SPATIAL DISTRIBUTION OF EMISSIONS TO AIR – THE SPREAD MODEL

NERI Technical Report no. 823 2011

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Data sheet

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Abstract: The National Environmental Research Institute (NERI), Aarhus University, completes the annual national emission inventories for greenhouse gases and air pollutants according to Denmark's obligations under international conventions, e.g. the climate convention, UNFCCC and the convention on long-range transboundary air pollution, CLRTAP. NERI has developed a model to distribute emissions from the national emission inventories on a 1x1 km grid covering the Danish land and sea territory. The new spatial high resolution distribution model for emissions to air (SPREAD) has been developed according to the requirements for reporting of gridded emissions to CLRTAP. Spatial emission data is e.g. used as input for air quality modelling, which again serves as input for assessment and evaluation of health effects. For these purposes distributions with higher spatial resolution have been requested. Previously, a distribution on the 17x17 km EMEP grid has been set up and used in research projects combined with detailed distributions for a few sectors or sub-sectors e.g. a distribution for emissions from road traffic on 1x1 km resolution. SPREAD is developed to generate improved spatial emission data for e.g. air quality modelling in exposure studies. SPREAD includes emission distributions for each sector in the Danish inventory system; stationary combustion, mobile sources, fugitive emissions from fuels, industrial processes, solvents and other product use, agriculture and waste. This model enables generation of distributions for single sectors and for a number of sub-sectors and single sources as well. This report documents the methodologies in this first version of SPREAD and presents selected results. Further, a number of potential improvements for later versions of SPREAD are addressed and discussed.

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Contents

List of abbreviations

ADT	Annual Daily Traffic
AS	Area Sources are sources where neither the fuel consumption nor the emission factors are known at plant level. Emission calculations are based on the total fuel consumption and the assumed average emission factor.
BI5	Approximation for the content of degradable organic matter in waste water
CHP	Combined heat and power
CHR	Central Husbandry Register
CRF	Common Reporting Format used for reporting to UNFCCC, EU and the Kyoto Protocol
DKN	Danish Grid Net (Danske Kvadrat Net). The grid is designed in an orthogonal coordinate system referring to the UTM projection, zone 32 using EUREF89. The cells are defined and named by the lower left corner coordinate. The grid can be set up by the freeware program "Kvadratnetmotoren" developed by Uffe Kousgaard, NERI and hosted by the National Survey and Cadastre: http://www.kms.dk/Produktkatalog/gratis/kvadratnet.htm.
EMEP	European Monitoring and Evaluation Programme is a scientifically based and policy driven programme under the Convention on Long-range Transboundary Air Pollution
FC	Fuel consumption
GLR	General Agriculture Register
ISAG	Information system on waste and recycling (InformationsSystem for Affald og Genanvendelse) hosted by the Danish EPA
LPS	Large Point Source with plant or installation specific emissions or emission factors. LPSs are treated in a separate part of the inventory system and include emissions from stationary combustion, mobile sources (Copenhagen Airport, Kastrup), fugitive emissions and industrial processes.
NFR	Nomenclature For Reporting. Table format used for reporting to UNECE and the NEC directive
NRTD	National Road and Traffic Database
PM	Particulate Matter

PM_{10}	Particulate Matter with an aerodynamic diameter less than 10 µm
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than 2.5 µm
PS	Point Sources are sources where the fuel consumption is given on plant or installation level but standard emission factors are used for emission calculations.
ROEM	Road Emission Model developed in the research project REBECa
SNAP	Selected Nomenclature for Air Pollution
SPREAD	Spatial High Resolution Emission to Air Distribution Model
TSP	Total Suspended Particles
UNECE-CLRTAP	United Nations Economic Commission for Europe - Convention on Long-range Transboundary Air Pollution
UNFCCC	United Nations Framework Convention on Climate Change, called the climate convention

Preface

This report documents the methodology and data foundation for the spatial distribution of emissions to air on high resolution grid. The distribution includes emissions of greenhouse gases and air pollutants in 2008 as reported to the UNFCCC and UNECE -CLRTAP.

The Department of Policy Analysis of the National Environmental Research Institute (NERI), Aarhus University (AU), has carried out the work as part of the emission inventory project in preparation for the mandatory reporting of gridded emissions due in the spring of 2012.

The work on creating an updated model for high resolution emission distribution has gained valuable data and information from a number of external experts.

The authors would like to thank:

The Danish Energy Agency for providing the Regional Inventory of energy consumption for heating for oil boilers, natural gas boilers and solid fuel installations.

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The research project REBECa founded by the Strategic Research Council for providing the emissions distribution model for road transport.

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Summary

The National Environmental Research Institute (NERI), Aarhus University (AU) completes the annual national emission inventories for greenhouse gases and air pollutants according to Denmark's obligations under international conventions, e.g. the climate convention, UNFCCC and the convention on long-range transboundary air pollution, CLRTAP.

Previously the Danish emissions inventory has been available on 50x50 km EMEP grid for reporting of air pollutants to CLRTAP every fifth year, latest in 2007 for the emission year 2005 and the historical years 1990, 1995 and 2000. The methodology for the 50x50 km distribution is described in a Danish-language report (Jensen et al., 2008a).

Spatial emission data is e.g. used as input for air quality modelling, which again serves as input for assessment and evaluation of health effects. For these purposes distributions with higher spatial resolution has been requested and NERI carried out an improved distribution on the 17x17 km EMEP grid. This distribution has been used in research projects combined with detailed distributions for one or a few sectors or sub-sectors, e.g. a distribution for emissions from road traffic on 1x1 km resolution.

This report describes the new spatial high resolution distribution model for emissions to air (SPREAD) that has been developed to fulfil the requirements for reporting of gridded emissions to CLRTAP and to generate improved spatial emission data for air quality modelling in exposure studies, for one thing.

SPREAD includes emission distributions for each sector in the Danish inventory system; stationary combustion, mobile sources, fugitive emissions from fuels, industrial processes, solvents and other product use, agriculture and waste. This enables generation of distributions for single sectors and for a number of sub-sectors and single sources as well.

This report documents the methodologies in this first version of SPREAD and presents selected results. Further, a number of potential improvements for later versions of SPREAD are addressed and discussed.

Sammenfatning

Danmarks Miljøundersøgelser (DMU) ved Aarhus Universitet (AU) udarbejder de årlige nationale emissionsopgørelser for drivhusgasser og luftforurenende stoffer i henhold til Danmarks forpligtelser til internationale konventioner, f.eks. FN's klimakonvention, UNFCCC og konventionen om langtransporteret luftforurening, CLRTAP.

Tidligere har den danske emissionsopgørelse været tilgængelig på 50x50 km EMEP grid for rapportering til CLRTAP hvert femte år, senest i 2007 for emissionsåret 2005 og de historiske år 1990, 1995 og 2000. Metoden til fordeling på 50x50 km er beskrevet i Jensen et al. (2008a).

Rumlige emissionsdata bruges som input til modelberegning af luftkvaliteten, der igen tjener som input til vurdering og evaluering af virkninger for sundheden. Til disse formål efterspørges fordelinger med høj rumlig opløsning og DMU udarbejdede en forbedret fordeling på 17x17 km EMEP grid som, kombineret med mere detaljerede fordelinger for én eller enkelte sektorer eller delsektorer, f.eks. emissioner fra vejtrafikken på 1x1 km opløsning, er blevet anvendt i forskningsprojekter.

Denne rapport beskriver den nye model SPREAD til fordeling af emissioner til luft med høj opløsning (1x1 km). Modellen er udviklet til at opfylde kravene til rapportering af rumligt fordelte emissioner til CLRTAP og til at skabe bedre emissionsdata, f.eks. til modelberegning af luftkvalitet i eksponeringen undersøgelser.

SPREAD er bygget op om separate fordelingsmodeller for sektorerne i det danske opgørelsessystem; stationær forbrænding, mobile kilder, flygtige emissioner fra brændsler, industrielle processer, opløsningsmidler og anvendelse af andre stoffer, landbrug og affald. Dermed er det muligt at lave fordelinger for enkelte sektorer samt for en række delsektorer og separate kilder.

Denne rapport dokumenterer metoderne i denne første version af SPREAD og præsenterer udvalgte resultater. Desuden er en række potentielle forbedringer i senere versioner af SPREAD beskrevet og diskuteret.

1 Introduction

The National Environmental Research Institute (NERI), Aarhus University completes the annual national emission inventories for greenhouse gases and air pollutants. The methodologies in the Danish emission inventories follows the international guidelines provided by the IPCC, i.e. the Revised 1996 IPCC Guidelines, the 2000 IPCC Good Practice Guidance for the greenhouse gas emission inventories and the EMEP/EEA Guidebook for the emission inventories for air pollution.

According to Denmark's international obligations the national emission inventories are reported to the United Nations Framework Convention on Climate Convention (UNFCCC) and the Kyoto Protocol, EU's Monitoring Mechanism (EU MM), United Nations Economic Commission for Europe - Convention on Long-Range Transboundary Air Pollution (UN-ECE - CLRTAP) and the National Emission Ceilings Directive (NECD). The emissions are reported as national totals and for a number of sectors and sub-sectors as defined by the Common Reporting Format (CRF) used for reporting to UNFCCC, EU-MM and the Kyoto Protocol and the Nomenclature For Reporting (NFR) used for reporting to CLRTAP and NECD, respectively.

Emission data from the national inventories are often used as input to model air quality, which again serves as input in e.g. assessment and evaluation of health effects. In order to make a more suitable input for air quality models, emissions must be given on a more disaggregated level than national level. Previously the Danish emissions inventory has been available on 50x50 km EMEP grid for reporting of air pollutants to CLRTAP every fifth year, latest in 2007 for the emission year 2005 and the historical years 2000, 1995 and 1990. The methodology is described in a Danish-language report (Jensen et al., 2008a).

Besides the emission distribution on 50x50 km resolution, a distribution on the 17x17 km EMEP grid has been set up and used in research projects combined with detailed distributions for relevant sectors or sub-sectors. The 17x17 km distribution has e.g. been used in combination with a detailed distribution of emissions from road traffic on 1x1 km resolution in the ongoing research project REBECa (Renewable Energy in the transport sector using Biofuels as Energy Carriers) and the completed project HYSCENE (Environmental and Health Impact Assessment of Scenarios for Renewable Energy Systems with Hydrogen). In the research project WOODUSE (Residential wood combustion and the interaction between technology, user and environment) the emission distribution on 17x17 km has been combined with a detailed distribution of emissions from wood combustion in the residential sector at address level.

In 2010 the new spatial high resolution distribution model for emissions to air, SPREAD, is completed at NERI (Department of Policy Analysis). SPREAD enables distribution of the Danish emissions for all pollutants and all sectors in the national emission database on a 1x1 km grid covering Denmark and its national sea territory. The model does not include

Greenland and the Faroe Islands although they are both included in the reporting to the UNFCCC and Greenland is also included in the reporting under the Kyoto Protocol. The model is set up in Microsoft Access databases and the distribution keys are set up in GIS (ArcMAP). Output tables are transformed to shape files for visualisation in GIS. The projection for all output shape files are UTM zone 32 N and the datum is ETRS89.

This report presents the methodologies in the first version of SPREAD set up for spatial distribution of the Danish emission inventory for 2008 on the 1x1 km Danish Grid Net. The model includes emissions of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the F-gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) as reported to the UNFCCC on May 27th, 2010 (Nielsen et al., 2010a) and emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), ammonia (NH_3), total suspended particulates (TSP), particulate matter with an aerodynamic diameter less than 10 µm (PM_{10}), particulate matter with an aerodynamic diameter less than 2.5 µm ($PM_{2.5}$), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn), dioxins and furans (PCDD/F), hexachlorobenzene (HCB) and the polycyclic aromatic hydrocarbons (PAHs): benzo(b)flouranthene, benzo(k)flouranthene, benzo(a)pyrene and indeno(1,2,3-c,d)pyrene as reported on February 15th, 2010 to CLRTAP (Nielsen et al., 2010b).

The distribution in SPREAD is made on SNAP categories 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 for sectors SNAP 2 or SNAP 1 level has been applied in the distribution model due to lack of detailed information (Appendix B: List of SNAP codes and corresponding NFR categories). An exception is the agricultural sector as this sector is not treated on SNAP level in the Danish emission database. Instead the agricultural data processing is carried out for the relevant NFR and CRF categories, and the same approach is applied in SPREAD. The SPREAD model is set up in order to be applicable for the mandatory reporting every five years of gridded emissions to CLRTAP next time in 2012 covering the emission year 2010 and the historical years 1990, 1995, 2000 and 2005. The CLRTAP reporting is based on GNFR categories (Appendix C: List of GNFR codes and corresponding NFR codes) and the distributions in SPREAD are made on the same or a more disaggregated level than the GNFR aggregation level.

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, Industry, F-gases, Solvents, Waste and a number of sub-models for the agricultural sector. The sub-models correspond to the methodology and groupings in the Danish emission inventory system and do not for all sectors match the sub-divisions in the reporting guidelines when a higher disaggregation is possible. SNAP and NFR categories are included in all SPREAD sub-models to enable a distribution in agreement with the international guidelines.

A number of plants are treated as Large Point Sources (LPS) in the Danish emission database. The LPSs are characterised by having more detailed data on fuel consumption, emission factors and/or emissions, as plant, installation or process specific data. Emissions from all LPSs are treated in the Large Point Source sub-model in SPREAD. LPSs represent emissions at all SNAP 1 categories except road traffic (SNAP 07). LPSs in agriculture (SNAP 10) 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 due to standard emission factors.

A spatial distribution is more relevant for some pollutants, e.g. particulate matter as they can cause health effects in the vicinity of the emission site. Other pollutants like the greenhouse gasses have no or little health effect but are more relevant regarding large-scale conditions such as climate change and global warming. Nevertheless SPREAD includes all pollutants and all sources in the Danish inventory system and thereby provides a complete spatial distribution of the Danish emissions on a 1x1 km grid.

In the following chapters the methodologies of the SPREAD model are described separately for the sub-models. The background data and methodological description applied in the national emission inventory is not included here. For a description of the methodologies, data foundation and emissions in the national emission inventories please refer to Denmark's National Inventory Report, NIR (Nielsen et al., 2010a) as reported to the UNFCCC and Denmark's Informative Inventory Report, IIR (Nielsen et al., 2010b) as reported to the UNECE. Further, detailed information on the inventory for selected sectors are presented in sectoral reports for stationary combustion (Nielsen et al., 2010c), mobile sources (Winther, 2008), fugitive emissions (Plejdrup et al., 2009), solvents (Fauser, 2010), agriculture (Mikkelsen et al., 2006) and waste-water treatment (Thomsen & Lyck, 2005). For a Danish-language description of the inventory for greenhouse gases and Denmark's international obligations, please refer to (Plejdrup et al., 2009).

2 General methodology

The distribution of emissions in the Danish emission inventory is carried out in databases and in the geographical information system ArcGIS.

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 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 given in the Danish emission 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 present data foundation. Instead a proxy for the distribution is applied, in this case the location of industrial areas as given in KORT 10 by the National Survey and Cadastre (Figure 2.1). The GIS 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.

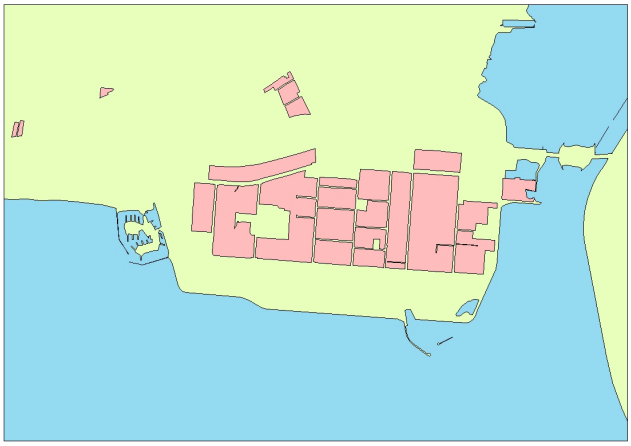

Figure 2.1 Segment around Avedøre of the map of industrial areas.

As SPREAD gives emissions on 1x1 km the map of industrial areas must be combined with the Danish 1x1 km Grid Net. The grid is an orthogonal coordinate system where the cells are defined and named by their lower left corner coordinates, e.g. 1km_6 495_735 where 1km refers to the cell size, 6 495 refers to the Y coordinate of the grid cell (Y = 6 495 000 m) and 375 refers to the X coordinate (X = 375 000 m). The grid net map is a shape file and the grid cells are polygons (Figure 2.2).

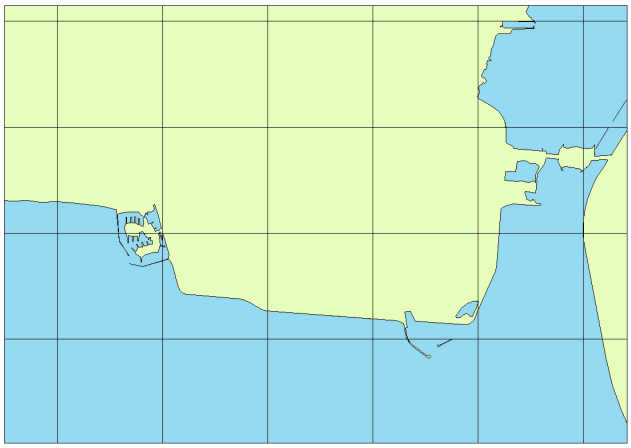

Figure 2.2 Segment around Avedøre of the map of the Danish 1x1 km grid net.

To be able to distribute the emissions on 1x1 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. These functionalities are available in a geographical information system (GIS) – in the present work ArcMap is used. The split is made using the intersect tool and afterwards the areas are applied to each cell using the Calculate Area function.

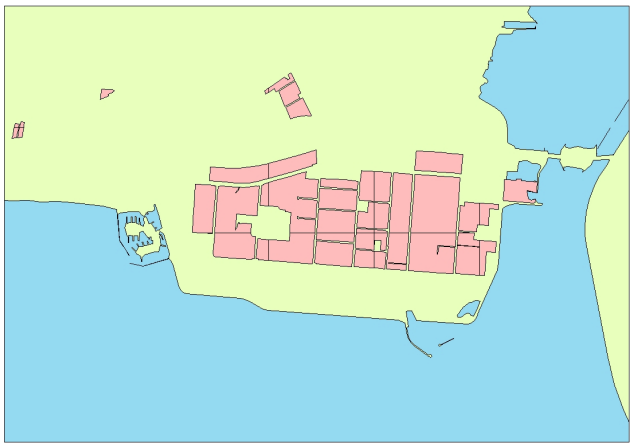

Figure 2.3 Segment around Avedøre of the map of industrial areas and the Danish 1x1 km grid net.

The remaining part of the emission distribution is carried out in a database. The share of the 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 1x1 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, and therefore the gain from setting up distribution keys for all years is limited. 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. For a number of sources it would be preferable to apply annual distribution keys, but it is not possible as annual data is not available, e.g. for road transport and central heating plants.

3 Spatial distribution of fuel consumption and emissions from the energy sector

The energy sector covers three main groups of sources called sub-sectors and includes emissions of all pollutants. The sub-sectors are:

- Stationary combustion, which covers combustion for electricity and heat production in combined heat and power (CHP) plants and waste incineration plants, and combustion in households and industry. Fuel consumption in refineries and for off-shore energy production is also included in this sector.
- Mobile sources, which cover combustion of fuels in road transport, railways, national navigation, fishing vessels, aviation and combustion related to use of machineries in agriculture, industry and households. Emissions from electricity driven transport, e.g. trains are included under Stationary Combustion (power production). Emissions from international navigation and aviation are given in a special category – memo items – as these emissions are not included in the national total.
- Fugitive emissions from fuels, which cover fugitive emissions related to extraction, refining, storage, transmission and distribution of fossil fuels.

The spatial distribution of emissions from the energy sector is made separately for the three sub-sectors. The only exception is emissions from refineries and gas storage and treatment plants as these sources are handled as a Large Point Sources and therefore handled in the stationary combustion sub-sector even though it includes fugitive emissions from fuels.

3.1 Stationary combustion

In the Danish emission inventory system stationary combustion is treated in three groups:

1. Large Point Sources (LPS) are major point sources for which data on fuel consumption (FC) and plant specific emission factors or direct emissions are available to a large degree. Data are mainly based on environmental and annual reports, reports under the EU Emission Trading Scheme (EU ETS) and emission data provided by the major companies in the Danish transformation sector (plant specific data provided by DONG Energy and Vattenfall). Further, a number of companies and plants contribute additional data annually or on request.
2. Point sources (PS) are point sources with less detailed data available on FC and emissions. Data on FC are based on the annual database from the Danish Energy Agency (DEA) including FC for each district heating or power producing plant ("Energiproducenttællingen", EPT). Some LPS are included in the EPT and are therefore removed from the dataset to avoid double accounting.

3. Area sources (AS) cover the remaining FC and corresponding emissions for stationary combustion. The FC for AS are calculated as the difference between the FC given in the Danish energy statistics published by the DEA (DEA, 2009) and the sum of LPS and PS.

3.1.1 LPS

Emissions from LPS are implemented in the inventory system in one of three ways:

1. FC and emissions are given in environmental reports or similar plant specific reports at part level.
2. FC is given at part level but emissions are aggregated for some or all parts.
3. FC is given while emissions are estimated according to standard emission factors.

As LPS emissions appears in different ways in the inventory system a module has been developed to automate the data handling in order to extract emissions in the right order (1: direct emissions, 2: emissions estimated from activity data and emission factors). Further the model deals with unit conversions. The latter require some manual checks as a few LPS in the industrial sector do not follow the general unit definitions.

The emission inventory database system includes CO_2 emissions from biomass. These emissions are subtracted from the emissions in the spatial distribution according to the guidelines for inventories for UNFCCC. The biofuels included in the inventory are wood and similar wood wastes, municipal waste (the biogenic part), straw, bio oil, biogas and biomass producer gas.

The CO_2 emission from combustion of municipal waste in stationary combustion is split in two parts; one for the fossil part and one for the biogenic part of the municipal waste. Only CO_2 from combustion of the fossil part is included in SPREAD. The CO_2 emission from the fossil part of municipal waste in stationary combustion is calculated as an area source in the Danish inventory system but is reallocated to LPS in SPREAD to ensure the right allocation defined by the fuel combustion at the waste incineration plants.

To avoid errors in the data handling a number of checks are carried out at different steps in the model. The checks cover units, null values and sums.

3.1.2 PS

The distribution of emissions from stationary combustion at point sources is based on a database from DEA including fuel consumption for each district heating or power-producing plant on fuel and combustion technology (e.g. gas turbine, stationary engine or boilers, which are further divided by capacity; < 50 MW, 50 – 300 MW and > 300 MW). The DEA database is in the following referred to as EPT. Each of the 2 189 production units in the 2008 EPT is assigned with SNAP 3 codes and geographical coordinates and emissions are calculated from the FC given in EPT and standard emission factors for all pollutants for the specific

technology from national research or international guidelines (IPCC, 1996; IPCC, 2000; EMEP/EEA, 2009).

3.1.3 AS

AS includes all sources where only standard emission factors are available and where the fuel consumption is estimated as the difference between the national total fuel consumption given in the Energy Statistics and the sum of fuel consumption for LPS and PS (eq. 2.1). This part of the inventory covers all pollutants.

$$FC_{AS} = FC_{DK} - (FC_{LPS} + FC_{PS}) \qquad \text{(eq. 2.1)}$$

where FC refers to fuel consumption and DK refers to the national total.

The fuel consumption in the basic data table (DEA, 2009) is available on SNAP 2 level while the EPT is available on SNAP 3 level. Therefore the subtraction lined out in eq. 2.1 gives rise to fuel deficits for a number of SNAP categories. Every single fuel deficit is treated manually by transferring the deficit to another SNAP with the most similar emission properties.

The fuel re-allocation causes differences between the emissions calculated in SPREAD and in the Danish emissions inventory system, as the re-allocated fuel is combined with a different set of emission factors in SPREAD. The emission factors applied in SPREAD reflect standard conditions as the fuel consumption is not divided into different technologies. It is not possible to distinguish between e.g. boilers with different capacity, turbines and stationary engines, as this would require data on SNAP 3 level.

Corrections are applied to ensure that the calculated emissions in SPREAD equal the emissions in the national inventory. The correction is carried out in SPREAD for each combination of fuel, SNAP 2 and pollutant category.

To avoid errors in the data handling a number of checks are carried out at different steps in the model. The checks cover units, null values and sums. Further, a number of checks are incorporated in the model to check that all data are transferred correctly from one step to another.

The spatial distribution is carried out in a separate database in the SPREAD model based on the calculated emissions. As no information on the location of the area sources is available the choice of distribution keys is to a large degree based on expert judgements.

All area source emissions at SNAP 0101 and 0102 are distributed according to the distribution of PS for SNAP 0101 and 0102, respectively (Appendix B: List of SNAP codes and corresponding NFR categories). The reason for choosing the PS emission as key is that the fuel consumption at SNAP 0101 and 0102 should all be covered in LPS and PS, as these two classes together cover all plants that deliver power and heating to the public network. The relatively small fuel consumption for public power and electricity plants in AS is due to different accounting methods. In 2008 the fuel consumption at SNAP 0101 and 0102 allocated on area

sources made up only 1 % of the total fuel consumption for the relevant fuels (coal, gas oil, bio oil, natural gas, LPG and biomass producer gas).

AS emissions at SNAP 0103 are distributed evenly between the two Danish refineries. Again, the fuel consumption for AS results from different accounting methods. As for SNAP 0101 and 0102 only a minor amount of fuels are allocated at AS and by far the major part at LPS. In 2008 the fuel consumption at SNAP 0103 allocated on area sources made up 5 % of the total fuel consumption for the relevant fuels (residual oil, gas oil and refinery gas).

Emissions at SNAP 0105 are allocated on the offshore installations. The emissions are distributed evenly between all offshore installations with production, as no information is available to differentiate the FC between the installations.

DEA has made an inventory of the FC used for regional heating for 2005 "Regional inventory of energy consumption for heating for oil boilers, natural gas boilers and solid fuel installations" (in the following called the Regional Inventory). The inventory is based on the building and housing register (BBR) per ultimo 2005, which holds information on i.a. construction year, living area and primary and secondary heating installation at address level. The conversion from net heating requirement to gross energy consumption is based on efficiencies for heating installations as given in the Energy Statistics. The FCs are given for the 271 Danish municipalities as they appeared before the municipality reform in 2007. The inventory covers four SNAP categories, seven fuels and four heating categories (Table 3.1).

Table 3.1 SNAP, fuel and heating installations categories in the Regional Inventory of energy consumption for heating for oil boilers, natural gas boilers and solid fuel installations by the Danish Energy Agency.

SNAP category and SNAP code	Fuel name and fuel code	Heating installation category
Commercial and institutional plants – 0201	Steam coal – 102	Oil fired boiler
Residential plants – 0202	Brown coal briquettes – 106	Natural gas fired boiler
Plants in agriculture, forestry and aquaculture – 0203	Wood – 111	Other district heating
Manufacturing industries and construction - 0301	Municipal waste – 114	Ovens/other
	Oven coke – 107	
	Straw – 117	
	Gas oil – 204	
	Natural gas – 301	

To create a distribution key an intersection between the municipalities and the Danish 1x1 km Grid Net is carried out. Following, this is combined with the distribution of the FC at SNAP 2 and fuel level.

The combustion of residual oil (fuel 203) at SNAP 02 is distributed according to the location of industrial areas in Denmark, as this fuel is mainly used in industries. The location of the industrial area is based on KORT 10 by the National Survey and Cadastre. The same distribution key is used for FC for all fuels at SNAP 0303.

For the remaining fuels at SNAP 0202 no data are available that give information on the spatial distribution. A number of potential methods are considered, here among distribution according to LPS and/or PS, according to distribution of buildings, urban areas or population. The final

choice of methodology has been to distribute the FC according to the inventory for regional heating by DEA for the fuels with the most similar use pattern:

- Petroleum coke and LPG (fuel 110 and 303) are distributed as wood.
- Biogas and gas from waste tips (fuel 309 and 310) are distributed as straw as they are all related to agriculture.
- Bio oil and kerosene (fuel 215 and 206) are distributed as gas oil.
- Brown coal briquettes (fuel 106) are distributed as oven coke as no distribution key can be made for brown coal briquettes as the FC was 0 in 2005 in the Regional Inventory.

Table 3.2 gives a complete list of distribution keys for emissions from area sources in the categories 01, 02 and 03 at SNAP 1 level.

Table 3.2 Distribution keys for all categories in SNAP 1 categories 01, 02 and 03.

SNAP*	Fuel **	Distribution key	Note
0101	All	PS	
0102	All	PS	
0103	All	Refineries, evenly	
0105	All	Offshore installations, evenly	
0201, 0202, 0203, 0301	102, 107, 111, 114, 117, 204, 301	Regional Inventory of energy consumption for heating for oil boilers, natural gas boilers and solid fuel installations	
0201, 0202, 0203, 0301	203	Industrial areas	
0201, 0202, 0203, 0301	110, 303	As fuel 111	
0201, 0202, 0203, 0301	309, 310	As fuel 117	
0201, 0202, 0203, 0301	215, 206	As fuel 204	
0201, 0202, 0203, 0301	106	As fuel 107	
0303	All	Industrial areas	Emissions without associated fuel consumption

* A complete list of SNAP codes is given in Appendix B: List of SNAP codes and corresponding NFR categories.

** A complete list of fuels is given in Appendix A: List of fuel codes.

To avoid errors in the data handling a number of checks are carried out at different steps in the model. The checks cover units, null values and sums.

3.1.4 Results for stationary combustion

Figure 3.1 shows the spatial distribution of SO_2 emissions from stationary combustion, which is the aggregated result of the models for Large Point Sources, Point Sources and Area Sources excluding LPS emissions from industrial processes and mobile sources. Emissions are to a large degree located on point sources (LPS and PS). To enhance areas with large emissions the relevant grid cells are symbolised with circles, which sizes represent the emission amounts. Notice that the enhanced grid cells might cover more than one point source.

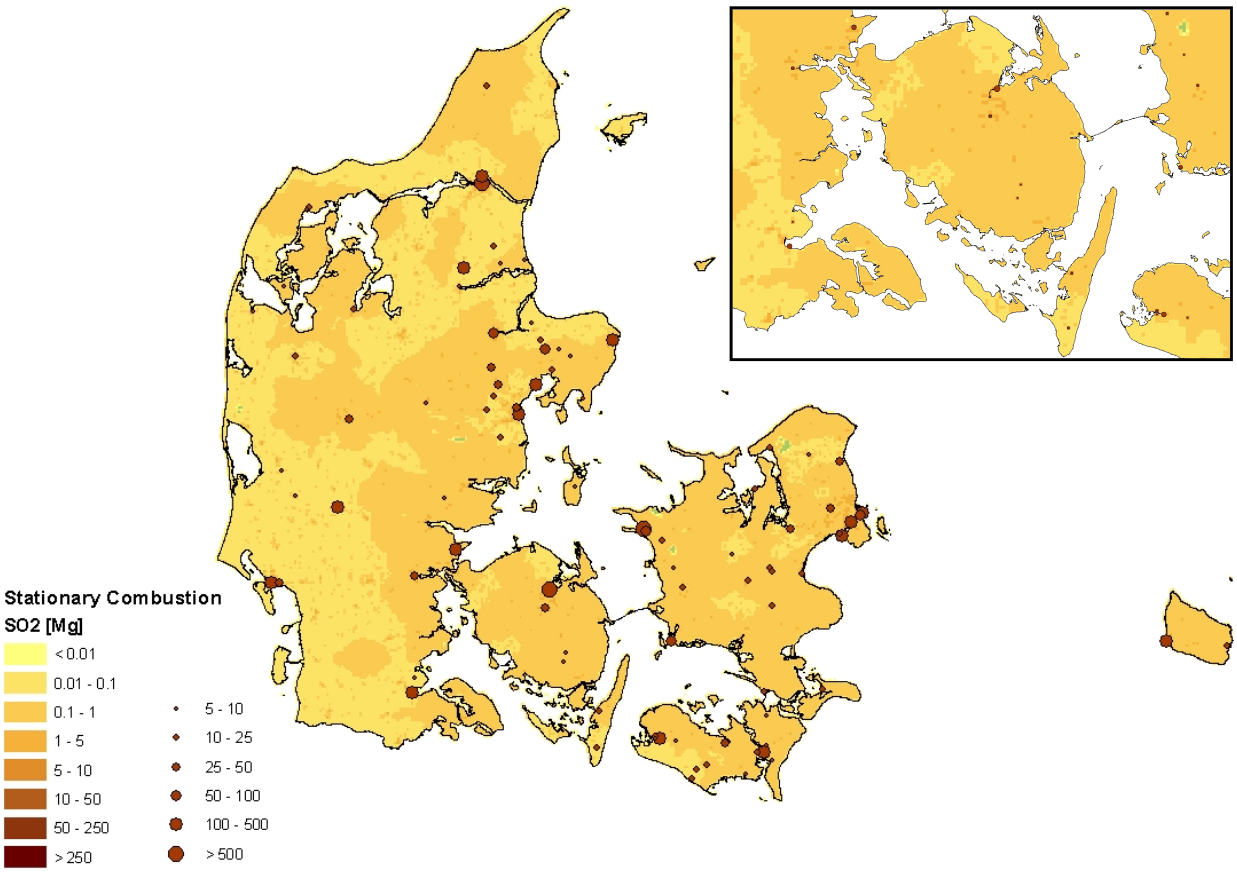

Figure 3.1 Emission of SO_2 from Stationary Combustion in 2008. Green and blue areas are land and sea areas without emissions. The grid cells with largest emissions are enhanced by use of symbols.

The distribution of e.g. $PM_{2.5}$ is less dominated by emissions from point sources than SO_2 (Figure 3.2). The main reason that area sources are more dominating for $PM_{2.5}$ than for SO_2 is the large share of $PM_{2.5}$ emissions originating from wood combustion in households, mainly from wood fired stoves, ovens and boilers. The flue gas cleaning for particulate matter is very efficient at many large plants and the emissions have shown a marked decrease in the later years. In residential plants no flue gas cleaning is installed and the emissions have increased due to increasing wood consumption, even though the newer stoves and ovens have improved combustion technology.

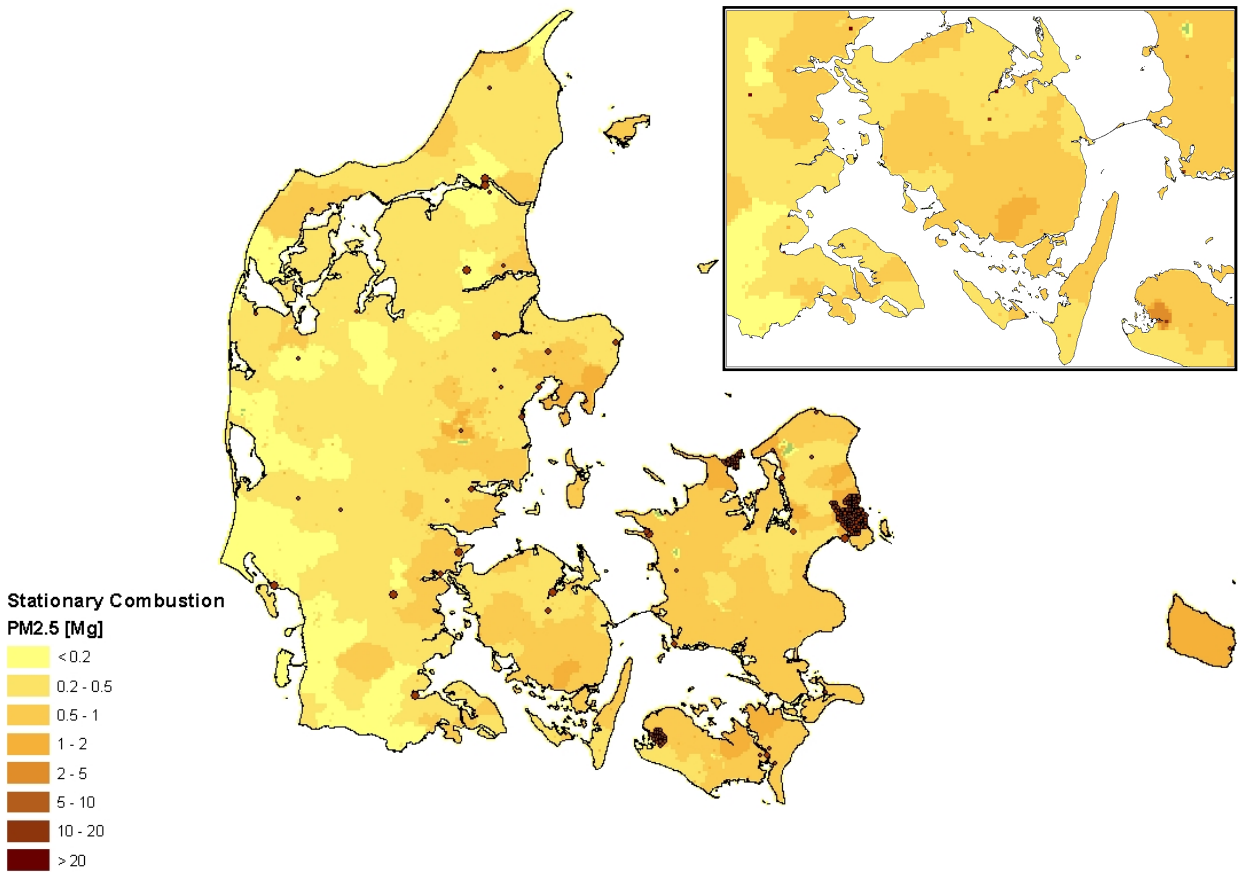

Figure 3.2 Emission of $PM_{2.5}$ from Stationary Combustion in 2008. Green and blue areas are land and sea areas without emissions. The grid cells with largest emissions are enhanced by use of symbols.

3.2 Mobile sources

This sub-sector includes emissions from road transport, railways, navigation and aviation. Further, transport and use of machinery in military, agriculture, forestry, industry and household and gardening is included. This part of the inventory includes emissions of all pollutants except HCB. Maps of airport areas, forest areas, industrial areas, one-storage buildings and the railway network are based on KORT 10 by the National Survey and Cadastre.

Distributions of emissions from other mobile sources than road transportation follow the methodology from the latest reporting for CLRTAP in 2007 (Jensen et al., 2008a). The data used for the 2007 distribution has been applied as no updated or more detailed data are available or because the introduction of new methodologies is considered to bring no significant improvements to the model. The 2007 methodologies are applied for military, railways, agriculture, forestry, industry and household & gardening. For navigation the 2007 methodology has been applied, but the distribution is different as the borders for the sea territory are not identical. In SPREAD the sea territory refers to the Exclusive Economic Zone (EEZ) in which Denmark has the right to exploration and exploit of the natural resources. Further, the 2007 methodology is applied for cruise (national aviation) while a new methodology is applied for national and international landing and take-off (LTO).

3.2.1 Road transport

Emissions from road transport are distributed by use of the Road Emission Distribution Model (ROEM) prepared for work package II in the research project REBECa funded by the Danish Council for Strategic Research. ROEM is based on a Danish national GIS-based road network and traffic database for 1960-2005 (Jensen et al., 2008b). In the following this work will be referred to as the national road and traffic database (NRTD).

The national road and traffic database holds data on annual average daily traffic (ADT) for every fifth year. ADT is split into five road types (motorways, express ways, road width > 6 m, road width 3 – 6 m and road width < 3 m) and four vehicle types (passenger cars, vans, trucks and busses) (Table 3.3). The database provides information for each segment of the road network on e.g. road type and ADT for different vehicle types. The modelled data is aggregated at the Danish grid with the resolution 1x1 km. For a detailed description of the model refer to Jensen et al. (2008).

Table 3.3 Road and vehicle types in the national road and traffic database.

Road type	Vehicle type
Road width < 3 m	Passenger cars
Road width 3 – 6 m	Vans
Road width > 6 m	Trucks
Expressways	Busses
Motorways	

ROEM calculations for 2008 are based on ADT for 2005, which is the most recent year in the national road and traffic database. It is assumed that the spatial distribution of ADT has not changed significantly from 2005 to 2008 and hence that the 2005 distribution is appropriate for 2008.

The distribution for road traffic is carried out in ROEM for nine categories defined by the combination of three vehicle categories (passenger cars, vans and heavy duty) and three road categories (motorways, urban roads and rural roads) as lined out in Table 3.4. This categorisation is the same that is used for calculations in the national emission inventory system.

Table 3.4 Road and vehicle types used in ROEM.

Road type	Vehicle type
Roads in urban areas, U	Passenger cars and two-wheelers, P
Roads in rural areas, R	Vans, V
Highway, H	Heavy duty (trucks and busses), T

The ADT for highways can be transferred directly to the distribution as it occurs in both NRTD and in the Danish inventory system. ADT for the remaining road categories are summarised and divided between urban and rural areas. The urban/rural split is made in accordance with the proportion of each grid cell located in urban/rural areas, which is analysed in GIS (ArcMAP) by intersection of a map covering urban zones and the Danish 1x1 km grid. The urban zone map used in the spatial analysis is based on the zone map from 2007 from the Agency for Spatial

and Environmental Planning slightly modified by adding a small number of urban areas from a zone map from AIS in 1999 (Levin, 2009).

ADT of roads in urban areas is determined for each grid cell based on the assumption that roadwork is distributed in the same proportion as the area of urban and rural areas within each grid cell. This approach is chosen over an analysis of the entire road network since it is far less labour intensive and since it is assumed that the benefit to the total uncertainty will be insignificant, the purpose (modelling of air quality) taken into account. The same approach is applied for roads in rural areas. Figure 3.3 shows the traffic load for passenger cars on the Danish road network aggregated on the 1x1 km grid.

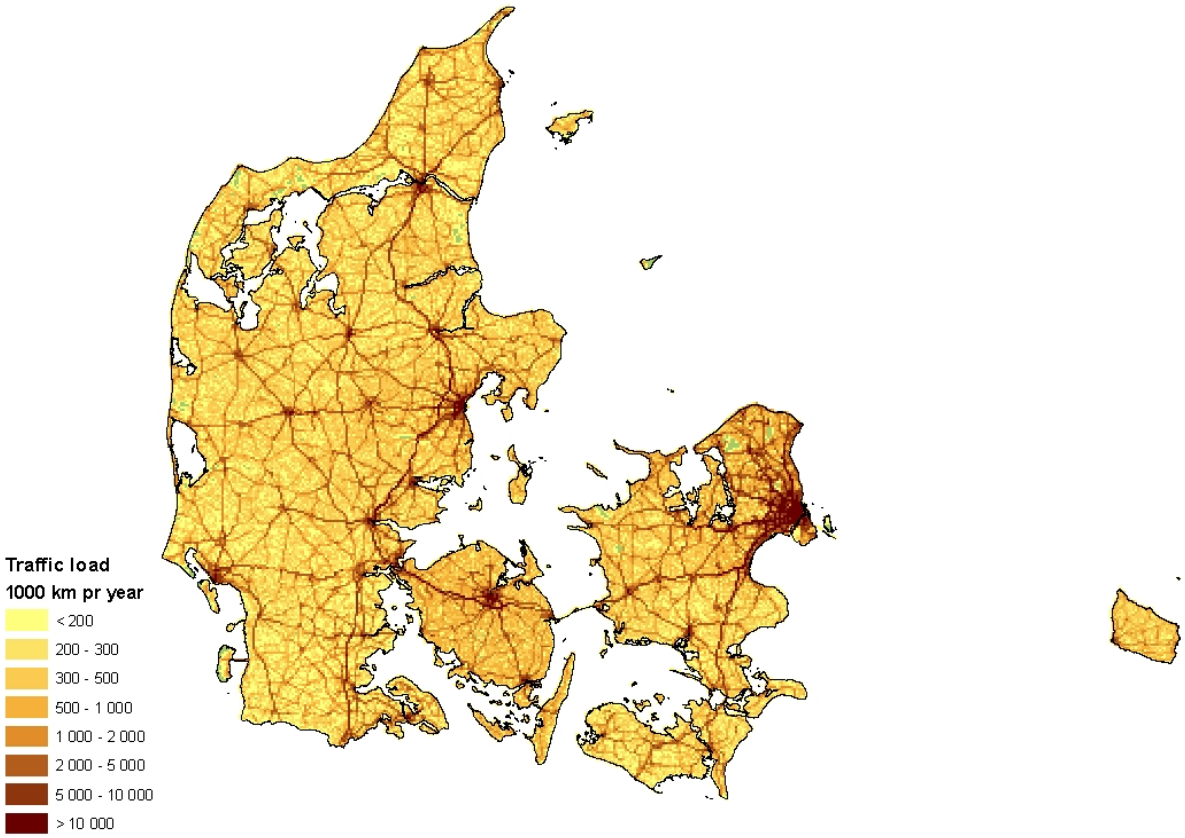

Figure 3.3 Traffic load for passenger cars including two-wheelers on the Danish road network according to the National Road and Traffic Database (NRTD).

A set of distribution keys based on ADT for the nine categories is set up in a Microsoft Access database model for subsequent data processing. A number of checks are run to test the model e.g. sum check of the total ADT. Further, a visual validation is made in GIS to ensure that all grid cells with an associated ADT are located on land or at the road network including piers and bridges. A grid net covering a square around the Danish economic zone is applied to ensure that cells outside the border of the Danish area of land is not lost during data processing.

The Danish emission inventory system includes mileage comparable to ADT in NRTD. Deviations between ADT and mileage are expected as they are based on different input data and methodology. The deviations owe to differences in assumptions of the total ADT and to difference in the estimation of traffic loads for the road and vehicle categories. A comparison of ADT and mileage is made to identify and quantify the devia-

tion. Two categories stand out with particular large deviations; passenger cars in rural areas and heavy duty on highways. The deviations are shown in Table 3.5.

Table 3.5 Deviation (%) on summarised ADT in the national road and traffic database and mileage in the Danish emissions inventory. Negative values indicate that ADT is less than the corresponding mileage.

	U	R	H
P	- 13	66	10
V	- 37	6	9
T	- 27	- 10	- 59

For passenger cars on rural road the divergence can be explained in the methodology applied in the NRTD. As input data were missing for a number of road segments (mainly roads with road width less that 3 m in rural areas) they were all assigned with a default ADT value. The default value might be too high and thereby lead to an overestimation of ADT. The comparison shows that ADT for passenger cars on rural roads is 66 % higher than the corresponding mileage in the emission inventory.

For heavy duty on highway the divergence is due to a correction of the mileage applied in the Danish inventory system. The fuel consumption in the emission inventory is required to equal the sale amounts given in the Energy Statistics by DEA (DEA, 2009). This is not the case for the fuel consumption estimated from the mileage included in the inventory, which assumingly owe to refuelling of foreign vehicles in Denmark. Most refuelling of foreign vehicles is expected to concern long distance transport (trucks and buses). Further, it is expected that foreign traffic mainly occurs on highways. Therefore the mileage for heavy duty on highway is upscaled so the total fuel consumption equals the actual fuel sale in the current year.

Emissions from road traffic are split between exhaust and non-exhaust in the Danish inventory system. Exhaust includes emissions of all pollutants. Non-exhaust covers emissions from tire and brake wear and from road abrasion and only includes emissions of particulate matter (TSP, PM_{10} and $PM_{2.5}$). The inventory for both exhaust and non-exhaust are divided into the nine categories listed in Table 3.4.

Emissions for 2008 for each of the 18 categories (nine for exhaust and nine for non-exhaust) are extracted from the national emission inventory model for road traffic. In ROEM the emissions are distributed spatially according to the nine distribution keys based on NRTD on 1x1 km grid.

3.2.2 Results for road transport

NO_x emissions from road traffic are shown in Figure 3.4. The largest emissions are located on the major road network as is the largest ADT.

As described above the mileage for heavy duty vehicles is upscaled to fit the national total fuel consumption, which leads to the assumption that more heavy traffic occurs on motorways than given in the NRTD and thereby a larger emission is distributed for heavy duty on highways than would be the case if the emissions were calculated from the ADT in NRTD. Further, the ADT for passenger cars on rural roads are larger in NRTD than the corresponding mileage in the national inventory. This

leads to a smaller emission being allocated on rural roads than if the emissions were calculated from the ADT in NRTD. The different approaches in the Danish inventory system and in NRTD taken into account ADT and mileage are very much alike.

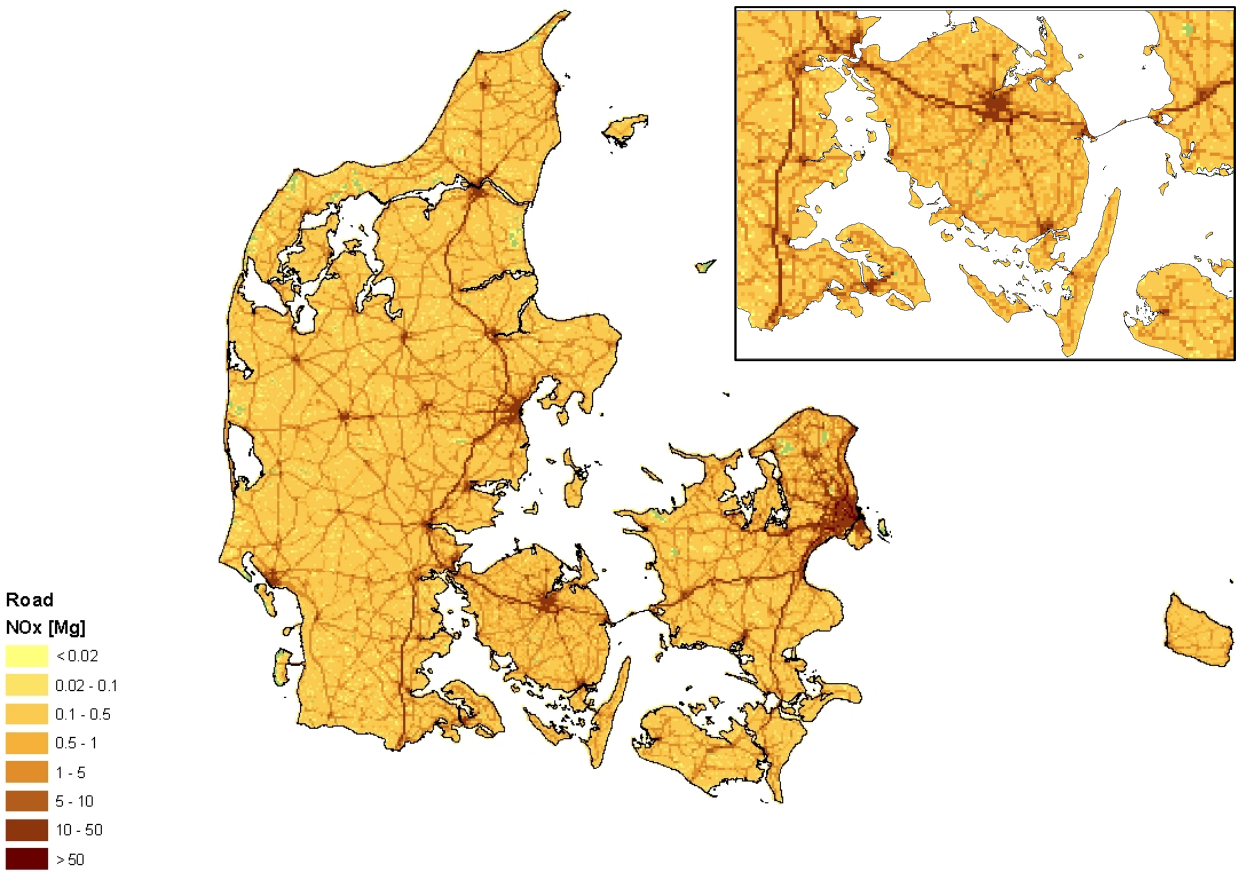

Figure 3.4 Emission of NO_x from road transport in 2008. Green and blue areas are land and sea areas without emissions.

3.2.3 Military

Emissions from military include road and off-road transport, navigation, aviation and use of machinery for military purpose. The emissions are distributed evenly on the Danish military exercise areas given by the Danish Forest and Nature Agency as no further data are available but the total fuel consumption. The share of the 1x1 km grid cells being covered by military exercise areas are found via intersection in GIS, and the emissions are distributed according to the share of the total military exercise area in each 1x1 km gird cell. The methodology has not been changed since the 2007 reporting for CLRTAP (Jensen et al., 2008a).

3.2.4 Railways

Emissions from railways are distributed evenly on the Danish rail network as given in KORT 10 from the National Survey and Cadastre. The length of railways in each 1x1 km grid cell is used for distribution of the national railway emissions. The methodology has not been changed since the 2007 reporting for CLRTAP (Jensen et al., 2008a).

3.2.5 Navigation

Navigation is divided into two main categories;

- Inland waterways, which covers pleasure crafts.
- Maritime activities, which covers national sea traffic (ferries) and national fishing.

The six major ferry services Sjællands Odde - Aarhus, Sjællands Odde - Ebeltoft, Kalundborg - Aarhus, Køge - Rønne, Kalundborg - Samsø and Tårs – Spodsberg are treated separately and emissions are calculated according to the number of trips, fuel consumption and engine information for the ferries. The routes used for spatial distribution of the emissions are straight lines between the harbours and the emissions are distributed evenly on the routes. The major ferry services are shown in Figure 3.5.

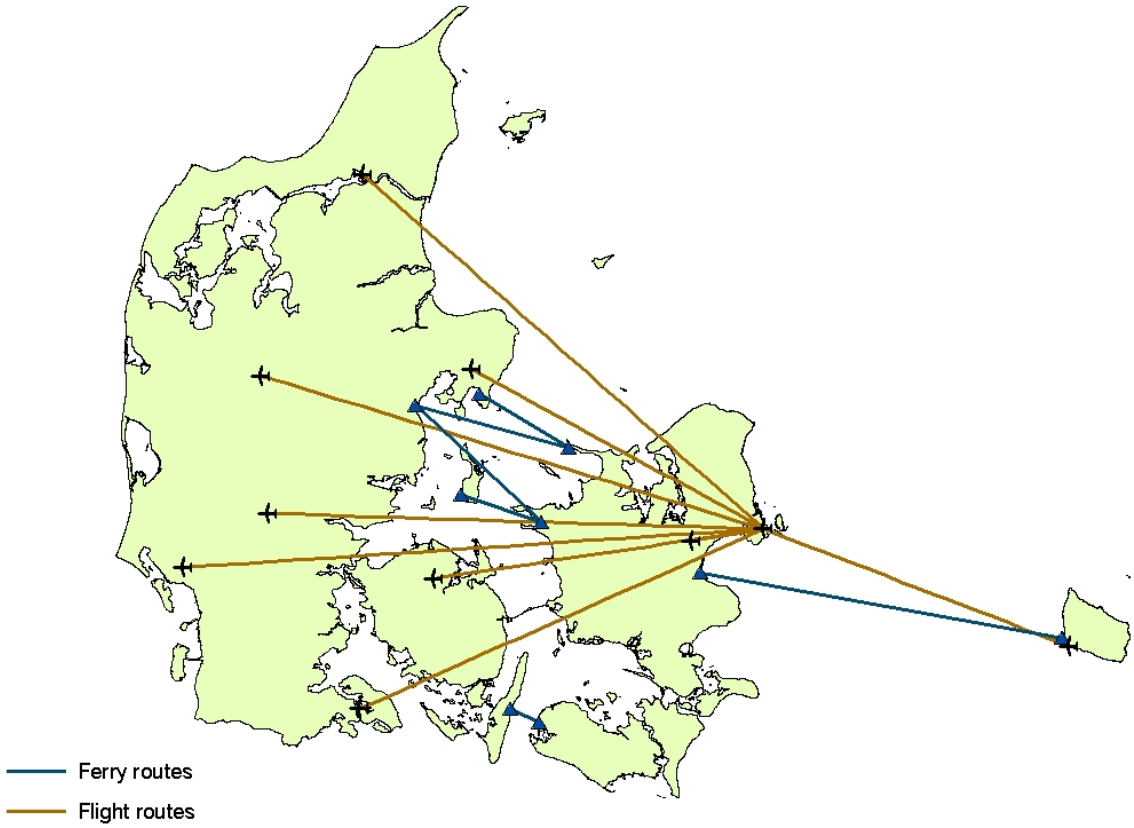

Figure 3.5 Major ferry and flight routes used for distribution of emissions in SPREAD.

Emissions from the remaining ferries and other navigation are distributed evenly on the Danish sea territory like the approach in the 2007 reporting for CLRTAP (Jensen et al., 2008).

3.2.6 Aviation

Aviation is divided into three categories; Domestic LTO, International LTO and domestic cruise. LTO refers to Landing and Take Off and is defined as activities below 1000 m. Cruise refers to flights above 1000 m.

Emissions from domestic cruise are calculated separately for nine major routes according to number of trips, fuel consumption and information on the flights and planes. The methodology from the 2007 reporting for CLRTAP has been applied in SPREAD (Jensen et al., 2008). The nine major routes are defined as a straight line between Denmark's largest airport Copenhagen Airport Kastrup and the nine following airports; Aalborg, Karup, Billund, Tirstrup, Rønne, Sønderborg, Odense, Esbjerg and Copenhagen Airport Roskilde (Figure 3.5). The emissions are distributed

on route network created as straight lines between the airports. Emissions from the remaining routes are added to the nine major routes using the same distribution. The nine major routes accounts for 57 % of the total fuel consumption for domestic cruise in 2008. The remaining 43 % include other routes, mainly to Greenland and Faroe Islands and routes performed by private/taxi flights.

The largest airport in Denmark is Copenhagen Airport, Kastrup (EKCH). In the national inventory EKCH is treated as a Large Point Source (LPS), both concerning LTO and cruise. In SPREAD domestic cruise from EKCH is treated as an area source and distributed on the route network, while emissions from LTO are located at the position of EKCH.

The same background data are used for calculation of emissions from LTO. Emissions from domestic and international LTO at Copenhagen Airport Kastrup are allocated on the site (point) included in the Danish inventory system. The remaining emissions from LTO are distributed on the nine major airports according to the airport areas given in KORT10 by the National Survey and Cadastre. LTO for the 10 major airports accounts for 82 % of the national fuel consumption for LTO in 2008.

3.2.7 Agriculture, Forestry, Industry, Household & gardening

The emissions from the national emission inventory for mobile sources in Forestry, Industry as well as Household and gardening are distributed according to land use maps in KORT10 by the National Survey and Cadastre. The category "low settlements" are used as distribution key for Household & gardening. Emissions from mobile sources in Agriculture are distributed on the Danish agricultural area from the field block map.

3.2.8 Results for mobile sources

Emissions of NO_x from other mobile sources (excluding road traffic) are dominated by the major aviation and navigation routes and the railway network (Figure 3.6). Also the military exercise areas are clear on the map. Only very few and relatively small areas have no emissions from other mobile sources. Emissions on the national sea territory occur because emissions from navigation other than the major ferry routes are distributed evenly on the national sea area. On land emissions are allocated to areas of agriculture, forest, industry and low buildings, which by far cover the major part of the Danish land area.

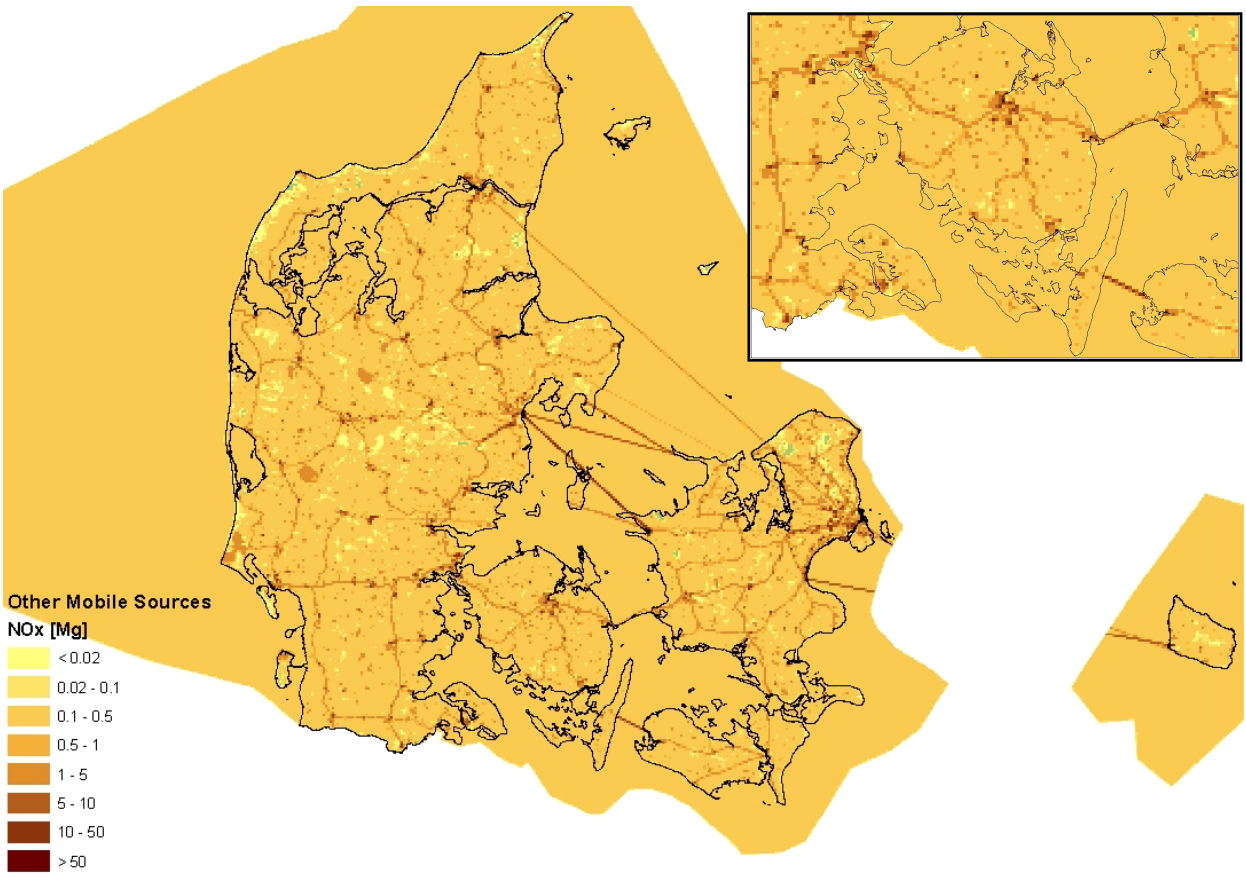

Figure 3.6 Emission of NO_x from Other Mobile Sources (excluding road traffic) in 2008.

3.3 Fugitive Emissions from Fuels

This sub-sector covers emissions from exploration, transport, processing and storage of solid, gaseous and liquid fuels. The spatial distribution is carried out separately for each source listed in Table 3.6, including SNAP codes and the relevant pollutants.

Table 3.6 Sources and pollutants included in the inventory of fugitive emissions from fuels.

Source	SNAP code	Note
Storage of coal	050103	TSP, PM_{10} and $PM_{2.5}$
Extraction of oil and natural gas	050202	NMVOC and CH_4.
Flaring offshore	090206	All pollutants except HCB
Offshore loading of ships	050202	NMVOC and CH_4.
Onshore loading of ships	050201	NMVOC and CH_4.
Oil transport in pipeline and storage at the raw oil terminal	050201	NMVOC and CH_4.
Service stations	050503	NMVOC
Transmission of natural gas	050601	NMVOC and CH_4.
Distribution of natural gas	050603	NMVOC and CH_4.
Distribution of town gas	050603-F02	NMVOC and CH_4.
Gas storage plants	090206	All pollutants except HCB.
Gas treatment plants	050601, 090206	NMVOC, CH_4 for SNAP 050601. All pollutants except HCB for SNAP 090206.
Refineries	040101, 040103, 090203	NMVOC and CH_4 for SNAP 040101. SO_2 for SNAP 040103. All pollutants except HCB for SNAP 090203.

3.3.1 Solid fuels

Fugitive emissions from solid fuels in the Danish inventory cover storage of coal in coal piles and include emissions of particulate matter (TPS, PM_{10} and $PM_{2.5}$). Coal piles appear on coal harbours and at coal fired CHP plants. Most of the coal fired CHP plants are located at or near the harbours. 50 % of the emission from coal storage is distributed on coal harbours and 50 % on coal fired CHP plants. Further, the emissions are distributed according to the unloaded amounts for harbours and the consumed amount for CHP plants.

3.3.2 Extraction of oil and natural gas

This category includes emissions from extraction of oil and natural gas by the Danish operators on the North Sea. The inventory includes emissions of NMVOC and CH_4. Emissions from extraction are distributed on the offshore installations with production weighted by the produced amounts of natural gas, as the produced amounts of natural gas is far more influential on the emissions from extraction than produced amounts of oil.

3.3.3 Offshore flaring

Offshore flaring covers burning of gas for technical or safety reasons on the offshore installations in relation to extraction activities. Emissions from flaring include all pollutants except HCB, which are assumed not applicable in the EMEP/EEA Guidebook (2009). Data on offshore flaring is available for the fields and the emissions are distributed on the installations with flaring for each field.

3.3.4 Offshore loading

Offshore loading takes place on two installations and the emissions are distributed according to the oil production at the two installations.

3.3.5 Pipeline oil

Raw oil extracted on the North Sea is transported to storage tanks at the Danish onshore raw oil terminal via a sea and land pipeline. The emission is by far dominated by emissions from storage tanks while emissions from transport through the pipeline are assumed to be negligible. Emissions from the oil terminal include NMVOC and CH_4 and all emissions are located at the site for the raw oil terminal in SPREAD.

3.3.6 Service stations

The source called service stations includes unloading of tanker trucks, storage in tanks at the service stations and refuelling of vehicles. Emissions of NMVOC are calculated according to the gasoline sales for consumption for a number of uses i.a. road traffic, households, industries, navigation, aviation and agriculture. Even though a number of small industrial and private gasoline tanks occur, the major part of the gasoline is sold from service stations. A dataset including location of 2 260 service stations in Denmark from the Danish Petroleum Association are used for distribution of emissions from service stations. As the dataset does not include information on annual gasoline amounts the emissions are distributed evenly between the service stations. The methodology for service stations are adopted from the 2007 reporting for CLRTAP (Jensen et al., 2008a) as the list of service stations from the Danish Petroleum Association has not been updated in the meantime.

3.3.7 Transmission of natural gas

The Danish gas transmission network is owned and run by the transmission company Energinet.dk who has delivered spatial data on the location of the measurement and regulator stations (M/R stations). The transmission network is made of plastic, which results in only minimal fugitive losses. However, the pipes are vulnerable and the major part of the fugitive emissions owe to excavations and construction work. Venting due to damages and maintenance work are measured or estimated in each case. Further, emissions occur at the M/R stations. Emissions of NMVOC and CH_4 from transmission of natural gas are distributed evenly on the 72 M/R stations as data on single venting situations is not available. The methodology for transmission of natural gas is adopted from the 2007 reporting for CLRTAP (Jensen et al., 2008).

3.3.8 Distribution of natural gas

Three companies carry out distribution of natural gas and the network covers a large part of the Danish land area (Figure 3.7). As the location of the network is not known and the distribution amounts are only available as annual sums for each company the spatial distribution is carried out according to information in the Regional Inventory by the Danish Energy Agency. The Regional Inventory holds fuel consumptions of natural gas on SNAP 2 and municipality level. The emissions of NMVOC and CH_4 are distributed according to the Regional Inventory and are fur-

ther distributed on the grid cells in each municipality according to the grid cells share of the total municipality area determined by intersection of a municipality map and the Danish 1x1 km grid in GIS.

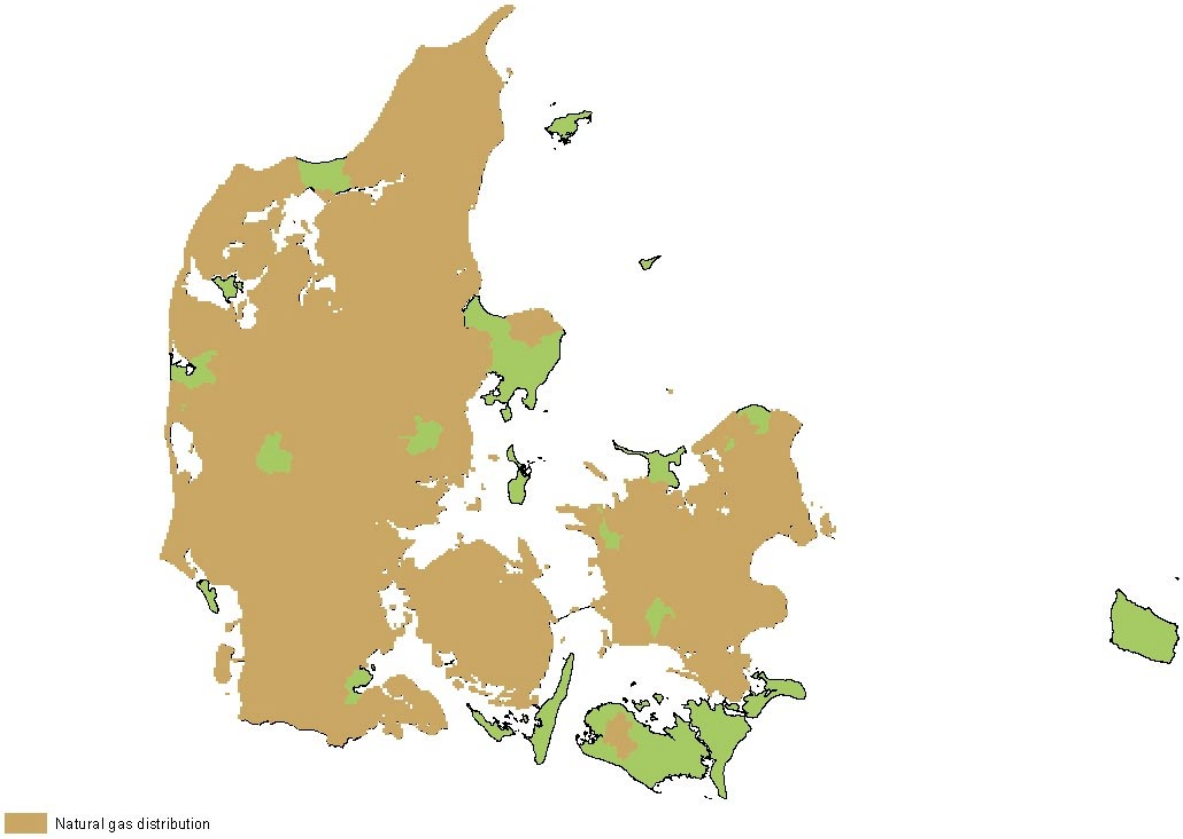

Figure 3.7 Distribution of natural gas in Denmark. Green areas have no gas distribution.

3.3.9 Distribution of town gas

Town gas is distributed in two Danish cities, Copenhagen and Aalborg. As maps of the entire distribution network are not available the same approach is used for spatial distribution for town gas distribution as for distribution of natural gas, but only for the two relevant municipalities. The inventory includes NMVOC and CH_4 emissions from town gas distribution.

3.3.10 Oil refining

Denmark has two refineries, which are treated as large point sources in the Danish inventory system. The inventory covers emissions of SO_2, NMVOC and CH_4 from petroleum product processing including fugitive emissions from valves and storage tanks, emissions of SO_2 from sulphur recovery at one refinery and emissions of all pollutants except HCB for flaring in refineries. Emissions are available for the refineries separately and are located at the geographical position registered in the inventory database.

3.3.11 Gas plants

Natural gas extracted on the North Sea is lead to the gas treatment plant. Part of the natural gas is stored in the two Danish gas storage plants. All

three plants are treated as LPS in the inventory system and the emissions are allocated on the site of the plants in SPREAD. The inventory covers venting and flaring in the gas treatment and storage plants and includes all pollutants excluding HCB.

3.3.12 Results for fugitive emissions from fuels

Fugitive NMVOC emissions from fuels are shown in Figure 3.8. A few grid cells have large emissions due to the presence of point sources both onshore and offshore. Among the most important point sources are the raw oil terminal and the refineries onshore and the extraction and flaring sites offshore. Green areas have no emissions. This is mainly due to no distribution of natural gas, which is given on municipality level. Areas without emissions do therefore correspond to the municipality without natural gas distribution. Please notice that a number of separate grid cells in all parts of Denmark have emissions due to the presence of service stations as shown in the enlarged part of Figure 3.8.

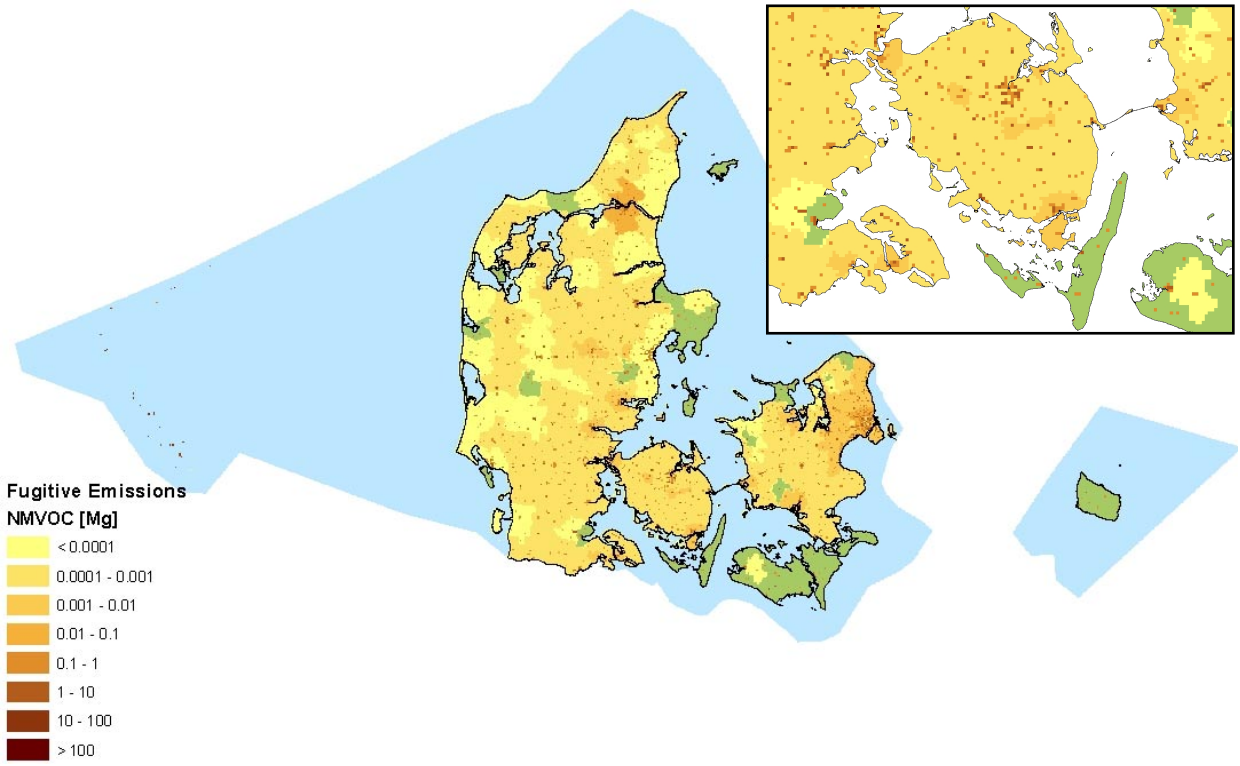

Figure 3.8 Fugitive emission of NMVOC in 2008. Green and blue areas are land and sea areas without emissions. The square in the upper right corner shows an enlargement of the Funen area where the emissions in separate grid cells are visible.

4 Spatial distribution of emissions from Industrial Processes

Industrial processes cover a number of industries in the Danish emission inventory. The major companies are treated as large point sources in the Danish inventory system and the emissions are either calculated from plant specific data or provided directly by the company. The LPSs cover processes in inorganic and organic chemical industries and processes in wood, paper, pulp, food and drink and other industries. The inventory of industrial processes include emissions of SO_2, NO_x, NMVOC, CH_4, CO, CO_2, NH_3, TSP, PM_{10}, $PM_{2.5}$, Cd, Cu, Pb, Zn and dioxin.

The most important industries in the Danish emission inventory are processes in wood, paper pulp, food, drink and other industries according to emissions of NMVOC and production of cement (decarbonising) according to emissions of CO_2. Emissions of other pollutants are relatively small compared to the national emissions.

It is only the minority of the industries that are represented in the LPS part of the emission inventory. The rest of the industries are treated as area sources and are incorporated in the inventory by use of production statistics. Emissions from industrial processes from area sources are distributed equally on the Danish industrial area as given in KORT10 by the National Survey and Cadastre. The SPREAD methodology corresponds the methodology in the 2007 reporting for CLRTAP (Jensen et al., 2008).

4.1 Results for industrial processes

Emissions from industrial processes are distributed according to the industrial area and the emissions in the cell depend on the share of the grid cell intersecting, the industrial areas and the total emission. Only exception is emissions from industrial LPSs, which are for the major part located in the industrial areas. The resulting emission distribution for industrial processes is shown in Figure 4.1.

Figure 4.1 NMVOC from Industrial Processes in 2008. Green and blue areas are land and sea areas without emissions.

5 Spatial distribution of emissions from Solvents and other product use

The inventory for solvents and other product use covers 38 categories based on industry and use. The sector includes emissions of NMVOC, CO_2 and N_2O. All sources in the sector are treated as area sources as no data on the geographical location is available. For spatial distribution three distribution keys have been applied based on location of industrial areas, of low settlements and of the population. Industrial areas and low settlements are based on KORT 10 from the National Survey and Cadastre. Data from the Civil Registration System (CPR) is used to set up a distribution key for the population at the 1x1 km grid. The categories and the corresponding distribution keys are listed in Table 5.1.

CO_2 emissions in the inventory for solvents and other product use refer to secondary CO_2 from NMVOC. In SPREAD it is assumed that the emissions of NMVOC and CO_2 are located at the same site.

Table 5.1 Emission sources and distribution keys for solvents and other product use.

Distribution key	SNAP	Source (SNAP 2 level)	Source (SNAP 3 level)
Industry	60101	Paint application	Manufacture of Automobiles
Industry	60102	Paint application	Car Repairing
Low settlements	60103	Paint application	Constructions and Buildings
Population	60104	Paint application	Domestic Use
Industry	60105	Paint application	Coil Coating
Industry	60106	Paint application	Boat Building
Population	60107	Paint application	Wood
Industry	60108	Paint application	Other Industrial Paint Applications
Population	60109	Paint application	Other Non-Industrial Paint Application
Industry	60201	Degreasing, dry cleaning and electronics	Metal Degreasing
Low settlements	60202	Degreasing, dry cleaning and electronics	Dry Cleaning
Industry	60203	Degreasing, dry cleaning and electronics	Electronic Components Manufacturing
Industry	60204	Degreasing, dry cleaning and electronics	Other Industrial Dry Cleaning
Industry	60301	Chemical products manufacturing or processing	Polyester Processing
Industry	60302	Chemical products manufacturing or processing	Polyvinylchlorid Processing
Industry	60303	Chemical products manufacturing or processing	Polyurethan Foam Processing
Industry	60304	Chemical products manufacturing or processing	Polystyrene Foam Processing
Industry	60305	Chemical products manufacturing or processing	Rubber Processing
Industry	60306	Chemical products manufacturing or processing	Pharmaceuticals Products Manufacturing
Industry	60307	Chemical products manufacturing or processing	Paints Manufacturing
Industry	60308	Chemical products manufacturing or processing	Inks Manufacturing
Industry	60309	Chemical products manufacturing or processing	Glues Manufacturing
Population	60310	Chemical products manufacturing or processing	Asphalt Blowing
Industry	60311	Chemical products manufacturing or processing	Adhesive, Magnetic Tapes, Film & Photographs Manufacturing
Industry	60312	Chemical products manufacturing or processing	Textile Finishing
Industry	60313	Chemical products manufacturing or processing	Leather Tanning
Industry	60314	Chemical products manufacturing or processing	Other
Industry	60401	Other use of solvents and related activities	Glass Wool Enduction
Industry	60402	Other use of solvents and related activities	Mineral Wool Enduction
Industry	60403	Other use of solvents and related activities	Printing Industry
Industry	60404	Other use of solvents and related activities	Fat, Edible and Non-Edible Oil Extraction
Industry	60405	Other use of solvents and related activities	Application of Glues and Adhesives
Population	60406	Other use of solvents and related activities	Preservation of Wood
Industry	60407	Other use of solvents and related activities	Underseal Treatment and Conservation of Vehicles
Population	60408	Other use of solvents and related activities	Domestic Solvent Use (Other Than Paint Application)
Industry	60409	Other use of solvents and related activities	Vehicles Dewaxing
Population	60411	Other use of solvents and related activities	Domestic Use of Pharmaceutical Products
Industry	60412	Other use of solvents and related activities	Other (Preservation of Seeds)

5.1 Results for solvents and other product use

Emissions from solvents and other product use are allocated on the major part of the Danish land area as the distribution is based on industrial areas, areas with low settlements and the location of the population, the latter covering by far the largest area. Also densely populated areas stand out with large emissions. Areas without emissions have no popu-

lation and are mainly agricultural areas and natural areas, e.g. lakes, dunes and moor (Figure 5.1).

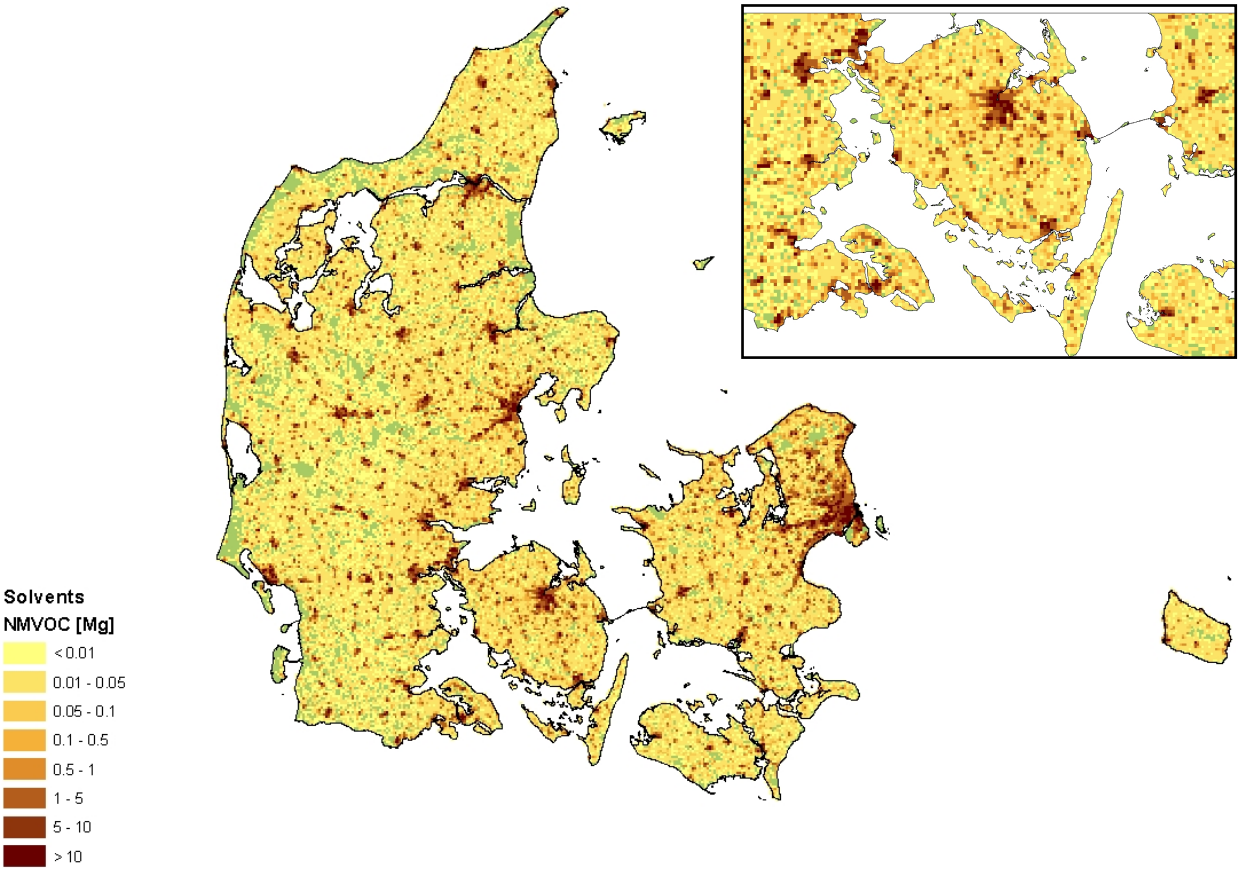

Figure 5.1 Emissions of NMVOC from solvents and other product use in 2008. Green and blue areas are land and sea areas without emissions.

6 Spatial distribution of emissions from the Agricultural sector

The Danish emission inventory for the agricultural sector covers five sub-sectors:

1. Enteric fermentation, which covers emissions of CH_4 from animals' digestion.
2. Manure management, which covers emissions of CH_4, N_2O, NH_3 and PM from handling of manure in housings and during storage in slurry tanks and manure heaps.
3. Agricultural soils, which cover emissions of N_2O from crop residues, N fixing crops, animal manure applied to soils, synthetic fertiliser, leaching and run-off, atmospheric deposition, N-excretion on pasture range and paddock, cultivation of histosols and sludge applied to soils. Further, agricultural soils cover NMVOC and NH_3 from crops.
4. Field burning of agricultural residues covers emissions of all pollutants from field burning in the inventory system except CO_2 as this is treated as biomass and HCB, which are not occurring.
5. Other covers NH_3 from sludge (including e.g. fruit juice and potato juice e.g. from potato flour plants). As the categorisation is different for UNFCCC and CLRTAP, emission from sludge is included in different categories in the two reporting formats; in Agricultural soils for UNFCCC and in Other for CLRTAP. Prior to 2008 NH_3 from sludge was allocated in the agricultural soils sub-sector in both reporting formats, but due to a shift to the new NFR categories from the 2008 reporting, the shift in sub-category was carried out.

The emission inventory for the agricultural sector is using detailed methodologies and a large number of very detailed datasets, e.g. figures from Statistics Denmark, feedstuffs tables, normative feed consumption and nitrogen excretion figures, and data from the Central Husbandry Register (CHR) and the General Agriculture Register (GLR). The emission calculation is taking into account a number of conditions related to e.g. animals, housings, manure management, litter, fodder, crops, use of fertiliser and sludge.

The spatial distribution of emissions from agriculture is carried out separately for each source. The distributions are based on a large amount of very detailed data, e.g. the CHR, GLR, the Land Parcel Identification System (LPIS) and the nitrogen accounts for each individual farmer. CHR holds information on the population and location of animals on a large number of animal-categories. GLR holds data on types of crops on field and farm level. LPIS hold the geographical location of all Danish agricultural soils. The land parcels are split by natural boundaries in the landscape, e.g. trenches, hedgerows and roads. Although one land parcels can cover one or more fields this dataset combined with GLR and CHR gives very detailed information on the location of fields, crops and animals. On average one land parcels covers approximately 11 hectares and includes three fields.

As lined out the agricultural sector covers a number of sources, which are distributed according to different spatial keys. Emissions from the agricultural sources are calculated with a bottom-up approach for the spatial distribution. The bottom-up calculation is carried out on a 100x100 m grid, which is aggregated into a 1x1 km grid in SPREAD.

The emissions estimated by the bottom-up approach are not completely consistent with the emissions in the national inventory, which are calculated with a top-down approach as the emission calculation must be consistent with the national statistics. In order to ensure that the emissions in SPREAD are equal to the reported emissions for 2008, the reported emissions are distributed according to the distribution keys set up by the bottom-up approach.

6.1 Enteric Fermentation

CH_4 from enteric fermentation is distributed according to data on the number and categories of animals on farm level. CHR holds data for the majority of the livestock covering animal-categories related to e.g. breed and age (e.g. calf, heifer and cow or sow and piglets) and use (e.g. dairy cattle and beef cattle). The horse breeding register holds addresses of the owners, and this is the best dataset for spatial distribution of emissions from horses even though the horses might be located at different sites than the owners address. As the register for horses does not hold information on pasture areas, emissions from both stables, storage and grazing are located at the owners address.

6.2 Manure Management

The distribution of CH_4, N_2O, NH_3, TSP, PM_{10} and $PM_{2.5}$ from manure management is based on the data from GLR and CHR. As for enteric fermentation the location of the animals, housing systems and manure systems is important for distribution of emissions from manure management.

Emissions of NH_3 from manure management are related to activities at the farms and are treated as point sources. Calculations are based on the normative figures on N-excretion per farm corrected for grazing. As for enteric fermentation data the horse breeding register is included in the calculation.

6.3 Agricultural soils

Agricultural soils covers ten sources; crops, application of manure, application of synthetic fertiliser, N-excretion on pasture range and paddock, NH_3 treated straw, crop residue, N-fixing crops, cultivation of histosols, leaching and atmospheric deposition. Emissions of NMVOC, N_2O and NH_3 are included in one or more of the sources.

6.3.1 Crops

Calculation of NH_3 evaporation from crops on agricultural soils are based on data from GLR, CHR and LPIS data and are carried out for four crop types; winter seeds, early spring sowed crops, late spring sowed crops, and grass. The calculated emissions are summarised and aggregated to set up a final distribution key.

Emissions of NMVOC from crops at agricultural fields are included in the emission inventory. The distribution is based on data from GLR on crop types and the LPIS data for location of the relevant fields.

6.3.2 Application of manure

Application of manure on fields causes emissions of NH_3 and N_2O. The distribution model for NH_3 from manure application is based on fertiliser accountings and the LPIS data. The manure produced on each farm corrected for manure import and export is assumed to be distributed evenly on the entire farm fields in rotation even though there might be some prioritising if there is only a limited amount of manure available. This assumption is applied as no consistent prioritising has been identified. Fields outside rotation is only given attributes for grazing capacity.

6.3.3 Application of fertiliser

Use of mineral fertilisers causes emissions of NH_3 and N_2O. Application of fertiliser is given in the fertiliser accountings by amount of purchased N at farm level. The average Danish NH_3 emission factor for mineral fertilise is used on farm level as there is no data on different types on mineral fertilisers on farm level. The amount of bought mineral fertiliser on farm level is distributed into each field according to each crops recommended nitrogen application rate for that soil type. No fertiliser is assigned to fields without N-norm, e.g. peas and fallow. Purchased N and N-norms are compared for the farms and a correction factor has been applied for the N application for farms where the purchased amount exceeds the amount calculated from the N-norms.

6.3.4 N excretion on pasture range and paddock (PRP)

Emission calculations of N_2O from animals' N excretion on pasture range and paddock are based on average information from the Danish Agricultural Advisory Services, Department for Cattle. The share of N-excretion from cattle is separated between conventional and organic farming as the latter has extended periods of grazing. Further, the assumption has been applied that no grazing occurs in the summer period if the grass area is less than 0.15 ha. per dairy cattle. This mainly affects the farms with a large number of livestock. As outdoor pigs area are located in CHR these are also included in the calculations and allocated to field level as grazing animals.

6.3.5 NH_3 treated straw

Use of NH_3 treated straw has been phased out and is not occurring in the 2008 inventory. This source will be included in the model when applied for earlier years e.g. in relation to reporting in 2012 of gridded emissions for 2010 and historical years to CLRTAP. The distribution key has been

set up for future use. Emissions of NH_3 from NH_3 treated straw are allocated to conventional dairy cattle farms excluding a minor number of suckling cattle farms that might use NH_3 treated straw.

6.3.6 Crop residue

Input data for calculation of N_2O emissions from crop residue is available in the GLR register, which include crop types on field level and from the LPIS data due to location of the fields.

6.3.7 N-fixing crops

Calculation of N_2O emissions from N-fixing crops are based on data from the GLR register on crop types on field level and from the LPIS data where the location of the relevant fields are available.

6.3.8 Histosols

Distribution of N_2O from histosols is based on the LPIS data in combination with a map of organic soils in the soil map based on the Danish soil classification. The emission is distributed evenly on the area identified by intersection of the field area and the organic soil area.

6.3.9 Leaching

When the fields are fertilised part of the applied N is not assimilated by the crops. The surplus cause leaching and run-off, which again leads to emission of N_2O. The emission calculations are based on N-content of the applied fertiliser, manure and sludge. The spatial distribution is based on the recommended application rate for each crop from the GLR database in combination with LPIS data. The leaching factor is assumed to be independent of soil type.

6.3.10 Atmospheric deposition

The distribution key for emission of N_2O from NH_3 evaporation is estimated as a sum of NH_3 from point sources and area sources covering manure and mineral fertiliser application. This approach is subject to some degree of inaccuracy as the emission of N_2O takes place at the site for deposition of NH_3 and not at the site for evaporation of NH_3 as given in the distribution key. Introduction of a transport model to make a deposition map would improve the distribution key. This has not been included in SPREAD, as the available deposition maps include long-range transboundary NH_3, which is not to be included in the Danish emission inventory. Further, NH_3 from agriculture is not transported very far before deposition and therefore the inaccuracy is assumed to be of little importance for the allocation of the emissions.

All NH_3 emissions from the Danish territory are included in the emissions distribution although studies have shown that only part of the Danish ammonia emission is deposited on the Danish area. The Danish share of the NH_3 deposition on Danish land area is around 36 % and the corresponding share for the Danish sea area is 14 % (Ellermann et al. 2010.

6.4 Field burning of agricultural residues

Field burning of agricultural residues is very limited in Denmark due to a legal prohibition implemented in 1990. The legislation leaves the possibility of field burning of straw related to production of some varieties of grass seeds and burning of wet or broken bales of straw. Emissions from field burning include all pollutants in the inventory system except HCB. The distribution is based on GLR regarding fields with the relevant crops and the LPIS data regarding the location of the relevant fields.

6.5 Other

The category named Other covers emissions of N_2O from sludge. The emission is distributed according to the fertiliser accounts where the sludge amounts are given for each farm, GLR where the relevant crops and fields are identified and the LPIS data for location of the fields.

6.6 Results for agriculture

NH_3 emissions from the agricultural sector cover by far the major part of Denmark (Figure 6.1). Agricultural soils cover a large part of the rural area. Emissions from horses are allocated on the addresses of the owners, which may lead to emissions in areas with no agricultural activities and no animals. Further, the small number of animals present in urban areas is included, covering poultry in residential areas and grazing animals e.g. on the mounds and common. As expected the largest emissions are found in Jutland where many large livestock are located, as emissions from manure management is the major source of agricultural NH_3 in Denmark.

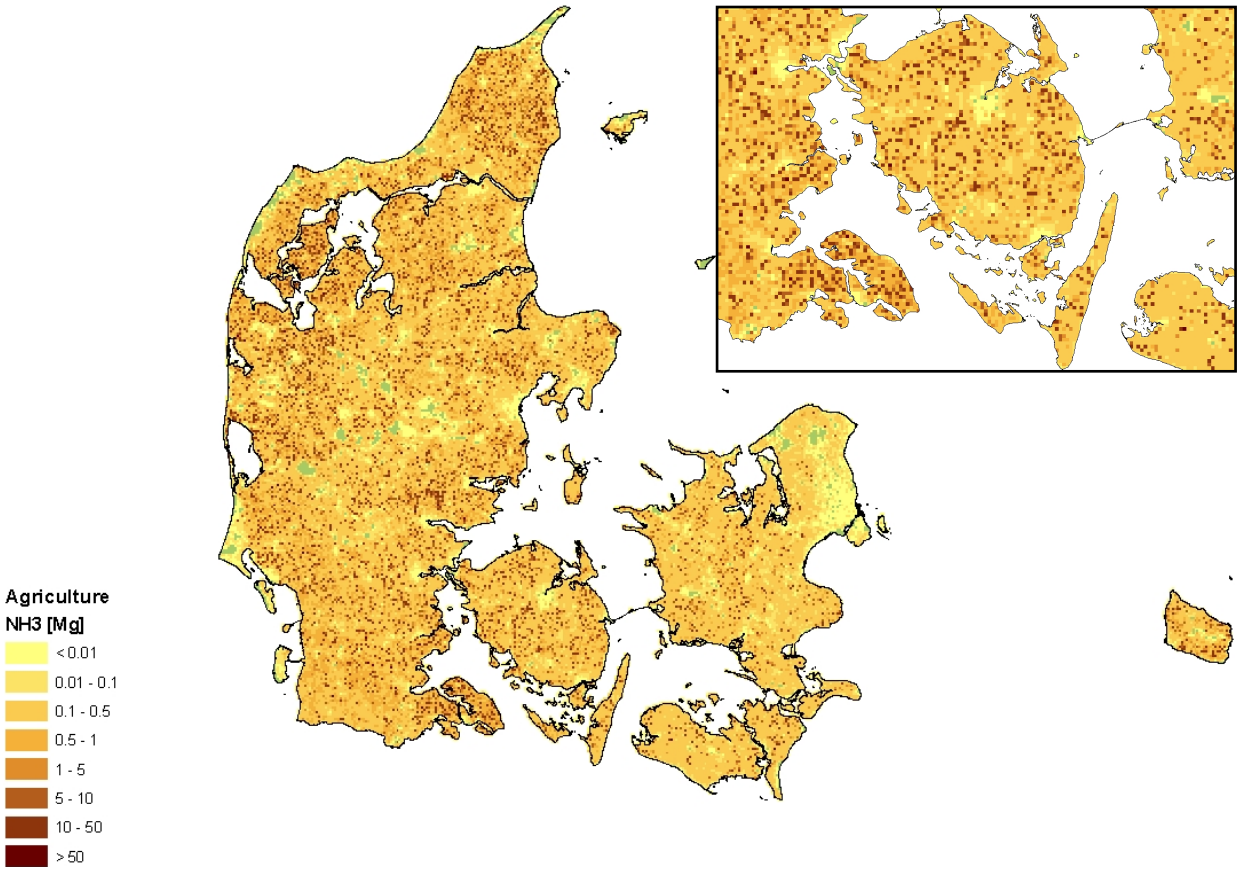

Figure 6.1 Emission of NH_3 from the agriculture sector in 2008. Green and blue areas are land and sea areas without emissions.

7 Spatial distribution of emissions from the waste sector

The waste sector includes solid waste disposal on land, wastewater treatment, cremations, incineration of carcasses, compost production, accidental fires and N_2O from human sewage. Compost production is included in SPREAD even though it was not implemented in the 2008 reporting for UNFCCC and CLRTAP. All waste incineration in Denmark is included in the heat and power production at CHP plants and waste incineration plants and the emissions are included in stationary combustion in the energy sector.

7.1 Solid waste disposal

The inventory for solid waste disposal covers only managed disposal sites as all solid waste disposal sites in Denmark are managed and includes emissions of CH_4. The emission calculations are based on data from the ISAG database (InformationsSystem for Affald og Genanvendelse) hosted by Danish EPA. ISAG holds addresses for waste treatment companies with processing, incineration, deposition, special treatment and/or temporary storage. The ISAG database includes CVR numbers and addresses for the companies and waste amounts in the different categories. The Danish waste model estimates emissions on a national basis. The waste composition and the corresponding emission vary widely among the waste treatment sites, but as this information is not incorporated in the Danish waste model, the emissions are distributed evenly on the 99 Danish landfill sites.

7.2 Wastewater treatment

Wastewater treatment occurs at 586 plants and this part of the inventory covers emissions of CH_4 and N_2O. The internet site "Miljøportalen.dk" hosts a database including addresses, flow rates and information on the content of degradable organic matter in the inlet waste water (referred to as BI5). The emission calculation is carried out as national total in the wastewater emission model in the Danish emission inventory system. Emissions are spatially distributed according to the BI5 value for each plant.

7.3 Cremations

Cremation covers both cremation of corpses and incineration of carcasses and includes emissions of all pollutants except CO_2, which is excluded in line with the procedure for other biomass related CO_2 emissions. The Danish Crematorium Association registers the number of cremation of corpses at the 32 Danish crematories on an annual basis and the estimated emission is distributed on the crematories weighted by the number of cremations in the current year. Incineration of carcasses takes place at three pet crematories and information on the weight of carcasses

cremated a year collected from the pet crematories are used for distribution of the national emission.

7.4 Compost production

Compost production was not implemented in the reporting for 2008, but as the data is available and will be included in future reporting this source is implemented in SPREAD. The inventory for composting includes emissions of CH_4, CO, N_2O and NH_3. Compost production in Denmark is dominated by garden and park waste, which mainly occurs at a large number of recycling depots. In the present spatial distribution emissions from compost production are distributed according to the areas with one-storey buildings as the recycling depots are not geocoded yet.

7.5 Accidental fires

Accidental fires are grouped in a number of categories covering vehicles, detached houses, undetached houses, apartment buildings and industrial buildings. The inventory include emissions of all pollutants except N_2O, NH_3, Se, HCB and benzo(b)flouranthene due to lack of emission factors. Geographical location of the fires is not yet included in the inventory for accidental fires and the emission is distributed according to the population distribution.

7.6 N_2O from human sewage

The source called N_2O from human sewage covers direct emissions from wastewater treatment processes and indirect emissions from the outlet wastewater. The calculated emissions are distributed between the wastewater treatment plants according to BI5 in the same way as emissions from wastewater treatment.

7.7 Results for waste

Figure 7.1 shows the emissions of CH_4 from the waste sector. The grid cells with the largest emissions are enhanced with circular symbols. The largest emissions occur at the point sources covering wastewater treatment plants and solid waste disposals, the latter having the largest total and site-specific emissions. Accidental fires are assumed to happen where the population is located, which leads to emissions at almost the entire land area.

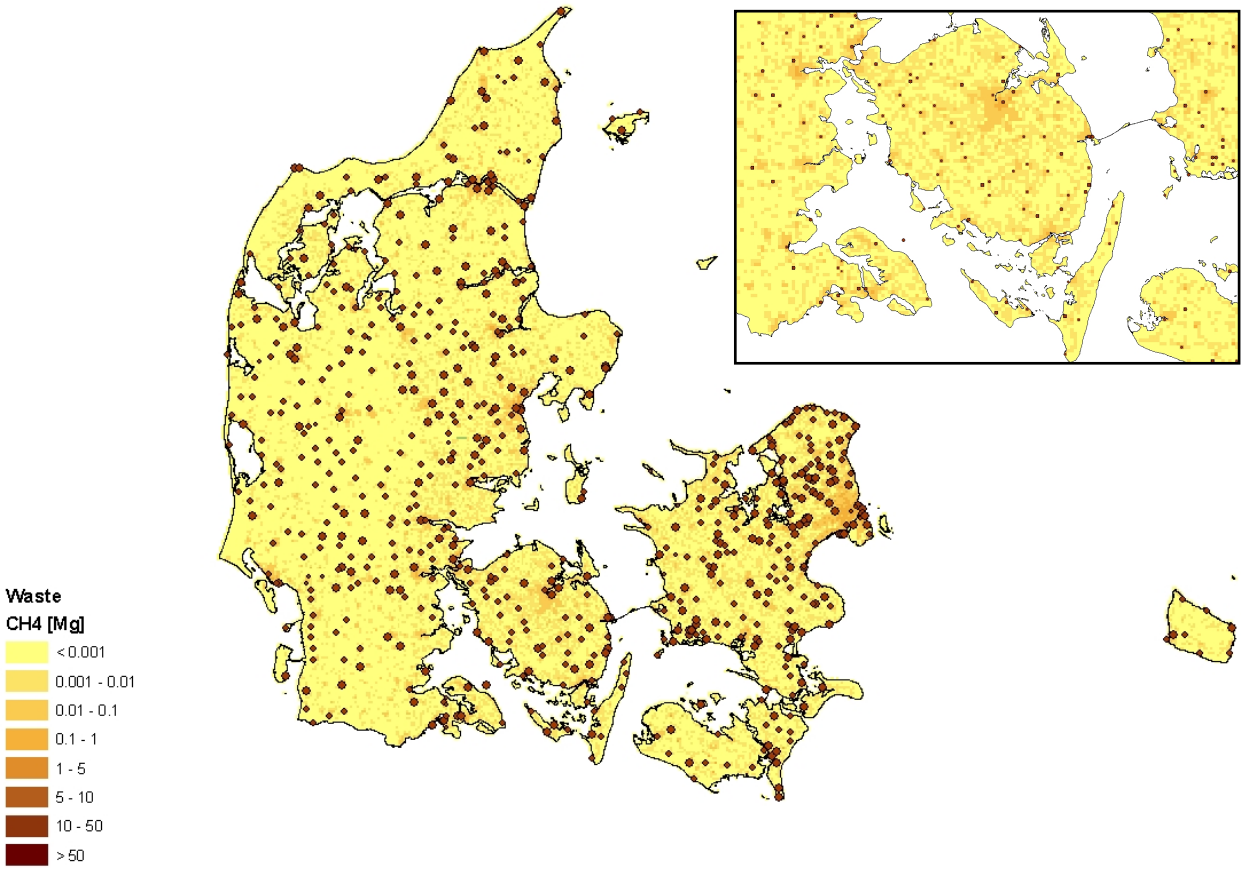

Figure 7.1 Emission of CH_4 from the waste sector in 2008. Green and blue areas are land and sea areas without emissions. The grid cells with largest emissions are enhanced by use of symbols.

8 Spatial distribution of national emissions

A component in SPREAD combines all sub-models to get a distribution of the total Danish emissions. The pattern of the emissions depends on the pollutant, as different sources are dominant for different pollutants. In Figure 8.1, Figure 8.2 and Figure 8.3 the emissions of greenhouse gases in CO_2 equivalents, of NMVOC and of$PM_{2.5}$ are shown. The pattern for emissions of greenhouse gases is more homogeneous than is the case for NMVOC and $PM_{2.5}$. The more even distribution owe to two facts. First, agriculture is a major source of the greenhouse gases CH_4 and N_2O, which both have high global warming potentials (21 and 310, respectively) and thereby are weighted higher in CO_2 equivalents than CO_2. Second, energy consumption for power and heat production and transport are important sources of greenhouse gases emissions. Together these circumstances contribute to allocate emissions in all parts of Denmark.

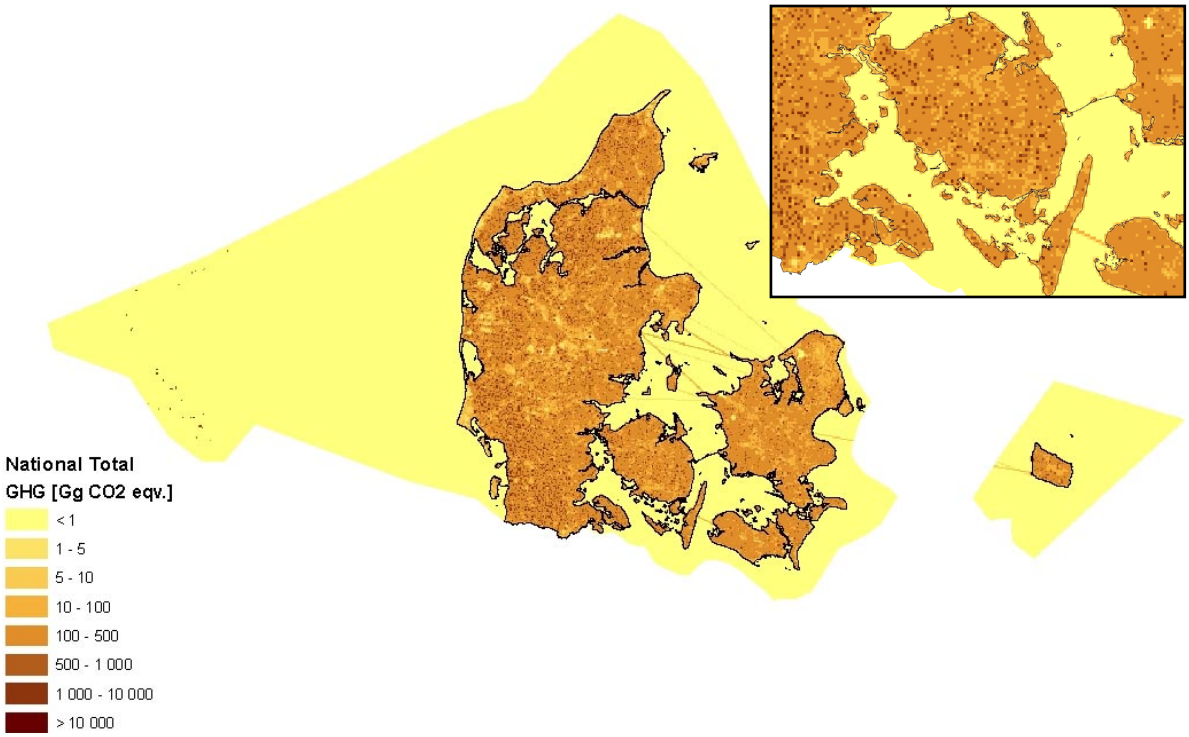

Figure 8.1 National emission of greenhouse gases in 2008.

Emissions of NMVOC are far more concentrated in urban and industrial areas. Emissions from solvents and other product use and emissions from industrial processes are also important sources. Furthermore a number of point sources (LPS and PS) contribute with very large emissions.

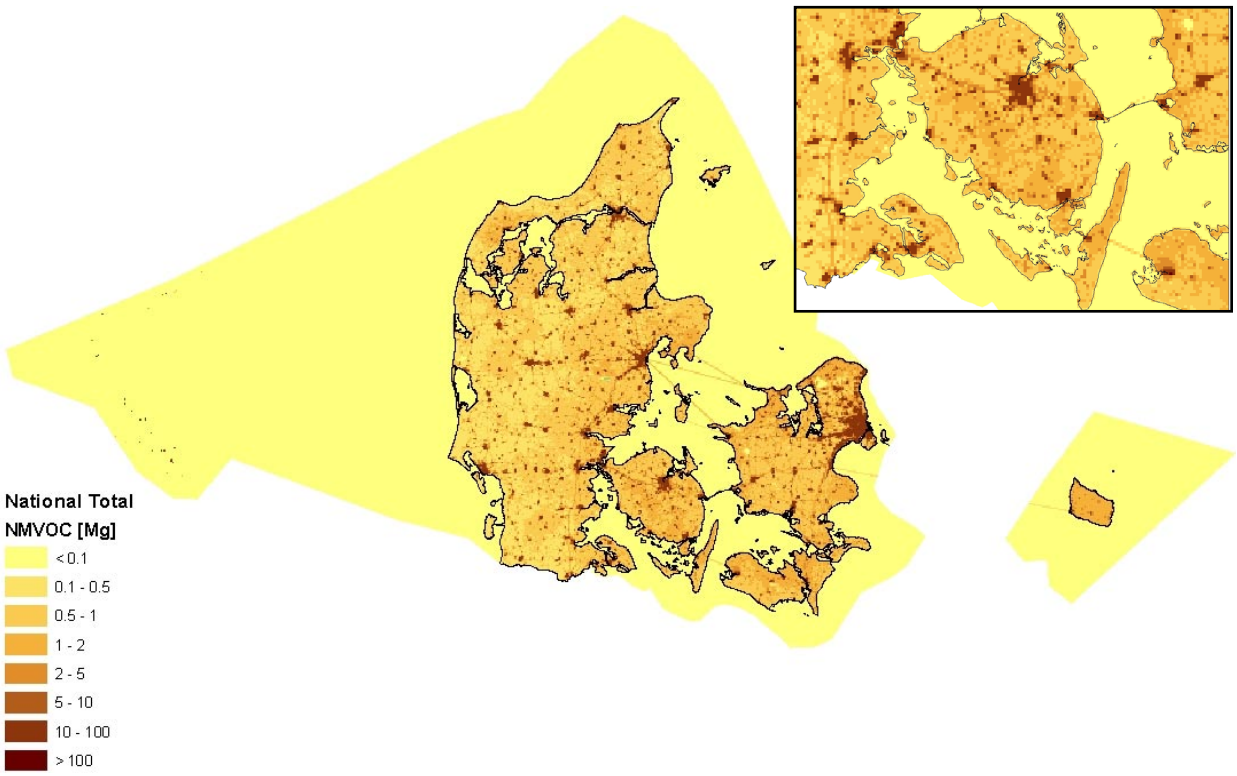

Figure 8.2 National emission of NMVOC in 2008.

Wood combustion in residential plants is the main source of emission from particulate matter in Denmark. Other important sources are mobile sources, especially road transport, and agriculture, especially manure management. The national distribution of $PM_{2.5}$ is relatively homogeneous according to the distribution of emissions from residential plants on municipality level. $PM_{2.5}$ from mobile sources enhances the major roads (highways) and the military exercise areas.

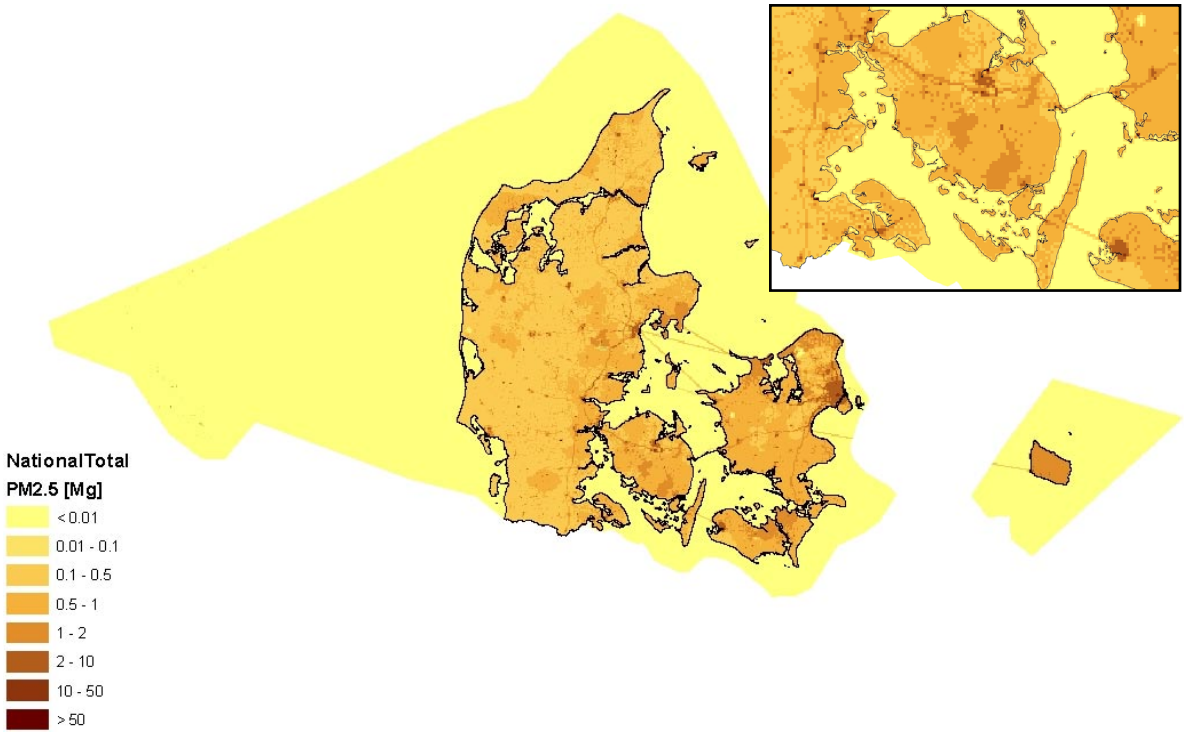

Figure 8.3 National emission of $PM_{2.5}$ in 2008.

9 Discussion and potential improvements

This report describes the first version of SPREAD. During the work process on setting up the model a number of potential improvements has been identified. In some cases the necessary data are available but is not yet implemented in the inventory calculations or in SPREAD. In other cases it is not known if data required for improvements exists and if it can be made available for use in the inventory system or in SPREAD. The potential improvements are described in the following paragraphs. In all cases it will be considered both if it is possible to include the improvement and if the benefit of the improvement is in proportion with the required workload of implementation.

9.1 Stationary combustion, point sources

In 2010 work has been carried out to improve the correctness of the EPT (database from the DEA including fuel consumption for each district heating or power-producing plant) e.g. all SNAP codes has been checked and corrected according to the given facility type and size. The improved dataset will be included in the next version of SPREAD.

9.2 Stationary combustion, area sources

Improvements of the conversions will be incorporated if possible. The Regional Inventory of energy consumption for heating for oil boilers, natural gas boilers and solid fuel installations by the Danish Energy Agency used for distribution of part of the emissions from stationary combustion from area sources at SNAP 01, 02 and 03, is made for the year 2005. It would improve the distribution to use an updated data set for the latest historical year. The Regional Inventory is based on data from the Building and Housing Register (BBR) by the end of 2005. In 2009 a new version of BBR was released and inclusion of this new BBR could lead to a better distribution. Wood combustion in residential plants is an important source for a number of pollutants, e.g. particulate matter, PAHs and some heavy metals. In the present model emissions from residential wood combustion are distributed on municipality level according to the Regional Inventory. To improve this part a model for distribution of emissions from residential wood combustion created in the research project WOODUSE could be applied. This model is based on a bottom-up approach where the heating requirements are estimated on address level. Data from BBR are used as input in the model and a number of criteria are set up for estimation of the heating requirements, here among a selection of which addresses should be included in the model. Before a potential implementation of this sub-model, the criteria and equations will be re-evaluated. A detailed description of the model is required if it is implemented in a later version of SPREAD.

9.3 Mobile Sources

For the sources Aviation and Navigation it will be considered if more flight and ferry routes are to be handled separately to reduce the residual emissions that are distributed on the major flight routes and on the Danish sea territory, respectively.

The distribution of emissions from railways is distributed evenly on the railway network in the present version of SPREAD. This part could be improved by including further data on the rail activity or number of passengers on different parts of the network, e.g. data on numbers of passenger and goods trains between given stations from Statistics Denmark. This improvement is considered very time consuming and the gains are assumed to be relatively small for the model performance.

It will be considered whether the distribution would be improved if emissions from national fishing were distributed on the major fishing banks instead of on the national sea territory.

9.4 Fugitive emissions from fuels

Work will continue to try to get data on the natural gas distribution network to improve the distribution. Also an updated list of service stations will be included if it becomes available as the list used in the present model is from 2001.

9.5 Industrial processes

It will be evaluated if a better distribution key for emissions from industrial processes could be set up. For some industry categories a small number of companies account for a large part of the emissions but are not treated as LPS in the inventory database. If direct or estimated emissions for some single companies become available this would be an improvement. Even if emissions for single companies are not available there could still be room for improvements in splitting up the emission from a defined industry by an assumption of how much a number of major companies make up of the total for the industry. Another approach is to include employment statistics on municipality and industry from Statistics Denmark. The employment statistics might be combined with the industrial area at least for some industries.

For some industries it might be an improvement to use another distribution key than the industrial area. This might be the case for e.g. the food and drink industries as part of the emissions come from bakeries, which are assumed to be situated more like the population than like the industrial areas.

9.6 F-gases

The distribution of F-gas emissions could be improved by splitting the emissions into categories, e.g. household and industries. It will be evaluated if the necessary data is available.

9.7 Solvents and other product use

As for industrial processes it will be evaluated if the emissions related to industries could be distributed more appropriate than evenly on the industrial area. Again employment statistics might be a useful data source.

9.8 Solid waste disposal

In the present version of SPREAD emissions from solid waste disposal are distributed evenly on the disposal sites. It would improve the distribution if the inventory was made at site level and not at national level as is the case now. Data to restructure the emission inventory on disposal site level is available, but the restructuring would be very time consuming and would only improve the spatial distribution and not the national inventory. This improvement will be included if a restructuring is carried out.

9.9 Wastewater treatment

In the present inventory emissions from wastewater treatment are distributed according to the degradable organic matter in the inlet wastewater. It would improve the distribution to include the fraction being treated under anaerobic conditions. Data are not available at the moment but efforts will be made to gain access to such data due to improvement of the emission inventory for wastewater.

9.10 Compost production

Geographical coordinates are not available for the Danish recycling depots for use in SPREAD and the emissions are distributed on areas with one-storage buildings in the present version of SPREAD. It would be an improvement to distribute part of the emissions on the recycling depots, as only a limited amount is composted in private gardens.

The distribution could be improved if the plants handling garden and park waste were geo-coded and used for either equal distribution or weighted due to the waste amounts.

9.11 Accidental fires

It will be evaluated if it would be possible to allocate all or a part of the accidental fires on a geographical level, e.g. municipality, city, fire department or fire station.

10 Conclusion

The SPREAD model has been prepared as part of the emission inventory project at the National Environmental Research Institute, Aarhus University. SPREAD will be applied for the next mandatory reporting of gridded emissions to CLRTAP primo 2012.

Former spatial distributions have had a rather low resolution (50x50 km and 17x17 km) compared to the Danish area and are considered less useful for air quality modelling, health effect estimation and associated cost-benefit analysis. As emissions in the national inventory in most cases are based on very detailed data and as the resulting emissions are considered to have small uncertainties, a high spatial resolution distribution will improve the use of emission data in many contexts.

To ensure that the spatial distribution reflect the degree of detail in the inventory, the emissions are distributed on a highly disaggregated level. Therefore the SPREAD model is based on SNAP categories rather than the NFR and CRF categories used in the national emission reporting. This has lead to demand for setting up a larger number of distribution keys.

A large workload has been put in the distribution of emissions in the energy sector. The inventory system handles Large Point Sources and area sources, but as the calculations in the national inventory system include data from a large number of point sources, these emissions are allocated on the site of each single plant. As this approach differ from the approach in the inventory system, much work has been done to re-allocate fuel consumptions on SNAP categories and to apply corrections to ensure that the emissions in the inventory and in the distribution are exactly the same.

The distribution of emissions from agriculture is based on a complex bottom-up approach including more very large and very detailed datasets. Emissions related to animals are based on information on all registered animals in Denmark and thereby it is possible to allocate the emissions very accurately. Emissions related to soils and crops are calculated on field level in consideration of crop types and soil types, and this emission allocation is very accurate as well. As is the case for the energy sector, the emission calculation approach differs between the inventory system and the bottom-up methodology, and the latter is corrected to make sure the emissions in the distribution and in the national emission inventory equal.

A number of point sources have been geo-coded manually either by use of the public Information Server (OIS) administrated by the Danish Enterprise and Construction Authority, where coordinates can be found via addresses, or via visual identification in Google Earth. Manual geocoding has been used for e.g. municipal solid waste disposals and waste water treatment plants.

The completion of the SPREAD model has enhanced national emission data with a high spatial resolution for all sources and all pollutants in the national emission inventory system. The spatial emission dataset has contributed new knowledge on both sectoral and national level concerning the location of emissions. The model is considered very useful and brings highly improved spatial emission data for e.g. air quality modelling and health effect calculations.

This first version of the model makes use of simple distribution keys for some sources. In coming versions the applied distribution keys will be reconsidered and improvements will be applied if possible. Industrial processes and stationary combustion in area sources are considered to be the sources with the most deficient distribution and these will be given priority in the next version, especially according to emissions from food and drink industries and from stationary combustion in residential plants.

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Appendix A: List of fuel codes

Fuel code	Fuel
101	COKING COAL (GHV > 23865 kJ/kg)
102	STEAM COAL (GHV > 23865 kJ/kg)
103	SUB-BITUMINOUS(17435 kJ/kg <GHV< 23865 kJ/kg)
104	PATENT FUELS (from hard/sub-bituminous coal)
105	BROWN COAL / LIGNITE (GHV < 17435 kJ/kg)
106	BROWN COAL BRIQUETTES
107	COKE OVEN COKE FROM HARD COAL
108	COKE OVEN COKE FROM BROWN COAL
109	GAS COKE
110	PETROLEUM COKE
111 *	WOOD AND SIMILAR WOOD WASTES
112	CHARCOAL
113	PEAT
114 *	MUNICIPAL WASTES
115	INDUSTRIAL WASTES
116	WOOD WASTES (except wastes similar to wood)
117 *	AGRICULTURAL WASTES (corncobs, straw, etc...)
118 *	SEWAGE SLUDGE
119	REFUSE DERIVED FUELS
120	OIL-SHALE
121	OTHER SOLID FUELS (tar, benzol, pitch, etc.)
201	CRUDE OIL
203	RESIDUAL OIL
204	GAS OIL
205	DIESEL OIL FOR ROAD TRANSPORT
206	KEROSENE
207	JET FUEL
208	MOTOR GASOLINE
209	AVIATION GASOLINE
210	NAPHTA
211	SHALE-OIL
212	GASOLINE ENGINE WASTE OIL
213	DIESEL ENGINE WASTE OIL
214	WASTE SOLVENTS
215 *	BIO OIL
216	MIXTURE OF FUEL OIL AND COAL
217	REFINERY FEEDSTOCKS AND ADDITIVES
218	OTHER LIQUID WASTES
219	LUBRICANTS
220	WHITE SPIRIT
221	PARAFFIN WAXES
222	BITUMEN
223	BIO-ALCOHOL
224	OTHER PËTROLEUM PROD. (grease,aromatics,etc.)
225	ORIMULSION
301	NATURAL GAS (except liquefied natural gas)
302	NATURAL GAS LIQUIDS
303	LIQUEFIED PETROLEUM GASES (LPG)
304	COKE OVEN GAS

Fuel code	Fuel
305	BLAST FURNACE GAS
306	MIXTURE OF COKE OVEN AND BLAST FURNACE GASES
307	WASTE GAS (especially chemical industry)
308	REFINERY AND PETROCHEM. GAS (not condensable)
309 *	BIOGAS
310 *	BIOMASS PRODUCER GAS
311	GAS WORKS GAS
312	STEEL PLANT FURNACE GAS
313	HYDROGEN
314	OTHER GASEOUS FUELS

* Biofuel

Appendix B: List of SNAP codes and corresponding NFR categories

SNAP codes are set up in three levels (ETC/AEM – CITEPA, 1996):

- SNAP 1 level refers to the upper level covering 11 source categories of which 9 are used in the Danish inventory system as agriculture are treated on NFR categories and natural sources as not occurring.
- SNAP 2 level refers to the intermediate level covering 77 sub-source categories. The intermediate level mainly reflects technological criteria.
- SNAP 3 level refers to the lower level and covers 375 source activities. The lower level aims to structure sources and sinks to achieve homogeneous sections according to emission generation. Further, the lower level aims to give an exhaustive enumeration of sources and sinks in detail.

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
010100	Public power	1A1a	Electricity and heat production
010101	Combustion plants >= 300 MW (boilers)	1A1a	Electricity and heat production
010102	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	Electricity and heat production
010103	Combustion plants < 50 MW (boilers)	1A1a	Electricity and heat production
010104	Gas turbines	1A1a	Electricity and heat production
010105	Stationary engines	1A1a	Electricity and heat production
010200	District heating plants	1A1a	Electricity and heat production
010201	Combustion plants >= 300 MW (boilers)	1A1a	Electricity and heat production
010202	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	Electricity and heat production
010203	Combustion plants < 50 MW (boilers)	1A1a	Electricity and heat production
010204	Gas turbines	1A1a	Electricity and heat production
010205	Stationary engines	1A1a	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	Manufacture of solid fuels and other energy industries
010401	Combustion plants >= 300 MW (boilers)	1A1c	Manufacture of solid fuels and other energy industries
010402	Combustion plants >= 50 and < 300 MW (boilers)	1A1c	Manufacture of solid fuels and other energy industries
010403	Combustion plants < 50 MW (boilers)	1A1c	Manufacture of solid fuels and other energy industries
010404	Gas turbines	1A1c	Manufacture of solid fuels and other energy industries
010405	Stationary engines	1A1c	Manufacture of solid fuels and other energy industries
010406	Coke oven furnaces	1A1c	Manufacture of solid fuels and other energy industries
010407	Other (coal gasification, liquefaction)	1A1c	Manufacture of solid fuels and other energy industries
010500	Coal mining, oil / gas extraction, pipeline compressors	1A1c	Manufacture of solid fuels and other energy industries
010501	Combustion plants >= 300 MW (boilers)	1A1c	Manufacture of solid fuels and other energy industries
010502	Combustion plants >= 50 and < 300 MW (boilers)	1A1c	Manufacture of solid fuels and other energy industries
010503	Combustion plants < 50 MW (boilers)	1A1c	Manufacture of solid fuels and other energy industries
010504	Gas turbines	1A1c	Manufacture of solid fuels and other energy industries
010505	Stationary engines	1A1c	Manufacture of solid fuels and other energy industries
010506	Pipeline compressors	1A3e i	Transport-Other transportation, Pipeline compressors
020100	Commercial and institutional plants	1A4a i	Commercial/Institutional plants
020101	Combustion plants >= 300 MW (boilers)	1A4a i	Commercial/Institutional plants
020102	Combustion plants >= 50 and < 300 MW (boilers)	1A4a i	Commercial/Institutional plants
020103	Combustion plants < 50 MW (boilers)	1A4a i	Commercial/Institutional plants
020104	Stationary gas turbines	1A4a i	Commercial/Institutional plants
020105	Stationary engines	1A4a i	Commercial/Institutional plants
020106	Other stationary equipments	1A4a i	Commercial/Institutional plants
020200	Residential plants	1A4b i	Residential plants
020201	Combustion plants >= 50 MW (boilers)	1A4b i	Residential plants
020202	Combustion plants < 50 MW (boilers)	1A4b i	Residential plants
020203	Gas turbines	1A4b i	Residential plants
020204	Stationary engines	1A4b i	Residential plants
020205	Other equipments (stoves, fireplaces, cooking)	1A4b i	Residential plants
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

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
030100	Combustion in boilers, gas turbines and stationary engines	1A2f i	Industry-Other
030101	Combustion plants >= 300 MW (boilers)	1A2f i	Industry-Other
030102	Combustion plants >= 50 and < 300 MW (boilers)	1A2f i	Industry-Other
030103	Combustion plants < 50 MW (boilers)	1A2f i	Industry-Other
030104	Gas turbines	1A2f i	Industry-Other
030105	Stationary engines	1A2f i	Industry-Other
030106	Other stationary equipments	1A2f i	Industry-Other
030200	Process furnaces without contact	1A2f i	Industry
030203	Blast furnace cowpers	1A2a	Industry-Iron and steel
030204	Plaster furnaces	1A2f i	Industry-Other
030205	Other furnaces	1A2f i	Industry-Other
030300	Processes with contact	1A2f i	Industry-Iron and steel
030301	Sinter and pelletizing plants	1A2a	Industry-Iron and steel
030302	Reheating furnaces steel and iron	1A2a	Industry-Iron and steel
030303	Gray iron foundries	1A2a	Industry-Iron and steel
030304	Primary lead production	2C5b	Industry-Non-ferrous metals
030305	Primary zinc production	2C5d	Industry-Non-ferrous metals
030306	Primary copper production	2C5a	Industry-Non-ferrous metals
030307	Secondary lead production	2C5b	Industry-Non-ferrous metals
030308	Secondary zinc production	2C5d	Industry-Non-ferrous metals
030309	Secondary copper production	2C5a	Industry-Non-ferrous metals
030310	Secondary aluminium production	2C3	Industry-Non-ferrous metals
030311	Cement	1A2f i	Industry-Other
030312	Lime (incl. iron and steel and paper pulp industry)	1A2f i	Industry-Other
030313	Asphalt concrete plants	1A2f i	Industry-Other
030314	Flat glass	1A2f i	Industry-Other
030315	Container glass	1A2f i	Industry-Other
030316	Glass wool (except binding)	1A2f i	Industry-Other
030317	Other glass	1A2f i	Industry-Other
030318	Mineral wool (except binding)	1A2f i	Industry-Other
030319	Bricks and tiles	1A2f i	Industry-Other
030320	Fine ceramic materials	1A2f i	Industry-Other
030321	Paper-mill industry (drying processes)	1A2d	Industry-Pulp, Paper and Print
030322	Alumina production	1A2b	Industry-Non-ferrous metals
030323	Magnesium production (dolomite treatment)	1A2b	Industry-Non-ferrous metals
030324	Nickel production (thermal process)	2C5c	Industry-Nickel production
030325	Enamel production	1A2f i	Industry-Other
030326	Other	1A2f i	Industry-Other
040100	Processes in petroleum industries	1B2a iv	Fugitive Emissions from Fuels, Refining / storage
040101	Petroleum products processing	1B2a iv	Fugitive Emissions from Fuels, Refining / storage
040102	Fluid catalytic cracking - CO boiler	1B2a iv	Fugitive Emissions from Fuels, Refining / storage
040103	Sulphur recovery plants	1B2a iv	Fugitive Emissions from Fuels, Refining / storage
040104	Storage and handling of petroleum produc. in refinery	1B2a iv	Fugitive Emissions from Fuels, Refining / storage
040105	Other	1B2a iv	Fugitive Emissions from Fuels, Refining / storage
040200	Processes in iron and steel industries and collieries	2C1	Industrial Processes-Metal Production-Iron and steel
040201	Coke oven (door leakage and extinction)	1B1b	Fugitive emissions from fuels-Solid fuels/Transformation
040202	Blast furnace charging	2C1	Industrial Processes-Metal Production-Iron and steel
040203	Pig iron tapping	2C1	Industrial Processes-Metal Production-Iron and steel
040204	Solid smokeless fuel	1B1b	Fugitive emissions from fuels-Solid fuels/Transformation
040205	Open hearth furnace steel plant	2C1	Industrial Processes-Metal Production-Iron and steel

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
040206	Basic oxygen furnace steel plant	2C1	Industrial Processes-Metal Production-Iron and steel
040207	Electric furnace steel plant	2C1	Industrial Processes-Metal Production-Iron and steel
040208	Rolling mills	2C1	Industrial Processes-Metal Production-Iron and steel
040209	Sinter and pelletizing plant (except comb. 03.03.01)	2C1	Industrial Processes-Metal Production-Iron and steel
040210	Other	2C5f	Industrial Processes-Metal Production-Storage, handling and transport
040300	Processes in non-ferrous metal industries	2C3	
040301	Aluminium production (electrolysis)	2C3	Industrial Processes-Metal Production-Aluminium
040302	Ferro alloys	2C2	Industrial Processes-Metal Production-Ferroalloys
040303	Silicium production	2C5e	Industrial Processes-Metal Production-Other
040304	Magnesium production (except 03.03.23)	2C5e	Industrial Processes-Metal Production-Other
040305	Nickel production (except 03.03.24)	2C5e	Industrial Processes-Metal Production-Other
040306	Allied metal manufacturing	2C5e	Industrial Processes-Metal Production-Other
040307	Galvanizing	2C5e	Industrial Processes-Metal Production-Other
040308	Electroplating	2C5e	Industrial Processes-Metal Production-Other
040309	Other	2C5e	Industrial Processes-Metal Production-Other
040400	Processes in inorganic chemical industries	2B5a	
040401	Sulfuric acid	2B5a	Industrial Processes-Chemical Industry/Other
040402	Nitric acid	2B2	Industrial Processes-Chemical Industry-Nitric Acid
040403	Ammonia	2B1	Industrial Processes-Chemical Industry-Ammonia
040404	Ammonium sulphate	2B5a	Industrial Processes-Chemical Industry/Other
040405	Ammonium nitrate	2B5a	Industrial Processes-Chemical Industry/Other
040406	Ammonium phosphate	2B5a	Industrial Processes-Chemical Industry/Other
040407	NPK fertilisers	2B5a	Industrial Processes-Chemical Industry/Other
040408	Urea	2B5a	Industrial Processes-Chemical Industry/Other
040409	Carbon black	2B5a	Industrial Processes-Chemical Industry/Other
040410	Titanium dioxide	2B5a	Industrial Processes-Chemical Industry/Other
040411	Graphite	2B5a	Industrial Processes-Chemical Industry/Other
040412	Calcium carbide production	2B4	Industrial Processes-Chemical Industry-Carbide
040413	Chlorine production	2B5a	Industrial Processes-Chemical Industry/Other
040414	Phosphate fertilizers	2B5a	Industrial Processes-Chemical Industry/Other
040415	Storage and handling of inorganic chemical products	2B5b	Industrial Processes-Storage, handling and transport
040416	Other	2B5a	Industrial Processes-Chemical Industry/Other
040500	Processes in organic chemical industry (bulk production)	2B5a	
040501	Ethylene	2B5a	Industrial Processes-Chemical Industry-Other
040502	Propylene	2B5a	Industrial Processes-Chemical Industry/Other
040503	1,2 dichloroethane (except 04.05.05)	2B5a	Industrial Processes-Chemical Industry/Other
040504	Vinylchloride (except 04.05.05)	2B5a	Industrial Processes-Chemical Industry/Other
040505	1,2 dichloroethane + vinylchloride (balanced process)	2B5a	Industrial Processes-Chemical Industry/Other
040506	Polyethylene Low Density	2B5a	Industrial Processes-Chemical Industry/Other
040507	Polyethylene High Density	2B5a	Industrial Processes-Chemical Industry/Other
040508	Polyvinylchloride	2B5a	Industrial Processes-Chemical Industry/Other
040509	Polypropylene	2B5a	Industrial Processes-Chemical Industry/Other
040510	Styrene	2B5a	Industrial Processes-Chemical Industry/Other
040511	Polystyrene	2B5a	Industrial Processes-Chemical Industry/Other
040512	Styrene butadiene	2B5a	Industrial Processes-Chemical Industry/Other
040513	Styrene-butadiene latex	2B5a	Industrial Processes-Chemical Industry/Other
040514	Styrene-butadiene rubber (SBR)	2B5a	Industrial Processes-Chemical Industry/Other
040515	Acrylonitrile Butadiene Styrene (ABS) resins	2B5a	Industrial Processes-Chemical Industry/Other
040516	Ethylene oxide	2B5a	Industrial Processes-Chemical Industry/Other
040517	Formaldehyde	2B5a	Industrial Processes-Chemical Industry/Other
040518	Ethylbenzene	2B5a	Industrial Processes-Chemical Industry/Other

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
040519	Phtalic anhydride	2B5a	Industrial Processes-Chemical Industry/Other
040520	Acrylonitrile	2B5a	Industrial Processes-Chemical Industry/Other
040521	Adipic acid	2B3	Industrial Processes-Chemical Industry-Adipic Acid
040522	Storage and handling of organic chemical products	2B5b	Industrial Processes-Chemical Industry-Other
040523	Glyoxylic acid	2B5a	Industrial Processes-Chemical Industry/Other
040525	Pesticide production	2B5a	Industrial Processes-Chemical Industry/Other
040526	Production of persistent organic compounds	2E	Industrial Processes-Production of POP's
040527	Other (phytosanitary)	2B5a	Industrial Processes-Chemical Industry-Other
040600	Processes in wood, paper pulp, food, drink and other industries	2D1	
040601	Chipboard	2D1	Industrial processes-Other Production-Pulp and Paper
040602	Paper pulp (kraft process)	2D1	Industrial processes-Other Production-Pulp and Paper
040603	Paper pulp (acid sulfite process)	2D1	Industrial processes-Other Production-Pulp and Paper
040604	Paper pulp (Neutral Sulphite Semi-Chemical process)	2D1	Industrial processes-Other Production-Pulp and Paper
040605	Bread	2D2	Food and Drink
040606	Wine	2D2	Food and Drink
040607	Beer	2D2	Food and Drink
040608	Spirits	2D2	Food and Drink
040610	Roof covering with asphalt materials	2A5	Industrial processes-Mineral Products-Asphalt Roofing
040611	Road paving with asphalt	2A6	Industrial processes-Mineral Products-Road Paving with Asphalt
040612	Cement (decarbonizing)	2A1	Industrial processes-Mineral Products-Cement production
040613	Glass (decarbonizing)	2A7d	Industrial processes-Mineral Products-Other
040614	Lime (decarbonizing)	2A2	Industrial processes-Mineral products/Lime production
040615	Batteries manufacturing	2A7d	Industrial processes-Mineral Products-Other
040616	Extraction of mineral ores	2A7a	Industrial processes-Mineral Products-Quarrying and mining
040617	Other (including asbestos products manufacturing)	2G	Industrial processes-Other
040618	Limestone and dolomite use	2A3	Industrial processes-Limestone and Dolomite use
040619	Soda ash production and use	2A4	Industrial processes-Soda Ash production and use
040620	Wood manufacturing	2D3	Wood processing
040621	Cereals handling	2D2	Food and drink
040622	Explosives manufacturing	2B5a	Other chemical industry
040624	Public works and building sites	2A7b	Construction and demolition
040625	Sugar production	2D2	Food and drink
040626	Flour production	2D2	Food and drink
040627	Meat curing	2D2	Food and drink
040628	Bricks and tiles (decarbonizing)	2A7d	Other mineral products
040629	Fine ceramic materials (decarbonizing)	2A7d	Other mineral products
040630	Paper mill industry (decarbonizing)	2A7d	Other mineral products
040691	Production of yellow bricks	2A2	Industrial processes-Mineral products/Lime production
040692	Expanded clay products	2A2	Industrial processes-Mineral products/Lime production
040698	Margarine and solid cooking fats	2D2	Food and drink
040699	Coffee roasting	2D2	Food and drink
040800	Production of halocarbons and sulphur hexafluoride		
040801	Halogenated hydrocarbons production - By-products		
040802	Halogenated hydrocarbons production - Fugitive		
040803	Halogenated hydrocarbons production - Other		
040804	Sulphur hexafluoride production - By-products		
040805	Sulphur hexafluoride production - Fugitive		
040806	Sulphur hexafluoride production - Other		
050100	Extraction and 1st treatment of solid fossil fuels	1B1a	Coal mining and handling

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
050101	Open cast mining	1B1a	Coal mining and handling
050102	Underground mining	1B1a	Coal mining and handling
050103	Storage of solid fuel	1B1a	Coal mining and handling
050200	Extraction, 1st treatment and loading of liquid fossil fuels	1B2a i	Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport
050201	Land-based activities	1B2a i	Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport
050202	Off-shore activities	1B2a i	Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport
050300	Extraction, 1st treatment and loading of gaseous fossil fuels	1B2b	Fugitive Emissions from Fuels, Natural gas
050301	Land-based desulfuration	1B2b	Fugitive Emissions from Fuels, Natural gas
050302	Land-based activities (other than desulfuration)	1B2b	Fugitive Emissions from Fuels, Natural gas
050303	Off-shore activities	1B2b	Fugitive Emissions from Fuels, Natural gas
050400	Liquid fuel distribution (except gasoline distribution)	1B2a i	Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport
050401	Marine terminals (tankers, handling and storage)	1B2a i	Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport
050402	Other handling and storage (including pipeline)	1B2a i	Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport
050500	Gasoline distribution	1B2a v	Fugitive Emissions from Fuels, Distribution of oil products
050501	Refinery dispatch station	1B2a v	Fugitive Emissions from Fuels, Distribution of oil products
050502	Transport and depots (except 05.05.03)	1B2a v	Fugitive Emissions from Fuels, Distribution of oil products
050503	Service stations (including refuelling of cars)	1B2a v	Fugitive Emissions from Fuels, Distribution of oil products
050600	Gas distribution networks	1B2b	Fugitive Emissions from Fuels, Natural gas
050601	Pipelines	1B2b	Fugitive Emissions from Fuels, Natural gas
050603	Distribution networks	1B2b	Fugitive Emissions from Fuels, Natural gas
050699	Venting in gas storage	1B2c	Fugitive emissions from fuels-Oil and natural gas/Flaring in oil/gas extraction
050700	Geothermal energy extraction	1B2a vi	Geothermal energy extraction
060100	Paint application	3A1	Solvent and other product use-Paint application
060101	Paint application : manufacture of automobiles	3A2	Solvent and other product use-Paint application
060102	Paint application : car repairing	3A2	Solvent and other product use-Paint application
060103	Paint application : construction and buildings	3A1	Solvent and other product use-Paint application
060104	Paint application : domestic use (except 06.01.07)	3A1	Solvent and other product use-Paint application
060105	Paint application : coil coating	3A2	Solvent and other product use-Paint application
060106	Paint application : boat building	3A2	Solvent and other product use-Paint application
060107	Paint application : wood	3A2	Solvent and other product use-Paint application
060108	Other industrial paint application	3A2	Solvent and other product use-Paint application
060109	Other non industrial paint application	3A3	Solvent and other product use-Paint application
060200	Degreasing, dry cleaning and electronics	3B1	Solvent and other product use-Degreasing and dry cleaning
060201	Metal degreasing	3B1	Solvent and other product use-Degreasing and dry cleaning
060202	Dry cleaning	3B2	Solvent and other product use-Degreasing and dry cleaning
060203	Electronic components manufacturing	3B1	Solvent and other product use-Degreasing and dry cleaning
060204	Other industrial cleaning	3B1	Solvent and other product use-Degreasing and dry cleaning
060300	Chemical products manufacturing or processing	3C	Solvent and other product use-Chemical products
060301	Polyester processing	3C	Solvent and other product use-Chemical products

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
060302	Polyvinylchloride processing	3C	Solvent and other product use-Chemical products
060303	Polyurethane processing	3C	Solvent and other product use-Chemical products
060304	Polystyrene foam processing	3C	Solvent and other product use-Chemical products
060305	Rubber processing	3C	Solvent and other product use-Chemical products
060306	Pharmaceutical products manufacturing	3C	Solvent and other product use-Chemical products
060307	Paints manufacturing	3C	Solvent and other product use-Chemical products
060308	Inks manufacturing	3C	Solvent and other product use-Chemical products
060309	Glues manufacturing		
060310	Asphalt blowing	3C	Solvent and other product use-Chemical products
060311	Adhesive, magnetic tapes, films and photographs	3C	Solvent and other product use-Chemical products
060312	Textile finishing	3C	Solvent and other product use-Chemical products
060313	Leather tanning	3C	Solvent and other product use-Chemical products
060314	Other	3C	Solvent and other product use-Chemical products
060400	Other use of solvents and related activities	3D3	Solvent and other product use-Other
060401	Glass wool enduction	3D3	Solvent and other product use-Other
060402	Mineral wool enduction	3D3	Solvent and other product use-Other
060403	Printing industry	3D1	Solvent and other product use-Other
060404	Fat, edible and non edible oil extraction	3D3	Solvent and other product use-Other
060405	Application of glues and adhesives	3D3	Solvent and other product use-Other
060406	Preservation of wood	3D3	Solvent and other product use-Other
060407	Underseal treatment and conservation of vehicles	3D3	Solvent and other product use-Other
060408	Domestic solvent use (other than paint application)	3D2	Solvent and other product use-Other
060409	Vehicles dewaxing	3D3	Solvent and other product use-Other
060411	Domestic use of pharmaceutical products	3D3	Solvent and other product use-Other
060412	Other (preservation of seeds)	3D3	Solvent and other product use-Other
060500	Use of HFC, N2O, NH3, PFC and SF6	3D3	
060501	Anaesthesia	3D3	Anaesthesia
060502	Refrigeration and air conditioning equipments using halocarbons		
060503	Refrigeration and air conditioning equipments using other products than halocarbons	3D3	Refrigeration and air conditioning equipment
060504	Foam blowing (except 060304)		
060505	Fire extinguishers		
060506	Aerosol cans	3D3	Aerosol cans
060507	Electrical equipments		
060508	Other	3D3	Solvent and other product use-Other (except halocarbons and sulphur hexafluoride)
060601	Use of fireworks	3D3	Other product use
060602	Use of tobacco	3D3	Other product use
060603	Use of shoes	3D3	Other product use
060604	Lubricants		
070100	Passenger cars	1A3b i	Road Transportation, Passenger Cars
070101	Highway driving	1A3b i	Road Transportation, Passenger Cars
070102	Rural driving	1A3b i	Road Transportation, Passenger Cars
070103	Urban driving	1A3b i	Road Transportation, Passenger Cars
070200	Light duty vehicles < 3.5 t	1A3b ii	Road Transportation, Light duty vehicles
070201	Highway driving	1A3b ii	Road Transportation, Light duty vehicles
070202	Rural driving	1A3b ii	Road Transportation, Light duty vehicles
070203	Urban driving	1A3b ii	Road Transportation, Light duty vehicles
070300	Heavy duty vehicles > 3.5 t and buses	1A3b iii	Road Transportation, Heavy duty vehicles
070301	Highway driving	1A3b iii	Road Transportation, Heavy duty vehicles
070302	Rural driving	1A3b iii	Road Transportation, Heavy duty vehicles
070303	Urban driving	1A3b iii	Road Transportation, Heavy duty vehicles
070400	Mopeds and Motorcycles < 50 cm3	1A3b iv	Road Transportation, Mopeds and motorcycles

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
070500	Motorcycles > 50 cm3	1A3b iv	Road Transportation, Mopeds and motorcycles
070501	Highway driving	1A3b iv	Road Transportation, Mopeds and motorcycles
070502	Rural driving	1A3b iv	Road Transportation, Mopeds and motorcycles
070503	Urban driving	1A3b iv	Road Transportation, Mopeds and motorcycles
070600	Gasoline evaporation from vehicles	1A3b v	Gasoline Evaporation from vehicles
070700	Automobile tyre and brake wear	1A3b vi	Automobile tyre and brake wear
070800	Automobile road abrasion	1A3b vii	Automobile road abraision
080100	Military	1A5b	Other, Mobile (including military)
080200	Railways	1A3c	Transport-Railways
080201	Shunting locs	1A3c	Transport-Railways-Shunting logs
080202	Rail-cars	1A3c	Transport-Railways-Rail cars
080203	Locomotives	1A3c	Transport-Railways-Locomotives
080300	Inland waterways	1A3d ii	Transport-Navigation, National navigation
080301	Sailing boats with auxilliary engines	1A3d ii	Transport-Navigation, National navigation
080302	Motorboats / workboats	1A3d ii	Transport-Navigation, National navigation
080303	Personal watercraft	1A3d ii	Transport-Navigation, National navigation
080304	Inland goods carrying vessels	1A3d ii	Transport-Navigation, National navigation
080400	Maritime activities	1A3d ii	
080402	National sea traffic within EMEP area	1A3d ii	Transport-Navigation, National navigation
080403	National fishing	1A4c iii	Small combustion-Agriculture/Forestry/Fishing
080404	International sea traffic (international bunkers)	1A3d i (i)	Transport-Navigation, International marine (bunkers)
080500	Air traffic	1A3a	
080501	Domestic airport traffic (LTO cycles - <1000 m)	1A3a ii (i)	Transport-Civil aviation, Domestic, LTO
080502	International airport traffic (LTO cycles - <1000 m)	1A3a i (i)	Transport-Civil aviation, International, LTO
080503	Domestic cruise traffic (>1000 m)	1A3a ii (ii)	Transport-Civil aviation, Domestic, Cruise
080504	International cruise traffic (>1000 m)(i)	1A3a i (ii)	Transport-Civil aviation, International, Cruise
080600	Agriculture	1A4c ii	Small combustion-Agriculture/Forestry/Fishing - Off road vehicles and other machinery
080700	Forestry	1A4c ii	Small combustion-Agriculture/Forestry/Fishing - Off road vehicles and other machinery
080800	Industry	1A2f ii	Industry-Mobile
080900	Household and gardening	1A4b ii	Small combustion-Residential, Household and gardening (mobile)
081000	Other off-road	1A4a ii	Commercial/Institutional-Mobile
081100	Off-road - Commercial and institutional	1A4a ii	Commercial/Institutional-Mobile
081101	Exhaust engine		
081102	Tyre and brake wear abrasion		
090200	Waste incineration	6C	
090201	Incineration of domestic or municipal wastes	6Cc	MSW-Incineration
090202	Incineration of industrial wastes (except flaring)	6Cb	Industrial waste-Incineration
090203	Flaring in oil refinery	1B2c	Fugitive emissions from fuels-Oil and natural gas/Flaring in oil refinery
090204	Flaring in chemical industries	6Ca	Flaring in chemical industry
090205	Incineration of sludges from waste water treatment	6Cb	Sludge from waste water treatment-Incineration
090206	Flaring in gas and oil extraction	1B2c	Fugitive emissions from fuels-Oil and natural gas/Flaring in oil/gas extraction
090207	Incineration of hospital wastes	6Ca	Hospital waste-Incineration
090208	Incineration of waste oil	6Cb	Waste oil-Incineration
090400	Solid Waste Disposal on Land	6A	
090401	Managed Waste Disposal on Land	6A	Waste-Solid waste disposal on land-Managed Disposal
090402	Unmanaged Waste Disposal Sites	6A	Waste-Solid waste disposal on land-Unmanaged Sites
090403	Other	6A	Waste-Solid waste disposal on land-Other
090700	Open burning of agricultural wastes (except SNAP 1003)	6Ce	Open burning of agricultural waste

List of SNAP codes, SNAP names and corresponding NFR codes and names:

SNAP id	SNAP name	NFR id	NFR name
090900	Cremation	6Cd	Cremation
090901	Incineration of corpses	6Cd	Incineration of corpses
090902	Incineration of carcasses	6Cd	Incineration of carcasses
091000	Other waste treatment	6B	
091001	Waste water treatment in industry	6B	Waste-Wastewater treatment/Industrial
091002	Waste water treatment in residential/commercial sector	6B	Waste-Wastewater treatment/Domestic and commercial
091003	Sludge spreading	6D	Sludge spreading
091005	Compost production	6D	Compost production
091006	Biogas production	6D	Biogas production
091007	Latrines	6B	Waste-Wastewater treatment/Latrines
091008	Other production of fuel (refuse derived fuel)		
091009	Accidental fires	6D	Accidental fires
091099	N_2O from human sewage		

Appendix C: List of GNFR codes and corresponding NFR codes

GNFR code	NFR code	Longname
A_PublicPower	1 A 1 a	Public Electricity and Heat Production
B_IndustrialComb	1 A 1 b	Petroleum refining
B_IndustrialComb	1 A 1 c	Manufacture of Solid Fuels and Other Energy Industries
B_IndustrialComb	1 A 2 a	Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel
B_IndustrialComb	1 A 2 b	Stationary Combustion in Manufacturing Industries and Construction: Non-ferrous Metals
B_IndustrialComb	1 A 2 c	Stationary Combustion in Manufacturing Industries and Construction: Chemicals
B_IndustrialComb	1 A 2 d	Stationary Combustion in Manufacturing Industries and Construction: Pulp, Paper and Print
B_IndustrialComb	1 A 2 e	Stationary Combustion in Manufacturing Industries and Construction: Food Processing, Beverages and Tobacco
B_IndustrialComb	1 A 2 f i	Stationary Combustion in Manufacturing Industries and Construction: Other
B_IndustrialComb	1 A 5 a	Other, Stationary (including Military)
C_SmallComb	1 A 4 a i	Commercial / institutional: Stationary
C_SmallComb	1 A 4 b i	Residential: Stationary plants
C_SmallComb	1 A 4 c i	Agriculture/Forestry/Fishing: Stationary
D_IndProcess	2 A 1	Cement Production
D_IndProcess	2 A 2	Lime Production
D_IndProcess	2 A 3	Limestone and Dolomite Use
D_IndProcess	2 A 4	Soda Ash Production and use
D_IndProcess	2 A 5	Asphalt Roofing
D_IndProcess	2 A 6	Road Paving with Asphalt
D_IndProcess	2 A 7 a	Quarrying and mining of minerals other than coal
D_IndProcess	2 A 7 b	Construction and demolition
D_IndProcess	2 A 7 c	Storage, handling and transport of mineral products
D_IndProcess	2 A 7 d	Other Mineral products
D_IndProcess	2 B 1	Ammonia Production
D_IndProcess	2 B 2	Nitric Acid Production
D_IndProcess	2 B 3	Adipic Acid Production
D_IndProcess	2 B 4	Carbide Production
D_IndProcess	2 B 5 a	Other chemical industry
D_IndProcess	2 B 5 b	Storage, handling and transport of chemical products
D_IndProcess	2 C 1	Iron and Steel Production
D_IndProcess	2 C 2	Ferroalloys Production
D_IndProcess	2 C 3	Aluminum Production
D_IndProcess	2 C 5 a	Copper Production
D_IndProcess	2 C 5 b	Lead Production
D_IndProcess	2 C 5 c	Nickel Production
D_IndProcess	2 C 5 d	Zinc Production
D_IndProcess	2 C 5 e	Other metal production
D_IndProcess	2 C 5 f	Storage, handling and transport of metal products
D_IndProcess	2 D 1	Pulp and Paper
D_IndProcess	2 D 2	Food and Drink
D_IndProcess	2 D 3	Wood processing
D_IndProcess	2 E	Production of POPs
D_IndProcess	2 F	Consumption of POPs and Heavy Metals (e.g. electrical and scientific equipment)
D_IndProcess	2 G	Other production, consumption, storage, transportation or handling of bulk products
E_Fugitive	1 B 1 a	Fugitive emission from Solid Fuels: Coal Mining and Handling
E_Fugitive	1 B 1 b	Fugitive emission from Solid Fuels:Solid fuel transformation

GNFR code	NFR code	Longname
E_Fugitive	1 B 1 c	Other fugitive emissions from solid fuels
E_Fugitive	1 B 2 a i	Exploration Production, Transport
E_Fugitive	1 B 2 a iv	Refining / Storage
E_Fugitive	1 B 2 a v	Distribution of oil products
E_Fugitive	1 B 3	Other fugitive emissions from geothermal energy production , peat and other energy extraction not included in 1 B 2
E_Fugitive	1 B 2 b	Natural gas
E_Fugitive	1 B 2 c	Venting and flaring
F_Solvents	3 A 1	Decorative coating application
F_Solvents	3 A 2	Industrial coating application
F_Solvents	3 A 3	Other coating application
F_Solvents	3 B 1	Degreasing
F_Solvents	3 B 2	Dry cleaning
F_Solvents	3 C	Chemical products
F_Solvents	3 D 1	Printing
F_Solvents	3 D 2	Domestic solvent use including fungicides
F_Solvents	3 D 3	Other product use
G_RoadRail	1 A 3 b i	Road Transport:, Passenger cars
G_RoadRail	1 A 3 b ii	Road Transport:, Light duty vehicles
G_RoadRail	1 A 3 b iii	Road transport:, Heavy duty vehicles
G_RoadRail	1 A 3 b iv	Road Transport:, Mopeds & Motorcycles
G_RoadRail	1 A 3 b v	Road Transport:, Gasoline evaporation
G_RoadRail	1 A 3 b vi	Road Transport:, Automobile tyre and brake wear
G_RoadRail	1 A 3 b vii	Road transport:, Automobile road abrasion
G_RoadRail	1 A 3 c	Railways
H_Shipping	1 A 3 d i (ii)	International inland waterways
H_Shipping	1 A 3 d ii	National navigation (Shipping)
H_Shipping	1A 4 c iii	Agriculture/Forestry/Fishing: National Fishing
I_OffRoadMob	1 A 2 f ii	Mobile Combustion in Manufacturing Industries and Construction
I_OffRoadMob	1 A 3 e	Pipeline compressors
I_OffRoadMob	1 A 4 a ii	Commercial / institutional: Mobile
I_OffRoadMob	1 A 4 b ii	Residential: Household and gardening (mobile)
I_OffRoadMob	1 A 4 c ii	Agriculture/Forestry/Fishing: Off-road Vehicles and Other Machinery
I_OffRoadMob	1 A 5 b	Other, Mobile (Including military, land based and recreational boats)
J_CivilLTO	1 A 3 a ii (i)	Civil Aviation (Domestic, LTO)
K_InternationalLTO	1 A 3 a i (i)	International aviation (LTO)
L_OtherWasteDisp	6 A	Solid waste disposal on land
L_OtherWasteDisp	6 D	Other waste(e)
M_WasteWater	6 B	Waste-water handling
N_WasteIncin	6 C a	Clinical waste incineration (d)
N_WasteIncin	6 C b	Industrial waste incineration (d)
N_WasteIncin	6 C c	Municipal waste incineration (d)
N_WasteIncin	6 C d	Cremation
N_WasteIncin	6 C e	Small scale waste burning
O_AgriLivestock	4 B 1 a	Cattle dairy
O_AgriLivestock	4 B 1 b	Cattle non-dairy
O_AgriLivestock	4 B 2	Buffalo
O_AgriLivestock	4 B 3	Sheep
O_AgriLivestock	4 B 4	Goats
O_AgriLivestock	4 B 6	Horses
O_AgriLivestock	4 B 7	Mules and asses
O_AgriLivestock	4 B 8	Swine
O_AgriLivestock	4 B 9 a	Laying hens
O_AgriLivestock	4 B 9 b	Broilers

GNFR code	NFR code	Longname
O_AgriLivestock	4 B 9 c	Turkeys
O_AgriLivestock	4 B 9 d	Other Poultry
O_AgriLivestock	4 B 13	Other
P_AgriOther	4 D 1 a	Synthetic N-fertilizers
P_AgriOther	4 D 2 a	Farm-level agricultural operations including storage, handling and transport of agricultural products
P_AgriOther	4 D 2 b	Off-farm storage, handling and transport of bulk agricultural products
P_AgriOther	4 D 2 c	N-excretion on pasture range and paddock Unspecified
P_AgriOther	4 G	Agriculture other(c)
Q_AgriWastes	4 F	Field burning of agricultural wastes
R_Other	7 A	Other (included in National Total for Entire Territory)
S_Natural	7 B	Other not included in national total of the entire territory
S_Natural	11A	X (11 08 Volcanoes)
S_Natural	11 B	FF Forest fires
z_Memo	1 A 3 a ii (ii)	Civil aviation (Domestic, Cruise)
z_Memo	1 A 3 a i (ii)	International aviation (Cruise)
z_Memo	1 A 3 d i (i)	International maritime navigation
z_Memo	1 A 3	Transport (fuel used)
z_Shipping	1 A 3 d i (ii)	International inland waterways

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SPATIAL DISTRIBUTION OF EMISSIONS TO AIR – THE SPREAD MODEL

The National Environmental Research Institute (NERI), Aarhus University, completes the annual national emission inventories for greenhouse gases and air pollutants according to Denmark's obligations under international conventions, e.g. the climate convention, UNFCCC and the con-vention on long-range transboundary air pollution, CLRTAP. NERI has developed a model to distribute emissions from the national emission inventories on a 1x1 km grid covering the Dan-ish land and sea territory. The new spatial high resolution distribution model for emissions to air (SPREAD) has been developed according to the requirements for reporting of gridded emis-sions to CLRTAP. Spatial emission data is e.g. used as input for air quality modelling, which again serves as input for assessment and evaluation of health effects. For these purposes dis-tributions with higher spatial resolution have been requested. Previously, a distribution on the 17x17 km EMEP grid has been set up and used in research projects combined with detailed distributions for a few sectors or sub-sectors e.g. a distribution for emissions from road traffic on 1x1 km resolution. SPREAD is developed to generate improved spatial emission data for e.g. air quality modelling in exposure studies. SPREAD includes emission distributions for each sec-tor in the Danish inventory system; stationary combustion, mobile sources, fugitive emissions from fuels, industrial processes, solvents and other product use, agriculture and waste. This model enables generation of distributions for single sectors and for a number of sub-sectors and single sources as well. This report documents the methodologies in this first version of SPREAD and presents selected results. Further, a number of potential improvements for later versions of SPREAD are addressed and discussed.

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