69	23272	39			
2005	1073	1	104551	65	20965	35			
2010	1152	1	89141	77	15986	32	4	58	94
2013	1069	0	79045	68	12998	18	2	50	115
2014	1053	0	79045	68	12998	18	2	50	115
2015	1053	0	79045	68	12998	18	2	50	115

The average weights of a passenger car, bus, light- and heavy commercial vehicle and motorcycle/moped are known for every year back to 1993 (Statistics Denmark, 2015), the weight of combined harvesters is based on an expert judgement. The corresponding weights from 1980 to 1992 and the average weight of the units from the remaining categories are estimated by an expert judgment; see Table 6.26 and Annex 3E-13.

Table 6.26 Average weight of different vehicle categories, kg.

	Cars	Buses	Light Duty Vehicles	Heavy Duty Vehicles	Motorcycles/ Mopeds	Combined Harvester
1980	850	10000	2000	15000	75	8000
1985	850	10000	2000	15000	75	8750
1990	850	10000	2000	15000	86	9500
1995	923	10807	2492	14801	97	10250
2000	999	11195	3103	15214	103	11000
2005	1068	11560	3793	13258	116	11750
2010	1144	11804	4498	11883	133	12500
2011	1154	11907	4296	11291	135	12650
2012	1160	11625	4150	10844	136	12800
2013	1162	11463	4046	10861	137	12950
2014*	1162	11463	4046	10861	137	12950
2015*	1162	11463	4046	10861	137	12950

*The statistics for 2014 and 2015 has been set equal to 2013.

It is assumed that the average weight of a boat equals that of a bus. That tractors and vans weigh the same and that trains and airplanes have the same average weight as trucks.

Bicycles, machines and other transport can only be calculated for the years 2007-2015 due to the lack of surrogate data (number of nationally registered vehicles). The average weight of a bicycle, caravan, machine and other transport is estimated as 12 kg, 90 % of a car, 50 % of a car and 40 % of a car respectively.

By multiplying the number of full scale fires with the average weight of the vehicles respectively, the total amount of combusted vehicle mass can be calculated. The result is shown in Table 6.27 and in Annex 3E-12.

Table 6.27 Burnt mass of different vehicle categories, Mg.

	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
Passenger cars	365	387	407	466	557	625	739	555	524	524
Buses	116	115	116	223	242	251	266	121	217	217
Light duty vehicles	19	29	37	55	82	138	171	118	105	105
Heavy duty vehicles	902	893	869	902	969	829	715	455	422	422
Motorcycle, moped	6	5	5	6	8	11	10	11	12	12
Other transport	-	-	-	-	-	-	33	26	27	27
Caravan	-	-	30	36	44	53	63	59	55	55
Train	130	130	128	121	89	51	24	18	18	18
Boat	246	246	257	228	218	229	189	100	111	111
Airplane	12	12	12	11	12	10	7	5	4	4
Bicycle	-	-	-	-	-	-	0	0	0	0
Tractor	174	160	164	202	216	247	347	330	346	346
Combine harvester	515	518	530	476	425	409	398	402	469	469
Machine	-	-	-	-	-	-	43	53	53	53
Total	2484	2495	2555	2727	2863	2858	3006	2253	2364	2364

Emission factors

In the process of selecting the most reliable emission factors for the calculation of the emissions from Danish vehicle fires, a range of different sources have been studied. Unfortunately it is difficult to make an interrelated comparison of the different sources because they all establish emission factors on different assumptions and many of these assumptions are not fully accounted for. Table 6.28 lists the accepted emission factors and their respective references.

Table 6.28 Emission factors vehicle fires.

	Unit, per Mg	Emission factor	Source
SO_2	kg	5	Lönnermark et al., 2004
NO_x	kg	2	Lemieux et al., 2004
NMVOC	kg	8.5	Lönnermark et al., 2004
CO	kg	63	Lönnermark et al., 2004
TSP	kg	38	Lönnermark et al., 2004
PM_{10}	kg	38	Lönnermark et al., 2004
$PM_{2.5}$	kg	38	Lönnermark et al., 2004
As	g	0.26	Lönnermark et al., 2004
Cd	g	1.70	Lönnermark et al., 2004
Cr	g	3.80	Lönnermark et al., 2004
Cu	g	27.0	Lönnermark et al., 2004
Ni	g	2.80	Lönnermark et al., 2004
Pb	g	820	Lönnermark et al., 2004
Zn	g	3200	Lönnermark et al., 2004
PCDD/F	mg	0.04	Hansen, 2000
Benzo(b)fluoranthene	g	32.3	Lemieux et al., 2004
Benzo(k)fluoranthene	g		Lemieux et al., 2004
Benzo(a)pyrene	g	14.7	Lemieux et al., 2004
Indeno(1,2,3-cd)pyrene	g	23.3	Lemieux et al., 2004

No data are available for Hg, Se, HCB and PCBs. NH_3 is assumed not to be emitted.

Emissions

Table 6.29 shows the total national emissions from vehicle. The entire time series is shown in Annex 3E-15.

Table 6.29 National emissions from vehicle fires.

	unit	1980	1985	1990	1995	2000	2005	2010	2013	2014	2015
SO_2	Mg	12.42	12.47	12.77	13.64	14.32	14.29	15.12	11.27	11.82	11.82
NO_X	Mg	4.97	4.99	5.11	5.45	5.73	5.72	6.05	4.51	4.73	4.73
NMVOC	Mg	21.11	21.21	21.72	23.18	24.34	24.29	25.71	19.15	20.09	20.09
CO	Mg	156.48	157.18	160.95	171.80	180.40	180.04	190.57	141.95	148.94	148.94
TSP	Mg	94.39	94.81	97.08	103.63	108.81	108.60	114.95	85.62	89.84	89.84
PM_{10}	Mg	94.39	94.81	97.08	103.63	108.81	108.60	114.95	85.62	89.84	89.84
$PM_{2.5}$	Mg	94.39	94.81	97.08	103.63	108.81	108.60	114.95	85.62	89.84	89.84
As	kg	0.65	0.65	0.66	0.71	0.74	0.74	0.79	0.59	0.61	0.61
Cd	kg	4.22	4.24	4.34	4.64	4.87	4.86	5.14	3.83	4.02	4.02
Cr	kg	9.44	9.48	9.71	10.36	10.88	10.86	11.49	8.56	8.98	8.98
Cu	kg	67.06	67.36	68.98	73.63	77.31	77.16	81.67	60.84	63.83	63.83
Ni	kg	6.95	6.99	7.15	7.64	8.02	8.00	8.47	6.31	6.62	6.62
Pb	Mg	2.04	2.05	2.09	2.24	2.35	2.34	2.48	1.85	1.94	1.94
Zn	Mg	7.95	7.98	8.18	8.73	9.16	9.14	9.68	7.21	7.57	7.57
PCDD/F	g I-TEQ	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.09	0.09	0.09
Benzo(b)fluoranthene	kg	40.11	40.29	41.26	44.04	46.25	46.15	48.85	36.39	38.18	38.18
Benzo(k)fluoranthene	kg	40.11	40.29	41.26	44.04	46.25	46.15	48.85	36.39	38.18	38.18
Benzo(a)pyrene	kg	36.51	36.68	37.56	40.09	42.09	42.01	44.47	33.12	34.75	34.75
Indeno(1.2.3-cd)pyrene	kg	57.87	58.13	59.53	63.54	66.72	66.59	70.48	52.50	55.08	55.08

6.5.4 Other

Other combustion sources include open burning of yard waste and bonfires.

Due to the cold and wet climatic conditions in Denmark wild fires very seldom occur. Controlled field burnings and the occasional wild fires are categorised under the sectors Agriculture and Land Use. Land Use Change and Forestry (LULUCF), respectively.

In Denmark, the open burning of private yard waste is under different restrictions according to the respective municipality. These restrictions involve what can be burned but also the quantity. and how. when and where. or in some cases a complete ban is imposed. The burning of yard waste is not allowed within urban areas (DEPA. 2011). There is no registration of private waste burning and the activity data on this subject are very difficult to estimate. Citizens are generally encouraged 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 activity data and consequently. Bonfires are not included in this inventory.

6.6 Uncertainties and time series consistency

This section covers the uncertainty estimates

6.6.1 Input data

The uncertainty of the number of human cremations is miniscule. However, for the purpose of the calculation it has been set to 1 %.

The uncertainty of the activity data from animal cremations is also minimal for the most recent years (1998-2015) but is increasing back in time (to 200 % in 1980). The uncertainty is set to 40 % for all years.

Activity data for composting are estimated for the years 1990-1994 and 2010-2015 resulting in a higher level of uncertainty these years; this is set at 40 %.

The uncertainty of the total number of accidental fires is very small but the division into building and transportation types and also the calculation of full scale equivalents will lead to some uncertainty - partly caused by the category "other". The uncertainty for both building and vehicle activity data is therefore set to 10 % for all years. The uncertainty is however lowest for the most recent years (2007-2015).

Activity data for combustion of biogas at biogas production facilities are available from the national energy statistics; the uncertainty for this activity is set to 5 %.

The following Table 6.30 lists the uncertainties for activity data in the waste sector.

Table 6.30 Estimated uncertainty rates for activity data.

	Human cremation	Animal cremation	Composting	Building fires	Vehicle fires	Biogas Production*
Activity data uncertainty. %	1	80	50	10	10	5*

*This category only exists from 1994-2004 and is therefore (with the exception of particles) not included in the uncertainty calculations included in this report. Uncertainties for all pollutants are calculated for 1990 and 2014, except for those for particles which are calculated for 2000 and 2013.

The uncertainties for emission factors in the waste sector and at the present level of available information are listed in Table 6.31. The uncertainties are assumed valid for all years 1990-2014.

Table 6.31 Estimated uncertainty rates for emission factors, %.

Pollutant	Human cremation	Animal cremation	Compos-ting	Building fires	Vehicle fires	Biogas production
SO_2	100	100		300	500	100
NO_x	150	150		500	500	100
NMVOC	100	300		500	500	100
CO	150	150	100	500	500	100
NH_3		300	100			
TSP	500	300		500	700	500
PM_{10}	500	300		500	700	500
$PM_{2.5}$	500	300		500	700	500
As	700	700		500	500	400
Cd	700	500		500	500	150
Cr	700	500		500	500	100
Cu	700	500		500	500	100
Hg	150			500		100
Ni	700	500			500	100
Pb	600	500		500	500	100
Se	700	700				100
Zn	700	500			500	150
HCB	500	500				1000
PCDD/F	300	300		100	100	1000
Benzo(b)flouranthene	1000	1000		500	500	
Benzo(k)flouranthene	1000	1000		500	500	
Benzo(a)pyrene	1000	1000		500	500	
Indeno(1.2.3-c.d)pyrene	1000	1000		500	500	
PCB	1000	1 000				1000

6.6.2 Uncertainty results

The Tier 1 uncertainty estimates for the waste sector are calculated from 95 % confidence interval uncertainties. Results are shown in Table 6.32.

Table 6.32 Tier 1 uncertainty results for waste.

Pollutant	Emission 2015. Mg	Total emission uncertainty. %	Trend 1990-2015. %	Trend Uncertainty. %-age points
SO_2	923	294.2	60.0	23.9
NO_x	96	225.1	32.2	36.5
NMVOC	221	450.7	29.7	34.4
CO	1285	237.2	67.1	142.9
NH_3	726	107.4	251.1	198.1
TSP	254	403.3	-4.9	12.8
PM_{10}	254	404.5	-5.1	12.6
$PM_{2.5}$	254	404.9	-5.1	12.5
As	2.37E-03	352.1	-16.3	130.1
Cd	4.99E-03	414.1	-10.0	27.9
Cr	1.05E-02	432.7	-10.7	34.3
Cu	6.72E-02	475.5	-7.9	13.4
Hg	1.44E-03	336.0	-96.9	10.3
Ni	6.69E-03	494.6	-15.0	64.1
Pb	1.94E+00	499.9	-7.5	13.1
Se	3.49E-04	684.1	-59.3	370.6
Zn	7.57E+00	500.1	-7.5	13.1
HCB	9.16E-06	385.1	39.6	228.5
PCDD/F	7.68E-06	99.1	25.7	17.6
Benzo(b)flouranthene	6.44E-02	359.7	4.9	59.4
Benzo(k)flouranthene	4.74E-02	414.3	-1.9	35.1
Benzo(a)pyrene	5.13E-02	375.3	2.1	51.2
Indeno(1.2.3-c.d)pyrene	7.30E-02	396.8	-0.4	42.0
PCB	2.50E-05	769.9	39.6	455.3

6.7 QA/QC and verification

A list of QA/QC tasks are performed directly in relation to the emissions from the waste sector part of the Danish emission inventories. The following procedures are carried out to ensure the data quality:

- Checking of time series in the NFR and SNAP source categories. Considerable changes are controlled and explained.
- Comparison with the inventory of the previous year. Any major changes are verified.
- A manual log table is applied to collect information about recalculations.
- Some automated checks have been prepared for the emission databases:
- Check of units for fuel rate and emission factors
- Additional checks on database consistency

The QC work will continue in future years.

6.7.1 Data deliveries

Table 6.33 lists the external data deliveries used for the waste emission inventory. Further the table holds information on the contacts at the data delivery companies.

Table 6.33 List of external data sources.

Category	Data description	Activity data. emission factors or emissions	Reference	Contact(s)	Data agreement/ Comment	http. file or folder name
Human cremation	Annual number of cremated persons	Activity data	Association of Danish Crematories	Hanne Ring	Public access	http://www.dkl.dk
Human cremation	Population statistics	Activity data	Statistics Denmark		Public access	http://www.statistikbanken.dk/BEF5
Animal cremation	Annual number of cremated carcasses	Activity data	Dansk Dyre-kremering ApS	Knud Ribergaard	Personal contact	
Animal cremation	Annual number of cremated carcasses	Activity data	Ada's Kæle-dyrskrematorium ApS	Frederik Møller	Personal contact	
Animal cremation	Annual number of cremated carcasses	Activity data	Kæledyrs-krematoriet	Annette Laursen	Personal contact	
Accidental building fires	Average floor space in buildings	Activity data	Statistics Denmark		Public access	http://www.statistikbanken.dk/BOL511
Accidental fires	Categorised fires	Activity data	The Danish Emergency Management Agency	Steen Hjere Nonnemann	Public access	https://statistikbank.brs.dk
Accidental building fires	Building type statistics	Activity data	Statistics Denmark		Public access	http://www.statistikbanken.dk/ BOL11. BOL3. BOL33 AND BYGB11
Accidental vehicle fires	Weight categorisation of vehicles (passenger cars. busses. vans and trucks)	Activity data	Statistics Denmark		Public access	http://www.statistikbanken.dk BIL10. BIL12. BIL15 and BIL18
Composting	Waste categories for composting	Activity data	Waste Statistics (Affaldsstatistik)		Public access	http://www2.mst.dk/udgiv/publikationer/2010/978-87-92668-21-9/pdf/978-87-92668-22-6.pdf

6.8 Source-specific recalculations and improvements

No recalculations have been made.

6.9 Source-specific planned improvements

There are currently no planned improvements for this sector.

6.10 References

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7 Other and natural emissions

Denmark does not report emissions in the NFR category “Other” (NFR 6). Regarding natural emissions volcanoes do not occur in Denmark and hence the category is reported as NO (Not Occurring).

Emissions from forest fires are for most years negligible but have not been estimated. Any other natural emissions, to be reported under NFR category 11C, have also not been estimated.

8 Gridded emissions

This chapter include descriptions on input data, methodology and results of the Danish gridded emissions for the years 2005 and 2010. A detailed methodological description is given in Plejdrup & Gyldenkærne (2011).

Updated gridded emissions are due to be reported on 1 May 2017, the results will be documented in the 2018 IIR submission.

8.1 Background for reporting

According to the UNECE Convention on Long-Range Transboundary Air Pollution parties are obligated to report gridded emissions.

In December 2013 the Executive Body for the Convention on Long-range Transboundary Air Pollution adopted new reporting guidelines, which include requirement of four-year reporting of gridded emissions from 2017. The new reporting guidelines are yet not implemented for gridded emissions, why the data and methodology presented in this chapter refer to the latest reporting of gridded emissions according to the previous guidelines.

In the 2012 reporting Denmark reported gridded emissions for the years 2005 and 2010. The mandatory reporting of gridded emissions includes the following 13 pollutants: SO_x, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, benzo(b)flouranthene, benzo(k)flouranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, HCB, and dioxins and furans. The reporting includes GNFR sectoral emissions as well as national total emissions disaggregated to the standard EMEP grid with a resolution of 50 km x 50 km. Table 9.1 lists the categories (sectors) used for reporting gridded emission data based on the Danish inventories.

Table 9.1 GNFR categories and corresponding NFR categories and SNAP IDs in the Danish gridded emission inventory.

GNFR ID	GNFR (long name)	NFR	SNAP	Note
A_PublicPower	PublicPower	1A1a	0101, 0102	
B_IndustrialComb	IndustrialCombustion	1A1c, 1A2a, 1A2b, 1A2c, 1A2d, 1A2e, 1A2f i	0103, 0105, 0301, 0302, 0304, 0305, 0306, 0307, 0308, 0309, 0310 , 0311, 0312, 0313, 0314, 0315, 0316, 0320	
C_SmallComb	SmallCombustion	1A4a i, 1A4b i, 1A4c i	0201, 0202, 0203	
D_IndProcess	IndustrialProcesses	2	0303, 0402, 0404, 0405, 0406	
E_Fugitive	Fugitive emissions from fuels	1B1, 1B2	0401, 0501, 0502, 0505, 0506, 0902	
F_Solvents	Solvent and other product use	3	06	
G_RoadRail	RoadRailway	1A3b, 1A3c	07, 0802	
H_Shipping	Shipping	1A3d ii, 1A4c iii	0803, 080402, 080403	
I_OffRoadMob	OffRoadMobile	1A2f ii, 1A4a ii1A4b ii, 1A4c ii, 1A5b	0801, 0806, 0807, 0808, 0809, 0811	
J_AviationLTO	AviationLTO	1A3 a i (i), 1A3 a ii (i)	080501, 080502	
L_OtherWasteDisp	OtherWasteDisposal	6D	0910	
M_WasteWater	WasteWater			NE
N_WasteIncin	WasteIncineration	6C	0909	
O_AgriLivestock	AgricultureLivestock	4B	*	
P_AgriOther	AgricultureOther	4D, 4G	*	
Q_AgriWaste	AgricultureWaste	4F	*	
R_Other	Other			NO
S_Natural	Natural			NO
K_CivilAviCruise	CivilAviationCruise	1A3a ii (ii)	080503	
T_IntAviCruise	IntAviationCruise	1A3a i (ii)	080504	
Z_memo	memo	1A3d i (i)	080404	

* The Danish national emission inventory system for agriculture builds on NFR categories and not SNAP categories as is the case for the remaining sectors in the Danish emission inventory system.

The Guidelines used for this reporting are included in UNECE (2009). The methodology in Danish emission gridding model SPREAD follows the EMEP/EEA Guidebook (2009)[1]. The gridded emission data in the 2012 reporting are available at the EIONET Central Data Repository homepage:

http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_EMEP_UNECE

Further, a detailed methodological description is given in Plejdrup & Gyldenkærne (2011).

8.2 Methods and data for disaggregation of emission data

A national model for high resolution spatial distribution of emissions to air, the SPREAD model, has been developed at Department of Environmental Science, Aarhus University. SPREAD includes all sources and pollutants in the Danish emission inventory system, and generates emissions on a resolution of 1 km x 1 km.

SPREAD covers the area defined by the Exclusive Economic Zone (EEZ) and the national boarder. Denmark is geographically the peninsula of Jutland and 443 named islands and islets, of which approximately 72 are inhabited.

[1] The SPREAD version used for the 2012 reporting follow the 2009 EMEP/EEA Guidebook. From the 2017 reporting, the gridded emissions will be prepared according to the 2013 EMEP/EEA Guidebook.

The country is located in Scandinavia neighbouring the sea (the Baltic Sea, Skagerrak, Kattegat and the North Sea) as well as Germany, which Jutland are adjacent to the south (Figure 9.1).

The spatial emission distribution is carried out on the most disaggregated level possible and therefore SPREAD includes a large number of distribution keys related to single sources, sub categories and in a single case to a whole sector. Gridded emissions reported to UNECE LRTAP are based on the results from SPREAD, aggregated on the 50 km x 50 km EMEP grid.

The spatial distribution in SPREAD is based on a number of national geographical data sets. As the model is very complex and include many spatial data, only the most important input data and methodology descriptions are included in the IIR report. For a more detailed description, please refer to Plejdrup & Gyldenkærne (2011).

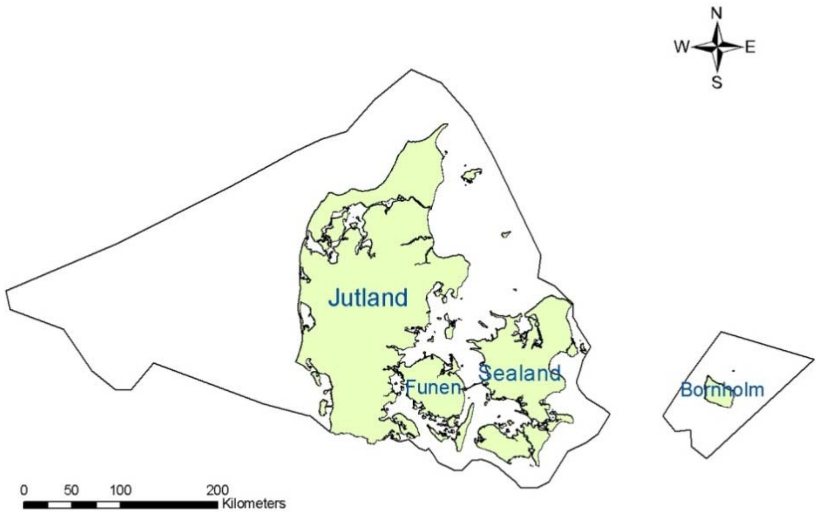

Figure 9.1 Map of Denmark including names of regions and the Exclusive Economic Zone.

8.2.1 The SPREAD model

The distribution in SPREAD is made on SNAP category level to assure the most accurate distribution of the emissions. It has been aimed to use the most disaggregated SNAP level (SNAP 3 level) but for some categories and sectors SNAP 2 or SNAP 1 level has been applied in the distribution model, due to a lack of detailed geographical information. An exception is the agricultural sector, as this sector is not treated on SNAP level in the Danish inventory system. Instead the agricultural data processing is carried out for the relevant NFR categories, and the same approach is applied in SPREAD. The SPREAD model is prepared in order to be applicable for the mandatory reporting of gridded emissions under CLRTAP.

SPREAD includes a number of sub-models covering separate sources or groups of sources in the emission inventory; Large Point Sources, Stationary combustion for point sources, Stationary combustion for area sources, Mobile sources, Aviation, Fugitive emissions from fuels, Industrial Processes, F-gases, Solvent and other product use, Waste, and a number of sub-models for the agricultural sector. All sub-models correspond to the methodology and groupings in the Danish inventory system. A number of sub-models include a higher disaggregation level compared to the NFR tables. Both SNAP and NFR categories are included in all SPREAD sub-models to enable a distribution in agreement with the international guidelines.

Emissions from all Large Point Sources (LPS) are treated in the LPS sub-model in SPREAD. LPSs represent emissions at all SNAP 1 categories except solvents (SNAP 06) and road traffic (SNAP 07). Further, LPSs in agriculture are included in a separate part of the emission database system covering agriculture and are not included in the LPS sub-model in SPREAD. The Point Sources sub-model covers emissions from stationary combustion from point sources, which refer to the large number of plants, for which the fuel consumption is known at plant level but emissions are calculated using standard emission factors.

General methodology

The distribution of emissions in the Danish emission inventory is carried out in databases and in a geographical information system, GIS.

The methodology applied in the part of the distribution carried out in GIS is shortly described in this chapter. The description is made for the Industrial Processes sector as a case, as this distribution is rather simple.

The emission inventory for Industrial Processes covers both point sources and area sources. Emissions from point sources are allocated to the coordinates for the individual plants included in the Danish inventory system and are not relevant in relation to the GIS procedure. Emissions from area sources are calculated from production statistics and the resulting emissions are national totals as allocation of the sources (industrial plants) is not possible with the available data. Instead a proxy for the distribution is applied, in this case the location of industrial areas as given in the national topographic map KORT10 by the National Survey and Cadastre (Figure 9.2). The map of industrial areas is not reflecting differences in the location for different industries, but only holds industrial buildings (referred to as the industrial area as the buildings are treated as areas rather than units). The map is a shape file and the industrial areas are polygons.

Figure 9.2 Segment around Avedøre (close to Copenhagen) of the map of industrial areas (KORT10).

As SPREAD gives emissions on 1 km x 1 km, the map of industrial areas must be combined with the Danish 1 km x 1 km Grid Net. The grid is an orthogonal coordinate system and the cells are defined and named by their lower left corner coordinates. The grid net map is a shape file and the grid cells are polygons (Figure 9.3).

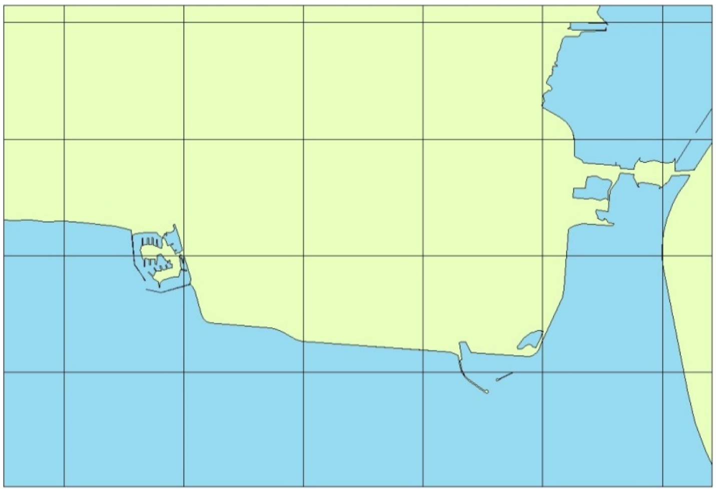

Figure 9.3 Segment around Avedøre in Copenhagen of the map of the Danish 1 km x 1 km grid net (KORT10).

To be able to distribute the emissions on 1 km x 1 km it is necessary to split the industrial polygons between the grid cells and thereby be able to calculate the industrial area in each grid cell (Figure 9.4). These functionalities are available in GIS, in this case ArcMAP. The split is made using the intersect tool, and afterwards the areas are applied to each cell using the Calculate Area function.

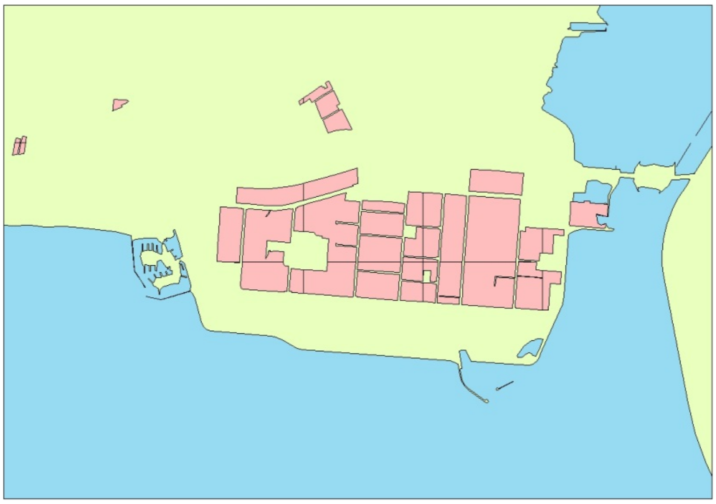

Figure 9.4 Segment around Avedøre in Copenhagen of the map of industrial areas and the Danish 1 km x 1 km grid net (KORT10).

The remaining part of the emission distribution for industrial processes is carried out in a database. The share of the national emissions that should be allocated to each grid cell is calculated as the industrial area of the cell divided by the total industrial area. The same distribution key is applied for all pollutants.

In the case of the Industrial Processes sector only one map is combined with the grid, but more maps or layers could be combined to make a distribution key. This is the case for some sources in the agricultural sector, e.g. emissions from organic soils where the distribution key is based on a map of organic soils, a map of the agricultural fields and the Danish Grid Net. A number of area sources are distributed on line features, e.g. emissions from railways and road traffic. In these cases the lines are split into segments by intersection with the 1 km x 1 km grid net. The emission in each grid cell is calculated as the national emission multiplied by the length of the line segment(s) in the cell and divided by the total length of the line feature.

For some sources the same distribution key can be applied for more or all years, while other sources demands a separate distribution key for every year. For Industrial Processes the distribution key can be applied for more years, as the dataset is not available on annual basis. Further, the industrial area does not change much from year to year. In other cases the distribution keys must be set up on annual basis as large changes occur from year to year. This is the case for e.g. agricultural soils and point sources (PS) in the energy sector.

National geographical data

A large number of national geographical data sets are implemented in the SPREAD model in preparation of the various distribution keys. The data sets are listed in Table 9.2 with specification of data owner and a short description of the content of each data set.

Table 9.2 List of geographic data applied in the emission gridding.

Data owner	Data set	Contents
The National Survey and Cadastre	Topographic map	Geo-referenced basic map layers on administrative units, Land cover, territorial borders, coastline and infrastructure.
National Agency for Enterprise and Construction	Central Dwelling and Building Register (Danish abbreviation BBR)	Geo-referenced information on dwellings and buildings
Danish Ministry of the Environment	The Area Information System (AIS)	National maps of spatial data related to nature and environment (e.g. railways, industrial areas and one-storey settlements)
The Directorate for Food, Fisheries and Agri Business	The Central Husbandry Register (CHR)	Information on stock of livestock at farm level
	The General Agricultural Register (GLR)	Information on agricultural farms and crops on field level
Ministry of food, agriculture and fisheries	The fertilizer and husbandry register (Danish abbreviation GHI)	Information on manure and fertiliser amounts on farm level
	The Land Parcel Identification System (LPIS)	Geo-referenced data on agricultural land parcels, including field IDs for fields located in the parcels
The Central Business Register	Central Business Register (Danish abbreviation CVR)	Geo-referenced information on businesses with a CVR number, e.g. farms
The Central Office of the Civil Registration	The Civil Registration System (Danish abbreviation CPR)	Geo-referenced information on population on address level
The Department of Environmental Science, Aarhus University	National road and traffic database	Geo-referenced traffic load on the Danish road network
The Danish Energy Agency	Energy producer accountings	Geo-referenced information on fuel consumption for district heating and/or power producing plants
	The regional inventory	Regional inventory of energy consumption for heating for oil boilers, natural gas boilers and solid fuel installations on municipality level
DCE - Danish Centre for Environment and Energy	Large Point Sources (LPS)	Geo-referenced information on power plants, large industrial plants and off-shore installations
Danish Petroleum association	Service stations	Geo-referenced information on addresses for all Danish service stations
Energinet.dk	Measurement and regulator stations	Geo-referenced information on location of measurement and regulator stations in the Danish natural gas transmission network
Danish Forest and Nature Agency	Military training terrain	Geo-referenced information on military training terrains
The Danish Environmental Protection Agency	Information system for waste and recycling (Danish abbreviation ISAG)	Data on waste treatment companies on address level
Miljøportalen.dk	Waste water treatment plants	Data on waste water treatment on facility level, including flow rates and organic matter content

8.3 Gridded emission data

In this section selected maps of gridded emissions are presented, all referring to the year 2010. The selected maps in Figure 9.5 illustrate the emissions included in the national total in the NFR table (all emissions excluding Civil Aviation - Domestic and International Cruise, and international Maritime Navigation). All figures illustrate the sum of all included GNFR sectors. The Danish high resolution gridded emissions are aggregated on the 50 km x 50 km EMEP grid for reporting to CLRTAP. The share of each 1 km x 1 km grid cell located in the relevant EMEP grid cells are calculated and the aggregated emissions are calculated as the weighted sum of emissions in the 1 km grid cells intersecting each EMEP grid cell being partial or fully part of the Danish Exclusive Economic Zone, EEZ.

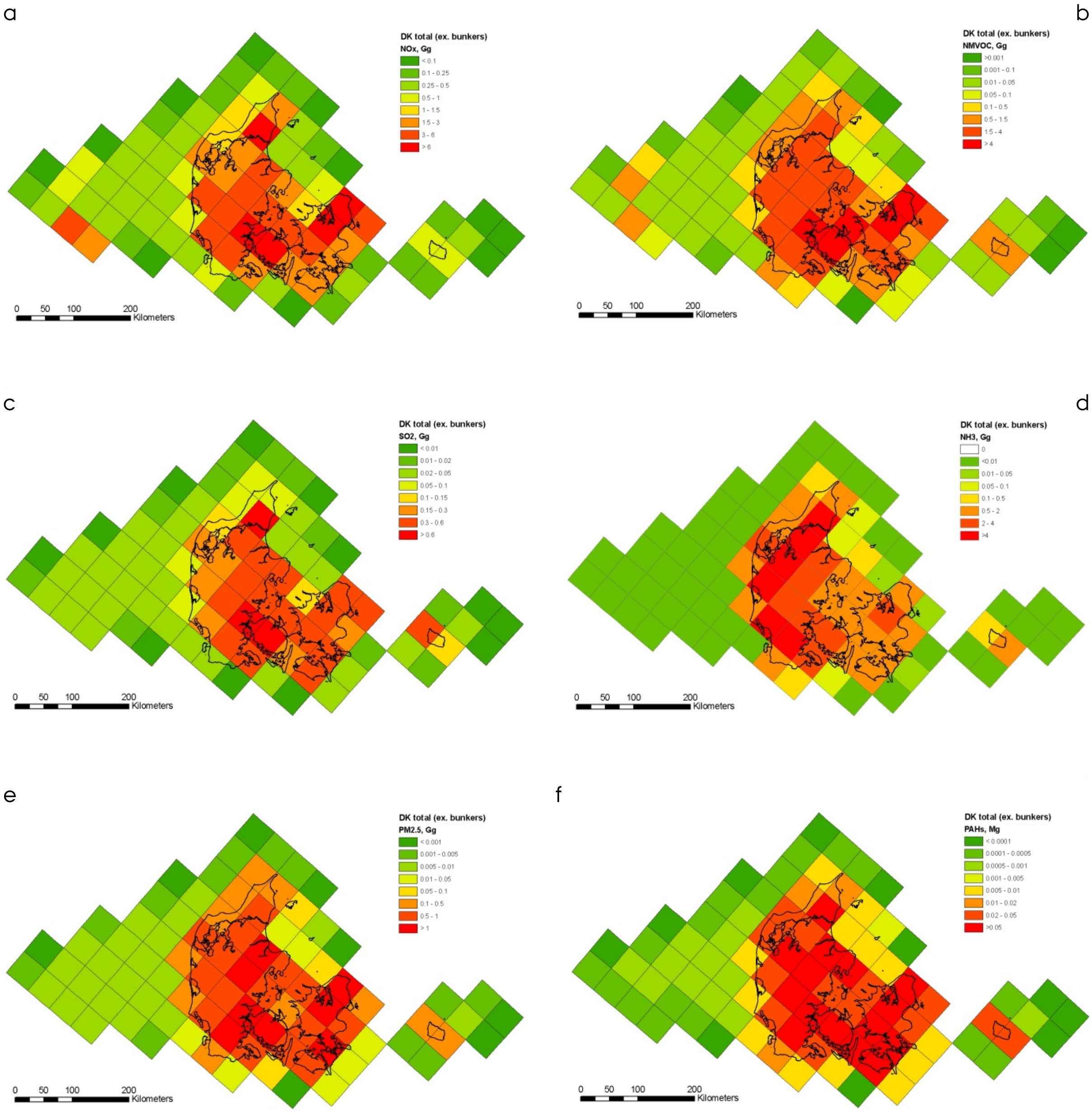

Figure 9.5 National total gridded emissions excluding civil aviation and international navigation of a) NO_x, b) NMVOC, c) SO_2, d) NH_3, e) $PM_{2.5}$ and f) PAHs (the sum of benzo(b)flouranthene, benzo(k)flouranthene, benzo(a)pyrene and indeno(1,2,3-c,d)pyrene) for the year 2010.

Even on the 50 km x 50 km aggregated level spatial patterns from the major sectors are recognisable for different pollutants.

8.3.1 NO_X

The major GNFR source to NO_x emissions is RoadRail followed by Shipping, OffRoadMob, PublicPower and IndustrialComb contributing 36 %, 16 %, 15 %, 15 % and 11 %, respectively. The pattern of the gridded NO_x emissions reflect the major road and rail network located in the eastern part of Jutland and across Funen and Zealand to Copenhagen (figure 9.5). Further, large emissions from PublicPower and IndustrialComb are seen around the major cities. Part of the fugitive emissions is located offshore due to extraction of oil and gas on the North Sea.

8.3.2 NMVOC

The major source of NMVOC is Solvents followed by SmallComb, RoadRail, OffRoadMob and Fugitive contributing 31 %, 18 %, 15 %, 11 % and 11 %, respectively. Both emissions from Solvents, SmallComb and OffRoadMob are to a large degree allocated according to population density and location of one-storey settlements. Part of the fugitive emissions is located offshore due to extraction of oil and gas on the North Sea.

8.3.3 SO_2

The major sources of SO_2 are PublicPower and IndustrialComb followed by SmallComb and Shipping contributing 27 %, 26 %, 19 %, and 13 %, respectively. Even though the SO_2 emission has decreased over the years due to implementation of techniques for reduction of sulphur in the flue gas, it still produces a distinct pattern reflecting the localisation of large power plants in Denmark. The allocation of emissions from IndustrialComb reflect the location of a large number of CHP plants not reported as LPS due to no plant specific emission factors. The allocation of emissions from SmallComb reflects the areas with high population density and mainly one-storey settlements.

For the ferries operating between Copenhagen and Bornholm part of the route is outside the Danish EEZ. The emissions from all these ferries are included in Shipping and distributed on the part of the straight line between Copenhagen and Bornholm inside the Danish EEZ. This leads to an aggregation of the emissions in few EMEP cells, and thereby artificial high emissions at the part of the route inside the EEZ.

8.3.4 NH_3

The agricultural sector is by far the major contributor to the NH_3 emission. 81 % of the national emissions excluding civil aviation and international navigation derive from AgriLivestock and another 15 % from AgriOther. Emission of NH_3 is mainly related to livestock farming and especially to manure management. Emissions are distributed according to very detailed data on animals and fields, and the geographical pattern is in good agreement with the localisation of the major Danish livestock farming in Jutland.

8.3.5 $PM_{2.5}$

The major source of $PM_{2.5}$ emissions is SmallComb contributing 73 %. RoadRail is the second largest source contributing 10 % of the $PM_{2.5}$ emission. Emissions from SmallComb are allocated rather evenly on the land area as a major source is residential wood combustion. Emissions from the residential sector are distributed on municipality level leading to equal emissions for larger areas. Further emissions from CHP plants are located in all parts of the country, also leading to a rather even distribution.

8.3.6 PAHs

Emissions of PAHs are the sum of benzo(b)flouranthene, benzo(k)flouranthene, benzo(a)pyrene and indeno(1,2,3-c,d)pyrene. The major source to emissions of PAHs in Denmark is SmallComb and hereof the all-important source is residential wood combustion. As described for $PM_{2.5}$ the distribution are made on municipality level leading to a rather even distribution on the land area.

8.4 References

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9 Recalculations and Improvements

In general, considerable work is being carried out to improve the inventories. Investigations and research carried out in Denmark and abroad produce new results and findings, which are given consideration and, to the extent which is possible, are included as the basis for emission estimates and as data in the inventory databases. Furthermore, the updates of the EMEP/EEA Guidebook, and the work of the Task Force on Emission Inventories and its expert panels are followed closely in order to be able to incorporate the best scientific information as the basis for the inventories.

The implementation of new results in inventories is made in a way so that improvements, as far as possible, better reflect Danish conditions and circumstances. This is in accordance with good practice. Furthermore, efforts are made to involve as many experts as possible in the reasoning, justification and feasibility of implementation of improvements.

In improving the inventories, care is taken to consider implementation of improvements for the whole time series of inventories to make it consistent. Such efforts lead to recalculation of previously submitted inventories. This submission includes recalculated inventories for the whole time series. The recalculations are shown in Table 9.1 below. The table shows the difference between the latest and the previous submission, i.e. a positive number indicates an increase in emission.

Table 9.1 Recalculations by selected pollutants and main sectors.

NO_X, kt	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	0.00	0.21	0.22	0.20	0.22	0.20	0.05	0.07	0.11	0.14
Mobile combustion	-1.76	-2.23	-3.12	-3.34	-2.82	-1.58	-1.53	-1.59	-1.43	-0.46
Fugitive emissions from fuels										0.00
Industrial processes	0.08	0.08	0.09	0.08	0.03	0.00	0.00	0.00	0.00	0.00
Agriculture	2.49	2.32	2.17	2.23	2.07	2.13	2.16	2.25	2.23	2.19
Waste										
Total	0.81	0.38	-0.64	-0.83	-0.50	0.74	0.69	0.73	0.91	1.86
NMVOC, kt	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	0.00	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.56	0.63
Mobile combustion	0.56	0.76	0.96	0.67	0.35	0.22	0.18	0.17	0.14	0.08
Fugitive emissions from fuels		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Industrial processes	0.16	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.02
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Waste										
Total	0.72	0.81	1.02	0.73	0.40	0.30	0.26	0.26	0.73	0.74
SO_2, kt	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion		0.23	0.06	0.07	0.06	0.09	0.09	-0.01	-0.04	-0.23
Mobile combustion	-0.59	-0.23	-0.25	-0.07	-0.01	-0.01	0.00	0.00	0.00	0.00
Fugitive emissions from fuels										0.00
Industrial processes	0.30	0.25	0.28	0.29	0.26	0.09	0.04	0.03	0.03	0.08
Agriculture										
Waste										
Total	-0.29	0.25	0.09	0.29	0.32	0.17	0.13	0.01	-0.02	-0.15

Continued

NH_3, kt	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
Stationary combustion	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.09	0.11
Mobile combustion	0.00	0.00	-0.02	-0.03	-0.01	0.00	0.01	0.01	0.01	0.01
Fugitive emissions from fuels										
Industrial processes	0.02									0.03
Agriculture	2.63	-0.71	-3.52	-1.84	-1.30	-1.69	-1.89	-1.65	-1.56	-1.26
Waste		0.00	0.00	0.00	0.00	0.12	-0.02	0.03	-0.19	-0.06
Total	2.65	-0.71	-3.54	-1.87	-1.30	-1.56	-1.89	-1.59	-1.65	-1.17

TSP, kt	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
Stationary combustion	NR	13.40	15.12	0.01	0.01	0.02	0.02	0.02	0.64	0.78
Mobile combustion	NR	11.12	10.89	-0.54	-0.44	-0.24	-0.23	-0.21	-0.20	-0.22
Fugitive emissions from fuels	NR	1.54	1.96							0.00
Industrial processes	NR	5.62	5.89	0.23	-2.22	-2.04	0.18	0.20	0.03	0.52
Agriculture	NR	75.23	69.86	-3.68	-3.95	-3.71	-3.56	-3.39	-3.22	-3.22
Waste	NR	0.27	0.30							
Total	NR	107.18	104.01	-3.97	-6.60	-5.98	-3.58	-3.37	-2.75	-2.14

PM_{10}, kt	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
Stationary combustion	NR	12.43	14.07	0.01	0.01	0.02	0.02	0.02	0.62	0.74
Mobile combustion	NR	10.46	10.12	-0.54	-0.44	-0.24	-0.23	-0.21	-0.20	-0.22
Fugitive emissions from fuels	NR	0.62	0.79							0.00
Industrial processes	NR	3.20	3.31	0.19	-2.14	-1.93	0.19	0.19	0.11	0.51
Agriculture	NR	9.40	9.01	-3.32	-3.41	-3.32	-3.26	-3.16	-3.06	-3.02
Waste	NR	0.27	0.30							
Total	NR	36.38	37.61	-3.65	-5.97	-5.48	-3.28	-3.16	-2.54	-1.99

$PM_{2.5}$, kt	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
Stationary combustion	NR	11.67	13.29	0.01	0.01	0.02	0.02	0.02	0.60	0.72
Mobile combustion	NR	9.93	9.52	-0.55	-0.44	-0.24	-0.23	-0.21	-0.20	-0.22
Fugitive emissions from fuels	NR	0.07	0.08							0.00
Industrial processes	NR	1.23	1.24	0.04	-1.45	-1.29	0.04	0.04	0.03	0.15
Agriculture	NR	1.41	1.36	-0.78	-0.82	-0.80	-0.79	-0.76	-0.74	-0.74
Waste	NR	0.27	0.30							
Total	NR	24.57	25.79	-1.26	-2.70	-2.31	-0.96	-0.90	-0.31	-0.08

BC, kt	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
Stationary combustion	NR	1.54	1.69	0.01	0.01	0.00	0.00	0.00	0.08	0.12
Mobile combustion	NR	4.67	4.48	-0.18	-0.21	-0.17	-0.16	-0.15	-0.14	-0.16
Fugitive emissions from fuels	NR	1.03	1.30							0.00
Industrial processes	NR	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Agriculture	NR	0.02	0.02							
Waste	NR									
Total	NR	7.27	7.51	-0.17	-0.19	-0.15	-0.15	-0.14	-0.05	-0.04

CO, kt	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014
Stationary combustion	0.00	0.07	0.08	0.08	0.08	0.14	0.16	0.24	3.65	4.47
Mobile combustion	-6.19	-6.11	-5.02	-2.82	-1.51	-0.24	-0.26	-0.26	-0.36	-0.35
Fugitive emissions from fuels										0.00
Industrial processes	0.00	0.00	0.00	0.00	0.00					0.00
Agriculture										
Waste		0.00	0.00	0.00	0.00	0.10	-0.02	0.02	-0.14	-0.04
Total	-6.19	-6.04	-4.93	-2.73	-1.42	-0.01	-0.12	0.01	3.14	4.08

Continued										
Pb, t	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04
Mobile combustion	NR	0.00	0.00	0.00	0.00	-0.02	-0.02	0.06	0.09	-0.02
Fugitive emissions from fuels	NR									0.00
Industrial processes	NR								0.00	0.00
Agriculture	NR									
Waste	NR									
Total	NR	0.00	0.00	0.00	0.00	-0.02	-0.02	0.07	0.11	0.02

Cd, t	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Mobile combustion	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fugitive emissions from fuels	NR									0.00
Industrial processes	NR								0.00	0.00
Agriculture	NR									
Waste	NR									
Total	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02

Hg, t	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	NR	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mobile combustion	NR	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fugitive emissions from fuels	NR	NR								
Industrial processes	NR	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	NR	NR								
Waste	NR	NR								
Total	NR	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PCDD/F, g I-TEQ	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	NR	NR	0.01	0.01	0.02	0.01	0.03	0.04	0.06	0.51
Mobile combustion	NR	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fugitive emissions from fuels	NR	NR								
Industrial processes	NR	NR	0.00	0.00	0.00	0.55	0.00	0.00	0.00	-0.06
Agriculture	NR	NR								
Waste	NR	NR								
Total	NR	NR	0.01	0.02	0.02	0.57	0.03	0.03	0.06	0.45

BaP, t	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Stationary combustion	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.09
Mobile combustion	NR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fugitive emissions from fuels	NR									0.00
Industrial processes	NR	0.07	0.09	0.08	0.03					
Agriculture	NR									
Waste	NR									
Total	NR	0.07	0.09	0.08	0.03	0.00	0.00	0.00	0.07	0.09

NR = Not Reported. This notation key is used for years proceeding the base year of the relevant protocol.

0.00 indicates that the recalculation is between -0.0049 and 0.0049.

The reasoning for the recalculations performed is to be found in the sectoral chapters of this report. The text below focuses on recalculations, in general, and further serves as an overview and summary of the relevant text in the sectoral chapters. For sector specific planned improvements please also refer to the relevant sectoral chapters.

9.1 Energy

Improvements and updates of the Danish energy statistics are made regularly by the producer of the statistics, the Danish Energy Agency. In close cooperation with the DEA, these improvements and updates are reflected in the emission inventory for the energy sector. The Danish energy statistics have, for the most part, been aggregated to the SNAP categorisation.

The inventories are still being improved through work to increase the number of large point sources, e.g. power plants, included in the databases as individual point sources. Such an inclusion makes it possible to use plant-specific data for emissions, etc., available e.g. in annual environmental reports from the plants in question.

9.1.1 Stationary Combustion

For stationary combustion plants, the emission estimates for the years 1990-2014 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation sectors as well as a source category update. The changes in the energy statistics are largest for the years 2012, 2013 and 2014.

In addition the disaggregation of fuels applied for manufacturing industries and construction have been updated according to the latest reporting from DEA. The consumption and emissions for the sector *1A2b Stationary combustion in manufacturing industries and construction: Non-ferrous metals* is now reported NO which is in agreement with the updated DEA data.

The largest recalculations are related to a recalculation of the consumption of wood in residential plants in 2013-2014 in the energy statistics.

SO_2 emission measurements for 2014 have been implemented for a number of plants for which the data were not available prior to the reporting in 2016. In addition, the emission factor for one plant has been improved based on measurements from former years.

9.1.2 Mobile sources

Road transport

The fuel consumption and emission factors for road transport have been updated with data from the updated COPERT model – COPERT V. In addition CNG vehicles and gasoline hybrid cars and vans have been explicitly included in the model.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are: SO_2 (0 %), NO_x (-0.4 %; 3.5 %, 2014), NMVOC (1.1 %; 2.3 %, 2013), NH_3 (-1.7 %; 1.1 %, 1994), TSP (-22.2 %; -2.0 %, 1985) and BC (-2.6 %; -0.1 %, 1993).

Navigation

A few changes have been made in relation to engine load factors for two specific ferries in 2013 and 2014.

The following largest percentage differences (in brackets) for domestic navigation are noted for: SO_2 (0 %), NO_x (-0.1 %), NMVOC (-0.1 %), TSP (-0.1 %) and BC (-0.2 %).

Agriculture/forestry

Diesel fuel consumption has been updated for agricultural machinery due to changes in the non-road emission calculation model. From Stage IIIA engine emission levels onwards, input factors for specific fuel consumption have been updated based on engine manufacturers advice.

The following largest percentage differences (in brackets) for domestic navigation are noted for: SO_2 (-9 %), NO_x (-3.6 %), NMVOC (-1.4 %), NH_3 (-1.7 %), TSP (-3.7 %) and BC (-2.9 %).

Fisheries

Small changes have been made in DEA fuel statistics for diesel in 2014 and fuel transferal made between fisheries and national sea transport has also resulted in minor changes in fuel consumption for fisheries.

The following largest percentage differences (in brackets) for fisheries are noted for: SO_2 (0.2 %), NO_x (0.2 %), NMVOC (0.2 %), TSP (0.2 %) and BC (0.2 %).

Industry

A complete revision of the non-road model containing building and construction machinery has been made. From engine manufacturers new input data for engine load factors have been provided based on electronic engine power registrations. Further, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of engine age has been included in the model. From Stage IIIA engine emission levels onwards, specific fuel consumption factors have been updated also based on engine manufacturers advice.

The following largest percentage differences (in brackets) for industrial non road are noted for: SO_2 (-30 %), NO_x (-29 %), NMVOC (-16 %), NH_3 (-27 %), TSP (-33 %) and BC (-34 %).

Railways

No changes have been made.

Civil aviation

Small changes in the list of aircraft types – representative aircraft types has been made in the model used for calculating civil aviation emissions.

The following largest percentage differences (in brackets) for civil aviation are noted for: SO_2 (-0.4 %), NO_x (1.2 %), NMVOC (0.4 %), TSP (-0.2 %) and BC (-0.9 %).

Other (Military and recreational craft)

Emission factors derived from the updated road transport calculations have caused a few emission changes from 1985-2014. The following largest percentage differences (in brackets) for military are noted for: SO_2 (0.0 %), NO_x (1.7 %), NMVOC (-0.1 %), NH3 (-0.7 %), TSP (-2.3 %) and BC (-3.8 %).

9.1.3 Fugitive emissions

Oil transport(1B2a i)

Activity data for the oil terminal are updated for 2011-2014 according to the annual environmental report. The change of the total fugitive NMVOC emissions is negligible.

Distribution of oil products (1B2a v)

Activity data for service stations are updated according to the Danish Energy Statistics by the DEA. The statistics has revisions for 2013 and 2014. The recalculation has changed the total fugitive NMVOC emission by – 0.2 and +0.1 %, respectively.

Venting and flaring (1B2c)

Flaring in gas transmission has been updated for 2014 according to information from the Danish gas transmission company Energinet.dk.

Further, activity data and emissions are updated for one of the gas storage plants; for 2014 as the 2014 environmental report has become available, and for 2012 due to updated values in the 2015 environmental report.

The recalculations have decreased the total fugitive NMVOC emission by 0.06 %. For other pollutants the change is negligible.

9.2 Industrial processes

9.2.1 Mineral industry

All particle emissions are reported back to 1990.

Glass production

More decimals have been included for the container glass emission factors for BC (2013-2014), As, Cr, Ni (2006-2014), Se (2010-2011; 2014) and Zn (2002-2014). The resulting recalculations are between -8 % (Cr) and 20 % (Ni).

Quarrying and mining of minerals other than coal

Activity data are gathered from Statistics Denmark. Recalculations in activity data of -2 % to -4 % occur for 2010-2014.

Construction and demolition

BC from construction and demolition is new in this year's submission.

Activity data are gathered from Statistics Denmark. Recalculations in activity data of 0.02 % (2000) to 24.2 % (2014) occur for 2000-2014; 2.5 % in average.

Storage, handling and transport of mineral products

Emissions from storage, handling and transport of mineral products had by mistake not been reported in the NFR tables in last year's submission, this has been corrected.

Other mineral products

NMVOC emissions from the production of stone wool are new in this year's submission.

An error in the calculation of the emission factor for SO_2 emissions from ceramics has been corrected. This has resulted in an increase of emissions of 0.03-0.29 Gg SO_2 (2.2-14.9 %).

The 2014 environmental report for Rockwool was not available in time for last year's submission. An update to measured emissions for CO, NH_3 and particles has led to increases in emissions of 1 % (CO) to 31 % (TSP).

9.2.2 Chemical industry

All particle emissions are reported back to 1990.

NMVOC emissions from production of chemical ingredients have been extrapolated back to 1985.

For the production of tar products, SO_2 emissions have been extrapolated back to 1980 and Hg emissions have been estimated for 2013-2014.

BC emissions from the production of catalysts are calculated based on the $PM_{2.5}$ emission. This year's submission included an extra decimal to these calculated values leading to recalculations of between -20 % (2004, 2006, 2012) and 50 % (2003), 1 % in average.

9.2.3 Metal industry

All particle emissions are reported back to 1990.

Iron and steel production

SO_2, NO_x, CO, Se and PAHs are new pollutants estimated from steel production in the electric arc furnace.

NMVOC emissions from the electro steelwork have been extrapolated back to 1985. By mistake, NMVOC was not included from the EAF for 2001, this has been corrected.

BC emissions from the rolling mills steel productions and the grey iron foundries are new in this year's inventory, as well as Hg from secondary lead production.

The correction of a factor 1000 error in the measured particle emissions from rolling mills in 2009-2010 results in drastic decreases in particle emissions for 2003-2010.

Secondary aluminium production

Data on raw material (aluminium scrap) for 2013-2014 has gathered by contacting the industry. Based on these new data the estimated production of secondary aluminium was updated, leading to decreases in emissions of -21.5 % (2013) and -22.7 % (2014).

Lead production

Hg is a new pollutant estimated from secondary lead production.

9.2.4 Non-energy products from fuels and solvent use

Emissions of TSP, PM_{10}, $PM_{2.5}$ and BC have be included for road paving and asphalt roofing, with emissions and abatement factors from EMEP/EEA (2013) and US EPA (2004).

9.2.5 Other production

All particle emissions are extrapolated back to 1990.

New pollutants included in this year's inventory include NOx from fireworks and BC from tobacco and barbeques.

Particle emissions from flour production are new in this year's submission.

An update of the activity data from Statistics Denmark has led to recalculations in the NMVOC emissions of 2000, 2003 and 2010-2014 of -0.1 % (2014) to 0.4 % (2010).

Emissions of NH_3 from slaughterhouse waste have been extrapolated back to 1985.

9.2.6 Wood processing

Particle emissions are extrapolated back to 1990.

The TSP emission for 2014 was estimated based on historical data due to lack of actual data. 2014 data have now been collected and reported along with PM_{10} and $PM_{2.5}$ data; these were mistakenly not reported for 2014 in last submission. The recalculation for TSP in 2014 is an increase of 10 %.

9.3 Agriculture

Compared with the previous NH_3, NMVOC and PM emissions inventory (submission 2016), some changes and updates have been made. These changes cause a decrease/increase in the total NH_3, NMVOC and PM emission for all years (1985–2014).

For the emission of NH_3 a change is seen in the emission from manure management, animal manure applied to soil, inorganic N-fertiliser and NH_3-straw. Change in the emission from manure management is due to changes in normative figures for sheep and goats (1985-1999), change in number of weaners and fattening pigs (2011-2014) due to change in the statistics and change in normative figures and emission factors for hens (2012-2014) due to errors. Emission from animal manure applied to soil are also changed due to the changes mentioned for manure management, but also by changes in emission factor for acidification of slurry applied (2006-2014).

Change in NH_3 emission from inorganic N-fertiliser is due to change in emission factors. The emission factors have been updated to emission factors given in EMEP/EEA guidebook 2016. The change in emission factors increases the emission in 1985-1989 and decreases the emission in 1990-2014. This is due to the combination of fertiliser types and increase and decrease in the emission factors.

The amount of NH_3 used for NH_3-treated straw has been changed for the years 2006-2014, due to updated estimates.

Change in the emission of NMVOC in 2011-2014 is due to change in the number of animals.

Emission of TSP from manure management is recalculated due to updates in emission factors in the latest version of the EMEP/EEA Guidebook. The updated emission factors decreases the emission from swine and poultry.

9.4 Waste

No recalculations have been made.

10 Projections

Projections of emissions are carried out by DCE periodically. The most recent projection was made in 2017, projecting the emissions of NO_x, SO_2, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$ and BC to 2035.

The total projected emissions for these pollutants for 2020, 2025, 2030 and 2035 are shown in the table below together with the historic emission for 2015. The general methodology is based on the methodologies used in the emission inventory as documented in this report. At the time of making the projection, the latest historical year was 2015, which has formed the basis of the emission projection. For parts of the activity projection for agriculture the latest historical year was 2014.

Table 10.1 2005 and 2015 emission and projected emissions for 2020, 2025, 2030 and 2035, tonnes.

Pollutant	2005	2015	2020	2025	2030	2035
SO_2	26 130	10 827	12 102	13 309	13 677	13 933
NO_x	202 784	114 490	99 061	88 758	78 776	73 010
NO_x*	185 601	97 555	79 103	68 477	58 259	52 494
NMVOC	148 701	109 477	102 246	100 411	98 833	96 054
NMVOC*	112 284	71 689	64 019	61 463	59 141	56 362
NH_3	87 555	72 759	70 320	69 657	68 917	68 885
NH_3**	84 162	70 701	67 335	66 652	65 912	65 879
NH_3***	78 825	65 300	62 032	61 461	60 802	60 770
$PM_{2.5}$	25 955	19 887	17 156	15 073	13 341	11 743
BC	5917	3932	3154	2859	2700	2481

* Excluding manure management and agricultural soils.

** Including adjustment for mineral fertiliser.

*** Including adjustment for mineral fertiliser and growing crops.

The detailed results of the projection are available online at:
http://envs.au.dk/videnudveksling/luft/emissioner/projection/air-pollution/

10.1 Trend by Pollutant

10.1.1 Nitrogen oxides, NO_X

The largest sources of NO_x are road transport, other mobile sources, agriculture and energy industries, accounting for 42 %, 20 %, 15 % and 14 % of the NO_x emission in 2015, respectively.

The NO_x emission is expected to decrease by 13 % from 2015 to 2020, 31 % from 2015 to 2030 and by 36 % from 2015 to 2035. 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).

It is not possible to quantify the effect of the change in NO_x tax. In the 2013 projection the possible effect of the increased tax was not estimated and likewise in this projection the effect of the lowering of the tax from DKK 25 to 5 per kg has not been estimated.

NO_x emissions from manure management and agricultural soils will not be part of the reduction commitment under the revised NEC Directive. This is due to the fact that methodologies were only recently included in the EMEP/EEA Guidebook, that the emissions from mineral fertiliser are very high and that this source was not included at the time when the reduction commitments were established.

Compared to 2005, the emission is projected to be 51.1 % lower in 2020, but 57.4 % lower when excluding emissions from animal husbandry, manure management and agricultural soils. The corresponding reductions for 2030 are 61.2 % and 68.6 %.

10.1.2 Sulphur dioxide, SO_2

The largest sources of SO_2 emissions are manufacturing industries and energy industries accounting for 27 % and 24 % of the national SO_2 emission in 2015.

The SO_2 emission is expected to increase by 12 % from 2015 to 2020, 26 % from 2015 to 2030 and by 29 % from 2015 to 2035. The emissions are projected to increase mainly from combustion in power plants, district heating plants and industrial plants. This increase is due to increased overall fuel consumption, specifically an increase in the use of coal and petroleum coke.

Compared to 2005, the emission is projected to be 53.7 % lower in 2020, and 47.7 % lower in 2030.

10.1.3 Non methane volatile organic compounds, NMVOC

The largest sources of emissions of NMVOC are agriculture followed by industrial processes, small combustion, fugitive emissions from fuels, transport and non-road machinery. These sources account for 35 %, 27 %, 13 %, 8 %, 8 % and 8 %, respectively, of the total NMVOC emission in 2015.

The NMVOC emission is expected to decrease by 6 % from 2015 to 2020, 10 % from 2015 to 2030 and by 12 % from 2015 to 2035. The largest decrease in emission is expected for residential plants but substantial decreases in emissions are also expected for road transport, other mobile sources and industrial processes.

NMVOC emissions from manure management and agricultural soils will not be part of the reduction commitment under the revised NEC Directive. This is due to the fact that methodologies were only recently included in the EMEP/EEA Guidebook, that the emissions from mineral fertiliser are very high (it’s a significant source) and that this source was not included at the time when the reduction commitments were established. Likewise, an adjustment has been approved under the UNECE as the source was not included when the current reduction targets were set.

Compared to 2005, the emission is projected to be 30.9 % lower in 2020, but 42.6 % lower when excluding emissions from animal husbandry, manure management and agricultural soils. The corresponding reductions for 2030 are 33.5 % and 47.4 %.

10.1.4 Ammonia (NH_3)

The dominant source of emissions of NH_3 is agriculture accounting for about 95 % of the total emission. The remaining 5 % is mainly emissions from small combustion, transport and composting. The largest sources are animal manure applied to soils followed by swine, dairy cattle, mink and mineral fertiliser. These sources account for 27 %, 22 %, 10 %, 10 % and 8 %, respectively, of the total NH_3 emission in 2015.

The NH_3 emission is expected to decrease by 3 % from 2015 to 2020, 5 % from 2015 to 2030 and by 5 % from 2015 to 2035. The largest decrease in emission is expected for residential plants, but substantial decreases in emissions are also expected for manure management especially swine mainly due to implementation of emission reducing technology in the animal housing systems. This is counteracted by an expected increase in the consumption of and hence emission from mineral fertiliser.

Denmark has applied for and been granted two adjustments under the UNECE and have applied for the same adjustments under the NECD. See Chapter 11 for more details.

Compared to 2005, the emission is projected to be 19.7 % lower in 2020, but 20.0 % lower when taking into account the adjustment for mineral fertiliser. The corresponding reductions for 2030 are 21.3 % and 21.7 %.

10.1.5 Particulate matter with diameter less than 2.5 µm - PM2.5

The single major source of the $PM_{2.5}$ emission is non-industrial combustion, mainly wood combustion in residential plants, which accounted for 70 % of the national $PM_{2.5}$ emission in 2015. Other important sources are road transport, other mobile sources and agriculture with 10 %, 6 % and 6 %, respectively

The $PM_{2.5}$ emission is expected to decrease by 14 % from 2015 to 2020, 33 % from 2015 to 2030 and by 41 % from 2015 to 2035. The emission reduction is mainly due to a decreasing emission from residential plants caused by the continued phase-in of new technologies with lower emissions.

Compared to 2005, the emission is projected to be 33.9 % lower in 2020 and 48.6 % lower in 2030.

10.1.6 Black carbon, BC

The single major source of the BC emission is small scale combustion, mainly wood combustion in residential plants, which accounted for 54 % of the national BC emission in 2015. Other important sources are transport, other mobile sources and fugitive emissions from fuels with 21 %, 16 % and 7 %, respectively.

The BC emission is expected to decrease by 20 % from 2015 to 2020, 31 % from 2015 to 2030 and by 36 % from 2015 to 2035. The emission reduction is mainly due to decreasing emissions from small combustion, due to implementation of newer technologies and from transport and other mobile sources, due to lower emission limit values for particulate matter.

10.2 Trend by sector

10.2.1 Stationary combustion

The trend in emissions from stationary combustion is mainly a result of the trend in the use of different fuels. The overall fuel consumption is projected to increase including the consumption of coal, petroleum coke and biomass. Due to the higher fuel consumption the emissions of NO_x and SO_2 increase from stationary combustion.

The emission projection is based on the official Danish energy projection (DEA, 2017).

The total NO_x emission increases from 2015 to 2035 due to increasing fuel consumption. The emission factor for wood is larger than for both natural gas and coal, which are the other largest fuel categories. Also, the increasing use of biogas leads to an increase in emissions due to the high emission factors for biogas. NO_x emissions from gas turbines used in the offshore sector are projected to decrease in the early part of the projection period, but then increases again to reach the same level in 2035 as in 2015.

The total SO_2 emission increases from 2015 to 2035 due to an increase in fuel consumption, especially coal, petroleum coke, fuel oil and biomass. This mainly occurs in power plants and industrial plants, while the emissions decrease from the residential sector, due to lower fuel consumption across all fuels. The other sectors remain relatively constant throughout the projection period.

From 2015 to 2035 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. Energy industries and manufacturing industries are projected to have increasing emissions due to the previously mentioned increase in fuel consumption. The residential sector will account for between 70 % and 81 % of the total NMVOC emission from stationary combustion plants, with the higher share being in the early part of the projection period.

Stationary combustion is a small source of NH_3 emissions. The by far dominant source is small combustion especially residential wood combustion. The emission from this source is projected to decrease due to a mix of newer technologies and decreasing wood consumption.

The $PM_{2.5}$ emission has increased in the historic years up to 2007 due to increasing wood combustion in residential plants followed by a decline in emissions due to improved technology. From 2015 to 2035 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 78 % and 90 % of the total $PM_{2.5}$ emission from stationary combustion plants in the period 2015-2035 with the share being highest in the beginning of the period.

The BC emission has increased in the historic years due to increasing wood combustion in residential plants. However, from 2015 to 2035 the BC 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 89 % of the total BC emission from stationary combustion plants in the period 2015-2035 with the share being highest in the beginning of the period.

Compared to the latest projection, the emissions generally show a higher overall level caused by the increasing fuel consumption, whereas the declining trend is similar to the previous projection. The emission factors used in the projection have been updated to take into account the latest historic year as well as other improvements to emission factors carried out for the historic emission inventory.

10.2.2 Road transport

Total fuel consumption and SO_2 emissions for road traffic are kept at a constant level during the 2016-2035 period. Passenger cars 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 development relies on the fuel consumption in the forecast period given that road transport fuel has a sulphur content of 10 ppm.

The NMVOC emissions from road transport are expected to decrease by 50 % (exhaust NMVOC) and 11 % (evaporation) from 2016 to 2035. The majority of the NMVOC emissions comes from gasoline passenger cars, and for this vehicle category the projected emissions decrease by 32 % from 2016 to 2025, explained by the gradually phasing out of less efficient catalytic converters. From 2025 onwards the emissions remain on a constant level proportionally with the total mileage for gasoline cars.

In terms of $PM_{2.5}$ and BC the total exhaust emission is expected to decline by 81 % and 95 %, respectively, from 2016 to 2035, in particular due to the introduction of diesel particulate filters (DPF) for Euro 5 cars/vans, and Euro VI trucks/buses. The largest emission source is passenger cars, followed by light duty vehicles, heavy duty vehicles and buses. Emission reductions are generally higher for BC than for $PM_{2.5}$ due to the very efficient removal of BC by particulate filters. The non-exhaust emissions of $PM_{2.5}$ and BC are proportional with total traffic volumes, and hence increase by 19 % from 2016 to 2035.

The NO_X emission for road transport declines by 69 % from 2016 to 2035. For trucks and buses high relative emission declines of 89 % and 92 %, respectively, are expected during the forecast period, due to the fleet turnover towards newer EU emission standards that in practice reduce the emission factors from Euro III onwards. For cars and vans the emission reductions (58 % and 65 %, respectively) are less favourable mainly due to the well-known problems for diesel cars (and vans) to comply with the EU emission legislation standards. The road transport emissions of NH_3 decrease by 49 % from 2016 to 2035.

Compared with the previous emission projections for the year 2025, the total fuel consumption and emissions of SO_2, exhaust $PM_{2.5}$, non-exhaust $PM_{2.5}$ and NH_3 have changed by 1 %, 2 %, -4 %, 2 % and -6 %, respectively. The 2025 emissions of NO_x have increased by 38 % compared with previous projections, mainly due to updated emission factors for Euro 6 diesel passenger cars and Euro 5 and 6 diesel vans that better reflect the NO_x emitted during real world driving. For NMVOC the 2025 emissions have decreased by 18 %, mainly due to a lower total fuel consumption of gasoline in the present energy forecast.

10.2.3 Other mobile sources

Other mobile sources are divided into the sub-sectors: National navigation, fishery, domestic air traffic, railways, working machinery and equipment in the sectors agriculture/forestry, industry, commercial/institutional and residential, and other (military activities and recreational craft).

From 2016-2035 the total fuel consumption decrease by 4 % for other mobile sources. The emissions of SO_2 increase by 9 %, due to an increase in fuel consumption for fishery, which uses marine diesel with relatively high sulphur content. For other mobile sources the emissions of NO_x, NMVOC, NH_3, $PM_{2.5}$ and BC decrease by 55 %, 15 %, 7 %, 58 % and 77 %, respectively.

The SO_2 emissions for other mobile sources are insignificant except for sea-going vessels. However, for navigation, the reduction of the sulphur content in heavy fuel oil used in the Baltic and North Sea SO_x emission control areas (SECAs) has had a major emission impact from 2015.

By far the most of the NMVOC emission comes from gasoline gardening machinery in commercial/institutional. The same gasoline equipment types also give considerable contributions for residential. The projected NMVOC emission reductions for commercial/institutional and residential are due to the introduction of the cleaner gasoline stage II and stage V emission technology for some types of equipment. For agriculture/forestry and industry, the gradually stricter emission standards for diesel engines and the decrease in fuel consumption will cause the NMVOC emission to decrease during the forecast period.

For $PM_{2.5}$, non-road machinery in agriculture/forestry is the largest emission source for other mobile sources in the beginning of the forecast period followed by non-road industry, fisheries and navigation. By the end of the forecast period, fisheries and navigation become the largest emission sources. Due to the penetration of cleaner engine technologies, in compliance with future emission standards, the $PM_{2.5}$ emissions from agriculture/forestry and industry decrease substantially throughout the forecast period.

The $PM_{2.5}$ emissions from fisheries and navigation are mainly due to combustion of marine fuels with a relative high content of sulphur (1000 ppm), and hence the $PM_{2.5}$ emissions increase proportionally with fuel consumption throughout the forecast period.

Being a sub part of total PM, the decline in BC emissions throughout the forecast period is driven by the general decrease in PM emissions for diesel fuelled agriculture/forestry and industry machinery and the step-wise introduction of Stage V machinery from 2019/2020. In order to meet the Stage V PM emission standards for engines >= 19 kW particulate filters are needed which in addition are very efficient removers of BC.

For agriculture/forestry, industry, navigation, fisheries and railways, substantial NO_x emission improvements are expected during the course of the forecast period due to the penetration of cleaner engine technologies, in compliance with future emission standards.

Compared with the previous emission projections for the year 2025, the total fuel consumption and emissions of $PM_{2.5}$, BC and NH_3 have decreased by 9 %, 7 %, 14 % and 7 %, respectively. These changes are due to revised bottom up estimates for industrial non road machinery which have resulted in significant fuel consumption and emission reductions for this inventory sector. The 2025 emissions of SO_2 and NO_x have increased by 4 % and 12 %, respectively, compared to the previous projection, due to an increase in fuel consumption and emissions for fishery and somewhat smaller fuel consumption and emission increases for navigation. For NMVOC the 2025 emissions remain practically unchanged between projections. In this case the drop in emissions for industrial non road machinery is outbalanced by the emission increase for sea vessels.

10.2.4 Fugitive emissions from fuels

This sector includes emissions from exploration, extraction, refining, storage, handling, and transport of fuels, the major sources being SO_2 and NMVOC from oil extraction/storage/refining and natural gas and BC emissions from coal storage.

SO_2 mainly stem from refining of oil, and fluctuates annually in the historical years due to unpredictable circumstances at the refineries, e.g. the performance of the sulphur recovery units. The mean of the latest five historical years are applied for all projection years. SO_2 from the fugitive sector contribute 5-6 % to the national SO_2 emission in the years 2015-2035.

The major NMVOC sources are refinery processes, onshore and offshore activities in oil and gas production, and service stations, refinery processes being by far the major single source in the projection years. Fugitive emissions from refineries are highly unpredictable and only very few measurements are available. Emissions from onshore and offshore activities and from service stations follow the prognosis for oil- and gas production and gasoline consumption for transport, respectively. NMVOC from the fugitive sector contribute 8-9 % to the national NMVOC emission in the years 2015-2035. The projected activity data for the oil and gas sector is provided by the Danish Energy Agency (DEA, 2016a).

The major BC source is storage of coal. BC from the fugitive sector contributes 7 % to the national BC emission in 2015, increasing to 20 % in 2035. The increasing share of the national total owe to decreasing emissions from other sectors (mainly transport and small combustion), as BC emissions from coal storage increases for the projection years following the trend in the projected coal consumption (DEA, 2017).

Compared to the latest projection, the amount of coal has increased in the later part of the projection period, which impacts the BC emission projection. Regarding the oil and gas projection, the projected production of oil is markedly lower in the current projection while the gas production is slightly higher. The amount of gas flared is similar for the first part of the projection period, but lower in the last years of the projection.

10.2.5 Industrial processes and product use

The projections of emissions from the industrial processes and product use (IPPU) sector are generally based on projection of activity data for the individual source categories and implied emission factors (IEF) for 2015. Activity data can be projected in four ways all of which has been used as described in the following chapters;

- By extrapolation of representative historical years using the projected production values for glass, steel and cement/construction industries available from the DEA (Danish Energy Agency, 2016b).
- By estimating an expected future activity level and the number of years for the given source category to reach this level.
- By using an average of representative historical years.
- By linear regression of a significant trend in the historical data.

The increasing trend of the projected SO_2 emissions is caused by increasing emission from the production of ceramics (bricks, tiles and expanded clay products.. Ceramics are projected using the projected production values from the DEA. Only the very small contribution to SO_2 emissions from the use of tobacco has a decreasing trend, the remaining four source categories are estimated as constant in the projection.

Only three small source categories in the IPPU sector lead to NO_x emissions and only the smallest of the three (use of tobacco) is expected to decrease, the remaining two source categories are projected as constant.

The predominant source of NMVOC emissions are from diffuse solvent use constituting highly diverse activities and product uses, each comprising a large number of chemicals. Emissions from industrial sectors are typically attributed relatively low emission factors. All projected solvent use categories show a decrease in NMVOC emissions, however, there is stagnation in the latest eight years of the historic emissions; i.e. the four solvent use categories show approximately constant emissions during the period (2008 to 2015).

The most realistic projection from 2015 to 2030 is assumed to represent 25 % of an exponential fit and 75 % of the, approximately constant, historic 2007 - 2014 estimates. However, if the emissions in the coming years continue the constant trend, a possible change in the coming projection will be to assign a higher weight of the constant 2007 to present emissions compared to the exponential fit of historic 1995 – present emissions. This is in agreement with new information and data on production, sale and import/export within and outside the EU supplied by the European Solvents Industry Group (ESIG), which predict a stabilized growth in Europe and probably also in Denmark.

Between 52 % (2015) and 61 % (2030) of the projected $PM_{2.5}$ emissions from IPPU are projected using the projected production values from the DEA. The largest of these sources, and the primary reason for the increasing trend in $PM_{2.5}$ emissions, is quarrying and mining of other minerals than coal. Around 25 % of the $PM_{2.5}$ emissions from IPPU are expected to remain constant, the largest of these is wood processing.

There are seven source categories emitting BC in the IPPU sector, the largest of which is stone wool production. In total the contribution is around 0.3 % of the national total.

10.2.6 Agriculture

Activity data used for projection of emission of NH_3, NMVOC, NO_x and PM is based on a range of sources.

Number of cattle, swine, broilers and hens in 2016-2035 is based on projections made in the model AGMEMOD (Jensen, 2017). Number of mink is projected by IFRO (Hansen, 2016) and the number of sheep, goats, horses and other poultry is based on the trend in 2013-2015.

Projection for distribution of animals in different housings types is based on estimations from SEGES and projection of amount of NH_3 reducing technology used in housings is based on estimations from MST (2017). Application methods for manure applied to the soils and acidification of manure applied to soils is projected by SEGES. Use of inorganic fertiliser in 2016-2035 is based on Jensen et al (2016) and estimations by SEGES and Olesen (2017).

In 2015 agriculture contributed with 95% of NH_3 emission, 35 % of the NMVOC emission, 15 % of the NO_x emission and 6 % of the $PM_{2.5}$ emission.

The total emission of NH_3 from agriculture is expected to decrease by 4 % from 2015 to 2035. Emission from manure management contributes with around 50 % of the total NH_3 emission from the agricultural sector and is expected to decrease from 2015 to 2035, despite an increase in number of cattle and mink. This is mainly due to increase in amount of NH_3 reducing technology used in housings and change in housing system over time. Emission from inorganic fertiliser is expected to increase due to new Danish regulation, which allows the farmers to use more fertiliser on the fields.

The total emission of NMVOC is expected to increase from 2015 to 2035. Around 90 % of the emission of NMVOC comes from manure management and the increase is due to increase in emission from manure management. Emission from manure management increases mainly due to increase in number cattle. The emission of NMVOC from cultivated crops and field burning of agricultural residue is almost unaltered.

The total emission of NO_x is expected to increase with 21 % from 2015 to 2035, this is mainly due to increase in emission of NO_x from inorganic N-fertiliser. Use of inorganic fertiliser is expected to increase due to Danish regulation, which allows the farmers to use more fertiliser on the fields. The emission from manure management decrease mainly for swine and dairy cattle due to change in housings with slurry, which have a lower emission of NO_x compared to solid manure. Emission from sewage sludge and field burning decreases due to reduction of the agricultural area. Emission of NO_x from manure applied to soil increase due to increase in amount of N applied.

The total emission of $PM_{2.5}$ is expected to increase slightly from 2015 to 2035 due to increase in the emission from manure management. The increase in $PM_{2.5}$ emission from manure management is mainly due to increase in emission from cattle because of increase in number of animals. The emission of

$PM_{2.5}$ from field operations and field burning of agricultural residue is expected to decrease due to decrease in agricultural area.

10.2.7 Waste

Since all municipal, industrial and hazardous waste incineration in Denmark occur with energy recovery, emissions from these activities are included in the stationary combustion part of the inventory and projection. The sources reported in the waste sector are human and animal cremations, accidental fires and composting.

The waste sector is only significant for SO_2, NH_3 and $PM_{2.5}$. During the years 2016-2035, the waste categories are projected to emit 5-6 % of the national SO_2 emission. For NH_3, the emission from composting accounts for about 1 % of the emission and the share is slightly increasing during the projection period, as composting is projected to continue an increasing trend. For $PM_{2.5}$, the emission mainly stems from accidental fires and accounts for 1-2 % of the national total. For the remaining pollutants the contribution from the waste sector are all around or under 1 % of the national emission. The emissions for all pollutants with the exception of NH_3 are projected to remain relatively stable during the time-series.

Compared to the latest projection, there are no significant changes.

10.3 References

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DEA, 2016b: Projection of production values. Danish Energy Agency, November 2016.

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SEGES: https://www.seges.dk/en

11 Adjustments

Decision 2012/3 of the Executive Body (UNECE, 2012a) decided that adjustments may be made under specific circumstances to the national emission inventories for the purpose of comparing the inventories with emission reduction commitments.

Under the revised NEC Directive (Directive 2016/2284/EU) Article V specifies flexibilities one of which is the possibility to establish adjusted emission inventories, where non-compliance with the national emission reduction commitments would result from applying improved emission inventory methods updated in accordance with scientific knowledge.

The circumstances under which an adjustment may be applied fall into three broad categories where:

- Emission source categories are identified that were not accounted for at the time when emission reduction commitments were set;
- Emission factors used to determine emissions levels for particular source categories for the year in which emissions reduction commitments are to be attained are significantly different than the emission factors applied to these categories when emission reduction commitments were set;
- The methodologies used for determining emissions from specific source categories have undergone significant changes between the time when emission reduction commitments were set and the year they are to be attained.

The supporting documentation required by Parties applying for an adjustment is set out in Decision 2012/12 (UNECE, 2012b) and in Annex IV Part 4 of Directive 2016/2284/EU and is summarised below.

A Party's/MS supporting documentation for an adjustment to its emission inventory or emission reduction commitments shall include:

- Evidence that the Party/MS exceeds its emission reduction commitments;
- Evidence of to what extent the adjustment to the emission inventory reduces the exceedance and possibly brings the Party/MS in compliance;
- An estimation of whether and when the reduction commitment is expected to be met based on emission projections without the adjustment, thereby using best available science;
- A full demonstration that the adjustment is consistent with one or more of the three broad categories above. Reference can be made, as appropriate, to relevant previous adjustments:
  - For new emission source categories:
    - Evidence that the new emission source category is acknowledged in scientific literature and/or the EMEP/EEA air pollutant emission inventory guidebook;
    - Evidence that this source category was not included in the relevant historic national emission inventory at the time when the emission reduction commitment was set;
    - Evidence that emissions from a new source category contribute to a Party being unable to meet its reduction commitments, support-

ed by a detailed description of the methodology, data and emission factors used to arrive at this conclusion;

- For significantly different emission factors used for determining emissions from specific source categories:
  - A description of the original emission factors, including a detailed description of the scientific basis upon which the emission factor was derived;
  - Evidence that the original emission factors were used for determining the emission reductions at the time when they were set;
  - A description of the updated emission factors, including detailed information on the scientific basis upon which the emission factor was derived;
  - A comparison of emission estimates made using the original and the updated emission factors, demonstrating that the change in emission factors contributes to a Party/MS being unable to meet its reduction commitments; and
  - The rationale for deciding whether the changes in emission factors are significant;
- For significantly different methodologies used for determining emissions from specific source categories:
  - A description of the original methodology used, including detailed information on the scientific basis upon which the methodology was based;
  - Evidence that the original methodology was used for determining the emission reductions at the time when they were set;
  - A description of the updated methodology used, including a detailed description of the scientific basis or reference upon which it has been derived;
  - A comparison of emission estimates made using the original and updated methodologies demonstrating that the change in methodology contributes to a Party/MS being unable to meet its reduction commitment; and
  - The rationale for deciding whether the change in methodology is significant;

11.1 Accepted adjustments

In the 2014 submission, Denmark applied for two adjustments related to the emission of NH_3, due to exceedance of the emission ceiling. One was related to ammonia from growing crops, which was a new emission source compared to when the emission reduction commitments were agreed. The other was related to the new NH_3 emission factors for inorganic fertilisers included in the 2013 EMEP/EEA Guidebook. The two adjustments were accepted during the technical review and approved by the EMEP Steering Body.

In the 2015 submission, Denmark applied for an adjustment to the emission of NMVOC, due to exceedance of the emission ceiling. The adjustment was related to NMVOC emission from animal husbandry and manure management, which was a new emission source compared to when the emission reduction commitments were agreed, since default methodology and emission factors were not available in the EMEP/EEA Guidebook until the 2013 version. The adjustment was accepted during the technical review and approved by the EMEP Steering Body.

The details on adjustments are included below.

11.2 NH_3 emissions from inorganic fertilisers

The 2013 EMEP/EEA Guidebook (EEA, 2013) contained updated EFs for NH_3 from the use of synthetic fertilizer. These emission factors are unlike the emission factors in the previous version of the EMEP/EEA Guidebook not temperature dependent. This means that the current emission factors are significantly higher compared to the previous emission factors. In the 2016 EMEP/EEA Guidebook (EEA, 2016) the default emission factors for inorganic fertilisers were updated, but still remain higher than the original emission factors used when setting the reduction target.

The NH_3 emission from inorganic fertilisers (NFR category 3Da1) using both the emission factors from the 2016 EMEP/EEA Guidebook and the original emission factors is shown in Table 11.1 below.

Table 1.1 Overview of the adjusted and unadjusted NH_3 emission from inorganic fertilisers, kt.

	2010	2011	2012	2013	2014	2015
NH_3 emission from inorganic fertilisers using new EFs	5.51	5.56	5.28	5.59	5.64	6.10
NH_3 emission from inorganic fertilisers using old EFs	3.47	3.94	3.77	3.54	3.39	4.04
Adjustment	-2.04	-1.63	-1.51	-2.05	-2.25	-2.06

The numbers presented in Table 11.1 for the old emission factors for 2010 to 2012 are identical to the numbers included in the expert review report (CEIP, 2014). The values for 2013 onwards are estimated using the same methodology as the methodology presented to and approved by the expert review team.

As mentioned, the 2016 edition of the EMEP/EEA Guidebook contains revised emission factors; these have been used for the calculation of the values labelled as new emission factors in Table 11.1. The result is that the adjustment is now lower than in previous submissions. A comparison between the emission factors are provided in Table 11.2.

Table 1.2. Comparison of NH_3 emission factors, kg NH3-N per kg N

Fertiliser type	Original EFs	2013 Guidebook	2016 Guidebook
Calcium and boron calcium nitrate	0.014	0.113	0.050
Ammonium sulphate	0.014	0.013	0.090
Calcium ammonium nitrate and other nitrate types	0.009	0.022	0.008
Ammonium nitrate	0.009	0.037	0.015
Liquid ammonia	0.020	0.011	0.019
Urea	0.128	0.243	0.155
Other nitrogen fertiliser	0.063	0.037	0.010
Magnesium fertiliser	0.014	0.113	0.050
NPK-fertiliser	0.009	0.037	0.050
Diammonphosphate	0.014	0.113	0.050
Other NP fertiliser types	0.014	0.113	0.050
NK fertiliser	0.009	0.037	0.015

No recalculation of the activity data, i.e. the amount of the different types of inorganic fertilisers has been made.

11.3 NH_3 from cultivated crops

NH_3 emissions from cultivated crops are acknowledged in the EMEP/EEA Guidebook, but no default emission factor is provided. Denmark uses a country specific emission factor to estimate emissions from cultivated crops as documented in Chapter 5. This source was not included in the consideration when establishing the emission ceiling neither is it included in the GAINS model.

The NH_3 emission from cultivated crops (NFR category 3De) is shown in Table 11.3 below.

Table 1.3 Overview of the adjusted and unadjusted NH_3 emission from cultivated crops, kt.

	2010	2011	2012	2013	2014	2015
NH_3 emission from cultivated crops	5.41	5.42	5.40	5.37	5.45	5.40
Adjustment	-5.41	-5.42	-5.40	-5.37	-5.45	-5.40

The numbers presented in Table 11.2 for 2010 to 2012 are identical to the numbers included in the expert review report (CEIP, 2014). The values for 2013 onwards are estimated using the same methodology as the methodology presented to and approved by the expert review team. No recalculations of previous reported values have been carried out.

11.4 NMVOC from animal husbandry and manure management

The 2013 EMEP/EEA Guidebook implemented a default methodology and default emission factors for NMVOC from animal husbandry and manure management.

The NMVOC emission from animal husbandry and manure management (NFR category 3B) is shown in Table 11.4 below.

Table 1 .4 Overview of the adjusted and unadjusted NMVOC emission from animal husbandry and manure management, kt.

	2010	2011	2012	2013	2014	2015
NMVOC from animal husbandry and manure management	35.44	35.31	35.66	35.88	35.75	35.68
Adjustment	-35.44	-35.31	-35.66	-35.88	-35.75	-35.68

The numbers presented in Table 11.3 are not identical to the numbers included in the expert review report (CEIP, 2015). This is due to recalculations related to the number of animals. The recalculations for the agriculture sector are described in Chapter 5. For the 2017 submission only very small recalculations were made. The emissions are estimated using the same methodology as the methodology presented to and approved by the expert review team.

11.5 Total effect of approved adjustments

The total effect of the approved NH_3 adjustments is documented in Table 11.5 below. The emission ceiling for NH_3 for Denmark was 69 kt.

Table 1.5 Total effect of NH_3 adjustments.

Emission, kt	2010	2011	2012	2013	2014	2015
Total NH_3 adjustment	-7.45	-7.05	-6.91	-7.42	-7.70	-7.46
Unadjusted NH_3 emission	78.17	76.53	74.71	71.97	72.15	72.76
Adjusted NH_3 emission	70.72	69.48	67.80	64.55	64.45	65.30

The total effect of the approved NMVOC adjustment is documented in Table 11.6 below. The emission ceiling for NMVOC for Denmark was 85 kt.

Table 1.6 Total effect of NMVOC adjustments.

Emission, kt	2010	2011	2012	2013	2014	2015
Total NMVOC adjustment	-35,44	-35,31	-35,66	-35,88	-35,75	-35.68
Unadjusted NMVOC emission	125,33	118,01	115,00	115,07	106,53	109,48
Adjusted NMVOC	89,90	82,71	79,34	79,19	70,78	73.79

11.6 Application for adjustment

No new application for an adjustment is made in this submission.

11.7 References

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Annex 1 - Key category analysis

Due to a lack of resources a key category analysis has not been performed for this submission.

Annex 2 – Information on the energy balance

The official Danish energy balance is prepared by the Danish Energy Agency (DEA). The DEA is responsible for reporting of energy data to Eurostat and the IEA. DCE uses the energy balance as published by the DEA. However, some reallocations between sectors are made in connection with the bottom-up modelling done at DCE for different subsectors within transport and mobile sources. For a more in-depth discussion of the energy statistics please see Annex 3A-9. For information on the reallocation of fuels please see Chapter 3.3.

Annex 3A - Stationary combustion

Annex 3A-1 Correspondence list for SNAP/CRF

Table 3A-1.1 Correspondence list for stationary combustion SNAP/NFR.

snap_id	snap_name	nfr_id_EA	nfr_name
010100	Public power	1A1a	Public electricity and heat production
010101	Combustion plants >= 300 MW (boilers)	1A1a	Public electricity and heat production
010102	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	Public electricity and heat production
010103	Combustion plants < 50 MW (boilers)	1A1a	Public electricity and heat production
010104	Gas turbines	1A1a	Public electricity and heat production
010105	Stationary engines	1A1a	Public electricity and heat production
010200	District heating plants	1A1a	Public electricity and heat production
010201	Combustion plants >= 300 MW (boilers)	1A1a	Public electricity and heat production
010202	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	Public electricity and heat production
010203	Combustion plants < 50 MW (boilers)	1A1a	Public electricity and heat production
010204	Gas turbines	1A1a	Public electricity and heat production
010205	Stationary engines	1A1a	Public electricity and heat production
010300	Petroleum refining plants	1A1b	Petroleum refining
010301	Combustion plants >= 300 MW (boilers)	1A1b	Petroleum refining
010302	Combustion plants >= 50 and < 300 MW (boilers)	1A1b	Petroleum refining
010303	Combustion plants < 50 MW (boilers)	1A1b	Petroleum refining
010304	Gas turbines	1A1b	Petroleum refining
010305	Stationary engines	1A1b	Petroleum refining
010306	Process furnaces	1A1b	Petroleum refining
010400	Solid fuel transformation plants	1A1c	Oil and gas extraction
010401	Combustion plants >= 300 MW (boilers)	1A1c	Oil and gas extraction
010402	Combustion plants >= 50 and < 300 MW (boilers)	1A1c	Oil and gas extraction
010403	Combustion plants < 50 MW (boilers)	1A1c	Oil and gas extraction
010404	Gas turbines	1A1c	Oil and gas extraction
010405	Stationary engines	1A1c	Oil and gas extraction
010406	Coke oven furnaces	1A1c	Oil and gas extraction
010407	Other (coal gasification, liquefaction)	1A1c	Oil and gas extraction
010500	Coal mining, oil / gas extraction, pipeline compressors	1A1c	Oil and gas extraction
010501	Combustion plants >= 300 MW (boilers)	1A1c	Oil and gas extraction
010502	Combustion plants >= 50 and < 300 MW (boilers)	1A1c	Oil and gas extraction
010503	Combustion plants < 50 MW (boilers)	1A1c	Oil and gas extraction
010504	Gas turbines	1A1c	Oil and gas extraction
010505	Stationary engines	1A1c	Oil and gas extraction
010506	Pipeline compressors	1A3e i	Pipeline transport
020100	Commercial and institutional plants	1A4a i	Commercial/institutional: Stationary
020101	Combustion plants >= 300 MW (boilers)	1A4a i	Commercial/institutional: Stationary
020102	Combustion plants >= 50 and < 300 MW (boilers)	1A4a i	Commercial/institutional: Stationary
020103	Combustion plants < 50 MW (boilers)	1A4a i	Commercial/institutional: Stationary
020104	Stationary gas turbines	1A4a i	Commercial/institutional: Stationary
020105	Stationary engines	1A4a i	Commercial/institutional: Stationary
020106	Other stationary equipments	1A4a i	Commercial/institutional: Stationary
020200	Residential plants	1A4b i	Residential: Stationary
020201	Combustion plants >= 50 MW (boilers)	1A4b i	Residential: Stationary
020202	Combustion plants < 50 MW (boilers)	1A4b i	Residential: Stationary
020203	Gas turbines	1A4b i	Residential: Stationary
020204	Stationary engines	1A4b i	Residential: Stationary
020205	Other equipments (stoves, fireplaces, cooking)	1A4b i	Residential: Stationary
020300	Plants in agriculture, forestry and aquaculture	1A4c i	Agriculture/Forestry/Fishing: Stationary
020301	Combustion plants >= 50 MW (boilers)	1A4c i	Agriculture/Forestry/Fishing: Stationary
020302	Combustion plants < 50 MW (boilers)	1A4c i	Agriculture/Forestry/Fishing: Stationary
020303	Stationary gas turbines	1A4c i	Agriculture/Forestry/Fishing: Stationary
020304	Stationary engines	1A4c i	Agriculture/Forestry/Fishing: Stationary
020305	Other stationary equipments	1A4c i	Agriculture/Forestry/Fishing: Stationary
030100	Comb. in boilers, gas turbines and stationary	1A2g viii	Other manufacturing industry
030101	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
030102	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
030103	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
030104	Gas turbines	1A2g viii	Other manufacturing industry
030105	Stationary engines	1A2g viii	Other manufacturing industry
030106	Other stationary equipments	1A2g viii	Other manufacturing industry
030200	Process furnaces without contact (a)	1A2g viii	Other manufacturing industry
030203	Blast furnace cowpers	1A2a	Iron and steel
030204	Plaster furnaces	1A2g viii	Other manufacturing industry
030205	Other furnaces	1A2g viii	Other manufacturing industry
030400	Iron and Steel	1A2a	Iron and steel
030401	Combustion plants >= 300 MW (boilers)	1A2a	Iron and steel
030402	Combustion plants >= 50 and < 300 MW (boilers)	1A2a	Iron and steel

snap_id	snap_name	nfr_id_EA	nfr_name
030403	Combustion plants < 50 MW (boilers)	1A2a	Iron and steel
030404	Gas turbines	1A2a	Iron and steel
030405	Stationary engines	1A2a	Iron and steel
030406	Other stationary equipments	1A2a	Iron and steel
030500	Non-Ferrous Metals	1A2b	Non-ferrous metals
030501	Combustion plants >= 300 MW (boilers)	1A2b	Non-ferrous metals
030502	Combustion plants >= 50 and < 300 MW (boilers)	1A2b	Non-ferrous metals
030503	Combustion plants < 50 MW (boilers)	1A2b	Non-ferrous metals
030504	Gas turbines	1A2b	Non-ferrous metals
030505	Stationary engines	1A2b	Non-ferrous metals
030506	Other stationary equipments	1A2b	Non-ferrous metals
030600	Chemical and Petrochemical	1A2c	Chemicals
030601	Combustion plants >= 300 MW (boilers)	1A2c	Chemicals
030602	Combustion plants >= 50 and < 300 MW (boilers)	1A2c	Chemicals
030603	Combustion plants < 50 MW (boilers)	1A2c	Chemicals
030604	Gas turbines	1A2c	Chemicals
030605	Stationary engines	1A2c	Chemicals
030606	Other stationary equipments	1A2c	Chemicals
030700	Non-Metallic Minerals	1A2f	Non-metallic minerals
030701	Combustion plants >= 300 MW (boilers)	1A2f	Non-metallic minerals
030702	Combustion plants >= 50 and < 300 MW (boilers)	1A2f	Non-metallic minerals
030703	Combustion plants < 50 MW (boilers)	1A2f	Non-metallic minerals
030704	Gas turbines	1A2f	Non-metallic minerals
030705	Stationary engines	1A2f	Non-metallic minerals
030706	Other stationary equipments	1A2f	Non-metallic minerals
030800	Mining and Quarrying	1A2g viii	Other manufacturing industry
030801	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
030802	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
030803	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
030804	Gas turbines	1A2g viii	Other manufacturing industry
030805	Stationary engines	1A2g viii	Other manufacturing industry
030806	Other stationary equipments	1A2g viii	Other manufacturing industry
030900	Food and Tobacco	1A2e	Food processing, beverages and tobacco
030901	Combustion plants >= 300 MW (boilers)	1A2e	Food processing, beverages and tobacco
030902	Combustion plants >= 50 and < 300 MW (boilers)	1A2e	Food processing, beverages and tobacco
030903	Combustion plants < 50 MW (boilers)	1A2e	Food processing, beverages and tobacco
030904	Gas turbines	1A2e	Food processing, beverages and tobacco
030905	Stationary engines	1A2e	Food processing, beverages and tobacco
030906	Other stationary equipments	1A2e	Food processing, beverages and tobacco
031000	Textile and Leather	1A2g viii	Other manufacturing industry
031001	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031002	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031003	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031004	Gas turbines	1A2g viii	Other manufacturing industry
031005	Stationary engines	1A2g viii	Other manufacturing industry
031006	Other stationary equipments	1A2g viii	Other manufacturing industry
031100	Paper, Pulp and Print	1A2d	Pulp, Paper and Print
031101	Combustion plants >= 300 MW (boilers)	1A2d	Pulp, Paper and Print
031102	Combustion plants >= 50 and < 300 MW (boilers)	1A2d	Pulp, Paper and Print
031103	Combustion plants < 50 MW (boilers)	1A2d	Pulp, Paper and Print
031104	Gas turbines	1A2d	Pulp, Paper and Print
031105	Stationary engines	1A2d	Pulp, Paper and Print
031106	Other stationary equipments	1A2d	Pulp, Paper and Print
031200	Transport Equipment	1A2g viii	Other manufacturing industry
031201	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031202	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031203	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031204	Gas turbines	1A2g viii	Other manufacturing industry
031205	Stationary engines	1A2g viii	Other manufacturing industry
031206	Other stationary equipments	1A2g viii	Other manufacturing industry
031300	Machinery	1A2g viii	Other manufacturing industry
031301	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031302	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031303	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031304	Gas turbines	1A2g viii	Other manufacturing industry
031305	Stationary engines	1A2g viii	Other manufacturing industry
031306	Other stationary equipments	1A2g viii	Other manufacturing industry
031400	Wood and Wood Products	1A2g viii	Other manufacturing industry
031401	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry

snap_id	snap_name	nfr_id_EA	nfr_name
031402	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031403	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031404	Gas turbines	1A2g viii	Other manufacturing industry
031405	Stationary engines	1A2g viii	Other manufacturing industry
031406	Other stationary equipments	1A2g viii	Other manufacturing industry
031500	Construction	1A2g viii	Other manufacturing industry
031501	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031502	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031503	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031504	Gas turbines	1A2g viii	Other manufacturing industry
031505	Stationary engines	1A2g viii	Other manufacturing industry
031506	Other stationary equipments	1A2g viii	Other manufacturing industry
031600	Cement production	1A2f	Non-metallic minerals
031601	Combustion plants >= 300 MW (boilers)	1A2f	Non-metallic minerals
031602	Combustion plants >= 50 and < 300 MW (boilers)	1A2f	Non-metallic minerals
031603	Combustion plants < 50 MW (boilers)	1A2f	Non-metallic minerals
031604	Gas turbines	1A2f	Non-metallic minerals
031605	Stationary engines	1A2f	Non-metallic minerals
031606	Other stationary equipments	1A2f	Non-metallic minerals
032000	Non-specified (Industry)	1A2g viii	Other manufacturing industry
032001	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
032002	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
032003	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
032004	Gas turbines	1A2g viii	Other manufacturing industry
032005	Stationary engines	1A2g viii	Other manufacturing industry
032006	Other stationary equipments	1A2g viii	Other manufacturing industry

Annex 3A-2 Fuel rate

Table 3A-2.1 Fuel consumption rate of stationary combustion plants 1990-2015, PJ.

Sum of Fuel_rate_PJ			Year									
fuel_type	**fuel_id**	**fuel_gr_abbr**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
SOLID	101A	ANODIC CARBON										
	102A	COAL	253.4	344.3	286.8	300.8	323.4	270.3	371.9	276.3	234.3	196.5
	103A	SUB-BITUMINOUS										
	106A	BROWN COAL BRI.	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
	107A	COKE OVEN COKE	1.3	1.4	1.2	1.2	1.2	1.3	1.2	1.3	1.3	1.4
LIQUID	110A	PETROLEUM COKE	4.5	4.4	4.3	5.7	7.5	5.3	5.9	6.0	5.3	6.8
	203A	RESIDUAL OIL	32.1	38.3	38.5	32.8	46.2	33.0	37.8	26.6	30.0	23.7
	204A	GAS OIL	63.8	67.4	58.6	64.6	56.5	56.3	60.8	53.9	51.3	50.4
	206A	KEROSENE	5.1	1.0	0.8	0.8	0.7	0.6	0.5	0.4	0.4	0.3
	225A	ORIMULSION						19.9	36.8	40.5	32.6	34.2
	303A	LPG	3.0	2.8	2.4	2.5	2.6	2.7	3.0	2.6	2.8	2.5
	308A	REFINERY GAS	14.2	14.5	14.9	15.4	16.4	20.8	21.4	16.9	15.2	15.7
GAS	301A	NATURAL GAS	76.1	86.1	90.5	102.5	114.6	132.7	156.3	164.5	178.7	187.9
WASTE	114A	WASTE	15.5	16.7	17.8	19.4	20.3	22.9	25.0	26.8	26.6	29.1
	115A	INDUSTR. WASTES										
BIOMASS	111A	WOOD	18.2	20.0	21.0	22.2	21.9	21.8	23.4	23.4	22.9	24.4
	117A	STRAW	12.5	13.3	13.9	13.4	12.7	13.1	13.5	13.9	13.9	13.7
	215A	BIO OIL	0.7	0.7	0.7	0.8	0.2	0.3	0.1	0.0	0.0	0.0
	309A	BIOGAS	0.8	0.9	0.9	1.1	1.3	1.8	2.0	2.4	2.7	2.7
	310A	BIO GASIF GAS					0.1	0.0	0.0	0.0	0.0	0.0
	315A	BIONATGAS										
Total			**501.3**	**612.1**	**552.4**	**583.2**	**625.6**	**602.9**	**759.6**	**655.5**	**618.1**	**589.4**

Sum of Fuel_rate_PJ			Year									
fuel_type	**fuel_id**	**fuel_gr_abbr**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
SOLID	101A	ANODIC CARBON										0.0
	102A	COAL	164.7	174.3	174.7	239.0	182.5	154.0	232.0	194.1	170.5	167.7
	103A	SUB-BITUMINOUS										
	106A	BROWN COAL BRI.	0.0	0.0	0.0	0.0					0.0	0.0
	107A	COKE OVEN COKE	1.2	1.1	1.1	1.0	1.1	1.0	1.0	1.1	1.0	0.8
LIQUID	110A	PETROLEUM COKE	6.8	7.8	7.8	8.0	8.4	8.1	8.5	9.2	6.9	5.9
	203A	RESIDUAL OIL	18.8	21.1	26.2	28.6	24.5	21.9	26.1	19.8	15.8	14.7
	204A	GAS OIL	44.1	46.3	41.2	41.4	38.2	34.2	29.5	25.3	25.0	27.4
	206A	KEROSENE	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.1	0.1	0.1
	225A	ORIMULSION	34.1	30.2	23.8	1.9	0.0					
	303A	LPG	2.4	2.2	2.0	2.1	2.2	2.2	2.3	1.9	1.7	1.5
	308A	REFINERY GAS	15.6	15.8	15.2	16.6	15.9	15.3	16.1	15.9	14.1	15.0
GAS	301A	NATURAL GAS	186.1	193.8	193.6	195.9	195.1	187.4	191.1	171.0	173.0	165.7
WASTE	114A	WASTE	29.8	31.3	33.3	35.1	35.3	35.8	36.9	38.1	39.6	37.6
	115A	INDUSTR. WASTES	0.5	1.4	1.9	1.5	2.0	2.0	1.5	1.6	2.0	1.7
BIOMASS	111A	WOOD	27.5	30.8	31.6	38.9	43.9	49.7	52.1	60.3	63.6	66.0
	117A	STRAW	12.2	13.7	15.7	16.9	17.9	18.5	18.5	18.8	15.9	17.4
	215A	BIO OIL	0.0	0.2	0.1	0.4	0.6	0.8	1.1	1.2	1.8	1.7
	309A	BIOGAS	2.9	3.0	3.4	3.6	3.7	3.8	3.9	3.9	3.9	4.2
	310A	BIO GASIF GAS	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
	315A	BIONATGAS										
Total			**547.1**	**573.4**	**571.7**	**631.2**	**571.6**	**535.1**	**621.0**	**562.4**	**535.1**	**527.7**

Sum of Fuel_rate_PJ			Year					
fuel_type	**fuel_id**	**fuel_gr_abbr**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
SOLID	101A	ANODIC CARBON	0.0	0.0	0.0	0.0		
	102A	COAL	163.0	135.5	105.6	135.0	107.0	75.9
	103A	SUB-BITUMINOUS		0.0	0.1	0.1	0.0	0.0
	106A	BROWN COAL BRI.	0.0	0.0	0.0	0.0	0.0	
	107A	COKE OVEN COKE	0.7	0.7	0.6	0.6	0.6	0.5
LIQUID	110A	PETROLEUM COKE	5.1	6.5	6.7	6.1	6.6	6.6
	203A	RESIDUAL OIL	13.0	8.0	7.3	5.7	4.5	4.1
	204A	GAS OIL	27.0	20.9	17.3	15.4	8.2	9.4
	206A	KEROSENE	0.1	0.0	0.0	0.0	0.0	0.0
	225A	ORIMULSION						
	303A	LPG	1.5	1.4	1.5	1.3	0.9	1.4
	308A	REFINERY GAS	14.3	13.7	14.8	14.8	15.4	16.2
GAS	301A	NATURAL GAS	186.0	157.5	147.3	139.5	119.5	120.8
WASTE	114A	WASTE	36.8	36.7	35.9	35.7	36.9	37.7
	115A	INDUSTR. WASTES	1.4	1.7	1.5	1.8	1.8	2.5
BIOMASS	111A	WOOD	81.3	78.8	81.8	81.3	80.2	85.7
	117A	STRAW	23.3	20.2	18.3	20.3	18.4	19.2
	215A	BIO OIL	2.0	0.8	1.1	0.9	0.7	0.6
	309A	BIOGAS	4.3	4.1	4.4	4.6	5.1	5.2
	310A	BIO GASIF GAS	0.2	0.3	0.4	0.4	0.4	0.5
	315A	BIONATGAS					0.3	1.0
Total			**560.0**	**486.9**	**444.6**	**463.3**	**406.7**	**387.4**

Table 3A-2.2 Detailed fuel consumption data for stationary combustion plants, PJ. 1990 – 2015.

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 3A-3 Default Lower Calorific Value (LCV) of fuels and fuel correspondance list

Table 3A-3.1 Time-series for calorific values of fuels (DEA 2016a).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Crude Oil, Average	GJ pr tonne	42.40	42.40	42.40	42.70	42.70	42.70	42.70	43.00	43.00	43.00
Crude Oil, Golf	GJ pr tonne	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	43.00	43.00	43.00
Refinery Feedstocks	GJ pr tonne	41.60	41.60	41.60	41.60	41.60	41.60	41.60	42.70	42.70	42.70
Refinery Gas	GJ pr tonne	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ pr tonne	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ pr tonne	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ pr tonne	40.40	40.40	40.40	40.40	40.40	40.40	40.70	40.65	40.65	40.65
Orimulsion	GJ pr tonne	27.60	27.60	27.60	27.60	27.60	28.13	28.02	27.72	27.84	27.58
Petroleum Coke	GJ pr tonne	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ pr tonne	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ pr 1000 Nm^3	39.00	39.00	39.00	39.30	39.30	39.30	39.30	39.60	39.90	40.00
Town Gas	GJ pr 1000 m^3							17.00	17.00	17.00	17.00
Electricity Plant Coal	GJ pr tonne	25.30	25.40	25.80	25.20	24.50	24.50	24.70	24.96	25.00	25.00
Other Hard Coal	GJ pr tonne	26.10	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50
Coke	GJ pr tonne	31.80	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ pr tonne	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ pr tonne	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ pr Cubic metre	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Wood Chips	GJ pr m^3	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ pr m^3	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ pr tonne	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ pr tonne	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ pr Cubic metre	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ pr 1000 m^3	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ pr tonne								23.00	23.00	23.00
Wastes	GJ pr tonne	8.20	8.20	9.00	9.40	9.40	10.00	10.50	10.50	10.50	10.50
Bioethanol	GJ pr tonne	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ pr tonne	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60
Bio Oil	GJ pr tonne	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20

Continued		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Crude Oil, Average	GJ pr tonne	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
Crude Oil, Golf	GJ pr tonne	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ pr tonne	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
Refinery Feedstocks	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Refinery Gas	GJ pr tonne	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ pr tonne	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ pr tonne	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ pr tonne	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65
Orimulsion	GJ pr tonne	27.62	27.64	27.71	27.65	27.65	27.65	27.65	27.65	27.65	27.65
Petroleum Coke	GJ pr tonne	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ pr tonne	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ pr 1000 Nm^3	40.15	39.99	40.06	39.94	39.77	39.67	39.54	39.59	39.48	39.46
Town Gas	GJ pr 1000 m^3	17.01	16.88	17.39	16.88	17.58	17.51	17.20	17.14	15.50	21.29
Electricity Plant Coal	GJ pr tonne	24.80	24.90	25.15	24.73	24.60	24.40	24.80	24.40	24.30	24.60
Other Hard Coal	GJ pr tonne	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50	25.81	25.13
Coke	GJ pr tonne	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ pr tonne	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ pr tonne	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ pr Cubic metre	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Wood Chips	GJ pr m^3	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ pr m^3	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ pr tonne	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ pr tonne	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ pr Cubic metre	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ pr 1000 m^3	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ pr tonne	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Wastes	GJ pr tonne	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50
Bioethanol	GJ pr tonne	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ pr tonne	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.50	37.50
Bio Oil	GJ pr tonne	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20

Continued		2010	2011	2012	2013	2014	2015
Crude Oil, Average	GJ pr tonne	43.00	43.00	43.00	43.00	43.00	43.00
Crude Oil, Golf	GJ pr tonne	41.80	41.80	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ pr tonne	43.00	43.00	43.00	43.00	43.00	43.00
Refinery Feedstocks	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70
Refinery Gas	GJ pr tonne	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ pr tonne	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ pr tonne	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ pr tonne	40.65	40.65	40.65	40.65	40.65	40.65
Orimulsion	GJ pr tonne	27.65	27.65	27.65	27.65	27.65	27.65
Petroleum Coke	GJ pr tonne	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ pr tonne	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ pr 1000 Nm3	39.46	39.51	39.55	38.99	39.53	39.64
Town Gas	GJ pr 1000 m3	21.35	21.37	19.30	19.31	20.10	20.31
Electricity Plant Coal	GJ pr tonne	24.44	24.38	24.23	24.49	24.70	24.10
Other Hard Coal	GJ pr tonne	24.44	24.38	24.23	24.49	24.70	24.10
Coke	GJ pr tonne	29.30	29.30	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ pr tonne	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ pr tonne	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ pr Cubic metre	2.80	2.80	2.80	2.80	2.80	2.80
Wood Chips	GJ pr m3	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ pr m3	10.40	10.40	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ pr tonne	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ pr tonne	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ pr Cubic metre	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ pr 1000 m3	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ pr tonne	23.00	23.00	23.00	23.00	23.00	23.00
Wastes	GJ pr tonne	10.50	10.50	10.50	10.60	10.60	10.60
Bioethanol	GJ pr tonne	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ pr tonne	37.50	37.50	37.50	37.50	37.50	37.50
Bio Oil	GJ pr tonne	37.20	37.20	37.20	37.20	37.20	37.20

Table 3A-3.2 Fuel category correspondence list, DEA, DCE and NFR.

Danish Energy Agency	DCE Emission database	IPCC fuel category
Other Hard Coal	Coal	Solid
Coke	Coke oven coke	Solid
Electricity Plant Coal	Coal	Solid
Brown Coal Briquettes	Brown coal briq.	Solid
-	Anode carbon	Solid
-	Fly ash	Solid
Orimulsion	Orimulsion	Liquid
Petroleum Coke	Petroleum coke	Liquid
Fuel Oil	Residual oil	Liquid
Waste Oil	Residual oil	Liquid
Gas/Diesel Oil	Gas oil	Liquid
Other Kerosene	Kerosene	Liquid
LPG	LPG	Liquid
Refinery Gas	Refinery gas	Liquid
Town Gas	Natural gas	Gas
Natural Gas	Natural gas	Gas
Straw	Straw	Biomass
Wood Waste	Wood and simil.	Biomass
Wood Pellets	Wood and simil.	Biomass
Wood Chips	Wood and simil.	Biomass
Firewood, Hardwood & Conifer	Wood and simil.	Biomass
Waste Combustion (biomass)	Municip. wastes	Biomass
Bio fuels	Liquid biofuels	Biomass
Biogas	Biogas	Biomass
Biogas, other	Biogas	Biomass
Biogas, landfill	Biogas	Biomass
Biogas, sewage sludge	Biogas	Biomass
(Wood applied in gas engines)	Biomass gasif. gas	Biomass
Biogas upgraded for distribution in the natural gas grid	Bio-natural gas	Biomass
Waste Combustion (fossil)	Fossil waste	Other fuel

Annex 3A-4 Emission factors

SO_2 emission factors are discussed in Nielsen et al. (2014). The emission factors applied for 2015 are shown in Table 3A-4.1.

Table 3A-4.1 SO_2 emission factors and references, 2015

Fuel type	Fuel	NFR	NFR_name	SNAP	SO_2 emission factor, g/GJ	Reference
SOLID	ANODE CARBON	1A2g	Industry - other	032002	574	Assumed equal to coal. DCE assumption.
	COAL	1A1a	Public electricity and heat production	0101	10	DCE estimate based on data reported by plant owners.
				0102	574	DCE calculation based on DEPA (2010c), DEA (2012) and EMEP (2006)
		1A2a-g	Industry	03	574	DCE calculation based on DEPA (2010c), DEA (2012) and EMEP (2006)
		1A4b i	Residential	020200	574	DCE calculation based on DEPA (2010c), DEA (2012) and EMEP (2006)
		1A4c i	Agriculture/ Forestry	0203	574	DCE calculation based on DEPA (2010c), DEA (2012) and EMEP (2006)
	FLY ASH FOSSIL	1A1a	Public electricity and heat production	010104	10	Assumed equal to the emission factor for coal in 2010. DCE assumption.
	BROWN COAL BRI.	1A4b	Residential	0202	574	Assumed equal to coal. DCE assumption.
	COKE OVEN COKE	1A2a-g	Industry	03	574	Assumed equal to coal. DCE assumption.
		1A4b	Residential	0202	574	Assumed equal to coal. DCE assumption.
LIQUID	PETROLEUM COKE	1A2a-g	Industry	03	605	DCE calculation based on DEPA (2001b), DEA (2012) and EMEP (2006).
		1A4a	Commercial/ Institutional	0201	605	DCE calculation based on DEPA (2001b), DEA (2012) and EMEP (2006).
		1A4b	Residential	0202	605	DCE calculation based on DEPA (2001b), DEA (2012) and EMEP (2006).
		1A4c	Agriculture/ Forestry	0203	605	DCE calculation based on DEPA (2001b), DEA (2012) and EMEP (2006).
	RESIDUAL OIL	1A1a	Electricity and heat production	0101	100	DCE estimate based on plant specific data for 2008 and 2009.
				0102	344	DCE estimate based on EOF (2013) and DEA (2012)
		1A1b	Petroleum refining	010306	537	DCE calculation based on plant specific data for year 2003.
		1A2a-g	Industry	03	344	DCE estimate based on EOF (2013) and DEA (2012)
		1A4a	Commercial/ Institutional	0201	344	DCE estimate based on EOF (2013) and DEA (2012)
		1A4b	Residential	0202	344	DCE estimate based on EOF (2013) and DEA (2012)
		1A4c i	Agriculture/ Forestry	0203	344	DCE estimate based on EOF (2013) and DEA (2012)
	GAS OIL	1A1a	Public electricity and heat production	0101 0102	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).
		1A1b	Petroleum refining	010306	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).
		1A1c	Oil and gas extraction	0105	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).
		1A2a-g	Industry	03	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).

Fuel type	Fuel	NFR	NFR_name	SNAP	SO_2 emission factor, g/GJ	Reference
		1A4a	Commercial/ Institutional	0201	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).
		1A4b i	Residential	0202	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).
		1A4c	Agriculture/Forestry	0203	23	DCE estimate based on DEPA (1998), Miljø- og planlægningsudvalget (1998) and DEA (2012).
	KEROSENE	1A2g	Industry - other	03	5	DCE estimate based on Tønder (2004) and Shell (2013).
		1A4a	Commercial/ Institutional	0201	5	DCE estimate based on Tønder (2004) and Shell (2013).
		1A4b i	Residential	0202	5	DCE estimate based on Tønder (2004) and Shell (2013).
		1A4c i	Agriculture/ Forestry	0203	5	DCE estimate based on Tønder (2004) and Shell (2013).
	LPG	1A1a	Public electricity and heat production	All	0.13	DCE estimate based on Augustesen (2003) and DEA (2012).
		1A2a-g	Industry	03	0.13	DCE estimate based on Augustesen (2003) and DEA (2012).
		1A4a	Commercial/ Institutional	0201	0.13	DCE estimate based on Augustesen (2003) and DEA (2012).
		1A4b i	Residential	0202	0.13	DCE estimate based on Augustesen (2003) and DEA (2012).
		1A4c i	Agriculture/ Forestry	0203	0.13	DCE estimate based on Augustesen (2003) and DEA (2012).
	REFINERY GAS	1A1b	Petroleum refining	0103	1	DCE estimate based on plant specific data for one plant, average value for 1995-2002.
GAS	NATURAL GAS	1A1a	Public electricity and heat production	0101, 0102, except engines	0.43	DCE estimate based on data from Energinet.dk (2013)
				010105, engines	0.5	Kristensen (2003)
		1A1b	Petroleum refining	0103	0.43	DCE estimate based on data from Energinet.dk (2013)
		1A1c	Oil and gas extraction	0105	0.43	DCE estimate based on data from Energinet.dk (2013)
		1A2a-g	Industry	03 except engines	0.43	DCE estimate based on data from Energinet.dk (2013)
				Engines	0.5	Kristensen (2003)
		1A4a	Commercial/ Institutional	0201 except engines	0.43	DCE estimate based on data from Energinet.dk (2013)
				Engines	0.5	Kristensen (2003)
		1A4b i	Residential	0202 except engines	0.43	DCE estimate based on data from Energinet.dk (2013)
				Engines	0.5	Kristensen (2003)
		1A4c i	Agriculture/ Forestry	0203 except engines	0.43	DCE estimate based on data from Energinet.dk (2013)

Fuel type	Fuel	NFR	NFR_name	SNAP	SO_2 emission factor, g/GJ	Reference
				Engines	0.5	Kristensen (2003)
WASTE	WASTE	1A1a	Public electricity and heat production	0101	8.3	Nielsen et al. (2010a)
				0102	14	DCE estimate based on plant specific data for four plants, 2009 data.
		1A2a-g	Industry	03	14	Assumed equal to district heating plants (DCE assump-tion).
		1A4a	Commercial/ Institutional	0201	14	Assumed equal to district heating plants (DCE assump-tion).
	INDU-STRIAL WA-STE	1A2f	Industry – non-metallic minerals	031600	14	Assumed equal to waste. DCE assumption.
BIO-MASS	WOOD	1A1a	Public electricity and heat production	0101	1.9	Nielsen et al. (2010a)
				0102	11	EEA (2013)
		1A2a-g	Industry	03	11	EEA (2013)
		1A4a	Commercial/ Institutional	0201	11	EEA (2013)
		1A4b i	Residential	0202	11	EEA (2013)
		1A4c i	Agriculture/ Forestry	0203	11	EEA (2013)
	STRAW	1A1a	Public electricity and heat production	0101	49	Nielsen et al. (2010a)
				0102	130	Nikolaisen et al. (1998)
		1A4b i	Residential	0202	130	Assumed equal to district heating plants. DCE assumption.
		1A4c i	Agriculture/ Forestry	0203	130	Assumed equal to district heating plants. DCE assumption.
	BIO OIL	1A1a	Public electricity and heat production	0101	0.1	DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2012).
				0102	0.1	DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2012).
		1A2a-g	Industry	03	0.1	DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2012).
		1A4b i	Residential	0202	0.1	DCE estimate based on Folkecenter for Vedvarende Energi (2000) and DEA (2012).
	BIOGAS	1A1a	Public electricity and heat production	0101, except engines	25	DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2012).
				Engines	19.2	Nielsen & Illerup (2003)
				0102	25	DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2012).
		1A2a-g	Industry	03, except engines	25	DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2012).
				03, engines	19.2	Nielsen & Illerup (2003)

Fuel type	Fuel	NFR	NFR_name	SNAP	SO_2 emission factor, g/GJ	Reference
		1A4a	Commercial/ Institutional	0201, except engines	25	DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2012).
				020105	19.2	Nielsen & Illerup (2003)
		1A4b	Residential	0202	25	DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2012).
		1A4c i	Agriculture/ Forestry	0203, except engines	25	DCE estimate based on Christiansen (2003), Hjort-Gregersen (1999) and DEA (2012).
				020304	19.2	Nielsen & Illerup (2003)
	BIO GASIF GAS	1A1a	Public electricity and heat production	010105	1.9	Assumed equal to wood. DCE assumption.
	BIONATGAS	1A1a	Public electricity and heat production	0101	0.43	Assumed equal to natural gas.
		1A2a-g	Industry	03	0.43	Assumed equal to natural gas.
		1A4a	Commercial/ Institutional	0201	0.43	Assumed equal to natural gas.
		1A4b	Residential	0202	0.43	Assumed equal to natural gas.
		1A4c	Agriculture/ Forestry	0203	0.43	Assumed equal to natural gas.

NO_x emission factors are discussed in Nielsen et al. (2014). The emission factors applied for 2015 are shown in Table 3A-4.2.

Table 3A-4.2 NO_x emission factors and references, 2015.

Fuel type	Fuel	NFR	NFR_name	SNAP	NOx emission factor, g/GJ	Reference
SOLID	ANODE CARBON	1A2g	Industry - other	032000	132	Assumed equal to coal. DCE assumption.
	COAL	1A1a	Public electricity and heat production	0101	29	DCE estimate based on Energinet.dk (2016) and EU ETS (2016)
				0102	95	DEPA (2001)
		1A2a-g	Industry	03 except cement produc-tion	132	DCE estimate based on plant specific data for 2011.
		1A2f	Industry, cement production	0316	179	DCE estimate based on plant specific data for 2015.
		1A4b i	Residential	020200	95	DEPA (2001)
		1A4c i	Agriculture/ Forestry	0203	95	DEPA (2001)
	FLY ASH FOSSIL	1A1a	Public electricity and heat production	0101	30	Assumed equal to the emission factor for coal in 2010.
	BROWN COAL BRI.	1A4b	Residential	0202	95	Assumed equal to coal. DCE assumption.
	COKE OVEN COKE	1A2a-g	Industry	03	132	Assumed equal to coal. DCE assumption.
		1A4b	Residential	0202	95	Assumed equal to coal. DCE assumption.
LIQUID	PETROLEUM COKE	1A2a-g	Industry	03	129	Assumed equal to residual oil. DCE assumption.
			Industry, non-metallic minerals	0316	179	DCE estimate based on plant specific data for 2015.
		1A4a	Commercial/ Institutional	0201	51	
		1A4b	Residential	0202	51	
		1A4c	Agriculture/ Forestry	0203	51	
	RESIDUAL OIL	1A1a	Public electricity and heat production	0101	138	DCE estimate based on Energinet.dk (2009); Energinet.dk (2010); Energinet.dk (2011): EU ETS (2009-2011)
				0102	142	DEPA (2001)
		1A1b	Petroleum refining	010306	200	IPCC (1997)
		1A2a-g	Industry	03	129	DCE estimate based on plant specific data from two plants, 2011
		1A4a	Commercial/ Institutional	0201	142	DEPA (2001)
		1A4b	Residential	0202	142	DEPA (2001)
		1A4c i	Agriculture/ Forestry	0203	142	DEPA (2001)
	GAS OIL	1A1a	Public electricity and heat production	010101, 010102	114	DCE estimate based on plant specific data for 2011. Data from Energinet.dk (2011) and EU ETS (2011).
				010103 0102	130	DEPA (2012b), DEPA (2003b) and DEPA (1990)
				010104	350	DCE estimate based on Eltra & Elkraft System, (2001) and DEA (2012b)
				010105	942	Nielsen et al. (2010a)
		1A1b	Petroleum refining	010306	65	DEPA (1990)
		1A1c	Oil and gas extraction	010504	350	Assumed equal to gas turbines applied in CHP plants. DCE assumption.

Fuel type	Fuel	NFR	NFR_name	SNAP	NOx emission factor, g/GJ	Reference
		1A2a-g	Industry	03 except engines	130	DEPA (2012b), DEPA (2003b) and DEPA (1990)
		1A2a-g	Industry	Engines	942	Nielsen et al. (2010a)
		1A4a	Commercial/ Institutional	0201	52	DEPA (2001)
				Engines	942	Nielsen et al. (2010a)
		1A4b i	Residential	0202	52	DEPA (2001a)
				Engines	942	Nielsen et al. (2010a)
		1A4c	Agriculture/Forestry	0203	52	DEPA (2001a)
				Engines	942	Nielsen et al. (2010a)
	KEROSENE	1A2g	Industry - other	03	50	EEA (2009)
		1A4a	Commercial/ Institutional	0201	50	EEA (2009)
		1A4b i	Residential	0202	50	EEA (2009)
		1A4c i	Agriculture/ Forestry	0203	50	EEA (2009)
	LPG	1A1a	Public electricity and heat production	All	96	IPCC (1997)
		1A2a-g	Industry	03	96	IPCC (1997)
		1A4a	Commercial/ Institutional	0201	71	IPCC (1997)
		1A4b i	Residential	0202	47	IPCC (1997)
		1A4c i	Agriculture/ Forestry	0203	71	IPCC (1997)
	REFINERY GAS	1A1b	Petroleum refining	010304	170	DCE estimate based on plant specific data for a gas turbine in year 2000.
				010306	94	DCE estimate based on plant specific data for year 2011.
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101, 010102	55	DEPA (2003b)
				010103	33.04	Schweitzer (2015)
				010104	48	Nielsen et al. (2010a)
				010105	135	Nielsen et al. (2010a)
				0102	33.04	Schweitzer (2015)
		1A1b	Petroleum refining	0103	33.04	Schweitzer (2015)
		1A1c	Oil and gas extraction	010504	199	Nielsen (2015d)
		1A2a-g	Industry	03	33.04	Schweitzer (2015)
				Engines	135	Nielsen et al. (2010a)
				Turbines	48	Nielsen et al. (2010a)
		1A2f		030700	87	DCE estimate based on plant specific data for 11 clay production plants, EU ETS (2011-2012); DEPA (2012)
		1A4a	Commercial/ Institutional	0201	33.04	Schweitzer (2015)
				Engines	135	Nielsen et al. (2010a)
		1A4b i	Residential	0202	25.6	Schweitzer (2014)
				Engines	135	Nielsen et al. (2010a)
		1A4c i	Agriculture/ Forestry	0203	33.04	Schweitzer (2015)
				Engines	135	Nielsen et al. (2010a)
WASTE	WASTE	1A1a	Public electricity and heat production	0101	102	Nielsen et al. (2010a)
				0102	164	DCE estimate based on plant specific data for year 2000.

Fuel type	Fuel	NFR	NFR_name	SNAP	NOx emission factor, g/GJ	Reference
		1A2a-g	Industry	03	164	DCE estimate based on plant specific data for district heating plants in year 2000.
		1A4a	Commercial/ Institutional	0201	164	DCE estimate based on plant specific data for district heating plants in year 2000.
	INDUSTRIAL WASTE	1A2f	Industry – non-metallic minerals	031600	179	Based on plant specific data.
BIOMASS	WOOD	1A1a	Public electricity and heat production	0101	81	Nielsen et al. (2010a)
				0102	90	Serup et al. (1999)
		1A2a-g	Industry	03	90	Serup et al. (1999)
		1A4a	Commercial/ Institutional	0201	90	Serup et al. (1999)
		1A4b i	Residential	0202	76.76	DCE estimate based on DEA (2015a), DEPA (2013) and EEA (2013).
		1A4c i	Agriculture/ Forestry	0203	90	Serup et al. (1999)
	STRAW	1A1a	Public electricity and heat production	0101	125	Nielsen et al. (2010a)
				0102	90	Nikolaisen et al. (1998)
		1A4b i	Residential	0202	90	Assumed equal to district heating plants. DCE assumption.
		1A4c i	Agriculture/ Forestry	0203	90	Assumed equal to district heating plants. DCE assumption.
	BIO OIL	1A1a	Public electricity and heat production	0101	249	Assumed equal to gas oil. DCE assumption. The emission factor for gas oil have been changed and the emission factor for biooil will also be changed in future inventories.
				0102	65	Assumed equal to gas oil. DCE assumption.
		1A2a-g	Industry	03	130	Assumed equal to gas oil. DCE assumption.
				Engines	700	Assumed equal to gas oil. DCE assumption.
		1A4b i	Residential	0202	65	Assumed equal to gas oil. DCE assumption.
	BIOGAS	1A1a	Public electricity and heat production	0101, not engines	28	DEPA (2001a)
				Engines	202	Nielsen et al. (2010a)
				0102	28	DEPA (2001a)
		1A2a-g	Industry	03, not engines	28	DEPA (2001a)
				03, engines	202	Nielsen et al. (2010a)
				030902	59	DEPA (1990); DEPA (1995)
		1A4a	Commercial/ Institutional	0201, not engines	28	DEPA (2001a)
				020105	202	Nielsen et al. (2010a)
		1A4b	Residential	0202	24.3	Assumed equal to natural gas (upgraded biogas)
		1A4c i	Agriculture/ Forestry	0203, not engines	28	DEPA (2001a)
				020304	202	Nielsen et al. (2010a)

Fuel type	Fuel	NFR	NFR_name	SNAP	NOx emission factor, g/GJ	Reference
	BIO GASIF GAS	1A1a	Public electricity and heat production	010101	96	IPCC (1997)
				010105	173	Nielsen et al. (2010a)
	BIONATGAS	1A1a	Public electricity and heat production	0101	55	Assumed equal to natural gas. DCE assumption.
				0102	33.04	Assumed equal to natural gas. DCE assumption.
		1A2a-g	Industry	03	33.04	Assumed equal to natural gas. DCE assumption.
		1A4a	Commercial/ Institutional	0201	33.04	Assumed equal to natural gas. DCE assumption.
		1A4b	Residential	0202	24.3	Assumed equal to natural gas. DCE assumption.
		1A4c	Agriculture/ Forestry	0203	33.04	Assumed equal to natural gas. DCE assumption.

Table 3A-4.3 NMVOC emission factors and references, 2015.

Fuel type	Fuel	NFR	NFR_name	SNAP	NMVOC, g/GJ	Reference
SOLID	ANODE CARBON	1A2g	Industry - other	0320	10	Assumed equal to coal. DCE assumption.
	COAL	1A1a	Public electricity and heat production	0101 0102	1.2	EEA (2009)
		1A2a-g	Industry	03	10	EEA (2009)
		1A4c i	Agriculture/ Forestry	0203	88.8	EEA (2009)
	FLY ASH FOSSIL	1A1a	Public electricity and heat production	0101	1.2	Assumed equal to coal. DCE assumption.
	BROWN COAL BRI.	1A4b i	Residential	0202	484	EEA (2009)
	COKE OVEN COKE	1A2a-g	Industry	03	10	EEA (2009)
		1A4b	Residential	0202	484	Assumed equal to coal. DCE assumption.
LIQUID	PETROLEUM COKE	1A2a-g	Industry	03	10	Assumed equal to coal. DCE assumption.
		1A4a	Commercial/ Institutional	0201	88.8	EEA (2009)
		1A4b	Residential	0202	484	EEA (2009)
		1A4c	Agriculture/ Forestry	0203	88.8	EEA (2009)
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101 010102 010103	0.8	Nielsen et al. (2010)
				010104	2.3	EEA (2009)
				010105	2.3	EEA (2009)
				010203	2.3	EEA (2009)
		1A1b	Petroleum refining	010306	2.3	EEA (2009)
		1A2a-g	Industry	03 except engines	0.8	Nielsen et al. (2010)
				Engines	10	EEA (2009)
		1A4a	Commercial/ Institutional	0201	5	EEA (2009)
		1A4b	Residential	0202	15	EEA (2009)
		1A4c i	Agriculture/ Forestry	0203	5	EEA (2009)
	GAS OIL	1A1a	Public electricity and heat production	010101 010102 010103	0.8	EEA (2009)
				010104	0.2	EEA (2009)
				010105	37	EEA (2009)
				0102	0.8	EEA (2009)
		1A1b	Petroleum refining	010306	0.8	EEA (2009)
		1A1c	Oil and gas extraction	010504	0.2	EEA (2009)
		1A2a-g	Industry	03 boilers > 50 MW	5	EEA (2009)
				03 boilers < 50 MW	10	EEA (2009)
				Gas turbines	0.2	EEA (2009)
				Engines	37	EEA (2009)
		1A4a	Commercial/ Institutional	0201 except engines	5	EEA (2009)
				Engines	37	EEA (2009)
		1A4b i	Residential	0202	15	EEA (2009)
		1A4c	Agriculture/Forestry	020302	5	EEA (2009)
	KEROSENE	1A2a-g	Industry	03	10	EEA (2009)
		1A4a	Commercial/ Institutional	0201	5	EEA (2009)
		1A4b i	Residential	0202	15	EEA (2009)

Fuel type	Fuel	NFR	NFR_name	SNAP	NMVOC, g/GJ	Reference
		1A4c i	Agriculture/ Forestry	0203	5	EEA (2009)
	LPG	1A1a	Public electricity and heat production	0101 0102	0.8	EEA (2009)
		1A2a-g	Iron and steel	03	5	EEA (2009)
		1A4a	Commercial/ Institutional	0201	5	EEA (2009)
		1A4b i	Residential	0202	10	EEA (2009)
		1A4c i	Agriculture/ Forestry	0203	5	EEA (2009)
	REFINERY GAS	1A1b	Petroleum refining	0103	1.4	Assumed equal to natural gas fuelled gas turbines. DCE assumption.
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101 010102 010103	2	Danish Gas Technology Centre (2001).
				010104	1.6	Nielsen et al. (2010)
				010105	92	Nielsen et al. (2010)
				0102	2	Danish Gas Technology Centre (2001).
		1A1b	Petroleum refining	0103	2	Danish Gas Technology Centre (2001).
		1A1c	Oil and gas extraction	0105	1.6	Nielsen et al. (2010)
		1A2a-g	Industry	03 except engines and turbines	2	Danish Gas Technology Centre (2001).
				Turbines	1.6	Nielsen et al. (2010)
				Engines	92	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201 except engines	2	Danish Gas Technology Centre (2001).
				Engines	92	Nielsen et al. (2010)
		1A4b i	Residential	0202 except engines	4	Gruijthuijsen & Jensen (2000)
				Engines	92	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203 except engines	2	Danish Gas Technology Centre (2001).
				Engines	92	Nielsen et al. (2010)
WASTE	WASTE	1A1a	Public electricity and heat production	0101	0.56	Nielsen et al. (2010)
				0102	2	EEA (2009)
		1A2a-g	Industry	03	2	EEA (2009)
		1A4a	Commercial/ Institutional	0201	2	EEA (2009)
	INDISTRIAL WASTE	1A2f	Industry	0316	2	EEA (2009)
BIO-MASS	WOOD	1A1a	Public electricity and heat production	0101	5.1	Nielsen et al. (2010)
				0102	7.3	EEA (2009)
		1A2a-g	Industry	03	10	EEA (2009)
		1A4a	Commercial/ Institutional	0201	146	EEA (2009)
		1A4b i	Residential	0202	293	DCE estimate based on DEA (2015a), DEPA (2013) and EEA (2013),
		1A4c i	Agriculture/ Forestry	0203	146	EEA (2009)
	STRAW	1A1a	Public electricity and heat production	0101	0.78	Nielsen et al. (2010)
				0102	7.3	EEA (2009)
		1A4b i	Residential	0202	600	EEA (2009)
		1A4c i	Agriculture/ Forestry	0203	600	EEA (2009). Plants are assued equal to residential plants.

Fuel type	Fuel	NFR	NFR_name	SNAP	NMVOC, g/GJ	Reference
				020302	10	EEA (2009)
	BIO OIL	1A1a	Public electricity and heat production	010102	0.8	EEA (2009)
				010105	37	EEA (2009)
				0102	0.8	EEA (2009)
		1A2a-g	Industry	03, not engines	10	EEA (2009)
				Engines	37	EEA (2009)
		1A4b i	Residential	0202	15	EEA (2009)
	BIOGAS	1A1a	Public electricity and heat production	0101	2	Assumed equal to natural gas. DCE assumption.
				010105	10	Nielsen et al. (2010)
				0102	2	Assumed equal to natural gas. DCE assumption.
		1A2a-g	Industry	03 except engines	2	Assumed equal to natural gas. DCE assumption.
				Engines	10	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201 except engines	2	Assumed equal to natural gas. DCE assumption.
				Engines	10	Nielsen et al. (2010)
		1A4b	Residential	0202	4	Assumed equal to natural gas. DCE assumption.
		1A4c i	Agriculture/ Forestry	0203 except engines	2	Assumed equal to natural gas. DCE assumption.
				Engines	10	Nielsen et al. (2010)
	BIO GASIF GAS	1A1a	Public electricity and heat production	010105	2	Nielsen et al. (2010)
				0101 except engines	0.8	Assumed equal to natural gas. DCE assumption.
	BIONATGAS	1A1a	Public electricity and heat production	0101 and 0102	2	Assumed equal to natural gas. DCE assumption.
		1A2a-g	Industry	03	2	Assumed equal to natural gas. DCE assumption.
		1A4a	Commercial/ Institutional	0201	2	Assumed equal to natural gas. DCE assumption.
		1A4b	Residential	0202	4	Assumed equal to natural gas. DCE assumption.
		1A4c	Agriculture/ Forestry	0203	2	Assumed equal to natural gas. DCE assumption.

Table 3A-4.4 CO emission factors and references, 2015.

Fuel type	Fuel	NFR	NFR_name	SNAP	CO emission factor g/GJ	Reference
SOLID	ANODE CARBON	1A2a-g	Industry	03	10	Assumed the same emission factor as for coal. DCE assumption.
	COAL	1A1a	Public electricity and heat production	0101 and 0102	10	Sander (2002)
		1A2a-g	Industry	03	10	Assumed equal to boilers in public electricity and heat production. DCE assumption.
		1A4c i	Agriculture/ Forestry	0203	931	EEA (2009)
	FLY ASH FOSSIL	1A1a	Public electricity and heat production	0101	10	Assumed equal to coal. DCE assumption.
	BROWN COAL BRI.	1A4b i	Residential	0202	2000	EEA (2009)
	COKE OVEN COKE	1A2a-g	Industry	03	10	Assumed the same emission factor as for coal. DCE assumption.
		1A4b	Residential	0202	2000	EEA (2009)
LIQUID	PETROLEUM COKE	1A2a-g	Industry	03	61	EEA (2013)
		1A4a	Commercial/Institutional	0201	1000	
		1A4b	Residential	0202	1000	
		1A4c	Agriculture/ Forestry	0203	1000	
	RESIDUAL OIL	1A1a	Electricity and heat production	010101 010104 010105	15	Sander (2002)
				010102 010103	2.8	Nielsen et al. (2010)
				0102	30	EEA (2007)
		1A1b	Petroleum refining	010306	30	EEA (2007)
		1A2a-g	Industry	03 except engines	2.8	Nielsen et al. (2010)
				Engines	100	EEA (2009)
		1A4a	Commercial/Institutional	0201	30	EEA (2007)
		1A4b	Residential	0202	30	EEA (2007)
		1A4c i	Agriculture/ Forestry	0203	30	EEA (2007)
	GAS OIL	1A1a	Public electricity and heat production	0101 except engines	15	Sander (2002)
				Engines	130	Nielsen et al. (2010)
				0102	30	EEA (2007)
		1A1b	Petroleum refining	010306	30	EEA (2007)
		1A1c	Oil and gas extraction	0105	15	Sander (2002)
		1A2a-g	Industry	03 except gas turbines and engines	30	EEA (2007)
				Gas turbines	15	Sander (2002)
				Engines	130	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201 except engines	30	EEA (2007)
				Engines	130	Nielsen et al. (2010)
		1A4b i	Residential	0202	43	EEA (2007)
		1A4c	Agriculture/Forestry	0203	30	EEA (2007)
	KEROSENE	1A2a-g	Industry	03	20	EEA (2007)
		1A4a	Commercial/ Institutional	0201	20	EEA (2007)
		1A4b i	Residential	0202	20	EEA (2007)

Fuel type	Fuel	NFR	NFR_name	SNAP	CO emission factor g/GJ	Reference
		1A4c i	Agriculture/ Forestry	0203	20	EEA (2007)
	LPG	1A1a	Public electricity and heat production	0101 and 0102	25	EEA (2007)
		1A2a-g	Industry	03	25	EEA (2007)
		1A4a	Commercial/ Institutional	0201	25	EEA (2007)
		1A4b i	Residential	0202	25	EEA (2007)
		1A4c i	Agriculture/ Forestry	0203	25	EEA (2007)
	REFINERY GAS	1A1b	Petroleum refining	0103	6.2	Assumed same emission factor as for natural gas fuelled gas turbines. DCE assumption.
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101 and 010102	15	Sander (2002)
				010103	28	DEPA (2001)
				010104	4.8	Nielsen et al. (2010)
				010105	58	Nielsen et al. (2010)
				0102	28	DEPA (2001)
		1A1b	Petroleum refining	0103	28	Assumed equal to district heating plants.
		1A1c	Oil and gas extraction	0105	4.8	Nielsen et al. (2010)
		1A2a-g	Industry	03 except gas turbines and engines	28	DEPA (2001)
				Gas turbines	4.8	Nielsen et al. (2010)
				Engines	58	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201 except engines	28	DEPA (2001)
				Engines	58	Nielsen et al. (2010)
		1A4b i	Residential	0202 except engines	20	Gruijthuijsen & Jensen (2000)
				Engines	58	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203 except engines	28	DEPA (2001)
				Engines	58	Nielsen et al. (2010)
WASTE	WASTE	1A1a	Public electricity and heat production	0101	3.9	Nielsen et al. (2010)
				0102	10	DCE calculation based on annual environmental reports for Danish plants year 2000.
		1A2a-g	Industry	03	10	Assumed equal to district heating plants. DCE assumption.
		1A4a	Commercial/ Institutional	0201	10	Assumed equal to district heating plants. DCE assumption.
	INDISTRIAL WASTE	1A2f	Industry	0316	10	Assumed equal to waste, district heating plants. DCE assumption.
BIOMASS	WOOD	1A1a	Public electricity and heat production	0101	90	Nielsen et al. (2010)
				010203	240	DEPA (2001)
		1A2a-g	Industry	03	240	DEPA (2001)
		1A4a	Commercial/ Institutional	020100	240	DEPA (2001)
		1A4b i	Residential	0202	2158	DCE estimate based on DEA (2015a), DEPA (2013) and EEA (2013),
		1A4c i	Agriculture/ Forestry	020300	240	DEPA (2001)
	STRAW	1A1a	Public electricity and heat production	0101	67	Nielsen et al. (2010)
				0102	325	DEPA (2001); Nikolaisen et al (1998)

Fuel type	Fuel	NFR	NFR_name	SNAP	CO emission factor g/GJ	Reference
		1A4b i	Residential	0202	4000	EEA (2007); Jensen & NIelsen (1990) and Bjerrum (2002)
		1A4c i	Agriculture/ Forestry	0203	4000	EEA (2007); Jensen & NIelsen (1990) and Bjerrum (2002)
				020302	325	DEPA (2001); Nikolaisen et al (1998)
	BIO OIL	1A1a	Public electricity and heat production	0101 and 0102	15	Assumed same emission factor as for gas oil. DCE assumption.
		1A2a-g	Industry	03	30	Assumed same emission factor as for gas oil. DCE assumption.
		1A4b i	Residential	0202	100	Assumed same emission factor as for gas oil. DCE assumption.
	BIOGAS	1A1a	Public electricity and heat production	0101 except engines	36	DEPA (2001)
				Engines	310	Nielsen et al. (2010)
				0102	36	DEPA (2001)
		1A2a-g	Industry	03 except engines	36	DEPA (2001)
				Engines	310	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201 except engines	36	DEPA (2001)
				Engines	310	Nielsen et al. (2010)
		1A4b	Residential	0202	20	Assumed equal to natural gas. DCE assumption.
		1A4c i	Agriculture/ Forestry	0203 except engines	36	DEPA (2001)
				Engines	310	Nielsen et al. (2010)
	BIO GASIF GAS	1A1a	Public electricity and heat production	010105	586	Nielsen et al. (2010)
				010101	25	-
	BIONATGAS	1A1a	Public electricity and heat production	0101	15	Assumed equal to natural gas. DCE assumption.
				0102	28	Assumed equal to natural gas. DCE assumption.
		1A2a-g	Industry	03	28	Assumed equal to natural gas. DCE assumption.
		1A4a	Commercial/ Institutional	0201	28	Assumed equal to natural gas. DCE assumption.
		1A4b i	Residential	0202	20	Assumed equal to natural gas. DCE assumption.
		1A4c i	Agriculture/ Forestry	0203	28	Assumed equal to natural gas. DCE assumption.

Table 3A-4.5 SO$_2$ emission factors time series, g per GJ for the years 1990 to 2015. This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.6 NO$_x$ emission factors time series, g per GJ for the years 1990 to 2015. This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.7 NMVOC emission factors time series, g per GJ for the years 1990 to 2015. This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.8 CO emission factors time series, g per GJ for the years 1990 to 2015. This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.9 PM emission factors (in g per GJ) and references, 2015.

fuel_type	fuel_id	fuel_gr_abbr	nfr_id_EA	snap_id	TSP	Ref	PM_{10}	Ref	$PM_{2.5}$	Ref
SOLID	101A	ANODIC CARBON	1A2g iii	0320	17	6	12	14	7	14
	102A	COAL	1A1a	0101	3	12	2.6	12	2.1	12
				0102	6	10	6	10	5	10
			1A2 a-g	03	17	6	12	14	7	14
			1A4c i	0203	17	6	12	14	7	14
	103A	FLY ASH FOSSIL	1A1a	0101	3	12	2.6	12	2.1	12
	106A	BROWN COAL BRI.	1A4b i	0202	17	16	12	16	7	16
	107A	COKE OVEN COKE	1A2 a-g	03	17	16	12	16	7	16
			1A4b	0202	17	16	12	16	7	16
LIQUID	110A	PETROLEUM COKE	1A2a-g	03	10	9	7	9	3	9
			1A4a	0201	100	9	60	9	30	9
			1A4b	0202	100	9	60	9	30	9
			1A4c	0203	100	9	60	9	30	9
	203A	RESIDUAL OIL	1A1a	010101	3	3	3	3	2.5	3
				010102	9.5	18	9.5	13	7.9	13
				010103	9.5	18	9.5	13	7.9	13
				010104	3	9	3	9	2.5	9
				010105	3	9	3	9	2.5	9
				0102	3	9	3	9	2.5	9
			1A1b	010306	50	9	40	9	35	9
			1A2 a-g	03	9.5	18	7.1	13	4.8	13
			1A4a	0201	14	6	10.5	13	7	13
			1A4b	0202	14	6	10.5	13	7	13
			1A4c i	0203	14	6	10.5	13	7	13
	204A	GAS OIL	1A1a	0101	5	9	5	9	5	9
				0102	5	9	5	9	5	9
			1A1b	010306	5	9	5	9	5	9
			1A1c	0105	5	9	5	9	5	9
			1A2a-g	03	5	9	5	9	5	9
			1A4a i	0201	5	9	5	9	5	9
			1A4b i	0202	5	9	5	9	5	9
			1A4c i	0203	5	9	5	9	5	9
	206A	KEROSENE	1A2 a-g	all	5	9	5	9	5	9
			1A4a i	0201	5	9	5	9	5	9
			1A4b i	0202	5	9	5	9	5	9
			1A4c i	0203	5	9	5	9	5	9
	303A	LPG	1A1a	0101, 0102	0.2	9	0.2	9	0.2	9
			1A2 a-g	03	0.2	9	0.2	9	0.2	9
			1A4a i	0201	0.2	9	0.2	9	0.2	9
			1A4b i	0202	0.2	9	0.2	9	0.2	9
			1A4c i	0203	0.2	9	0.2	9	0.2	9
	308A	REFINERY GAS	1A1b	0103	5	9	5	9	5	9
GAS	301A	NATURAL GAS	1A1a	0101	0.1	9	0.1	9	0.1	9
				Gas turbi-nes	0.1	3	0.061	3	0.051	3
				Engines	0.76	3	0.189	3	0.161	3
				0102	0.1	9	0.1	9	0.1	9
			1A1b	0103	0.1	9	0.1	9	0.1	9
			1A1c	0105	0.1	3	0.061	3	0.051	3
			1A2a-g	Engines	0.76	3	0.189	3	0.161	3
				Turbines	0.1	3	0.061	3	0.051	3
				Other	0.1	9	0.1	9	0.1	9
			1A4a i	0201	0.1	9	0.1	9	0.1	9
				Engines	0.76	3	0.189	3	0.161	3
			1A4b i	0202	0.1	9	0.1	9	0.1	9
				Engines	0.76	3	0.189	3	0.161	3
			1A4c i	0203	0.1	9	0.1	9	0.1	9
				Engines	0.76	3	0.189	3	0.161	3
WASTE	114A	WASTE	1A1a	0101	0.29	18	0.29	3	0.29	3
				0102	0.29	20	0.29	3	0.29	3
			1A2 a-g	03	4.2	20	3.2	20	2.1	20
			1A4a i	0201	4.2	20	3.2	20	2.1	20
	115A	INDUSTRIAL WA-STE	1A2f	0316	4.2	20	3.2	20	2.1	20
BIOMASS	111A	WOOD	1A1a	0101	10	18	7.45	8	4.82	8
				0102	19	1	13	2	10	1
			1A2 a-g	03	19	1	13	2	10	1

fuel_type	fuel_id	fuel_gr_abbr	nfr_id_EA	snap_id	TSP	Ref	PM_{10}	Ref	$PM_{2.5}$	Ref
			1A4a i	0201	143	1	143	9	135	9
			1A4b i	0202	367	17	348	17	340	17
			1A4c i	0203	143	1	143	9	135	9
	117A	STRAW	1A1a i	0101	2.3	18	1.71	3	1.11	3
				0102	21	1	15	2	12	2
			1A4b i	0202	234	4	222	5	211	5
			1A4c i	0203	234	4	222	5	211	5
				020302	21	1	15	2	12	2
	215A	BIO OIL	1A1a	0101	5	15	5	15	5	15
				0102	5	15	5	15	5	15
			1A2a-g	03	5	15	5	15	5	15
			1A4b i	0202	5	15	5	15	5	15
	309A	BIOGAS	1A1a	0101, not engines	1.5	6	1.5	7	1.5	7
				010105	2.63	3	0.451	3	0.206	3
				0102	1.5	6	1.5	7	1.5	7
			1A2a-g	Engines	2.63	3	0.451	3	0.206	3
				Other	1.5	6	1.5	7	1.5	7
			1A4a i	0201	1.5	6	1.5	7	1.5	7
				Engines	2.63	3	0.451	3	0.206	3
			1A4b	0202	0.1	11	0.1	11	0.1	11
			1A4c i	0203	1.5	6	1.5	7	1.5	7
				Engines	2.63	3	0.451	3	0.206	3
	310A	BIO GASIF GAS	1A1a	010105	2.63	19	0.451	19	0.206	19
				010101	0.2	21	0.2	21	0.2	21
	315A	BIONATGAS	1A1a	0101 and 0102	0.1	22	0.1	22	0.1	22
			1A2a-g	03	0.1	22	0.1	22	0.1	22
			1A4a	0201	0.1	22	0.1	22	0.1	22
			1A4b	0202	0.1	22	0.1	22	0.1	22
			1A4c	0203	0.1	22	0.1	22	0.1	22

1. Danish legislation, Miljøstyrelsen 2001. Luftvejledningen, Begrænsning af luftforurening fra virksomheder, Vejledning fra Miljøstyrelsen nr 2 2001 (DEPA, 2001).
2. Particulate size distribution for wood and straw combustion in power plants refers to the TNO CEPMEIP emission factor database 2001 (wood). Available at: http://www.air.sk/tno/cepmeip/ (05-02-2015).
3. Nielsen, M. & Illerup, J.B: 2003. Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme. Eltra PSO projekt 3141. Kortlægning af emissioner fra decentrale kraftvarmeværker. Delrapport 6. Danmarks Miljøundersøgelser. 116 s. – Faglig rapport fra DMU nr. 442.(In Danish, with an English summary). Available at: http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR442.pdf (05-02-2015).
4. German, L., 2003. The Danish Technological Institute, Personal communication, expert judgement, rough estimate.
5. Particulate size distribution for wood and straw combustion in residential plants refers to the TNO CEPMEIP emission factor database 2001 (wood). Available at: http://www.air.sk/tno/cepmeip/ (05-02-2015).
6. Danish legislation. Miljøstyrelsen 1990, Bekendtgørelse 689, 15/10/1990, Bekendtgørelse om begrænsning af emissioner af svovldioxid, kvælstofoxider og støv fra store fyringsanlæg. (and Bekendtgørelse 518/1995). (DEPA, 1990)
7. All TSP emission is assumed to be <2,5µm (DCE assumption).
8. Estimated based on the TSP emission factor.
9. The TNO CEPMEIP emission factor database 2001. Available on the internet at: http://www.air.sk/tno/cepmeip/ (05-02-2015).
10. TNO CEPMEIP emission factor database 2001. Available at: http://www.air.sk/tno/cepmeip/ (05-02-2015).
11. Biogas upgraded for the town gas grid. Assumed equal to natural gas.
12. Livbjerg, H. Thellefsen, M. Sander, B. Simonsen, P., Lund, C., Poulsen, K. & Fogh, C.L., 2001. Feltstudier af Forbrændingsaerosoler, EFP -98 Projekt, Aerosollaboratoriet DTU, FLS Miljø, Forskningscenter Risø, Elsam, Energi E2 (in Danish).
13. Particulate size distribution for residual oil combustion refers to the TNO CEPMEIP emission factor database 2001. Available at: http://www.air.sk/tno/cepmeip/ (05-02-2015).
14. Particulate size distribution for coal combustion refers to the TNO CEPMEIP emission factor database 2001. Available at: http://www.air.sk/tno/cepmeip/ (05-02-2015).
15. Assuming same emission factors as for gas oil (DCE assumption).
16. Same emission factor as for coal is assumed (DCE assumption).
17. DCE estimate based on DEA (2015a), DEPA (2013), Glasius et al. (2005), EEA (2013), Illerup et al. (2007), Nordic Swan label (2012)
18. Nielsen, M., Nielsen, O.K. & Thomsen, M. 2010: Emissionskortlægning for decentral kraftvarme, Energinet.dk miljøprojekt nr. 07/1882. Delrapport 5. Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme, 2006. National Environmental Research Institute, Aarhus University.
19. Same emission factor as for biogas assumed (DCE assumption).
20. The emission factor have been estimated by DCE based on plant specific data from MSW incineration plants, district heating, 2008.
21. Assumed equal to LPG.
22. Assumed equal to natural gas.

Table 3A-4.10 TSP emission factors, time series for the years 2000 to 2015.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.11 PM10 emission factors, time series for the years 2000 to 2015.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.12 PM2.5 emission factors, time series for the years 2000 to 2015.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.13 BC emission factors, time series for the years 2000 to 2015.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.14 HM emission factors (mg per GJ) and references, 2015.

fuel_type	fuel_gr_abbr	nfr	nfr_name	snap	As mg/GJ	Cd mg/GJ	Cr mg/GJ	Cu mg/GJ	Hg mg/GJ	Ni mg/GJ	Pb mg/GJ	Se mg/GJ	Zn mg/GJ	Reference
SOLID	ANODE CARBON	1A2g	Industry	all	4	1.8	13.5	17.5	7.9	13	134	25	200	2
	COAL	1A1a	Public electricity and heat production	all	0.51	0.07	0.86	0.48	1.3	0.97	0.62	5.9	1.9	1
		All other	All other	All	4	1.8	13.5	17.5	7.9	13	134	25	200	2
	FLY ASH FOSSIL	1A1a	Public electricity and heat production	0101	0.51	0.07	0.86	0.48	1.3	0.97	0.62	5.9	1.9	1
	BROWN COAL BRI.	1A4b i	Residential	0202	2.5	1.5	11.2	22.3	5.1	12.7	130	1	220	2
	COKE OVEN COKE	1A2 a-g	Industry	all	4	1.8	13.5	17.5	7.9	13	134	25	200	2
		1A4b	Residential	0202	2.5	1.5	11.2	22.3	5.1	12.7	130	1	220	2
LIQUID	PETROLEUM COKE	all	All	all	4.3	1.3	2.7	5.7	0.4	362	4.9	2.2	94	2
	RESIDUAL OIL	1A1a	Public electricity and heat production	all	2.1	0.53	2.6	2.4	0.21	362	2.6	1.2	7.4	1
		All other	All other	all	4.3	1.3	2.7	5.7	0.4	362	4.9	2.2	94	2
	GAS OIL	-	Engines (reciprocating)	all	0.055	0.011	0.2	0.3	0.11	0.013	0.15	0.22	58	4
		-	All other	all	0.002	0.001	0.2	0.13	0.12	0.005	0.012	0.002	0.42	3
	KEROSENE	All	All	all	0.002	0.001	0.2	0.13	0.12	0.005	0.012	0.002	0.42	5
	LPG	All	All	all	0.002	0.001	0.2	0.13	0.12	0.005	0.012	0.002	0.42	2
	REFINERY GAS	1A1b	Petroleum refining	all	1.8	1.4	1.4	2.7	1.4	1.4	4.1	6.8	1.8	2
GAS	NATURAL GAS	-	Engines (reciprocating)	all	0.05	0.003	0.05	0.01	0.1	0.05	0.04	0.01	2.9	4
		-	All other	all	0.119	0.00025	0.00076	0.000076	0.1	0.00051	0.0015	0.01	0.0015	7 and 2
WASTE	WASTE	-	All	all	0.59	0.44	1.56	1.3	1.79	2.06	5.52	1.11	2.33	4
	INDUSTRIAL WASTE	1A2f	Industry - Other	all	0.59	0.44	1.56	1.3	1.79	2.06	5.52	1.11	2.33	4
BIOMASS	WOOD	-	All non-residential	all	1.4	0.27	2.34	2.6	0.4	2.34	3.62	0.5	2.3	2 and 4
		1A4b i	Residential	all	0.19	13	23	6	0.56	2	27	0.5	512	8
	STRAW	1A1a	Public electricity and heat production	all	1.4	0.32	1.6	1.7	0.31	1.7	6.2	0.5	0.41	2 and 4
		1A4b i	Residential	0202	1	1.4	2.9	8.6	0.5	4.4	40	0.5	130	2
		1A4c i	Agriculture/ Forestry	0203	1	1.4	2.9	8.6	0.5	4.4	40	0.5	130	2
	BIO OIL	-	Engines	engines	0.055	0.011	0.2	0.3	0.11	0.013	0.15	0.22	58	5
		-	All other	-	0.002	0.001	0.2	0.13	0.12	0.005	0.012	0.002	0.42	5
	BIOGAS	-	All non-residential	all	0.04	0.002	0.18	0.31	0.12	0.23	0.005	0.21	3.95	4
		1A4b	Residential	all	0.119	0.00025	0.00076	0.000076	0.1	0.00051	0.0015	0.01	0.0015	9
	BIO GASIF GAS	1A1a	Public electricity and heat production	010105	0.12	0.009	0.029	0.045	0.54	0.014	0.022	0.18	0.058	4
				010101	0.002	0.001	0.2	0.13	0.12	0.005	0.012	0.002	0.42	5
	BIONATGAS	-	All	all	0.119	0.00025	0.00076	0.000076	0.1	0.00051	0.0015	0.01	0.0015	10

Reference:
1. Implied emission factor 2008 estimated by DCE based on plant specific emission data for power plants.
2. EMEP/EEA Emission inventory Guidebook, 2009 update (EEA 2009).
3. CONCAWE (Denier van der Gon & Kuenen, 2009).
4. Nielsen et al. 2010.
5. Assumed equal to gas oil. DCE assumption.
6. Assumed equal to natural gas fuelled engines.
7. Gruijthuijsen (2001).

8. EEA (2013)
9. Assumed equal to natural gas (biogas upgraded for distribution in the town gas grid).
10. Assumed equal to natural gas.

Table 3A-4.15 As emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.16 Cd emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.17 Cr emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.18 Cu emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.19 Hg emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.20 Ni emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.21 Pb emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.22 Se emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.23 Zn emission factors time series, mg per GJ, for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.24 PAH emission factors 2015.

fuel_type	fuel_id	fuel_gr_abbr	nfr_id	snap_id	Benzo(a)-pyrene µg per GJ	Ref.	Benzo(b)-flouran-thene µg per GJ	Ref.	Benzo(k)-flouran-thene µg per GJ	Ref.	Indeno-(1,2,3-c,d)-pyrene µg per GJ	Ref.
SOLID	102A	ANODE CARBON	1A2g	0320	23	4	929	4	929	4	698	4
		COAL	1A1a	All	0.14	4	0.29	4	0.29	4	0.28	4
			1A2 a-g	All	23	4	929	4	929	4	698	4
			1A4c i	0203	59524	4	63492	4	1984	4	119048	4
	103A	FLY ASH FOSSIL	1A1a	0101	0.14	4	0.29	4	0.29	4	0.28	4
	106A	BROWN COAL BRI.	1A4b i	0202	59524	4 (8)	63492	4 (8)	1984	4 (8)	119048	4 (8)
	107A	COKE OVEN COKE	1A2 a-g	all	23	4	929	4	929	4	698	4
			1A4b	0202	59524	4	63492	4	1984	4	119048	4
LIQUID	110A	PETROLEUM COKE	1A2 a-g	all	3184	5	9554	5	-	-	-	-
			1A4a i	all	3184	5	9554	5	-	-	-	-
			1A4b i	all	3184	5	9554	5	-	-	-	-
			1A4c i	all	3184	5	9554	5	-	-	-	-
	203A	RESIDUAL OIL	1A1a	All	109.6	4	475.41	4	93.21	4	177.28	4
			1A1b	010306	109.6	4	475.41	4	93.21	4	177.28	4
			1A2 a-g	all	80	4	42	4	66	4	160	4
			1A4a i	all	80	4	42	4	66	4	160	4
			1A4b i	all	80	4	42	4	66	4	160	4
			1A4c i	all	80	4	42	4	66	4	160	4
	204A	GAS OIL	1A1a	Not engines	109.6	4	475.41	4	93.21	4	177.28	4
				Engines	1.9	7	15	7	1.7	7	1.5	7
			1A1b	010306	109.6	4	475.41	4	93.21	4	177.28	4
			1A1c	010504	109.6	4	475.41	4	93.21	4	177.28	4
			1A2 a-g	Not engines	80	4	42	4	66	4	160	4
				Engines	1.9	7	15	7	1.7	7	1.5	7
			1A4a i	Not engines	80	4	42	4	66	4	160	4
				Engines	1.9	7	15	7	1.7	7	1.5	7
			1A4b i	0202	80	4	42	4	66	4	160	4
			1A4c i	0203	80	4	42	4	66	4	160	4
GAS	301A	NATURAL GAS	1A1a	010104	1	8	1	8	2	8	3	8
				010105	1.2	7	9	7	1.7	7	1.8	7
			1A1c	010504	1	8	1	8	2	8	3	8
			1A2 a-g	Turbines	1	8	1	8	2	8	3	8
				Engines	1.2	7	9	7	1.7	7	1.8	7
			1A4a i	020105	1.2	7	9	7	1.7	7	1.8	7
			1A4b i	020202	0.133	6	0.663	6	0.265	6	2.653	6
				020204	1.2	6	9	6	1.7	6	1.8	6
			1A4c i	020304	1.2	6	9	6	1.7	6	1.8	6
WASTE	114A	WASTE	1A1a	all	0.8	7	1.7	7	0.9	7	1.1	7
			1A4a i	0201	0.8	7	1.7	7	0.9	7	1.1	7
	115A	INDUSTRIAL WASTE	1A2f	0316	0.8	7	1.7	7	0.9	7	1.1	7
BIOMASS	111A	WOOD	1A1a	0101	11	7	15	7	5	7	0.8	7
				0102	6.46	4	1292.52	4	1292.52	4	11.56	4

fuel_type	fuel_id	fuel_gr_abbr	nfr_id	snap_id	Benzo(a)-pyrene		Benzo(b)-flouran-thene		Benzo(k)-flouran-thene		Indeno-(1,2,3-c,d)-pyrene	
			1A2 a-g	all	6.46	4	1292.52	4	1292.52	4	11.56	4
			1A4a i	0201	168707	4	221769	4	73469	4	119728	4
			1A4b i	All	44471	9	45593	9	16511	9	24782	9
			1A4c i	all	168707	4	221769	4	73469	4	119728	4
	117A	STRAW	1A1a	0101	0.5	7	0.5	7	0.5	7	0.5	7
				0102	1529	2	3452	2	1400	2	1029	2
			1A4b i	0202	12956	2	12828	2	6912	2	4222	2
			1A4c i	0203	12956	2	12828	2	6912	2	4222	2
	215A	BIO OIL	1A1a	all	109.6	3	475.41	3	93.21	3	177.28	3
			1A2 a-g	all	80	3	42	3	66	3	160	3
			1A4b i	0202	80	3	42	3	66	3	160	3
	309A	BIOGAS	Engines	All	1.3	7	1.2	7	1.2	7	0.6	7
	310A	BIO GASIF GAS	Engines	010105	2	7	2	7	2	7	2	7

1. -
2. Same emission factors as for gas oil is assumed (DCE assumption).
3. Berdowski J.J.M., Veldt C., Baas J., Bloos J.P.J., Klein A.E. 1995, Technical Paper to the OSPARCOM-HELCOM-UNECE Emission Inventory of heavy Metals and Persistent Organic Pollutants, TNO-report, TNO-MEP – R 95/247.
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5. Jensen, J. 2001, Danish Gas Technology centre, personal communication, e-mail 11-10-2001.
6. Nielsen, M., Nielsen, O.K. & Thomsen, M. 2010c: Emissionskortlægning for decentral kraftvarme, Energinet.dk miljøprojekt nr. 07/1882. Delrapport 5. Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme, 2006. National Environmental Research Institute, Aarhus University.
7. Nielsen, M. & Illerup, J.B. 2003. Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme. Eltra PSO projekt 3141. Kortlægning af emissioner fra decentrale kraftvarmeværker. Delrapport 6. Danmarks Miljøundersøgelser. 116 s. –Faglig rapport fra DMU nr. 442. (In Danish, with English summary). Available at : http://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR442.pdf (07-02-2011).
8. Same emission factor as for coal is assumed (DCE assumption).
9. Aggregated emission factor based on the technology distribution in the sector and guidebook (EEA 2013) emission factors. Technology distribution based on: DEPA (2013)

Table 3A-4.25 PAH emission factors time series, µg pr GJ for the years 1990 to 2015.

This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3A-4.26 Emission factors for PCDD/F, 2015.

fuel_type	fuel_id	fuel_gr_abbr	nfr_id	snap_id	PCDD/F, ng per GJ
SOLID	102A	ANODE CARBON COAL	1A2g	0320	1.32
			1A1a	0101 and 0102	1.32
			1A2 a-g	03	1.32
			1A4c i	0203	300
	103A	FLY ASH FOSSIL	1A1a	0101	1.32
	106A	BROWN COAL BRI.	1A4b i	0202	800
	107A	COKE OVEN COKE	1A2 a-g	03	1.32
			1A4c	0203	800
LIQUID	110A	PETROLEUM COKE	1A2 a-g	03	1.32
			1A4a i	0201	300
			1A4b i	0202	300
			1A4c i	0203	300
	203A	RESIDUAL OIL	1A1a	All	0.882
			1A1b	010306	0.882
			1A2 a-g	03	0.882
			1A4a i	0201	10
			1A4b i	0202	10
			1A4c i	0203	10
	204A	GAS OIL	1A1a	Not engines	0.882
				Engines	0.99
			1A1b	010306	0.882
			1A1c	010504	0.882
			1A2 a-g	Not engines	0.882
				Engines	0.99
			1A4a i	Not engines	10
				Engines	0.99
			1A4b i	0202	10
			1A4c i	0203	10
	206A	KEROSENE	1A2a-g	03	0.882
			1A4a i	0201	10
			1A4b i	0202	10
			1A4c i	0203	10
	303A	LPG	1A1a	0101 and 0102	0.025
			1A2a-g	03	0.025
			1A4a i	0201	2
			1A4b i	0202	2
			1A4c i	0203	2
	308A	REFINERY GAS	1A1b	0103	0.025
GAS	301A	NATURAL GAS	1A1a	Not engines	0.025
				Engines	0.57
			1A1b	0103	0.025
			1A1c	010504	0.025
			1A2 a-g	03, Not engines	0.025
				Engines	0.57
			1A4a i	0201	2
				020105	0.57
			1A4b i	0202	2
				020204	0.57
			1A4c i	0203	2
				020304	0.57
WASTE	114A	WASTE	1A1a	0101 and 0102	5
			1A4a i	0201	5
	115A	INDUSTRIAL WASTE	1A2f	0316	5
BIOMASS	111A	WOOD	1A1a	0101	14
				0102	1
			1A2 a-g	03	1
			1A4a i	0201	400

fuel_type	fuel_id	fuel_gr_abbr	nfr_id	snap_id	PCDD/F, ng per GJ
			1A4b i	0202	304
			1A4c i	0203	400
	117A	STRAW	1A1a	0101	19
				0102	22
			1A4b i	0202	500
			1A4c i	0203	400
	215A	BIO OIL	1A1a	0101 and 0102	0.882
			1A2 a-g	03	0.882
			1A4b i	0202	10
	309A	BIOGAS	1A1a	Engines	0.96
				Not engines	0.025
			1A2a-g	Not engines	0.025
				Engines	0.96
			1A4a i	Not engines	2
				Engines	0.96
			1A4b	Not engines	2
			1A4c i	Not engines	2
				Engines	0.96
	310A	BIO GASIF GAS	1A1a	010105	1.7
				010101	0.025
	315A	BIONATGAS	1A1a	0101 and 0102	0.025
			1A2a-g	03	0.025
			1A4a	0201	2
			1A4b	0202	2
			1A4c	0203	2

Table 3A-4.27 Emission factor time series for PCDD/F.

Year	Waste incineration, PCDD/F, ng/GJ	Residential wood combustion, PCDD/F, ng/GJ
1990	2095	696
1991	1746	695
1992	1396	694
1993	1047	693
1994	907	690
1995	767	685
1996	628	675
1997	488	667
1998	348	656
1999	253	619
2000	157	590
2001	157	537
2002	157	516
2003	157	512
2004	81	507
2005	5	487
2006	5	465
2007	5	470
2008	5	446
2009	5	416
2010	5	399
2011	5	383
2012	5	368
2013	5	343
2014	5	308
2015	5	304

References for HCB are discussed in Nielsen et al. (2014). Table 3A-4.28 presents the applied emission factors.

Table 3A-4.28 Emission factors for HCB, 2015.

Fuel	NFR (SNAP)	Emission factor, ng/GJ	Reference
Coal	1A1, 1A2	6,700	Grochowalski & Konieczyński (2008); EEA (2013)
Coal	1A4b	1,200,000	Syc et al. (2011)
Coal	1A4a and 1A4c	23,000	Syc et al. (2011)
Other solid fuels	1A1, 1A2	6,700	Assumed equal to coal.
Other solid fuels	1A4	1,200,000	Assumed equal to coal.
Liquid fuels[1)]	1A1, 1A2, 1A4	220	Nielsen et al. (2010)
Gaseous fuels	1A1, 1A2, 1A4	-	Negligible
Waste	1A1, 1A2, 1A4	4,300	Nielsen et al. (2010). A time series have been estimated. The emission factor for 1990 (190,000 ng/GJ) refer to Pacyna et al. (2003).
Wood	1A1, 1A2	5,000	EEA (2013)
Wood	1A4	5,000	EEA (2013)
Straw	1A1, 1A2	113	Nielsen et al. (2010)
Straw	1A4	5,000	EEA (2013)
Biogas	1A1, 1A2, 1A4	190	Nielsen et al. (2010)
Bio gasification gas	1A1, 1A2, 1A4	800	Nielsen et al. (2010)

1) Except LPG and refinery gas.

Table 3A-4.29 Emission factor time series for HCB from waste incineration.

Year	HCB, ng/GJ
1990	190000
1991	158000
1992	127000
1993	95000
1994	82000
1995	70000
1996	57000
1997	45000
1998	32000
1999	23000
2000	14000
2001	12000
2002	10000
2003	8000
2004	6000
2005	4300
2006	4300
2007	4300
2008	4300
2009	4300
2010	4300
2011	4300
2012	4300
2013	4300
2014	4300
2015	4300

Table 3A-4.30 Emission factors for PCB, 2015.

Fuel	NFR (SNAP)	Emission factor, ∑ dl-PCB, ng/GJ	Reference
Coal	1A1	839	Grochowalski & Konieczyński (2008)
Coal	1A2	5,700	Thistlethwaite (2001a)
Coal	1A4	7,403	Syc et al. (2011)
Other solid fuels	1A1	839	Assumed equal to coal.
Other solid fuels	1A2	5,700	Assumed equal to coal.
Other solid fuels	1A4	7,403	Assumed equal to coal.
Residual oil	1A1, 1A2, 1A4	839	The teq value refers to Dyke et al. (2003). The TEQ value is equal to the emission factor for coal combustion in power plants and the sum of dioxin-like PCB congeners has been assumed equal to the corresponding factor for coal.
Gas oil	1A1, 1A2, 1A4	93	Nielsen et al. (2010)
Other liquid fuels[1)]	1A1, 1A2, 1A4	93	Assumed equal to gas oil.
Gaseous fuels	1A1, 1A2, 1A4	-	Negligible
Waste	1A1, 1A2, 1A4	109 (time series)	Nielsen et al. (2010). A time series have been estimated. The emission factor for 1990 (46,000 ng/GJ / 117 ng WHO_{1998}teq/GJ) have been estimated based on the assumption that the PCB emission factor time series follow the PCDD/F time series.
Wood	1A1, 1A2, 1A4a/c	2,800	Thistlethwaite (2001a)
Wood	1A4b	2,308 (time series)	Hedman et al. (2006). A time series have been estimated based on time series for technologies applied in Denmark.
Straw	1A1, 1A2	3,110	Assumed equal to residential plants.
Straw	1A4	3,110	Syc et al. (2011)
Biogas	1A1, 1A2, 1A4	90	Nielsen et al. (2010)
Bio gasification gas	1A1, 1A2, 1A4	144	Nielsen et al. (2010)

1. Except LPG and refinery gas.

Emission factor time series for waste incineration and for residential wood combustion are shown in Table 3A-4.31.

Table 3A-4.31 PCB emission factor time series for waste incineration and for residential wood combustion.

Year	Waste incineration	Residential wood combustion
	∑dl-PCB, ng/GJ	∑dl-PCB, ng/GJ
1990	45671	6648
1991	38063	6622
1992	30433	6588
1993	22825	6559
1994	19773	6510
1995	16721	6445
1996	13690	6327
1997	10638	6231
1998	7586	6101
1999	5515	5708
2000	3423	5390
2001	3423	4834
2002	3423	4609
2003	3423	4548
2004	1766	4477
2005	109	4267
2006	109	4028
2007	109	4050
2008	109	3801
2009	109	3496
2010	109	3309
2011	109	3138
2012	109	2974
2013	109	2710
2014	109	2362
2015	109	2308

Table 3A-4.32 Technology specific PCB emission factors for residential wood combustion.

Technology	dl-PCB emission factor, ng WHO-teq/GJ	∑dl-PCB emission factor, ng/GJ	Reference and assumptions
Old stove	53	7049	Hedman (2006), old boiler
New stove	53	7049	Hedman (2006), old boiler
Modern stove (2008-2015)	7	931	Hedman (2006), modern boiler
Modern stove (2015-2017)	7	931	Hedman (2006), modern boiler
Modern stove (2017-)	7	931	Hedman (2006), modern boiler
Eco labelled stove / new advanced stove (-2015)	3.5	466	Hedman (2006), assumed ½ modern boiler
Eco labelled stove / new advanced stove (2015-)	3.5	466	Hedman (2006), assumed ½ modern boiler
Other stove	53	7049	Hedman (2006), old boiler
Old boiler with acc. tank	53	7049	Hedman (2006), old boiler
Old boiler without acc. tank	53	7049	Hedman (2006), old boiler
New boiler with acc. tank	7	931	Hedman (2006), modern boiler
New boiler without acc. tank	7	931	Hedman (2006), modern boiler
Pellet boilers/stoves	3.5	466	Hedman (2006), assumed ½ modern boiler

Table 3A-4.33 Emission factors for NH_3, 2015.

Fuel	NFR (SNAP)	Emission factor, g/GJ	Reference
Coal/BKB/COKE	1A4b	3.8	EEA (2009)
Wood	1A4b	37.4	EEA (2013), technology distribution based on DEPA (2013)
Waste	1A1a	0.29	Nielsen et al. (2010)
Straw	1A4b	3.8	EEA (2009)

Table 3A-4.34 Emission factor time series for NH_3, residential wood combustion.

Year	NH_3 emission, g/GJ
1990	68.6
1991	68.5
1992	68.3
1993	68.1
1994	67.8
1995	67.3
1996	66.3
1997	65.5
1998	64.4
1999	61.0
2000	58.5
2001	53.7
2002	51.9
2003	51.8
2004	51.5
2005	49.9
2006	48.0
2007	49.2
2008	47.7
2009	45.5
2010	44.3
2011	43.4
2012	42.5
2013	40.4
2014	37.0
2015	37.4

Table 3A-4.35 BC fraction of $PM_{2.5}$, 2015.

Fuel_id	**Fuel**	**SNAP**	**BC_%**	**Reference: EEA Guidebook 2013:**
101A	Anodic carbon	032000	2.2%	Energy Industries, Table 3-2
102A	Coal	010100	2.2%	Energy Industries, Table 3-2
102A	Coal	010101	2.2%	Energy Industries, Table 3-2
102A	Coal	010102	2.2%	Energy Industries, Table 3-2
102A	Coal	010103	2.2%	Energy Industries, Table 3-2
102A	Coal	010104	2.2%	Energy Industries, Table 3-2
102A	Coal	010105	2.2%	Energy Industries, Table 3-2
102A	Coal	010200	2.2%	Energy Industries, Table 3-2
102A	Coal	010201	2.2%	Energy Industries, Table 3-2
102A	Coal	010202	2.2%	Energy Industries, Table 3-2
102A	Coal	010203	2.2%	Energy Industries, Table 3-2
102A	Coal	020100	6.4%	Small Combustion, Table 3-7
102A	Coal	020200	6.4%	Small Combustion, Table 3-3
102A	Coal	020300	6.4%	Small Combustion, Table 3-7
102A	Coal	020304	6.4%	Small Combustion, Table 3-7
102A	Coal	030100	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030102	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030103	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030400	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030500	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030600	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030700	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030703	6.4%	Manufacturing Industries, Table 3-2

Fuel_id	Fuel	SNAP	BC_%	Reference: EEA Guidebook 2013:
102A	Coal	030800	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030900	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030902	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	030903	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	031100	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	031102	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	031200	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	031300	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	031400	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	031600	6.4%	Manufacturing Industries, Table 3-2
102A	Coal	032000	6.4%	Manufacturing Industries, Table 3-2
103A	Fly ash fossil	010104	2.2%	Assumed equal to coal. DCE assumption.
106A	Brown coal bri.	020100	6.4%	Small Combustion, Table 3-7
106A	Brown coal bri.	020200	6.4%	Small Combustion, Table 3-3
106A	Brown coal bri.	020300	6.4%	Small Combustion, Table 3-7
106A	Brown coal bri.	030100	6.4%	Manufacturing Industries, Table 3-2
106A	Brown coal bri.	030800	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	020200	6.4%	Small Combustion, Table 3-3
107A	Coke oven coke	030100	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	030400	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	030700	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	030800	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	030900	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	030902	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	030903	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	031200	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	031300	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	031400	6.4%	Manufacturing Industries, Table 3-2
107A	Coke oven coke	032000	6.4%	Manufacturing Industries, Table 3-2
110A	Petroleum coke	010100	5.6%	Energy Industries, table 3-5
110A	Petroleum coke	010102	5.6%	Energy Industries, table 3-5
110A	Petroleum coke	020100	56.0%	Small Combustion, Table 3-5
110A	Petroleum coke	020200	8.5%	Small Combustion, Table 3-5
110A	Petroleum coke	020300	56.0%	Small Combustion, Table 3-5
110A	Petroleum coke	030100	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	030400	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	030600	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	030700	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	030800	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	030900	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	031000	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	031100	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	031300	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	031400	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	031600	56.0%	Manufacturing Industries, Table 3-4
110A	Petroleum coke	032000	56.0%	Manufacturing Industries, Table 3-4
111A	Wood	010100	3.3%	Energy Industries, Table 3-7
111A	Wood	010101	3.3%	Energy Industries, Table 3-7
111A	Wood	010102	3.3%	Energy Industries, Table 3-7
111A	Wood	010103	3.3%	Energy Industries, Table 3-7
111A	Wood	010104	3.3%	Energy Industries, Table 3-7
111A	Wood	010200	3.3%	Energy Industries, Table 3-7
111A	Wood	010201	3.3%	Energy Industries, Table 3-7
111A	Wood	010202	3.3%	Energy Industries, Table 3-7
111A	Wood	010203	3.3%	Energy Industries, Table 3-7
111A	Wood	020100	28.0%	Small Combustion, Table 3-10
111A	Wood	020103	28.0%	Small Combustion, Table 3-10
111A	Wood	020105	28.0%	Small Combustion, Table 3-10
111A	Wood	020200	14.4%	See residential wood combustion
111A	Wood	020202	14.4%	See residential wood combustion
111A	Wood	020204	14.4%	See residential wood combustion
111A	Wood	020300	28.0%	Small Combustion, Table 3-10
111A	Wood	020302	28.0%	Small Combustion, Table 3-10
111A	Wood	020303	28.0%	Small Combustion, Table 3-10
111A	Wood	020304	28.0%	Small Combustion, Table 3-10
111A	Wood	030100	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030102	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030103	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030400	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030500	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030600	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030700	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030800	28.0%	Manufacturing Industries, Table 3-5

Fuel_id	Fuel	SNAP	BC_%	Reference: EEA Guidebook 2013:
111A	Wood	030900	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030902	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	030903	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031000	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031100	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031102	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031200	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031300	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031305	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031400	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031403	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	031603	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	032000	28.0%	Manufacturing Industries, Table 3-5
111A	Wood	032003	28.0%	Manufacturing Industries, Table 3-5
114A	Waste	010100	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010101	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010102	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010103	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010104	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010105	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010200	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010201	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010202	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	010203	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	020100	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	020103	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030100	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030102	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030400	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030600	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030700	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030800	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030900	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	030902	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	031000	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	031100	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	031200	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	031300	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	031400	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	031600	3.5%	Municipal waste Incineration, Table 3-1
114A	Waste	032000	3.5%	Municipal waste Incineration, Table 3-1
115A	Industrial waste	031600	3.5%	Municipal waste Incineration, Table 3-1
117A	Straw	010100	3.3%	Energy Industries, Table 3-7
117A	Straw	010101	3.3%	Energy Industries, Table 3-7
117A	Straw	010102	3.3%	Energy Industries, Table 3-7
117A	Straw	010103	3.3%	Energy Industries, Table 3-7
117A	Straw	010104	3.3%	Energy Industries, Table 3-7
117A	Straw	010200	3.3%	Energy Industries, Table 3-7
117A	Straw	010201	3.3%	Energy Industries, Table 3-7
117A	Straw	010202	3.3%	Energy Industries, Table 3-7
117A	Straw	010203	3.3%	Energy Industries, Table 3-7
117A	Straw	020103	28.0%	Small Combustion, Table 3-10
117A	Straw	020200	10.0%	Small Combustion, Table 3-6
117A	Straw	020300	28.0%	Small Combustion, Table 3-10
117A	Straw	020302	28.0%	Small Combustion, Table 3-10
117A	Straw	030100	28.0%	Manufacturing Industries, Table 3-5
117A	Straw	030103	28.0%	Manufacturing Industries, Table 3-5
117A	Straw	030105	28.0%	Manufacturing Industries, Table 3-5
117A	Straw	030903	28.0%	Manufacturing Industries, Table 3-5
117A	Straw	031305	28.0%	Manufacturing Industries, Table 3-5
117A	Straw	032003	28.0%	Manufacturing Industries, Table 3-5
203A	Residual oil	010100	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010101	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010102	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010103	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010104	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010105	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010200	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010202	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010203	5.6%	Energy Industries, Table 3-5
203A	Residual oil	010306	5.6%	Energy Industries, Table 4-4
203A	Residual oil	020100	56.0%	Small Combustion, Table 3-9
203A	Residual oil	020103	56.0%	Small Combustion, Table 3-9

Fuel_id	Fuel	SNAP	BC_%	Reference: EEA Guidebook 2013:
203A	Residual oil	020200	8.5%	Small Combustion, Table 3-5
203A	Residual oil	020300	56.0%	Small Combustion, Table 3-9
203A	Residual oil	020302	56.0%	Small Combustion, Table 3-9
203A	Residual oil	020304	56.0%	Small Combustion, Table 3-9
203A	Residual oil	030100	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030102	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030103	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030104	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030105	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030400	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030403	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030500	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030600	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030603	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030700	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030800	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030900	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030902	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030903	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030904	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	030905	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031000	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031100	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031102	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031200	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031300	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031305	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031400	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031403	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031500	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031503	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031600	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	031603	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	032000	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	032002	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	032003	56.0%	Manufacturing Industries, Table 3-4
203A	Residual oil	032005	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	010100	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010101	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010102	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010103	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010104	33.5%	Energy Industries, Table 3-18
204A	Gas oil	010105	78.0%	Energy Industries, Table 3-19
204A	Gas oil	010200	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010201	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010202	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010203	33.5%	Energy Industries, Table 3-6
204A	Gas oil	010204	33.5%	Energy Industries, Table 3-18
204A	Gas oil	010205	78.0%	Energy Industries, Table 3-19
204A	Gas oil	010306	33.5%	Energy Industries, Table 4-5
204A	Gas oil	010504	33.5%	Energy Industries, Table 3-18
204A	Gas oil	010505	78.0%	Energy Industries, Table 3-19
204A	Gas oil	020100	56.0%	Small Combustion, Table 3-9
204A	Gas oil	020102	56.0%	Small Combustion, Table 3-9
204A	Gas oil	020103	56.0%	Small Combustion, Table 3-9
204A	Gas oil	020105	78.0%	Energy Industries, Table 3-37
204A	Gas oil	020200	3.9%	Small Combustion, Table 3-21
204A	Gas oil	020204	78.0%	Energy Industries, Table 3-19
204A	Gas oil	020300	56.0%	Small Combustion, Table 3-9
204A	Gas oil	020302	56.0%	Small Combustion, Table 3-9
204A	Gas oil	020304	78.0%	Energy Industries, Table 3-37
204A	Gas oil	030100	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030102	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030103	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030104	33.5%	Energy Industries, Table 3-18
204A	Gas oil	030105	78.0%	Energy Industries, Table 3-19
204A	Gas oil	030400	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030402	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030403	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030500	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030600	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030602	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030604	33.5%	Energy Industries, Table 3-18

Fuel_id	Fuel	SNAP	BC_%	Reference: EEA Guidebook 2013:
204A	Gas oil	030700	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030703	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030800	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030900	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030902	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030903	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	030904	33.5%	Energy Industries, Table 3-18
204A	Gas oil	031000	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031100	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031102	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031103	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031200	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031205	78.0%	Energy Industries, Table 3-19
204A	Gas oil	031300	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031305	78.0%	Energy Industries, Table 3-19
204A	Gas oil	031400	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031403	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031505	78.0%	Energy Industries, Table 3-19
204A	Gas oil	031600	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	031603	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	032000	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	032002	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	032003	56.0%	Manufacturing Industries, Table 3-4
204A	Gas oil	032005	78.0%	Energy Industries, Table 3-19
206A	Kerosene	020100	56.0%	Small Combustion, Table 3-9
206A	Kerosene	020200	8.5%	Small Combustion, Table 3-5
206A	Kerosene	020300	56.0%	Small Combustion, Table 3-9
206A	Kerosene	030100	56.0%	Manufacturing Industries, Table 3-4
206A	Kerosene	031500	56.0%	Manufacturing Industries, Table 3-4
206A	Kerosene	032000	56.0%	Manufacturing Industries, Table 3-4
215A	Bio oil	010101	33.5%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	010102	33.5%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	010103	33.5%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	010105	78.0%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	010200	33.5%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	010202	33.5%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	010203	33.5%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	020105	78.0%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	020200	3.9%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	020304	78.0%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	030100	56.0%	Manufacturing Industries, Table 3-4
215A	Bio oil	030103	56.0%	Manufacturing Industries, Table 3-4
215A	Bio oil	030105	78.0%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	030605	56.0%	Manufacturing Industries, Table 3-4
215A	Bio oil	030903	56.0%	Manufacturing Industries, Table 3-4
215A	Bio oil	031305	78.0%	Assumed equal to gas oil. DCE assumption.
215A	Bio oil	031600	56.0%	Manufacturing Industries, Table 3-4
215A	Bio oil	032005	78.0%	Assumed equal to gas oil. DCE assumption.
225A	Orimulsion	010101	2.2%	Assumed equal to coal. DCE assumption.
301A	Natural gas	010100	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010101	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010102	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010103	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010104	2.5%	Energy Industries, Table 3-17
301A	Natural gas	010105	2.5%	Energy Industries, Table 3-20
301A	Natural gas	010200	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010202	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010203	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010205	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010502	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010503	2.5%	Energy Industries, Table 3-4
301A	Natural gas	010504	2.5%	Energy Industries, Table 3-17
301A	Natural gas	010505	2.5%	Energy Industries, Table 3-20
301A	Natural gas	020100	4.0%	Small Combustion, Table 3-8
301A	Natural gas	020103	4.0%	Small Combustion, Table 3-8
301A	Natural gas	020104	2.5%	Small Combustion, Table 3-34
301A	Natural gas	020105	2.5%	Energy Industries, Table 3-36
301A	Natural gas	020200	5.4%	Small Combustion, Table 3-19
301A	Natural gas	020202	5.4%	Small Combustion, Table 3-19
301A	Natural gas	020204	2.5%	Energy Industries, Table 3-20
301A	Natural gas	020300	4.0%	Small Combustion, Table 3-8
301A	Natural gas	020303	2.5%	Energy Industries, Table 3-17
301A	Natural gas	020304	2.5%	Energy Industries, Table 3-36

Fuel_id	Fuel	SNAP	BC_%	Reference: EEA Guidebook 2013:
301A	Natural gas	030100	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030102	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030103	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030104	2.5%	Energy Industries, Table 3-17
301A	Natural gas	030105	2.5%	Energy Industries, Table 3-20
301A	Natural gas	030106	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030400	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030402	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030500	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030600	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030602	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030603	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030604	2.5%	Energy Industries, Table 3-17
301A	Natural gas	030605	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030700	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030703	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030705	2.5%	Energy Industries, Table 3-20
301A	Natural gas	030800	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030900	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030902	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030903	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	030904	2.5%	Energy Industries, Table 3-17
301A	Natural gas	030905	2.5%	Energy Industries, Table 3-20
301A	Natural gas	031000	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031005	2.5%	Energy Industries, Table 3-20
301A	Natural gas	031100	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031102	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031103	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031104	2.5%	Energy Industries, Table 3-17
301A	Natural gas	031200	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031205	2.5%	Energy Industries, Table 3-20
301A	Natural gas	031300	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031305	2.5%	Energy Industries, Table 3-20
301A	Natural gas	031400	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031405	2.5%	Energy Industries, Table 3-20
301A	Natural gas	031500	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031503	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	031604	2.5%	Energy Industries, Table 3-17
301A	Natural gas	031605	2.5%	Energy Industries, Table 3-20
301A	Natural gas	032000	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	032003	4.0%	Manufacturing Industries, Table 3-3
301A	Natural gas	032004	2.5%	Energy Industries, Table 3-17
301A	Natural gas	032005	2.5%	Energy Industries, Table 3-20
303A	LPG	010100	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010101	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010102	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010103	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010104	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010200	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010202	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010203	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	010306	2.5%	Assumed equal to natural gas. DCE assumption.
303A	LPG	020100	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	020103	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	020105	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	020200	5.4%	Assumed equal to natural gas. DCE assumption.
303A	LPG	020300	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030100	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030400	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030402	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030500	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030600	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030602	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030700	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030800	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	030900	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	031000	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	031100	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	031200	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	031300	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	031400	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	031500	4.0%	Assumed equal to natural gas. DCE assumption.
303A	LPG	032000	4.0%	Assumed equal to natural gas. DCE assumption.

Fuel_id	Fuel	SNAP	BC_%	Reference: EEA Guidebook 2013:
308A	Refinery gas	010101	18.4%	Energy Industries, Table 4-2
308A	Refinery gas	010203	18.4%	Energy Industries, Table 4-2
308A	Refinery gas	010300	18.4%	Energy Industries, Table 4-2
308A	Refinery gas	010304	18.4%	Energy Industries, Table 4-2
308A	Refinery gas	010306	18.4%	Energy Industries, Table 4-2
308A	Refinery gas	032000	18.4%	Energy Industries, Table 4-2
309A	Biogas	010100	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010101	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010102	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010103	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010104	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010105	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010200	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010203	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010205	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	010505	3.3%	Assumed % equal to wood. DCE assumption
309A	Biogas	020100	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	020103	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	020104	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	020105	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	020300	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	020304	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030100	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030102	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030103	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030104	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030105	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030400	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030900	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030902	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030903	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	030905	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	031300	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	032000	28.0%	Assumed % equal to wood. DCE assumption
309A	Biogas	032005	28.0%	Assumed % equal to wood. DCE assumption
310A	Bio gasif. gas	010105	3.3%	Assumed % equal to wood. DCE assumption
310A	Bio gasif. gas	020105	3.3%	Assumed % equal to wood. DCE assumption
310A	Bio gasif. gas	020304	28.0%	Assumed % equal to wood. DCE assumption
310A	Bio gasif. gas	030105	28.0%	Assumed % equal to wood. DCE assumption
310A	Bio gasif. gas	031305	28.0%	Assumed % equal to wood. DCE assumption

Table 3A-4.36 Residential wood combustion, BC fraction of $PM_{2.5}$, time series.

Year	% of PM2.5
1990	12.30%
1991	12.29%
1992	12.29%
1993	12.28%
1994	12.27%
1995	12.27%
1996	12.26%
1997	12.26%
1998	12.25%
1999	12.28%
2000	12.36%
2001	12.44%
2002	12.52%
2003	12.59%
2004	12.66%
2005	12.74%
2006	12.84%
2007	13.04%
2008	13.27%
2009	13.48%
2010	13.67%
2011	13.88%
2012	14.11%
2013	14.37%
2014	14.65%
2015	14.92%

Annex 3A-5 Implied emission factors for waste incineration plants and power plants combustion coal

Table 3A-5.1 Implied emission factors for municipal waste incineration plants 2015.

Pollutant	Implied emission factor	Unit
SO_2	6.9	g /GJ
NO_x	75	g / GJ
TSP	0.65	g / GJ
PM_{10}	0.55	g / GJ
$PM_{2.5}$	0.47	g / GJ
As	0.57	mg / GJ
Cd	0.39	mg / GJ
Cr	1.52	mg / GJ
Cu	1.37	mg / GJ
Hg	1.64	mg / GJ
Ni	2.77	mg / GJ
Pb	4.79	mg / GJ
Se	1.16	mg / GJ
Zn	2.52	mg / GJ

Table 3A-5.2 Implied emission factors for power plants combusting coal, 2015.

Pollutant	Implied emission factor	Unit
SO_2	9.6	g pr GJ
NO_x	29	g pr GJ
TSP	1.7	g pr GJ
PM_{10}	1.4	g pr GJ
$PM_{2.5}$	1.2	g pr GJ
As	0.30	mg pr GJ
Cd	0.023	mg pr GJ
Cr	0.27	mg pr GJ
Cu	0.20	mg pr GJ
Hg	0.86	mg pr GJ
Ni	0.47	mg pr GJ
Pb	0.22	mg pr GJ
Se	6.8	mg pr GJ
Zn	0.85	mg pr GJ

Annex 3A-6 Large point sources

Table 3A-6.1 Large point sources, 2015.

Large point sources
AffaldPlus+, Naestved Forbraendingsanlaeg
AffaldPlus+, Naestved Kraftvarmevaerk
Affaldplus+, Slagelse Forbr. and DONG Slagelse KVV
Affaldscenter aarhus - Forbraendsanlaegget
Affaldsforbraendingsanlaeg I/S REFA
Amagerforbraending
Amagervaerket
Ardagh Glass Holmegaard A/S
Asnaesvaerket
Avedoerevaerket
AVV Forbraendingsanlaeg
Bofa I/S
Centralkommunernes Transmissionsselskab F_berg
Cheminova
DanSteel
DTU
Esbjergvaerket
Faxe Kalk
Fjernvarme Fyn, Centrum Varmecentral
Frederikshavn Affaldskraftvarmevaerk
Frederikshavn Kraftvarmevaerk
Fynsvaerket
Grenaa Forbraending
Grenaa Kraftvarmevaerk
H.C.Oerstedsvaerket
Haldor Topsoee
Hammel Fjernvarmeselskab
Helsingoer Kraftvarmevaerk
Herningvaerket
Hilleroed Kraftvarmevaerk
Hjoerring Varmeforsyning
Horsens Kraftvarmevaerk
I/S Faelles Forbraending
I/S Kara Affaldsforbraendingsanlaeg
I/S Kraftvarmevaerk Thisted
I/S Nordforbraending
I/S Reno Nord
I/S Reno Syd
I/S Vestforbraending
Koege Kraftvarmevaerk
Kolding Forbraendingsanlaeg TAS
Kommunekemi
Koppers
Kyndbyvaerket
L90 Affaldsforbraending
Maricogen
Masnedoevaerket
Maabjergvaerket
Nordic Sugar Nakskov
Nordic Sugar Nykoebing
Nordjyllandsvaerket
Nybro Gasbehandlingsanlaeg
Odense Kraftvarmevaerk
Oestkraft
Rensningsanlaegget Lynetten
Rockwool A/S Doense
Rockwool A/S Vamdrup
Saint-Gobain Isover A/S
Shell Raffinaderi
Silkeborg Kraftvarmevaerk
Skaerbaekvaerket

Large point sources
Skagen Forbraending
Soenderborg Kraftvarmevaerk
Special Waste System
Statoil Raffinaderi
Studstrupvaerket
Svanemoellevaerket
Svendborg Kraftvarmevaerk
Viborg Kraftvarme
Vordingborg Kraftvarme
Aalborg Portland
AarhusKarlshamn Denmark A/S
Danisco Grindsted Dupont
Randersvaerket Verdo
Dalum Kraftvarmevaerk
Duferco Danish Steel

Table 3A-6.2 Large point sources, aggregated fuel consumption in 2015.

nfr_id_EA	fuel_id	fuel_gr_abbr	Sum of Fuel_TJ
1A1a	102A	COAL	71487
	103A	SUB-BITUMINOUS	49
	111A	WOOD	30136
	114A	WASTE	37522
	117A	STRAW	7419
	203A	RESIDUAL OIL	1029
	204A	GAS OIL	433
	215A	BIO OIL	21
	301A	NATURAL GAS	14959
	303A	LPG	10
	309A	BIOGAS	116
	310A	BIO GASIF GAS	0
1A1a Total			163180
1A1b	203A	RESIDUAL OIL	624
	204A	GAS OIL	7
	301A	NATURAL GAS	0
	303A	LPG	0
	308A	REFINERY GAS	16166
1A1b Total			16797
1A1c	204A	GAS OIL	0
	301A	NATURAL GAS	116
1A1c Total			117
1A2a	204A	GAS OIL	0
	301A	NATURAL GAS	1539
	303A	LPG	9
1A2a Total			1548
1A2c	203A	RESIDUAL OIL	204
	204A	GAS OIL	22
	301A	NATURAL GAS	1479
	303A	LPG	0
1A2c Total			1706
1A2e	102A	COAL	880
	107A	COKE OVEN COKE	97
	111A	WOOD	22
	203A	RESIDUAL OIL	2152
	204A	GAS OIL	13
	215A	BIO OIL	157
	301A	NATURAL GAS	79
	309A	BIOGAS	95
1A2e Total			3495
1A2f	102A	COAL	1466
	110A	PETROLEUM COKE	6331
	115A	INDUSTR. WASTES	2488
	203A	RESIDUAL OIL	94
	204A	GAS OIL	99
	215A	BIO OIL	0
	301A	NATURAL GAS	4
1A2f Total			10482
1A2g viii	101A	ANODIC CARBON	0
	102A	COAL	184
	107A	COKE OVEN COKE	376
	204A	GAS OIL	1
	301A	NATURAL GAS	1266

	303A	LPG	1
1A2g viii Total			1828
1A4a i	114A	WASTE	153
	309A	BIOGAS	0
1A4a i Total			153
Grand Total			**199305**

Table 3A-6.3 Large point sources, plant specific emissions[1)].

Year nfr_id	2015 lps_name	SO_2	NO_x	NMVOC	CO	NH_3	TSP	PM_{10}[2)]	$PM_{2.5}$[2)]	BC[2)]	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	PCDD/F
1A1a	AffaldPlus+, Naestved Forbraendingsanlaeg	x	x	x	x	x	x	x	x	x					x					
1A1a	Affaldplus+, Slagelse Forbr. and DONG Slagelse KVV	x	x		x		x	x	x	x										
1A1a	Affaldscenter aarhus - Forbraendsanlaegget	x	x	x			x	x	x	x					x					x
1A1a	Affaldsforbraendingsanlaeg I/S REFA	x	x																	
1A1a	Amagerforbraending	x	x	x	x	x	x	x	x	x					x					x
1A1a	Amagervaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Asnaesvaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Avedoerevaerket	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	AVV Forbraendingsanlaeg	x	x		x															x
1A1a	Bofa I/S	x	x		x						x	x	x	x	x	x	x			x
1A1a	Centralkommunernes Transmissionsselskab F_berg	x	x																	
1A1a	Esbjergvaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Fjernvarme Fyn, Centrum Varmecentral		x																	
1A1a	Frederikshavn Affaldskraftvarmevaerk	x	x		x		x	x	x	x	x	x	x	x	x	x	x			x
1A1a	Frederikshavn Kraftvarmevaerk	x	x				x	x	x	x										
1A1a	Fynsvaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Grenaa Kraftvarmevaerk	x	x		x		x	x	x	x										
1A1a	H.C.Oerstedsvaerket		x		x															
1A1a	Helsingoer Kraftvarmevaerk		x																	
1A1a	Herningvaerket	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Hilleroed Kraftvarmevaerk		x																	
1A1a	Horsens Kraftvarmevaerk	x	x		x		x	x	x	x										x
1A1a	I/S Faelles Forbraending	x	x		x		x	x	x	x										
1A1a	I/S Kara Affaldsforbraendingsanlaeg	x	x		x		x	x	x	x					x					x
1A1a	I/S Nordforbraending	x	x																	
1A1a	I/S Reno Nord	x	x	x	x		x	x	x	x										
1A1a	I/S Reno Syd	x	x	x	x		x	x	x	x					x					x
1A1a	I/S Vestforbraending	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x			x
1A1a	Koege Kraftvarmevaerk		x																	
1A1a	Kolding Forbraendingsanlaeg TAS	x	x	x	x	x	x	x	x	x					x					x
1A1a	Kommunekemi	x	x	x	x		x	x	x	x										
1A1a	Kyndbyvaerket	x	x		x						x	x	x	x	x	x	x	x	x	
1A1a	L90 Affaldsforbraending	x	x		x		x	x	x	x					x					x
1A1a	Masnedoevaerket		x																	
1A1a	Maabjergvaerket	x	x		x															
1A1a	Nordjyllandsvaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Odense Kraftvarmevaerk		x																	
1A1a	Oestkraft	x	x				x													
1A1a	Silkeborg Kraftvarmevaerk		x																	
1A1a	Skaerbaekvaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	

1A1a	Skagen Forbraending	x	x														x			x
1A1a	Soenderborg Kraftvarmevaerk	x	x	x	x		x	x	x	x	x				x					x
1A1a	Special Waste System	x	x		x															
1A1a	Studstrupvaerket	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	
1A1a	Svanemoellevaerket		x		x															
1A1a	Svendborg Kraftvarmevaerk	x	x		x		x	x	x	x		x	x	x	x	x	x			x
1A1a	Viborg Kraftvarme		x																	
1A1a	Vordingborg Kraftvarme	x	x																	
1A1a	Dalum Kraftvarmevaerk	x	x																	
1A1a	Randersvaerket Verdo	x	x				x	x	x	x										
1A1a	I/S Kraftvarmevaerk Thisted	x	x												x					x
1A1a	Hammel Fjernvarmeselskab	x	x		x		x	x	x	x					x					x
1A1b	Shell Raffinaderi	x	x																	
1A1b	Statoil Raffinaderi	x	x																	
1A1c	Nybro Gasbehandlingsanlaeg		x																	
1A2a	DanSteel		x																	
1A2c	Haldor Topsoee		x																	
1A2c	Koppers	x	x	x																
1A2e	Maricogen		x																	
1A2e	Nordic Sugar Nakskov	x	x																	
1A2e	Nordic Sugar Nykoebing	x	x				x	x	x	x										
1A2e	AarhusKarlshamn Denmark A/S	x	x				x	x	x	x										
1A2e	Danisco Grindsted Dupont		x																	
1A2f	Faxe Kalk	x	x																	
1A2f	Aalborg Portland	x	x		x	x	x	x	x	x					x					
1A2g viii	Ardagh Glass Holmegaard A/S		x																	
1A2g viii	Rockwool A/S Doense	x	x																	
1A2g viii	Rockwool A/S Vamdrup	x	x																	
1A2g viii	Saint-Gobain Isover A/S		x																	
1A4a i	Rensningsanlaegget Lynetten	x	x		x		x	x	x	x		x			x		x			
Total		**3180**	**10535**	**14**	**3477**	**46**	**280**	**225**	**156**	**7**	**26**	**5**	**33**	**26**	**125**	**62**	**34**	**388**	**203**	**148**
Total emission from stationary combustion		7024	25922	13848	103464	1231	14154	13259	12722	1877	213	567	1133	564	252	1620	2144	686	21284	15574
Share of total emission from stationary combustion based on plant specific data, %		45%	41%	0.10%	3%	3.8%	2%	2%	1%	0.4%	12%	1%	3%	5%	50%	4%	2%	57%	1%	1%

1) Emissions of the pollutants marked with “x” are plant specific. Emission of other pollutants is estimated based on emission factors. The total shown *in this table* only includes plant specific data.

2) Based on particle size distribution and BC fractions.

Annex 3A-7 Uncertainty estimates, 2015

Table 3A-7.1 Uncertainty estimates.

SNAP	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg SO_2	Input data Mg SO_2	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	SO_2	126144.202	2316.504	1.000	10.000	10.050	3.236	-0.023	0.015	-0.228	0.021	0.229
1A1b Petroleum refining	SO_2	1058.722	224.732	1.000	10.000	10.050	0.314	0.001	0.001	0.011	0.002	0.012
1A1c_ii Oil and gas extraction	SO_2	4.077	10.725	1.000	10.000	10.050	0.015	0.000	0.000	0.001	0.000	0.001
1A2 Manufacturing industries and construction	SO_2	15891.619	2979.027	2.000	10.000	10.198	4.223	0.014	0.019	0.145	0.055	0.155
1A4a_i Commercial / institutional	SO_2	1877.428	88.482	3.000	20.000	20.224	0.249	0.000	0.001	0.000	0.002	0.002
1A4b_i Residential (excluding wood)	SO_2	6192.990	537.371	3.000	20.000	20.224	1.511	0.002	0.003	0.032	0.015	0.035
1A4b_i Residential wood	SO_2	98.499	410.122	20.000	20.000	28.284	1.612	0.003	0.003	0.052	0.075	0.092
1A4c_i Agriculture / forestry / fishing	SO_2	3286.622	627.400	3.000	20.000	20.224	1.764	0.003	0.004	0.061	0.017	0.064
	SO_2											
	SO_2											
Total	SO_2	154554.158	7194.362				36.456					0.090
Total uncertainties					Overall uncertainty i the year (%):		6.038			Trend uncertainty (%):		0.300

SNAP	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg NOx	Input data Mg NOx	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	NOx	90609.445	9974.353	1.000	15.000	15.033	5.731	-0.095	0.088	-1.420	0.124	1.426
1A1b Petroleum refining	NOx	1461.869	1153.424	1.000	20.000	20.025	0.883	0.007	0.010	0.144	0.014	0.144
1A1c_ii Oil and gas extraction	NOx	2370.571	4964.246	1.000	20.000	20.025	3.800	0.039	0.044	0.777	0.062	0.779
1A2 Manufacturing industries and construction	NOx	12151.582	4823.569	2.000	20.000	20.100	3.706	0.018	0.042	0.356	0.120	0.376
1A4a_i Commercial / institutional	NOx	1457.220	671.650	3.000	50.000	50.090	1.286	0.003	0.006	0.148	0.025	0.150
1A4b_i Residential (excluding wood)	NOx	3949.872	1252.519	3.000	30.000	30.150	1.443	0.003	0.011	0.091	0.047	0.102
1A4b_i Residential wood	NOx	538.279	2861.869	20.000	50.000	53.852	5.891	0.024	0.025	1.203	0.711	1.398
1A4c_i Agriculture / forestry / fishing	NOx	1244.323	461.025	3.000	50.000	50.090	0.883	0.002	0.004	0.077	0.017	0.079
	NOx											
	NOx											
Total	NOx	113783.162	26162.655				101.014					4.795
Total uncertainties					Overall uncertainty i the year (%):		10.051			Trend uncertainty (%):		2.190

SNAP	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg NMVOC	Input data Mg NMVOC	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	NMVOC	450.524	785.578	1.000	50.000	50.010	2.526	0.022	0.049	1.086	0.069	1.088
1A1b Petroleum refining	NMVOC	22.855	24.072	1.000	50.000	50.010	0.077	0.000	0.002	0.006	0.002	0.006
1A1c_ii Oil and gas extraction	NMVOC	13.275	39.873	1.000	50.000	50.010	0.128	0.002	0.002	0.084	0.004	0.084
1A2 Manufacturing industries and construction	NMVOC	1112.825	266.143	2.000	50.000	50.040	0.856	-0.051	0.017	-2.545	0.047	2.546
1A4a_i Commercial / institutional	NMVOC	131.949	220.424	3.000	50.000	50.090	0.710	0.006	0.014	0.288	0.058	0.294
1A4b_i Residential (excluding wood)	NMVOC	4627.208	1984.760	3.000	50.000	50.090	6.391	-0.157	0.124	-7.826	0.526	7.843
1A4b_i Residential wood	NMVOC	7275.847	10936.588	20.000	100.000	101.980	71.702	0.240	0.683	24.042	19.327	30.847
1A4c_i Agriculture / forestry / fishing	NMVOC	2370.629	1297.456	3.000	50.000	50.090	4.178	-0.063	0.081	-3.140	0.344	3.158
	NMVOC											
	NMVOC											
Total	NMVOC	16005.114	15554.896				5207.124					1030.801
Total uncertainties					Overall uncertainty i the year (%):		72.160			Trend uncertainty (%):		32.106

SNAP	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg CO	Input data Mg CO	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	CO	7941.876	10779.811	1.000	20.000	20.025	1.840	0.030	0.074	0.603	0.104	0.612
1A1b Petroleum refining	CO	125.940	119.147	1.000	20.000	20.025	0.020	0.000	0.001	0.002	0.001	0.003
1A1c_ii Oil and gas extraction	CO	58.790	119.626	1.000	20.000	20.025	0.020	0.000	0.001	0.010	0.001	0.010
1A2 Manufacturing industries and construction	CO	4693.759	3705.256	2.000	20.000	20.100	0.635	-0.000	0.025	-0.009	0.072	0.072
1A4a_i Commercial / institutional	CO	964.570	796.275	3.000	50.000	50.090	0.340	0.000	0.005	0.008	0.023	0.024
1A4b_i Residential (excluding wood)	CO	47956.458	12593.368	3.000	50.000	50.090	5.378	-0.177	0.086	-8.834	0.366	8.841
1A4b_i Residential wood	CO	52232.953	80454.328	20.000	100.000	101.980	69.949	0.263	0.551	26.272	15.573	30.540
1A4c_i Agriculture / forestry / fishing	CO	32152.313	8727.916	3.000	50.000	50.090	3.727	-0.117	0.060	-5.832	0.253	5.837
	CO											
	CO											
Total	CO	146126.661	117295.727				4939.636					1045.324
Total uncertainties					Overall uncertainty i the year (%):		70.283			Trend uncertainty (%):		32.331

SNAP	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg NH_3	Input data Mg NH_3	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	NH_3	0.287	15.403	1.000	1000.000	1000.000	10.531	0.023	0.024	23.151	0.034	23.151
1A1b Petroleum refining	NH_3			1.000	1000.000	1000.000						
1A1c_ii Oil and gas extraction	NH_3			1.000	1000.000	1000.000						
1A2 Manufacturing industries and construction	NH_3		40.000	2.000	1000.000	1000.002	27.347	0.063	0.063	62.808	0.178	62.809
1A4a_i Commercial / institutional	NH_3			3.000	1000.000	1000.004						
1A4b_i Residential (excluding wood)	NH_3	22.166	11.204	3.000	1000.000	1000.004	7.660	-0.062	0.018	-62.323	0.075	62.323
1A4b_i Residential wood	NH_3	614.406	1396.097	20.000	100.000	101.980	97.336	-0.023	2.192	-2.339	62.004	62.048
1A4c_i Agriculture / forestry / fishing	NH_3			3.000	1000.000	1000.004						
	NH_3											
	NH_3											
Total	NH_3	636.859	1462.705				10391.802					12215.012
Total uncertainties					Overall uncertainty i the year (%):		101.940			Trend uncertainty (%):		110.522

SNAP	Gas	Base year emission (year 1990)	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg TSP	Input data Mg TSP	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	TSP	979.220	595.274	1.000	20.000	20.025	0.743	-0.043	0.044	-0.861	0.063	0.863
1A1b Petroleum refining	TSP	135.351	112.052	1.000	50.000	50.010	0.349	-0.004	0.008	-0.187	0.012	0.187
1A1c_ii Oil and gas extraction	TSP	0.948	2.494	1.000	50.000	50.010	0.008	0.000	0.000	0.005	0.000	0.005
1A2 Manufacturing industries and construction	TSP	581.414	258.366	2.000	30.000	30.067	0.484	-0.033	0.019	-0.980	0.055	0.981
1A4a_i Commercial / institutional	TSP	120.637	180.647	3.000	50.000	50.090	0.564	0.003	0.013	0.135	0.057	0.147
1A4b_i Residential (excluding wood)	TSP	1538.417	723.799	3.000	50.000	50.090	2.259	-0.083	0.054	-4.168	0.229	4.174
1A4b_i Residential wood	TSP	9090.077	13677.583	20.000	200.000	200.998	171.264	0.207	1.020	41.367	28.863	50.441
1A4c_i Agriculture / forestry / fishing	TSP	957.337	502.008	3.000	50.000	50.090	1.566	-0.048	0.037	-2.403	0.159	2.408
	TSP											
	TSP											
Total	TSP	13403.402	16052.223				29339.973					2569.286
Total uncertainties					Overall uncertainty i the year (%):		171.289			Trend uncertainty (%):		50.688

SNAP	Gas	Base year emission (year 1990)	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg PM_{10}	Input data Mg PM_{10}	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	PM_{10}	831.218	438.817	1.000	20.000	20.025	0.583	-0.046	0.035	-0.914	0.050	0.915
1A1b Petroleum refining	PM_{10}	122.259	105.814	1.000	50.000	50.010	0.351	-0.003	0.009	-0.170	0.012	0.171
1A1c_ii Oil and gas extraction	PM_{10}	0.578	1.522	1.000	50.000	50.010	0.005	0.000	0.000	0.003	0.000	0.003
1A2 Manufacturing industries and construction	PM_{10}	419.148	186.929	2.000	30.000	30.067	0.373	-0.026	0.015	-0.774	0.043	0.776
1A4a_i Commercial / institutional	PM_{10}	112.436	178.947	3.000	50.000	50.090	0.595	0.003	0.014	0.172	0.061	0.182
1A4b_i Residential (excluding wood)	PM_{10}	1442.449	688.192	3.000	50.000	50.090	2.289	-0.085	0.055	-4.258	0.235	4.264
1A4b_i Residential wood	PM_{10}	8635.521	12987.985	20.000	200.000	200.998	173.321	0.202	1.045	40.328	29.554	49.998
1A4c_i Agriculture / forestry / fishing	PM_{10}	866.226	473.788	3.000	50.000	50.090	1.576	-0.046	0.038	-2.315	0.162	2.321
	PM_{10}											
	PM_{10}											
Total	PM_{10}	12429.835	15061.994				30048.681					2524.916
Total uncertainties					Overall uncertainty i the year (%):		173.346			Trend uncertainty (%):		50.249

SNAP	Gas	Base year emission (year 1990)	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Mg $PM_{2,5}$	Input data Mg $PM_{2,5}$	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	$PM_{2,5}$	673.299	340.317	1.000	20.000	20.025	0.470	-0.043	0.029	-0.852	0.041	0.853
1A1b Petroleum refining	$PM_{2,5}$	115.713	102.695	1.000	50.000	50.010	0.354	-0.004	0.009	-0.177	0.012	0.177
1A1c_ii Oil and gas extraction	$PM_{2,5}$	0.484	1.273	1.000	50.000	50.010	0.004	0.000	0.000	0.003	0.000	0.003
1A2 Manufacturing industries and construction	$PM_{2,5}$	273.279	119.385	2.000	30.000	30.067	0.247	-0.019	0.010	-0.567	0.029	0.568
1A4a_i Commercial / institutional	$PM_{2,5}$	103.768	169.442	3.000	50.000	50.090	0.585	0.003	0.015	0.173	0.062	0.184
1A4b_i Residential (excluding wood)	$PM_{2,5}$	1359.177	655.648	3.000	50.000	50.090	2.264	-0.089	0.056	-4.431	0.238	4.437
1A4b_i Residential wood	$PM_{2,5}$	8353.291	12673.061	20.000	200.000	200.998	175.563	0.194	1.086	38.870	30.728	49.549
1A4c_i Agriculture / forestry / fishing	$PM_{2,5}$	786.236	447.231	3.000	50.000	50.090	1.544	-0.045	0.038	-2.273	0.163	2.279
	$PM_{2,5}$											
	$PM_{2,5}$											
Total	$PM_{2,5}$	11665.245	14509.053				30830.645					2481.062
Total uncertainties					Overall uncertainty i the year (%):		175.587			Trend uncertainty (%):		49.810

SNAP	Gas	Base year emission (year 2000)	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		Gg BC	Gg BC	%	%	%	%	%	%	%	%	%
1A1a Public electricity and heat production	BC	0.021	0.013	1.000	1000.000	1000.000	5.879	-0.011	0.008	-11.327	0.012	11.327
1A1b Petroleum refining	BC	0.015	0.016	1.000	1000.000	1000.000	7.387	-0.004	0.010	-3.681	0.015	3.681
1A1c_ii Oil and gas extraction	BC	0.000	0.000	1.000	1000.000	1000.000	0.015	0.000	0.000	0.010	0.000	0.010
1A2 Manufacturing industries and construction	BC	0.083	0.021	2.000	1000.000	1000.002	9.677	-0.062	0.014	-61.977	0.039	61.977
1A4a_i Commercial / institutional	BC	0.048	0.050	3.000	1000.000	1000.004	22.967	-0.011	0.032	-11.290	0.138	11.291
1A4b_i Residential (excluding wood)	BC	0.121	0.064	3.000	1000.000	1000.004	29.172	-0.069	0.041	-69.228	0.175	69.228
1A4b_i Residential wood	BC	1.028	1.891	20.000	1000.000	1000.200	868.049	0.284	1.225	283.507	34.655	285.617
1A4c_i Agriculture / forestry / fishing	BC	0.228	0.124	3.000	1000.000	1000.004	57.027	-0.128	0.081	-127.620	0.342	127.621
	BC											
	BC											
Total	BC	1.543	2.179				758322.805					106767.321
Total uncertainties					Overall uncertainty i the year (%):		870.817			Trend uncertainty (%):		326.753

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		kg As	kg As	%	%	%	%	%	%	%	%	%
1A1a Public electricity and heat production	As	926.933	87.870	1.000	50.000	50.010	20.644	-0.069	0.075	-3.450	0.106	3.451
1A1b Petroleum refining	As	30.790	31.781	1.000	100.000	100.005	14.931	0.022	0.027	2.241	0.039	2.241
1A1c_ii Oil and gas extraction	As	1.128	2.966	1.000	100.000	100.005	1.393	0.002	0.003	0.236	0.004	0.236
1A2 Manufacturing industries and construction	As	156.332	69.550	2.000	100.000	100.020	32.680	0.035	0.060	3.511	0.169	3.515
1A4a_i Commercial / institutional	As	13.431	2.682	3.000	300.000	300.015	3.781	0.000	0.002	0.060	0.010	0.061
1A4b_i Residential (excluding wood)	As	14.210	5.985	3.000	300.000	300.015	8.435	0.003	0.005	0.872	0.022	0.872
1A4b_i Residential wood	As	1.701	7.084	20.000	1000.000	1000.200	33.286	0.006	0.006	5.803	0.172	5.806
1A4c_i Agriculture / forestry / fishing	As	22.707	4.945	3.000	300.000	300.015	6.969	0.001	0.004	0.207	0.018	0.207
	As											
	As											
Total	As	1167.232	212.862				2961.030					63.862
Total uncertainties					Overall uncertainty i the year (%):		54.415			Trend uncertainty (%):		7.991

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Cd	Input data kg Cd	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Cd	718.812	26.776	1.000	50.000	50.010	2.361	-0.409	0.028	-20.469	0.039	20.469
1A1b Petroleum refining	Cd	21.271	23.443	1.000	100.000	100.005	4.134	0.011	0.024	1.133	0.034	1.134
1A1c_ii Oil and gas extraction	Cd	0.002	0.006	1.000	100.000	100.005	0.001	0.000	0.000	0.001	0.000	0.001
1A2 Manufacturing industries and construction	Cd	53.970	23.484	2.000	100.000	100.020	4.142	-0.009	0.024	-0.865	0.069	0.867
1A4a_i Commercial / institutional	Cd	30.036	0.613	3.000	300.000	300.015	0.324	-0.018	0.001	-5.326	0.003	5.326
1A4b_i Residential (excluding wood)	Cd	9.745	4.146	3.000	300.000	300.015	2.193	-0.002	0.004	-0.498	0.018	0.498
1A4b_i Residential wood	Cd	116.408	484.690	20.000	600.000	600.333	513.093	0.432	0.504	259.136	14.247	259.527
1A4c_i Agriculture / forestry / fishing	Cd	11.985	3.942	3.000	300.000	300.015	2.086	-0.003	0.004	-0.973	0.017	0.973
	Cd											
	Cd											
Total	Cd	962.230	567.101				263313.354					67805.070
Total uncertainties					Overall uncertainty i the year (%):		513.141			Trend uncertainty (%):		260.394

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Cr	Input data kg Cr	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Cr	4639.758	143.982	1.000	50.000	50.010	6.358	-0.155	0.027	-7.765	0.038	7.765
1A1b Petroleum refining	Cr	23.104	24.318	1.000	100.000	100.005	2.147	0.004	0.005	0.363	0.006	0.363
1A1c_ii Oil and gas extraction	Cr	0.007	0.019	1.000	100.000	100.005	0.002	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	Cr	216.751	78.409	2.000	100.000	100.020	6.925	0.006	0.015	0.608	0.041	0.609
1A4a_i Commercial / institutional	Cr	177.281	3.648	3.000	300.000	300.015	0.966	-0.006	0.001	-1.899	0.003	1.899
1A4b_i Residential (excluding wood)	Cr	37.490	9.965	3.000	300.000	300.015	2.640	0.000	0.002	0.114	0.008	0.114
1A4b_i Residential wood	Cr	205.952	857.528	20.000	400.000	400.500	303.253	0.152	0.160	60.828	4.533	60.997
1A4c_i Agriculture / forestry / fishing	Cr	49.945	14.648	3.000	300.000	300.015	3.881	0.001	0.003	0.229	0.012	0.229
	Cr											
	Cr											
Total	Cr	5350.288	1132.517				92078.614					3785.086
Total uncertainties					Overall uncertainty i the year (%):		303.445			Trend uncertainty (%):		61.523

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		kg Cu	kg Cu	%	%	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Cu	2870.506	135.309	1.000	50.000	50.010	11.988	-0.089	0.038	-4.473	0.054	4.473
1A1b Petroleum refining	Cu	45.203	47.204	1.000	100.000	100.005	8.363	0.011	0.013	1.126	0.019	1.126
1A1c_ii Oil and gas extraction	Cu	0.001	0.002	1.000	100.000	100.005	0.000	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	Cu	307.084	99.593	2.000	100.000	100.020	17.647	0.014	0.028	1.429	0.079	1.431
1A4a_i Commercial / institutional	Cu	122.662	3.844	3.000	300.000	300.015	2.043	-0.004	0.001	-1.319	0.005	1.319
1A4b_i Residential (excluding wood)	Cu	69.877	26.277	3.000	300.000	300.015	13.966	0.004	0.007	1.281	0.031	1.281
1A4b_i Residential wood	Cu	53.727	223.703	20.000	1000.000	1000.200	396.374	0.061	0.063	60.526	1.780	60.552
1A4c_i Agriculture / forestry / fishing	Cu	85.425	28.554	3.000	300.000	300.015	15.176	0.004	0.008	1.265	0.034	1.265
	Cu											
	Cu											
Total	Cu	3554.485	564.486				158066.958					3694.851
Total uncertainties					Overall uncertainty i the year (%):		397.576			Trend uncertainty (%):		60.785

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		kg Hg	kg Hg	%	%	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Hg	2448.434	133.209	1.000	50.000	50.010	26.422	-0.030	0.047	-1.488	0.067	1.489
1A1b Petroleum refining	Hg	20.093	22.883	1.000	100.000	100.005	9.076	0.007	0.008	0.745	0.011	0.745
1A1c_ii Oil and gas extraction	Hg	0.948	2.492	1.000	100.000	100.005	0.988	0.001	0.001	0.085	0.001	0.085
1A2 Manufacturing industries and construction	Hg	192.197	59.957	2.000	100.000	100.020	23.785	0.015	0.021	1.513	0.060	1.514
1A4a_i Commercial / institutional	Hg	124.046	1.700	3.000	300.000	300.015	2.023	-0.003	0.001	-0.991	0.003	0.991
1A4b_i Residential (excluding wood)	Hg	16.349	4.838	3.000	300.000	300.015	5.757	0.001	0.002	0.358	0.007	0.359
1A4b_i Residential wood	Hg	5.014	20.879	20.000	200.000	200.998	16.645	0.007	0.007	1.444	0.209	1.459
1A4c_i Agriculture / forestry / fishing	Hg	22.875	6.174	3.000	300.000	300.015	7.346	0.001	0.002	0.438	0.009	0.438
	Hg											
	Hg											
Total	Hg	2829.957	252.132				1715.428					8.503
Total uncertainties					Overall uncertainty i the year (%):		41.418			Trend uncertainty (%):		2.916

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		kg Ni	kg Ni	%	%	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Ni	8038.635	218.562	1.000	50.000	50.010	6.748	-0.034	0.013	-1.698	0.019	1.698
1A1b Petroleum refining	Ni	493.501	248.434	1.000	100.000	100.005	15.338	0.012	0.015	1.207	0.021	1.207
1A1c_ii Oil and gas extraction	Ni	0.005	0.013	1.000	100.000	100.005	0.001	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	Ni	6274.978	1041.431	2.000	100.000	100.020	64.306	0.026	0.063	2.575	0.178	2.581
1A4a_i Commercial / institutional	Ni	587.219	4.676	3.000	300.000	300.015	0.866	-0.003	0.000	-0.952	0.001	0.952
1A4b_i Residential (excluding wood)	Ni	386.269	14.305	3.000	300.000	300.015	2.650	-0.001	0.001	-0.423	0.004	0.423
1A4b_i Residential wood	Ni	17.909	74.568	20.000	700.000	700.286	32.237	0.004	0.004	3.072	0.127	3.075
1A4c_i Agriculture / forestry / fishing	Ni	793.896	17.837	3.000	300.000	300.015	3.304	-0.004	0.001	-1.078	0.005	1.078
	Ni											
	Ni											
Total	Ni	16592.412	1619.826				5473.921					22.702
Total uncertainties					Overall uncertainty i the year (%):		73.986			Trend uncertainty (%):		4.765

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		kg Pb	kg Pb	%	%	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Pb	12005.915	330.050	1.000	50.000	50.010	7.700	-0.088	0.022	-4.406	0.031	4.406
1A1b Petroleum refining	Pb	63.725	69.337	1.000	100.000	100.005	3.235	0.004	0.005	0.396	0.006	0.396
1A1c_ii Oil and gas extraction	Pb	0.014	0.037	1.000	100.000	100.005	0.002	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	Pb	1483.855	452.695	2.000	100.000	100.020	21.122	0.016	0.030	1.599	0.084	1.601
1A4a_i Commercial / institutional	Pb	679.141	4.516	3.000	300.000	300.015	0.632	-0.006	0.000	-1.784	0.001	1.784
1A4b_i Residential (excluding wood)	Pb	308.283	118.086	3.000	300.000	300.015	16.527	0.005	0.008	1.470	0.033	1.470
1A4b_i Residential wood	Pb	241.770	1006.663	20.000	400.000	400.500	188.075	0.064	0.066	25.483	1.865	25.551
1A4c_i Agriculture / forestry / fishing	Pb	483.480	162.275	3.000	300.000	300.015	22.711	0.006	0.011	1.854	0.045	1.855
	Pb											
	Pb											
Total	Pb	15266.184	2143.657				36677.398					683.766
Total uncertainties					Overall uncertainty i the year (%):		191.513			Trend uncertainty (%):		26.149

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Se	Input data kg Se	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Se	3453.494	451.056	1.000	50.000	50.010	32.882	-0.037	0.114	-1.870	0.162	1.877
1A1b Petroleum refining	Se	97.931	111.300	1.000	100.000	100.005	16.225	0.024	0.028	2.387	0.040	2.388
1A1c_ii Oil and gas extraction	Se	0.095	0.249	1.000	100.000	100.005	0.036	0.000	0.000	0.006	0.000	0.006
1A2 Manufacturing industries and construction	Se	276.898	85.422	2.000	100.000	100.020	12.454	0.009	0.022	0.944	0.061	0.946
1A4a_i Commercial / institutional	Se	27.780	1.031	3.000	300.000	300.015	0.451	-0.001	0.000	-0.288	0.001	0.288
1A4b_i Residential (excluding wood)	Se	19.855	1.749	3.000	300.000	300.015	0.765	-0.000	0.000	-0.129	0.002	0.129
1A4b_i Residential wood	Se	4.477	18.642	20.000	200.000	200.998	5.462	0.005	0.005	0.905	0.134	0.915
1A4c_i Agriculture / forestry / fishing	Se	67.854	16.568	3.000	300.000	300.015	7.246	0.001	0.004	0.363	0.018	0.363
	Se											
	Se											
Total	Se	3948.384	686.017				1582.676					11.189
Total uncertainties					Overall uncertainty i the year (%):		39.783			Trend uncertainty (%):		3.345

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Zn	Input data kg Zn	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Zn	16298.113	367.845	1.000	50.000	50.010	0.864	-0.437	0.013	-21.858	0.019	21.858
1A1b Petroleum refining	Zn	148.226	87.735	1.000	100.000	100.005	0.412	-0.001	0.003	-0.095	0.004	0.095
1A1c_ii Oil and gas extraction	Zn	0.014	0.038	1.000	100.000	100.005	0.000	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	Zn	3706.423	958.165	2.000	100.000	100.020	4.503	-0.068	0.035	-6.831	0.098	6.831
1A4a_i Commercial / institutional	Zn	866.854	8.693	3.000	300.000	300.015	0.123	-0.024	0.000	-7.132	0.001	7.132
1A4b_i Residential (excluding wood)	Zn	927.408	387.000	3.000	300.000	300.015	5.455	-0.012	0.014	-3.537	0.059	3.537
1A4b_i Residential wood	Zn	4584.669	19089.313	20.000	200.000	200.998	180.275	0.561	0.690	112.299	19.512	113.982
1A4c_i Agriculture / forestry / fishing	Zn	1139.377	384.846	3.000	300.000	300.015	5.425	-0.018	0.014	-5.327	0.059	5.327
	Zn											
	Zn											
Total	Zn	27671.085	21283.634				32579.425					13608.061
Total uncertainties					Overall uncertainty i the year (%):		180.498			Trend uncertainty (%):		116.654

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data g Dioxin	Input data g Dioxin	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Dioxin	30.911	1.011	1.000	200.000	200.002	12.986	-0.195	0.022	-39.088	0.030	39.088
1A1b Petroleum refining	Dioxin	0.002	0.001	1.000	1000.000	1000.000	0.062	0.000	0.000	0.010	0.000	0.010
1A1c_ii Oil and gas extraction	Dioxin	0.000	0.001	1.000	1000.000	1000.000	0.040	0.000	0.000	0.012	0.000	0.012
1A2 Manufacturing industries and construction	Dioxin	0.905	0.054	2.000	1000.000	1000.002	3.445	-0.005	0.001	-5.247	0.003	5.247
1A4a_i Commercial / institutional	Dioxin	2.189	0.502	3.000	1000.000	1000.004	32.258	-0.005	0.011	-4.759	0.045	4.759
1A4b_i Residential (excluding wood)	Dioxin	4.297	1.591	3.000	1000.000	1000.004	102.127	0.004	0.034	3.525	0.144	3.528
1A4b_i Residential wood	Dioxin	6.231	11.351	20.000	600.000	600.333	437.541	0.197	0.242	118.457	6.836	118.654
1A4c_i Agriculture / forestry / fishing	Dioxin	2.430	1.064	3.000	1000.000	1000.004	68.311	0.005	0.023	5.495	0.096	5.496
	Dioxin											
	Dioxin											
Total	Dioxin	46.964	15.574				207759.588					15699.558
Total uncertainties					Overall uncertainty i the year (%):		455.807			Trend uncertainty (%):		125.298

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Benzo(b)	Input data kg Benzo(b)	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Benzo(b)	22.622	39.327	1.000	100.000	100.005	1.775	0.003	0.028	0.285	0.039	0.287
1A1b Petroleum refining	Benzo(b)	0.622	0.300	1.000	100.000	100.005	0.014	-0.000	0.000	-0.047	0.000	0.047
1A1c_ii Oil and gas extraction	Benzo(b)	0.009	0.025	1.000	100.000	100.005	0.001	0.000	0.000	0.001	0.000	0.001
1A2 Manufacturing industries and construction	Benzo(b)	49.044	73.166	2.000	100.000	100.020	3.303	-0.002	0.051	-0.234	0.146	0.275
1A4a_i Commercial / institutional	Benzo(b)	52.109	255.696	3.000	1000.000	1000.004	115.391	0.123	0.180	122.718	0.764	122.721
1A4b_i Residential (excluding wood)	Benzo(b)	121.877	38.117	3.000	1000.000	1000.004	17.201	-0.107	0.027	-106.856	0.114	106.856
1A4b_i Residential wood	Benzo(b)	943.771	1699.897	20.000	1000.000	1000.200	767.284	0.159	1.196	159.428	33.839	162.980
1A4c_i Agriculture / forestry / fishing	Benzo(b)	230.805	109.387	3.000	1000.000	1000.004	49.364	-0.176	0.077	-176.063	0.327	176.064
	Benzo(b)											
	Benzo(b)											
Total	Benzo(b)	1420.859	2215.915				604787.312					84039.541
Total uncertainties					Overall uncertainty i the year (%):		777.681			Trend uncertainty (%):		289.896

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Benzo(k)	Input data kg Benzo(k)	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Benzo(k)	10.404	25.254	1.000	100.000	100.005	3.210	0.017	0.053	1.710	0.074	1.711
1A1b Petroleum refining	Benzo(k)	0.122	0.059	1.000	100.000	100.005	0.007	-0.000	0.000	-0.029	0.000	0.029
1A1c_ii Oil and gas extraction	Benzo(k)	0.019	0.050	1.000	100.000	100.005	0.006	0.000	0.000	0.004	0.000	0.004
1A2 Manufacturing industries and construction	Benzo(k)	22.783	10.462	2.000	100.000	100.020	1.330	-0.056	0.022	-5.586	0.062	5.587
1A4a_i Commercial / institutional	Benzo(k)	16.050	84.811	3.000	1000.000	1000.004	107.785	0.122	0.177	121.773	0.749	121.775
1A4b_i Residential (excluding wood)	Benzo(k)	39.727	20.785	3.000	1000.000	1000.004	26.416	-0.092	0.043	-92.086	0.184	92.086
1A4b_i Residential wood	Benzo(k)	356.321	615.584	20.000	1000.000	1000.200	782.484	0.066	1.281	66.124	36.240	75.404
1A4c_i Agriculture / forestry / fishing	Benzo(k)	35.016	29.857	3.000	1000.000	1000.004	37.945	-0.057	0.062	-57.179	0.264	57.180
	Benzo(k)											
	Benzo(k)											
Total	Benzo(k)	480.441	786.863				626047.877					32298.441
Total uncertainties					Overall uncertainty i the year (%):		791.232			Trend uncertainty (%):		179.718

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Benzo(a)	Input data kg Benzo(a)	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Benzo(a)	6.881	10.263	1.000	100.000	100.005	0.508	0.000	0.007	0.029	0.010	0.031
1A1b Petroleum refining	Benzo(a)	0.143	0.069	1.000	100.000	100.005	0.003	-0.000	0.000	-0.010	0.000	0.010
1A1c_ii Oil and gas extraction	Benzo(a)	0.009	0.025	1.000	100.000	100.005	0.001	0.000	0.000	0.001	0.000	0.001
1A2 Manufacturing industries and construction	Benzo(a)	10.912	21.274	2.000	100.000	100.020	1.054	0.004	0.015	0.400	0.043	0.403
1A4a_i Commercial / institutional	Benzo(a)	40.998	194.606	3.000	1000.000	1000.004	96.368	0.096	0.138	96.343	0.586	96.344
1A4b_i Residential (excluding wood)	Benzo(a)	116.485	38.703	3.000	1000.000	1000.004	19.166	-0.091	0.027	-90.781	0.116	90.781
1A4b_i Residential wood	Benzo(a)	1023.279	1658.048	20.000	1000.000	1000.200	821.216	0.136	1.176	135.598	33.258	139.617
1A4c_i Agriculture / forestry / fishing	Benzo(a)	211.388	96.432	3.000	1000.000	1000.004	47.752	-0.146	0.068	-146.083	0.290	146.084
	Benzo(a)											
	Benzo(a)											
Total	Benzo(a)	1410.096	2019.420				686330.897					58357.065
Total uncertainties					Overall uncertainty i the year (%):		828.451			Trend uncertainty (%):		241.572

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg Indeno	Input data kg Indeno	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	Indeno	6.057	7.105	1.000	100.000	100.005	0.596	0.000	0.006	0.049	0.009	0.049
1A1b Petroleum refining	Indeno	0.232	0.112	1.000	100.000	100.005	0.009	-0.000	0.000	-0.013	0.000	0.013
1A1c_ii Oil and gas extraction	Indeno	0.028	0.074	1.000	100.000	100.005	0.006	0.000	0.000	0.004	0.000	0.004
1A2 Manufacturing industries and construction	Indeno	13.796	3.458	2.000	100.000	100.020	0.290	-0.010	0.003	-1.047	0.009	1.047
1A4a_i Commercial / institutional	Indeno	37.086	138.327	3.000	1000.000	1000.004	116.041	0.089	0.126	89.233	0.534	89.235
1A4b_i Residential (excluding wood)	Indeno	117.831	13.431	3.000	1000.000	1000.004	11.267	-0.104	0.012	-103.962	0.052	103.962
1A4b_i Residential wood	Indeno	599.052	923.962	20.000	1000.000	1000.200	775.255	0.248	0.841	248.135	23.779	249.272
1A4c_i Agriculture / forestry / fishing	Indeno	324.918	105.587	3.000	1000.000	1000.004	88.576	-0.224	0.096	-223.944	0.408	223.944
	Indeno											
	Indeno											
Total	Indeno	1099.001	1192.055				622458.32					131059.42
Total uncertainties					Overall uncertainty i the year (%):		788.960			Trend uncertainty (%):		362.021

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg HCB	Input data kg HCB	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	HCB	4.369	0.855	1.000	1000.000	1000.000	739.906	-0.002	0.147	-2.281	0.208	2.290
1A1b Petroleum refining	HCB	0.000	0.000	1.000	1000.000	1000.000	0.120	0.000	0.000	0.014	0.000	0.014
1A1c_ii Oil and gas extraction	HCB		0.000	1.000	1000.000	1000.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	HCB	0.140	0.066	2.000	1000.000	1000.002	56.834	0.007	0.011	6.504	0.032	6.504
1A4a_i Commercial / institutional	HCB	0.181	0.007	3.000	1000.000	1000.004	6.127	-0.005	0.001	-4.966	0.005	4.966
1A4b_i Residential (excluding wood)	HCB	0.932	0.016	3.000	1000.000	1000.004	13.927	-0.029	0.003	-29.054	0.012	29.054
1A4b_i Residential wood	HCB	0.045	0.186	20.000	500.000	500.400	80.721	0.031	0.032	15.264	0.907	15.291
1A4c_i Agriculture / forestry / fishing	HCB	0.147	0.025	3.000	1000.000	1000.004	21.773	-0.001	0.004	-0.684	0.018	0.684
	HCB											
	HCB											
Total	HCB	5.815	1.156				557912.225					1150.629
Total uncertainties					Overall uncertainty i the year (%):		746.935			Trend uncertainty (%):		33.921

SNAP		Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty i trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data kg PCB	Input data kg PCB	Input data %	Input data %	%	%	%	%	%	%	%
1A1a Public electricity and heat production	PCB	0.893	0.228	1.000	1000.000	1000.000	592.104	-0.054	0.193	-53.805	0.273	53.806
1A1b Petroleum refining	PCB	0.001	0.001	1.000	1000.000	1000.000	1.362	0.000	0.000	0.140	0.001	0.140
1A1c_ii Oil and gas extraction	PCB		0.000	1.000	1000.000	1000.000	0.000	0.000	0.000	0.000	0.000	0.000
1A2 Manufacturing industries and construction	PCB	0.121	0.046	2.000	1000.000	1000.002	118.898	0.005	0.039	5.257	0.110	5.259
1A4a_i Commercial / institutional	PCB	0.045	0.004	3.000	1000.000	1000.004	9.186	-0.009	0.003	-9.493	0.013	9.493
1A4b_i Residential (excluding wood)	PCB	0.027	0.010	3.000	1000.000	1000.004	25.322	0.001	0.008	0.815	0.035	0.816
1A4b_i Residential wood	PCB	0.060	0.086	20.000	1000.000	1000.200	223.697	0.057	0.073	56.510	2.066	56.548
1A4c_i Agriculture / forestry / fishing	PCB	0.031	0.011	3.000	1000.000	1000.004	29.476	0.001	0.010	0.953	0.041	0.953
	PCB											
	PCB											
Total	PCB	1.178	0.385				416360.794					6212.080
Total uncertainties					Overall uncertainty i the year (%):		645.260			Trend uncertainty (%):		78.817

This table is also available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 3A-8 Emission inventory 2015 based on SNAP sectors

Table 3A-8.1 Emission inventory 2015 based on SNAP sectors.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 3A-9 Description of the Danish energy statistics

This description of the Danish energy statistics has been prepared by Denmark's National Environmental Research Institute, NERI (now DCE) in co-operation with the Danish Energy Agency (DEA) as background information to the Danish National Inventory Report (NIR).

The Danish energy statistics system

DEA is responsible for the Danish energy balance. Main contributors to the energy statistics outside DEA are Statistics Denmark and Danish Energy Association (before Association of Danish Energy Companies). The statistics is performed using an integrated statistical system building on an Access database and Excel spreadsheets.

The DEA follows the recommendations of the International Energy Agency as well as Eurostat.

The national energy statistics is updated annually and all revisions are immediately included in the published statistics, which can be found on the DEA homepage. It is an easy task to check for breaks in a series because the statistics is 100 % time-series oriented.

The national energy statistics does not include Greenland and Faroe Islands.

For historical reasons, DEA receive monthly information from the Danish oil companies regarding Danish deliveries of oil products to Greenland and Faroe Islands. However, the monthly (MOS) and annual (AOS) reporting of oil statistics to Eurostat and IEA exclude Greenland and Faroe Islands. For all other energy products, the Danish figures are also excluding Greenland and Faroe Islands.

Reporting to the Danish Energy Agency

The Danish Energy Agency receives monthly statistics for the following fuel groups:

- Crude oil and oil products.
  - Monthly data from 46 oil companies, the main purpose is monitoring oil stocks according to the oil preparedness system.
- Natural gas.
  - Fuel/flare from platforms in the North Sea.
  - Natural gas balance from the regulator Energinet.dk (National monopoly).
- Coal and coke.
  - Power plants (94 %).
  - Industry companies (4 %).
  - Coal and coke traders (2 %).
- Electricity.
  - Monthly reporting by e-mail from the regulator Energinet.dk (National monopoly).
  - The statistics covers:
    - Production by type of producer.
    - Own use of electricity.
    - Import and export by country.
    - Domestic supply (consumption + distribution loss).
- Town gas (quarterly) from two town gas producers.

- The large central power plants also report monthly consumption of biomass.

Annual data includes renewable energy including waste. The DEA conducts a biannual survey on wood pellets and wood fuel. Statistics Denmark conducts biannual surveys on the energy consumption in the service and industrial sectors. Statistics Denmark prepares annual surveys on forest (wood fuel) & straw.

Other annual data sources include:

- DEA:
  - Survey on production of electricity and heat and fuels used.
  - Survey on end use of oil.
  - Survey on end use of natural gas.
  - Survey on end use of coal and coke.
- DCE (former NERI), Aarhus University.
  - Energy consumption for domestic air transport.
- Danish Energy Association (Association of Danish Energy companies).
  - Survey on electricity consumption.
- Ministry of Taxation.
  - Border trade.
- Centre for Biomass Technology.
  - Annual estimates of final consumption of straw and wood chips.

Annual revisions

In general, DEA follows the same procedures as in the Danish national account. This means that normally only figures for the last two years are revised.

Aggregating the energy statistics on SNAP level

The sectors used in the official energy statistics have been mapped to SNAP categories, used in the Danish emission database. DCE aggregates the official energy statistics to SNAP level based on a source correspondence table.

In cooperation between DEA and DCE, a fuel correspondence table has been developed mapping the fuels used by the DEA in the official energy statistics with the fuel codes used in the Danish national emission database. The fuel correspondence table between fuel categories used by the DEA, DCE and NFR is presented in Annex 3A-3.

The mapping between the energy statistics and the SNAP and fuel codes used by DCE can be seen in the table below.

Table 3A-9.1 Correspondence between the Danish national energy statistics and the SNAP nomenclature (only stationary combustion part shown).

Unit: TJ		End-use		Transformation 1980-1993	
	SNAP	Fuel (in Danish)	Fuel-code	SNAP	Fuel-code
Foreign Trade					
- Border Trade					
- - Motor Gasoline					
- - Gas-/Diesel Oil					
- - Petroleum Coke	0202	Petrokoks	110A		
Vessels in Foreign Trade					
- International Marine Bunkers					
- - Gas-/Diesel Oil					
- - Fuel Oil					
- - Lubricants					
Energy Sector					
Extraction and Gasification					
- Extraction					
- - Natural Gas	010504	Naturgas	301A		
- Gasification					
- - Biogas, Landfill	091006	Biogas	309A		
- - Biogas, Other	091006	Biogas	309A		
Refineries					
- Own Use					
- - Refinery Gas	010306	Raffinaderigas	308A		
- - LPG	010306	LPG	303A		
- - Gas-/Diesel Oil	010306	Gas & Dieselolie	204A		
- - Fuel Oil	010306	Fuelolie & Spildolie	203A		
Transformation Sector					
Large-scale Power Units					
- Fuels Used for Power Production					
- - Gas-/Diesel Oil				0101	204A
- - Fuel Oil				0101	203A
- - Electricity Plant Coal				0101	102A
- - Straw				0101	117A
Large-Scale CHP Units					
- Fuels Used for Power Production					
- - Refinery Gas				0103	308A
- - LPG				0101	303A
- - Naphtha (LVN)				0101	210A
- - Gas-/Diesel Oil				0101	204A
- - Fuel Oil				0101	203A
- - Petroleum Coke				0101	110A
- - Orimulsion				0101	225A
- - Natural Gas				0101	301A
- - Electricity Plant Coal				0101	102A
- - Straw				0101	117A
- - Wood Chips				0101	111A
- - Wood Pellets				0101	111A
- - Wood Waste				0101	111A
- - Biogas, Landfill				0101	309A
- - Biogas, Others				0101	309A
- - Waste, Non-renewable				0101	114A
- - Wastes, Renewable				0101	114A
- Fuels Used for Heat Production					
- - Refinery Gas				0103	308A
- - LPG				0101	303A
- - Naphtha (LVN)				0101	210A
- - Gas-/Diesel Oil				0101	204A
- - Fuel Oil				0101	203A
- - Petroleum Coke				0101	110A
- - Orimulsion				0101	225A
- - Natural Gas				0101	301A
- - Electricity Plant Coal				0101	102A
- - Straw				0101	117A
- - Wood Chips				0101	111A
- - Wood Pellets				0101	111A
- - Wood Waste				0101	111A
- - Biogas, Landfill				0101	309A
- - Biogas, Other				0101	309A
- - Waste, Non-renewable				0101	114A
- - Wastes, Renewable				0101	114A
Small-Scale CHP Units					

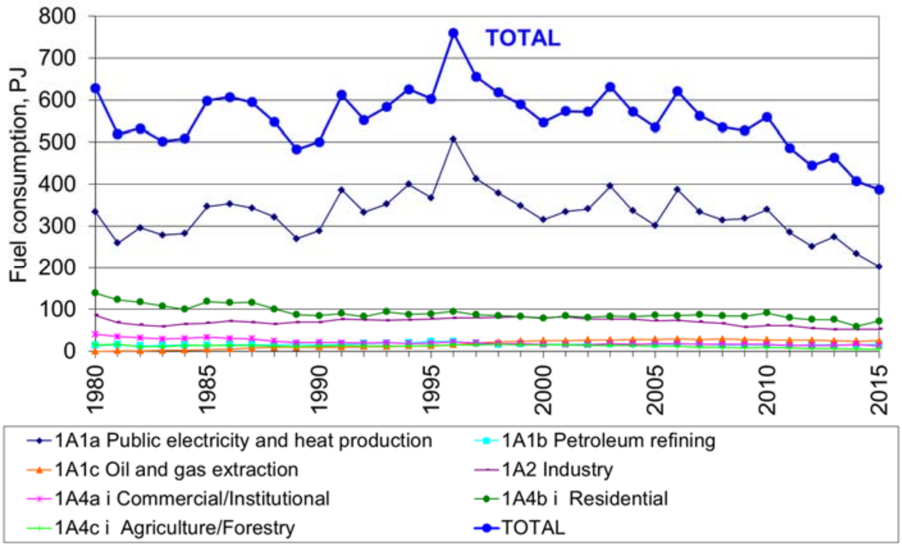
Unit: TJ	SNAP	End-use Fuel (in Danish)	Fuel-code	Transformation 1980-1993 SNAP	Fuel-code
- Fuels Used for Power Production					
- - Gas-/Diesel Oil				0101	204A
- - Fuel Oil				0101	203A
- - Natural Gas				0101	301A
- - Hard Coal				0101	102A
- - Straw				0101	117A
- - Wood Chips				0101	111A
- - Wood Pellets				0101	111A
- - Wood Waste				0101	111A
- - Biogas, Landfill				0101	309A
- - Biogas, Other				0101	309A
- - Waste, Non-renewable				0101	114A
- - Wastes, Renewable				0101	114A
- Fuels Used for Heat Production					
- - Gas-/Diesel Oil				0101	204A
- - Fuel Oil				0101	203A
- - Natural Gas				0101	301A
- - Coal				0101	102A
- - Straw				0101	117A
- - Wood Chips				0101	111A
- - Wood Pellets				0101	111A
- - Wood Waste				0101	111A
- - Biogas, Landfill				0101	309A
- - Biogas, Other				0101	309A
- - Waste, Non-renewable				0101	114A
- - Wastes, Renewable				0101	114A
District Heating Units					
- Fuels Used for Heat Production					
- - Refinery Gas				0103	308A
- - LPG				0102	303A
- - Gas-/Diesel Oil				0102	204A
- - Fuel Oil				0102	203A
- - Waste Oil				0102	203A
- - Petroleum Coke				0102	110A
- - Natural Gas				0102	301A
- - Electricity Plant Coal				0102	102A
- - Coal				0102	102A
- - Straw				0102	117A
- - Wood Chips				0102	111A
- - Wood Pellets				0102	111A
- - Wood Waste				0102	111A
- - Biogas, Landfill				0102	309A
- - Biogas, Sludge				0102	309A
- - Biogas, Other				0102	309A
- - Waste, Non-renewable				0102	114A
- - Wastes, Renewable				0102	114A
- - Fish Oil				0102	215A
Autoproducers, Electricity Only					
- Fuels Used for Power Production					
- - Natural Gas				0320	301A
- - Biogas, Landfill				0320	309A
- - Biogas, Sewage Sludge				0320	309A
- - Biogas, Other				0320	309A
Autoproducers, CHP Units					
- Fuels Used for Power Production					
- - Refinery Gas				0103	308A
- - Gas-/Diesel Oil				0320	204A
- - Fuel Oil				0320	203A
- - Waste Oil				0320	203A
- - Natural Gas				0320	301A
- - Coal				0320	102A
- - Straw				0320	117A
- - Wood Chips				0320	111A
- - Wood Pellets				0320	111A
- - Wood Waste				0320	111A
- - Biogas, Landfill				0320	309A
- - Biogas, Sludge				0320	309A
- - Biogas, Other				0320	309A
- - Fish Oil				0320	215A
- - Waste, Non-renewable				0320	114A

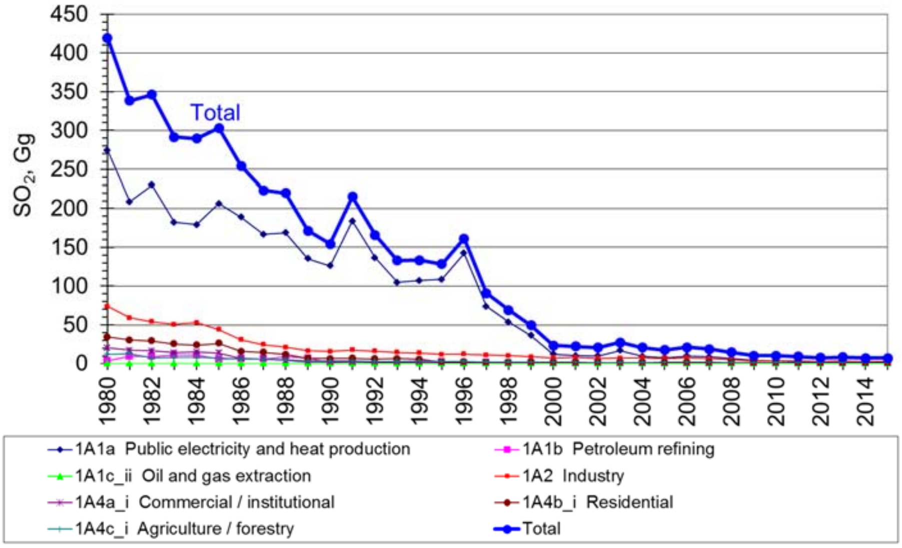
Unit: TJ	SNAP	End-use Fuel (in Danish)	Fuel-code	Transformation 1980-1993 SNAP	Fuel-code
- - Wastes, Renewable				0320	114A
- Fuels Used for Heat Production					
- - Refinery Gas				0103	308A
- - Gas-/Diesel Oil				0320	204A
- - Fuel Oil				0320	203A
- - Waste Oil				0320	203A
- - Natural Gas				0320	301A
- - Coal				0320	102A
- - Wood Chips				0320	111A
- - Wood Waste				0320	111A
- - Biogas, Landfill				0320	309A
- - Biogas, Sludge				0320	309A
- - Biogas, Other				0320	309A
- - Waste, Non-renewable				0320	114A
- - Wastes, Renewable				0320	114A
Autoproducers, Heat Only					
- Fuels Used for Heat Production					
- - Gas-/Diesel Oil				0320	204A
- - Fuel Oil				0320	203A
- - Waste Oil				0320	203A
- - Natural Gas				0320	301A
- - Straw				0320	117A
- - Wood Chips				0320	111A
- - Wood Chips				0320	111A
- - Wood Waste				0320	111A
- - Biogas, Landfill				0320	309A
- - Biogas, Sludge				0320	309A
- - Biogas, Other				0320	309A
- - Waste, Non-renewable				0102	114A
- - Wastes, Renewable				0102	114A
Town Gas Units	030106	Naturgas	301A		
- Fuels Used for Production of District Heating	030106	Kul (-83) / Gasolie (84-)	102A / 204A		
Transport sector					
Military Transport					
- Aviation Gasoline					
- Motor Gasoline					
- JP4					
- JP1					
- Gas-/Diesel Oil					
Road					
- LPG					
- Motor Gasoline					
- Other Kerosene	0202	Petroleum	206A		
- Gas-/Diesel Oil					
- Fuel Oil					
Rail					
- Motor Gasoline					
- Other Kerosene					
- Gas-/Diesel Oil					
- Electricity					
Domestic Sea Transport					
- LPG					
- Other Kerosene					
- Gas-/Diesel Oil					
- Fuel Oil					
Air Transport, Domestic					
- LPG					
- Aviation Gasoline					
- Motor Gasoline					
- Other Kerosene	0201	Petroleum	206A		
- JP1					
Air Transport, International					
- Aviation Gasoline					
- JP1					
Agriculture and Forestry					
- LPG					
- Motor Gasoline					
- Other Kerosene	0203	Petroleum	206A		
- Gas-/Diesel Oil					

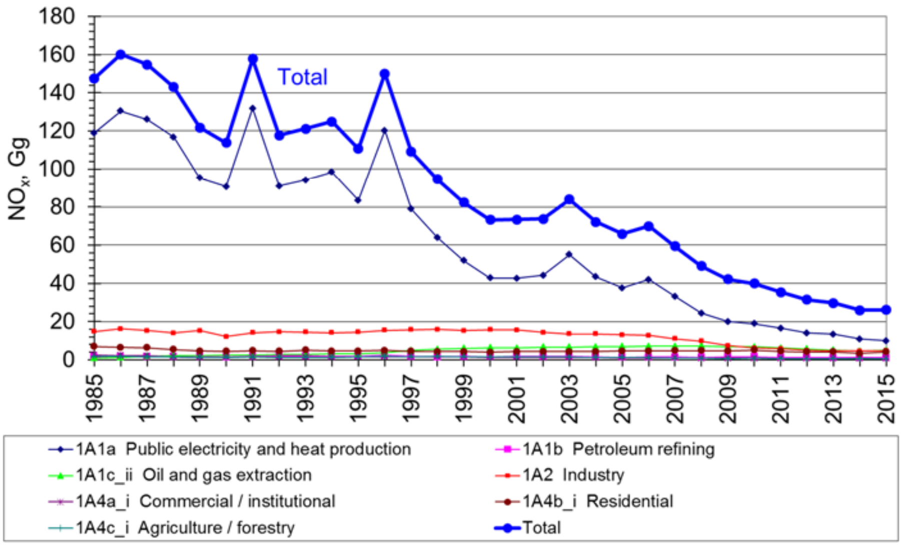
Unit: TJ	SNAP	End-use Fuel (in Danish)	Fuel-code	Transformation 1980-1993 SNAP	Fuel-code
- Fuel Oil	0203	Fuelolie & Spildolie	203A		
- Petroleum Coke	0203	Petrokoks	110A		
- Natural Gas	0203	Naturgas	301A		
- Coal	0203	Kul	102A		
- Brown Coal Briquettes	0203	Brunkul	106A		
- Straw	0203	Halm	117A		
- Wood Chips	0203	Træ	111A		
- Wood Waste	0203	Træ	111A		
- Biogas, Other	0203	Biogas	309A		
Horticulture					
- LPG					
- Motor Gasoline					
- Gas-/Diesel Oil					
- Fuel Oil	0203	Fuelolie & Spildolie	203A		
- Petroleum Coke	0203	Petrokoks	110A		
- Natural Gas	0203	Naturgas	301A		
- Coal	0203	Kul	102A		
- Wood Waste	0203	Træ	111A		
Fishing					
- LPG					
- Motor Gasoline					
- Other Kerosene					
- Gas-/Diesel Oil					
- Fuel Oil					
Manufacturing Industry					
- Refinery Gas	0320	Raffinaderigas	308A		
- LPG					
- Naphtha (LVN)					
- Motor Gasoline					
- Other Kerosene	0320	Petroleum	206A		
- Gas-/Diesel Oil					
- Fuel Oil	0320	Fuelolie & Spildolie	203A		
- Waste Oil	0320	Fuelolie & Spildolie	203A		
- Petroleum Coke	0320	Petrokoks	110A		
- Natural Gas	0320	Naturgas	301A		
- Coal	0320	Kul	102A		
- Coke	0320	Koks	107A		
- Brown Coal Briquettes	0320	Brunkul	106A		
- Wood Pellets	0320	Træ	111A		
- Wood Waste	0320	Træ	111A		
- Biogas, Landfill	0320	Biogas	309A		
- Biogas, Other	0320	Biogas	309A		
- Wastes, Non-renewable	0320	Affald	114A		
- Wastes, Renewable	0320	Affald	114A		
- Town Gas	0320	Naturgas	301A		
Construction					
- LPG	0320	LPG	303A		
- Motor Gasoline					
- Other Kerosene	0320	Petroleum	206A		
- Gas-/Diesel Oil					
- Fuel Oil	0320	Fuelolie & Spildolie	203A		
- Natural Gas	0320	Naturgas	301A		
Wholesale					
- LPG	0201	LPG	303A		
- Motor Gasoline	0201	Petroleum	206A		
- Other Kerosene	0201	Gas & Dieselolie	204A		
- Gas-/Diesel Oil	0201	Fuelolie & Spildolie	203A		
- Petroleum Coke	0201	Petrokoks	110A		
- Natural Gas	0201	Naturgas	301A		
- Wood Waste	0201	Træ	111A		
Retail Trade					
- LPG	0201	LPG	303A		
- Other Kerosene	0201	Petroleum	206A		
- Gas-/Diesel Oil	0201	Gas & Dieselolie	204A		
- Fuel Oil	0201	Fuelolie & Spildolie	203A		
- Petroleum Coke	0201	Petrokoks	110A		
- Natural Gas	0201	Naturgas	301A		
Private Service					
- LPG	0201	LPG	303A		
- Other Kerosene	0201	Petroleum	206A		

Unit: TJ		End-use		Transformation 1980-1993	
	SNAP	Fuel (in Danish)	Fuel-code	SNAP	Fuel-code
- Gas-/Diesel Oil	0201	Gas & Dieselolie	204A		
- Fuel Oil	0201	Fuelolie & Spildolie	203A		
- Waste Oil	0201	Fuelolie & Spildolie	203A		
- Petroleum Coke	0201	Petrokoks	110A		
- Natural Gas	0201	Naturgas	301A		
- Wood Chips	0201	Træ	111A		
- Wood Waste	0201	Træ	111A		
- Biogas, Landfill	0201	Biogas	309A		
- Biogas, Sludge	0201	Biogas	309A		
- Biogas, Other	0201	Biogas	309A		
- Wastes, Non-renewable	0201	Affald	114A		
- Wastes, Renewable	0201	Affald	114A		
- Town Gas	0201	Naturgas	301A		
Public Service					
- LPG	0201	LPG	303A		
- Other Kerosene	0201	Petroleum	206A		
- Gas-/Diesel Oil	0201	Gas & Dieselolie	204A		
- Fuel Oil	0201	Fuelolie & Spildolie	203A		
- Petroleum Coke	0201	Petrokoks	110A		
- Natural Gas	0201	Naturgas	301A		
- Coal	0201	Kul	102A		
- Brown Coal Briquettes	0201	Brunkul	106A		
- Wood Chips	0201	Træ	111A		
- Wood Pellets	0201	Træ	111A		
- Town Gas	0201	Naturgas	301A		
Single Family Houses					
- LPG	0202	LPG	303A		
- Motor Gasoline					
- Other Kerosene	0202	Petroleum	206A		
- Gas-/Diesel Oil	0202	Gas & Dieselolie	204A		
- Fuel Oil	0202	Fuelolie & Spildolie	203A		
- Petroleum Coke	0202	Petrokoks	110A		
- Natural Gas	0202	Naturgas	301A		
- Coal	0202	Kul	102A		
- Coke	0202	koks	107A		
- Brown Coal Briquettes	0202	Brunkul	106A		
- Straw	0202	Halm	117A		
- Firewood	0202	Træ	111A		
- Wood Chips	0202	Træ	111A		
- Wood Pellets	0202	Træ	111A		
- Town Gas	0202	Naturgas	301A		
Multi-family Houses					
- LPG	0202	LPG	303A		
- Other Kerosene	0202	Petroleum	206A		
- Gas-/Diesel Oil	0202	Gas & Dieselolie	204A		
- Fuel Oil	0202	Fuelolie & Spildolie	203A		
- Petroleum Coke	0202	Petrokoks	110A		
- Natural Gas	0202	Naturgas	301A		
- Coal	0202	Kul	102A		
- Coke	0202	Koks	107A		
- Brown Coal Briquettes	0202	Brunkul	106A		
- Town Gas	0202	Naturgas	301A		

Annex 3A-10 Time-series 1980/1985-2015







Continued

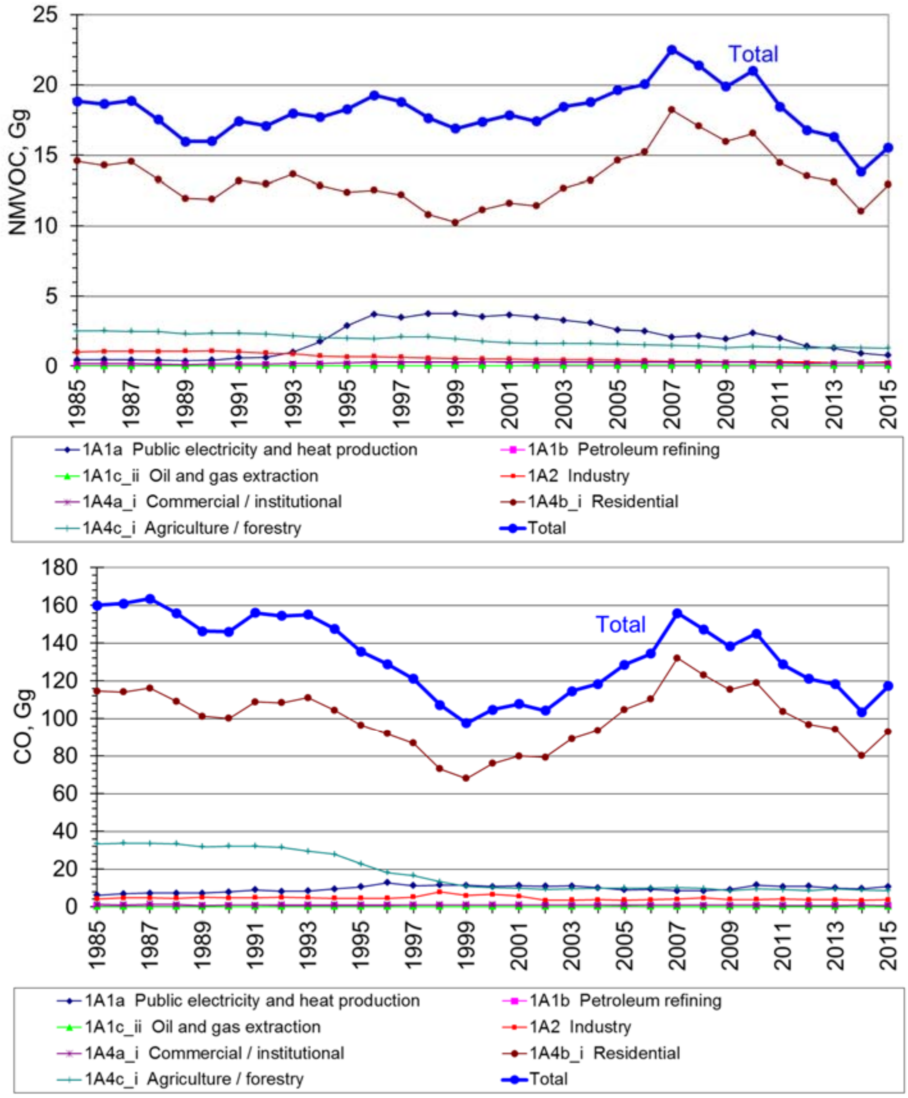


Figure 3A-10.1 Time-series for fuel consumption and emissions, 1980/1985 - 2015.

Annex 3A-11 QA/QC for stationary combustion

An updated quality manual for the Danish emission inventories has been published in 2013 (Nielsen et al. 2013). The quality manual describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Point for Measuring (PM).

Documentation concerning verification of the Danish emission inventories has been published by Fauser et al. (2013). The reference approach for the energy sector is shown in the annual National Inventory Report, Chapter 3.4.

The sector report for stationary combustion (Nielsen et al. 2014) has been reviewed by external experts in 2004, 2006, 2009 and 2014 (Nielsen et al. 2004; Nielsen et al. 2006; Nielsen et al. 2009; Nielsen et al., 2014). This forms a vital part of the QA activities for stationary combustion.

Source specific QA/QC and PM's are shown below.

Data storage, level 1

Table 3A-11.1 lists the sectoral PM's for data storage level 1.

Table 3A-11.1 List of PM, data storage level 1.

Level	CCP	Id	Description	Sectoral/general	Stationary combustion
Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values.	Sectoral	Uncertainties are estimated and references given in IIR chapter 3.2.
	2. Comparability	DS1.2.1	Comparability of the emission factors/calculation parameters with data from international guidelines, and evaluation of major discrepancies.	Sectoral	In general, if national referenced emission factors differ considerably from IPCC Guideline/EEA Guidebook values this is discussed in NIR chapter 3.2.4. This documentation is improved annually based on reviews. At CRF level, a project has been carried out comparing the Danish inventories with those of other countries (Fauser et al. 2013).
	3.Completeness	DS.1.3.1	Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets.	Sectoral	A list of external data are shown and discussed below.
	4.Consistency	DS.1.4.1	The original external data has to be archived with proper reference.	Sectoral	It is ensured that all external data are archived at DCE. Subsequent data processing takes place in other spreadsheets or databases. The datasets are archived annually in order to ensure that the basic data for a given report are always available in their original form. In addition all references are archived.
	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the conditions of delivery	Sectoral	For stationary combustion, a data delivery agreement is made with the DEA. DCE and DEA have renewed the data delivery agreement in 2014. Most of the other external data sources are available due to legislatory requirements. See Table 3.2.39.
	7.Transparency	DS.1.7.1	Listing of all archived datasets and external contacts.	Sectoral	A list of external datasets and external contacts is shown in Table 3A-11.2 below.

Table 3A-11.2 List of external data sources.

Dataset	Description	AD or Emf.	Reference	Contact(s)	Data agreement/ Comment
Energiproducenttællingen.xls	Data set for all electricity and heat producing plants.	Activity data	The Danish Energy Agency (DEA)	Kaj Stærkind	Data agreement.
Gas consumption for gas engines and gas turbines 1990-1994	Historical data set for gas engines and gas turbines.	Activity data	The Danish Energy Agency (DEA)	Jane Rusbjerg	No data agreement. Historical data
Basic data (Grunddata.xls)	The Danish energy statistics. Data set applied for both the reference approach and the national approach.	Activity data	The Danish Energy Agency (DEA)	Jane Rusbjerg	Data agreement. However, the data set is also published as part of national energy statistics
Energy statistics for industrial sub-sectors	Disaggregation of the industrial fuel consumption. The data set have been applied for the first time in the inventory reported in 2012.	Activity data	The Danish Energy Agency (DEA)	Jane Rusbjerg	Data agreement.
SO_2 & NO_x data, plants>25 MW_e	Annual emission data for all power plants > 25 MW_e. Includes information on methodology: measurements or emission factor.	Emissions	Energinet.dk	Christian F.B. Nielsen	No data agreement.
Emission factors	Emission factors refer to a large number of sources.	Emission factors	See chapter regarding emission factors		Some of the annually updated CO_2 emission factors are based on EU ETS data, see below. For the other emission factors no formal data delivery agreement.
HM and PM from public power plants	Emissions from the large power plant operator in DK DONG Energy	Emissions	Dong Energy	Rikke A. Steensborg	No formal data agreement.
Annual environmental reports / environmental data	Emissions from plants defined as large point sources	Emissions	Various plants		No data agreement necessary. Plants are obligated by law and data published on the Danish EPA homepage.
EU ETS data	Plant specific CO_2 emission factors	Emission factors and fuel consumption	The Danish Energy Agency (DEA)	Dorte Maimann Helen Falster	Plants are obligated by law. The availability of detailed information is part of the data agreement with DEA.

Energiproducenttaellingen - statistic on fuel consumption from district heating and power plants (DEA)
The data set includes all plants producing power or district heating. The spreadsheet from DEA is listing fuel consumption of all plants included as large point sources in the emission inventory. The statistic on fuel consumption from district heating and power plants is regarded as complete and with no significant uncertainty since the plants are bound by law to report their fuel consumption and other information.

Gas consumption for gas engines and gas turbines 1990-1994 (DEA)
For the years 1990-1994, DEA has estimated consumption of natural gas and biogas in gas engines and gas turbines. DCE assesses that the estimation by the DEA are the best available data.

Basic data (DEA)
The Danish energy statistics. The spreadsheet from DEA is used for the CO_2 emission calculation in accordance with the IPCC reference approach and is also the first data set applied in the national approach. The data set is included in the data delivery agreement with DEA, but it is also published annually on DEA's homepage.

Energy statistics for industrial subsectors (DEA)
The data includes disaggregation of the fuel consumption for industrial plants. The data set is estimated for the reporting to Eurostat. The dataset is included in the data agreement with DEA.

SO_2 and NO_x emission data from electricity producing plants > 25MW$_e$ (Energinet.dk)
Plants larger than 25 MW$_e$ are obligated to report emission data for SO_2 and NO_x to the DEA annually. Data are on production unit level and classified. The data on plant level are part of the plants annually environmental reports. DCE's QC of the data consists of a comparison with data from previous years and with data from the plants' annual environmental reports.

Emission factors
For specific references, see the chapter regarding emission factors. Some of the annually updated CO_2 emission factors are based on EU ETS data, se below.

Data for emission of heavy metals and particles from central power plants, DONG Energy
The major Danish power plant operator assess heavy metal emissions from their plants using model calculations based on fuel data and type of flue gas cleaning. DCE's QC of the data consists of a comparison with data from previous years and with data from the plants' annual environmental reports.

Annual environmental reports (DEPA)
A large number of plants are obligated by law to report annual environmental data including emission data. DCE compares the data with those from previous years and large discrepancies are checked.

EU ETS data (DEA)
EU ETS data are information on fuel consumption, heating values, carbon content of fuel, oxidation factor and CO_2 emissions. DCE receives the verified reports for all plants which utilises a detailed estimation methodology. DCE's QC of the received data consists of comparing to calculation using

standard emission factors as well as comparing reported values with those for previous years.

Data processing, level 1

Table 3A-11.3 lists the sectoral PM's for data processing level 1.

Table 3A-11.3 List of PM, data processing level 1.

Level	CCP	Id	Description	Sectoral / general	Stationary combustion
Data Proces-sing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of varia-bility.	Sectoral	Uncertainties are estimated and references given in NIR chapter 3.2.5.
	2.Comparability	DP.1.2.1	The methodologies have to follow the international guidelines sug-gested by UNFCCC and IPCC.	Sectoral	The methodological approach is consistent with international guidelines. An overview of tiers is given in NIR Chapter 3.2.5
	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.	Sectoral	The energy statistics is consid-ered complete.
	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.	Sectoral	The two main methodological changes in the time series; implementation of Energipro-ducenttaellingen (plant specific fuel consumption data) from 1994 onwards and implementa-tion of EU ETS data from 2006 onwards is discussed in NIR chapter 3.2.
	5.Correctness	DP.1.5.2	Verification of calculation results using time series	Sectoral	Time series for activity data on SNAP and CRF source catego-ry level are used to identify possible errors. Time series for emission factors and the emis-sion from CRF subcategories are also examined.
		DP.1.5.3	Verification of calculation results using other measures	Sectoral	The IPCC reference approach validates the fuel consumption rates and CO_2 emission. Both differ less than 2.0 % (1990-2014). The reference approach is further discussed in NIR Chapter 3.4.
	7.Transparency	DP.1.7.1	The calculation principle, the equa-tions used and the assumptions made must be described.	Sectoral	This is included in NIR chapter 3.2.5.
		DP.1.7.2	Clear reference to dataset at Data Storage level 1	Sectoral	This is included in NIR chapter 3.2.5.
		DP.1.7.3	A manual log to collect information about recalculations.	Sectoral	-

Data storage, level 2

Table 3A-11.4 lists the sectoral PM's for data storage level 2.

Table 3A-11.4 List of PM, data storage level 2.

Level	CCP	Id	Description	Sectoral / general	Stationary combustion
Data Storage level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made	Sectoral	To ensure a correct connection between data on level 2 and level 1 different controls are in place, e.g. control of sums and random tests.

Data storage level 4

Table 3A-11.5 lists the sectoral PM's for data storage level 4.

Table 3A-11.5 List of PM, data storage level 4.

Level	CCP	Id	Description	Sectoral / general	Stationary combustion
Data Storage level 4	4. Consistency	DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.	Sectoral	Large dips/jumps in time series are discussed and explained in NIR chapter 3.2.

Other QC procedures

The emission from each large point source is compared with the emission reported the previous year.

Some automated checks have been prepared for the emission databases:

- Check of units for fuel rate, emission factors and plant-specific emissions.
- Check of emission factors for large point sources. Emission factors for pollutants that are not plant-specific should be the same as those defined for area sources.
- Additional checks on database consistency.
- Emission factor references are included in this report.
- Annual environmental reports are kept for subsequent control of plant-specific emission data.
- QC checks of the country-specific emission factors have not been performed, but most factors are based on input from companies that have implemented some QA/QC work. The major power plant owner/operator in Denmark, DONG Energy has obtained the ISO 14001 certification for an environmental management system. The Danish Gas Technology Centre and Force Technology both run accredited laboratories for emission measurements.

National external review

The sector report for stationary combustion has been reviewed by external experts in 2004, 2006, 2009 and 2014 (Nielsen et al., 2004; Nielsen et al., 2006; Nielsen et al., 2009; Nielsen et al., 2014). This forms a vital part of the QA activities for stationary combustion.

Annex 3B - Transport and other mobile sources

List of content

Annex 3B-11-7: Stock data for household and gardening machinery 1985-2013

Annex 3B-11-8: Stock data and engine size data for recreational craft 1985-2013

Annex 3B-11-9: Proposed Stage V Emission Standards for Nonroad Engines

Annex 3B-11-10: Engine size, annual working hours (0 year engines), load factors and maximum lifetime for building and construction machinery

Annex 3B-12-1: Annual traffic data (no. of round trips) for Danish domestic ferries 1990-2013

Annex 3B-12-2: Ferry service, ferry name, engine year, main engine MCR (kW), engine type, specific fuel consumption (sfc), aux. engine (kW)

Annex 3B-12-3: Sailing time (single trip) for Danish domestic ferries

Annex 3B-12-4: Engine load factor (% MCR) for Danish domestic ferries

Annex 3B-12-5: Round trip shares for Danish domestic ferries

Annex 3B-13-1: Specific fuel consumption, NOx, CO, VOC, NMVOC and CH_4 emission factors (g pr kWh) per engine year for diesel ship engines

Annex 3B-13-2: S-%, SO_2 , PM and BC emission factors (g/kg fuel and g/GJ) per fuel type for diesel ship engines

Annex 3B-14: Fuel sales figures from DEA, and further processed fuel consumption data suited for the Danish inventory

Annex 3B-15-1: Emission factors for 1990 in CollectER format

Annex 3B-15-2: Emission factors for 2015 in CollectER format

Annex 3B-15-3: Emissions for 1990 in CollectER format

Annex 3B-15-4: Emissions for 2015 in CollectER format

Annex 3B-15-5: Non-exhaust emission factors, activity data and total non-exhaust emissions of TSP, PM1, PM2.5, BC and heavy metals in 2015

Annex 3B-16-1: Fuel consumption 1985-2015 in NFR format

Annex 3B-16-2: Emissions 1985-2015 in NFR format

Annex 3B-17: Uncertainty estimates

All annexes are availalbe at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 3C - Industrial processes (NFR 2)

Non-energy products from fuels and solvent use (NFR 2D)

Annex 3C-1:	Activity data for production of burnt lime, Mg per year
Annex 3C-2:	Emissions from production of burnt lime
Annex 3C-3:	Activity data for production of container glass and glass wool, Gg
Annex 3C-4:	Emissions from production of container glass and glass wool
Annex 3C-5:	Activity data for extracted minerals other than coal, Gg
Annex 3C-6:	Emissions from quarrying and mining of other minerals than coal
Annex 3C-7:	Activity data for construction and demolition, mill. m^2
Annex 3C-8:	Emissions from construction and demolition
Annex 3C-9:	Activity data for storage, handling and transport of mineral products, Gg mineral
Annex 3C-10:	Emissions from storage, handling and transport of mineral products
Annex 3C-11:	Activity data for production of Other mineral products, Gg $CaCO_3$ equivalents
Annex 3C-12:	Emissions from other mineral products
Annex 3C-13:	Activity data for production of nitric and sulphuric acid
Annex 3C-14:	Emissions from the production of nitric and sulphuric acid
Annex 3C-15:	Activity data for production of catalysts and potassium nitrate
Annex 3C-16:	Emissions from the production of catalysts and fertilisers
Annex 3C-17:	Emissions from the production of chemical ingredients
Annex 3C-18:	Activity data for production of pesticides, Mg

Annex 3C-43:	Emissions from wood processing, Mg
Annex 3C-44:	Activity data for treatment of slaughterhouse waste, Gg
Annex 3C-45:	Emissions from the treatment of slaughterhouse waste, Mg

All annexes are available online at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 3D - Agriculture

Table 3D-1: Number of animals allocated on subcategories. See: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-2a: Nitrogen excretion rates in average, kg N per head per year. See: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-2b: Nitrogen excretion given as TAN (Total Ammonical Nitrogen), kg N per head per year. See: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-3: Changes in housing type. See: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-4 Cover of slurry tanks 1985-2015, pct. with no or full cover.

	1985-1999	2000-2001	2002	2003-2015
Cattle		Percent		
No cover	20	5	5	2
Full cover	80	95	95	98
Swine				
No cover	40	20	10	5%
Full cover	60	80	90	95
Fur animals				
No cover	20	5	5	2
Full cover	80	95	95	98

Ref: COWI (2000)

Table 3D-5: PM emission from housings, Gg TSP, PM_{10} and $PM_{2.5}$. See: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-6 Assumptions for synthetic fertiliser

EMEP/EEA fertiliser types[1]	Danish fertiliser types
Anhydrous ammonia (AH)	Liquid ammonia
Ammonium nitrate (AN)	Ammonium nitrate
Ammonium phosphates (MAP, DAP)	Calcium and boron calcium nitrate Diammonphosphate Other NP fertiliser types Magnesium fertiliser
Ammonium sulphate (AS)	Ammonium sulphate
Calcium ammonium nitrate (CAN)	Calcium ammonium nitrate and other nitrate types
NK mixtures	NK-fertiliser
NPK mixtures	NPK-fertiliser
NP mixtures	-
Nitrogen solutions	-
Other straight N compounds	Other N-fertiliser
Urea	Urea

[1] EMEP/EEA emission inventory guidebook 2016, Table 3-2 Emission factors for total NH_3 emissions from soils due to N fertiliser volatilization.

Table 3D-7: Area of cultivated crops. See:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-8a-d: Number of treatments. See:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-9: Activity data for field burning of agricultural residues. See:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table 3D-10: Emissions of pollutants from field burning of agricultural residues. See:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

References

COWI, 2000: Overdækning af gyllebeholdere og kommunernes tilsyn hermed – undersøgelsesrapport. Danish Forest and Nature Agency. December 2000. (In Danish).

Annex 3E - Waste

All annexes are available online at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 4 – Completeness and use of notation keys

Not estimated categories

The Danish air emission inventory is generally complete. However, some categories and/or pollutants are reported as NE (Not estimated).

Mobile combustion

PAH emissions from tire and brake wear are not estimated, due to lack of emission factors.

Industrial processes

- Some pollutants from iron and steel production (Rolling mills and iron foundries) due to lack of emission factors.
- Some pollutants from aluminium production (secondary) due to lack of emission factors.
- Some pollutants from lead production (secondary) due to lack of emission factors.
- Some pollutants from other metal production due to lack of emission factors.
- Emissions of BC from construction and demolition are not estimated due to lack of emission factors.
- Emissions from pulp and paper production have not been estimated.
- Emissions from consumption of POPs and heavy metals have not been estimated.
- Emissions of PAH from road paving with asphalt and asphalt roofing have not been estimated.
- Emissions from some product uses have not been estimated, e.g. use of shoes.

Agriculture

- Emissions of PM from off-farm storage, handling and transport of bulk agricultural products have not been estimated, due to lack of emission factors.
- NO_x emissions from cultivated crops have not been estimated, due to lack of emission factors.

Waste

- Emissions from solid waste disposal on land have not been estimated.
- Emissions from wastewater handling have not been estimated.
- Emissions from small scale waste burning have not been estimated.
- The emission of selenium and HCB from accidental fires has not been estimated due to lack of available emission factors.

Categories reported as IE (Included Elsewhere)

The table below indicates the categories where the notation key IE has been used in the reporting for some or all pollutants.

Table A3.1 List of categories reported as included elsewhere.

Category reported as IE	Emissions where emissions are included
2A1 Cement production	1A2f Manufacturing industries and construction: Non-metallic minerals
2A2 Lime production	1A2f Manufacturing industries and construction: Non-metallic minerals
2A3 Glass production	1A2f Manufacturing industries and construction: Non-metallic minerals

Emissions from cement production (2A1), lime production (2A2) and glass production (2A3) are included in manufacturing industries and construction (1A2f). For some or all pollutants, it is not possible to separate the process emissions from the energy related emissions.

For some pollutants in other categories IE is also used. The specific reasons are explained in the sectoral chapters of the report.

ANNUAL DANISH INFORMATIVE INVENTORY REPORT TO UNECE

Emission inventories from the base year of the protocols to year 2015

This report is a documentation report on the emission inventories for Denmark as reported to the UNECE Secretariat under the Convention on Long Range Transboundary Air Pollution due by 15 February 2017. The report contains information on Denmark's emission inventories regarding emissions of (1) SO_X for the years 1980-2015, (2) NO_X, CO, NMVOC and NH_3 for the years 1985-2015, (3) Particulate matter: TSP, PM_{10}, $PM_{2.5}$ for the years 2000-2015, (4) Heavy Metals: Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn for the years 1990-2015, (5) Polyaromatic hydrocarbons (PAH): Benzo(a) pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene, PCDD/F and HCB for the years 1990-2015. Further, the report contains information on background data for emissions inventory

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