SPATIAL HIGH-RESOLUTION DISTRIBUTION OF EMISSIONS TO AIR – SPREAD 3.0

Technical Report from DCE – Danish Centre for Environment and Energy No. 215 2021

AARHUS
UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

[Blank page]

SPATIAL HIGH-RESOLUTION DISTRIBUTION OF EMISSIONS TO AIR – SPREAD 3.0

Technical Report from DCE – Danish Centre for Environment and Energy No. 215 2021

Marlene S. Plejdrup
Ole-Kenneth Nielsen
Steen Gyldenkærne
Henrik G. Bruun

Aarhus Universitet, Department of Environmental Science

AARHUS
UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

Data sheet

Series title and no.:	Technical Report from DCE – Danish Centre for Environment and Energy No. 215
Category:	Scientific advisory report
Title:	Spatial high-resolution distribution of emissions to air – SPREAD 3.0
Authors:	Marlene S. Plejdrup, Ole-Kenneth Nielsen, Steen Gyldenkærne, Henrik G. Bruun
Institution:	Aarhus University, Department of Environmental Science
Publisher:	Aarhus University, DCE – Danish Centre for Environment and Energy ©
URL:	http://dce.au.dk/en
Year of publication:	August 2021
Editing completed:	August 2021
Referee:	Kaj Mantzius Hansen
Quality assurance, DCE:	Vibeke Vestergaard Nielsen
Financial support:	No external financial support
Please cite as:	Plejdrup, M.S., Nielsen, O.-K., Gyldenkærne, S. & Bruun, H.G. 2021. Spatial high-resolution distribution of emissions to air – SPREAD 3.0. Aarhus University, DCE – Danish Centre for Environment and Energy, 208 pp. Technical Report No. 215 http://dce2.au.dk/pub/TR215.pdf

Abstract: The report documents the model for spatially distributing emissions. The model has undergone significant improvements since the last published version in 2018. The model covers all emissions of air pollutants included in the Danish reporting under the Convention on Long-Range Transboundary Air Pollution and the National Emission Ceilings Directive. The model distributes emissions on a 1 km x 1 km grid and the outputs are used for reporting under international agreements as well as for air quality modelling.

Keywords:	Emissions, spatial distribution, air pollution, SPREAD
Layout:	Ann-Katrine Holme Christoffersen
Front page photo:	Marlene S. Plejdrup
ISBN:	978-87-7156-618-5
ISSN (electronic):	2244-999X
Number of pages:	208
Internet version:	The report is available in electronic format (pdf) at http://dce2.au.dk/pub/TR215.pdf

Contents

List of abbreviations

AS	Area Sources
AU	Aarhus University
BaP	Benzo(a)pyrene
BbF	Benzo(b)fluoranthene
BBR	Building and dwelling register
BC	Black carbon
BkF	Benzo(k)flouranthene
CHP	Combined Heat and Power
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	Carbon dioxide
CRF	Common Reporting Format
DCE	Danish Centre for Environment and Energy
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EIONET	European Environment Information and Observation Network
EMEP	European Monitoring and Evaluation Programme
ENVS	Department of Environmental Science, AU
EPT	Database of electricity and / or heat producing plants to the grid
IDA	Integrated Database for Agriculture
GeoKey	Spatial distribution key
GIS	Geographical Information System
GNFR	Gridding Nomenclature for Reporting
HCB	Hexachlorobenzene
IcdP	Indeno(1,2,3-cd)Pyrene
IPPU	Industrial Processes and Product Use
LPS	Large Point Sources
NECD	National Emission Ceilings Directive
NFR	Nomenclature for Reporting
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen oxides
PAHs	Polycyclic Aromatic Hydrocarbons (BaP, BbF, BkF and IcdP)
PCBs	Polychlorinated biphenyls
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
TSP	Total Suspended Particulates
SFL	Association of Danish chimneysweepers
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
SPREAD	Spatial High Resolution Emission to Air Distribution Model
UNECE	United Nations Economic Commission for Europe

List of Tables

List of Figures

Preface

This report documents the methodology and data used for the spatial distribution of emissions of air pollution on a 1 km x 1 km grid.

This report describes the updated version of SPREAD that has been improved through continuous work primarily through some specific projects. The report documents the methodologies and data used in SPREAD and presents selected results. Further, a number of potential improvements for later versions of SPREAD are addressed and discussed.

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

The authors would like to thank:

- The Danish Energy Agency for providing the database on plants producing heat and/or electricity to the public grid, and for providing detailed information on location and activities for offshore installations in oil and gas production;
- The Association of Danish Chimney Sweepers for providing detailed data on the location and types of small-scale combustion installations;
- Michael Mucke Jensen, Danish Petroleum Association, for GIS data on service stations in Denmark;
- Erling Krappe, Danish Forest and Nature Agency, for delivering data on military training terrains;
- Jørn Hougaard Sørensen, Energinet.dk for data on location of transmissions stations on the natural gas network;
- Steen Solvang Jensen, Department of Environmental Science, , Aarhus University, for providing data on road traffic from the National Road and Transport Database;
- Trine Østergaard Rasmussen, for contributing to improvements of the GeoKeys for fishing, national navigation and non-road machinery in industry;
- Professor Henning Sten Hansen, Aalborg University, for reviewing and contributing valuable comments to the first version of the SPREAD model;
- Thomas Becker, Agency for Data Supply and Efficiency, for reviewing and contributing valuable comments to the previous report.

Additionally, the authors wish to acknowledge the improvements to the SPREAD model made possible through the following projects:

- ”Health impacts and external costs from air pollution in Denmark over 25 years” funded by the Danish Centre for Environment and Energy;
- NordicWelfAir (Understanding the link between Air pollution and Distribution of related Health Impacts and Welfare in the Nordic countries) funded by NordForsk;
- ”Luftforurening fra togdrift i byområder” (Air pollution from railways in urban areas) funded by the Danish Environmental Protection Agency;
- “Luftforurening fra mobile ikke-vejgående maskiner i byområder” (Air pollution from non-road machinery in urban areas) funded by the Danish Environmental Protection Agency.

Summary

The Department of Environmental Science (ENVS) at Aarhus University (AU) is working on research in several areas, one of which is atmospheric pollution. This research includes the links between emissions, atmospheric dispersion, human exposure and related costs. Part of this research is the spatial distribution of emissions as input to air quality modelling.

The Danish Centre on Environment and Energy (DCE), Aarhus University (AU) is contracted by the Ministry of Environment and the Ministry of Energy, Utilities and Climate to compile and report annual national emission inventories for greenhouse gases and air pollutants. The compilation and reporting is done in accordance with Denmark's obligations under international conventions, e.g. the Climate Convention (UNFCCC) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and EU regulations, e.g. the National Emission Ceilings Directive (NECD) and the Monitoring Mechanism Regulation (MMR).

The work is carried out by the Department of Environmental Science (ENVS).

Under the CLRTAP and the NECD, there is a requirement to report gridded emissions every four years. In addition, DCE is also tasked with publishing spatial data of diffuse emissions as defined under the Pollutant Release and Transfer Register (PRTR) regulation.

Before 2011, the Danish emission inventory was available on the 50 km x 50 km EMEP grid for reporting of air pollutants to CLRTAP every fifth year.

In 2011, the first version of a spatial high-resolution distribution model for emissions to air (SPREAD) was published. This model used a higher resolution (1 km x 1 km), to increase the usefulness of the data in air quality modelling. The higher resolution was also chosen in anticipation of changes to the EMEP grid moving towards a higher resolution. This high-resolution distribution has been used in research projects focussing on either all emission sectors or in case studies for one or a few sectors, e.g. a distribution of emissions from residential wood combustion on 1 km x 1 km resolution.

The current EMEP grid is a 0.1 degree x 0.1 degree resolution, which for Denmark implies grid cells with a dimension of approximately 6 km x 11 km.

The development of the SPREAD model has largely been driven by the participation in research projects. Resources from the framework contract between AU and the Ministry of Environment and Food has been used to implement the new EMEP grid.

SPREAD includes emission distributions for each sector emitting air pollution in the Danish inventory system. The main sectors are stationary combustion, mobile combustion, fugitive emissions from fuels, industrial processes and product use, agriculture and waste. However, the spatial distribution is carried out at the most detailed level possible. Currently, greenhouse gases are not included in the model.

Sammenfatning

Institut for Miljøvidenskab ved Aarhus Universitet beskæftiger sig med forskning inden for flere områder. Et af disse områder er luftforurening. Forskningen inkluderer sammenhængen mellem emissioner, spredning i atmosfæren, eksponering samt relaterede samfundsmæssige omkostninger. En del af denne forskning er geografisk fordeling af emissioner som input til atmosfærisk modellering.

Nationalt Center for Miljø og Energi (DCE) ved Aarhus Universitet udarbejder årligt emissionsopgørelser for luftforurening og drivhusgasser på kontrakt for Miljøministeriet og Energi-, Forsynings-, og Klimaministeriet. Emissionsopgørelsen og rapporteringen af denne udføres i henhold til Danmarks forpligtigelser under internationale konventioner som FN's klimakonvention (UNFCCC) og FN's konvention om langtransporteret grænseoverskridende luftforurening (UNECE - CLRTAP), samt Danmarks EU-forpligtigelser som direktivet om nationale emissionslofter (NECD) og forordningen om en mekanisme til overvågning og rapportering af drivhusgasemissioner (MMR).

Arbejdet udføres af Aarhus Universitet, Institut for Miljøvidenskab (ENVS).

Under CLRTAP og NECD er der også en forpligtigelse til at rapportere geografisk fordelte emissioner hvert fjerde år. Derudover er DCE også forpligtet til at offentliggøre geografisk fordelte data af diffuse emissioner som defineret under PRTR-forordningen (PRTR: Pollutant Release and Transfer Register).

Før 2011 var den danske geografiske fordeling tilgængelig på EMEP's gitternet med en opløsning på 50 km x 50 km, som blev brugt til rapporteringen til UNECE hvert femte år.

I 2011 blev den første udgave af en geografisk højopløsnings-fordelingsmodel for luftemissioner (SPREAD) publiceret. Denne model blev udviklet med en meget højere opløsning (1 km x 1 km) for at øge anvendelsen af data som input til luftkvalitetsmodellering. Skiftet til en højere opløsning, blev også foretaget i forventning om, at EMEP's gitternet ville blive opdateret med en højere opløsning. Fordelingen med den høje opløsning er anvendt i forskningsprojekter, der enten har fokuseret på alle emissionssektorer eller som detailstudie med fokus på en eller få sektorer, f.eks. fordeling af emissioner fra brændeovne.

Det nuværende EMEP-gitternet er med en opløsning på 0.1 grad x 0.1 grad, hvilket for Danmark svarer til et gitternet på ca. 6 km x 11 km.

Udviklingen af SPREAD-modellen har været drevet af deltagelse i forskningsprojekter. Ressourcer fra rammekontrakten mellem AU og Miljø- og Fødevareministeriet er blevet brugt til at implementere den nye EMEP-gitternet.

SPREAD inkluderer emissionsfordelinger for alle sektorer, der udleder luftforurening. Hovedsektorerne er stationær forbrænding, mobil forbrænding, industrielle processer, landbrug og affald. Den geografiske fordeling foretages på det mest detaljerede niveau muligt. På nuværende tidspunkt er drivhusgasser ikke omfattet af modellen.

1 Introduction

The Department of Environmental Science (ENVS) at Aarhus University (AU) is working on research in several areas, one of which is atmospheric pollution. This research includes the links between emissions, atmospheric dispersion, human exposure and related costs. Part of this research is the spatial distribution of emissions as input to the air quality modelling.

The Danish Centre on Environment and Energy (DCE), Aarhus University (AU) is contracted by the Ministry of Environment and the Ministry of Energy, Utilities and Climate to compile and report annual national emission inventories for greenhouse gases and air pollutants. The compilation and reporting is done in accordance with Denmark's obligations under international conventions, e.g. the Climate Convention (UNFCCC) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and EU regulations, e.g. the National Emission Ceilings Directive (NECD) (EU, 2016) and the Monitoring Mechanism Regulation (MMR) (EU, 2013).

The work is carried out by the Department of Environmental Science (ENVS).

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 and the MMR, and the Nomenclature for Reporting (NFR) used for reporting to CLRTAP and NECD, respectively.

The methodologies in the Danish emission inventories follow the international guidelines provided by the IPCC, i.e. the 2006 IPCC Guidelines (IPCC, 2006) for the greenhouse gas emission inventories and the EMEP / EEA Guidebook (EEA, 2019) for the emission inventories for air pollution.

Emission data from the national inventories are often used as input for modelling of air quality, which again serves as input in e.g. assessment and evaluation of health impacts. Spatial emissions from SPREAD are e.g. used as input to the Danish Air Quality Monitoring Programme, NOVANA (Ellermann et al., 2020). In order to make a more suitable input for air quality models, emissions must be given on a more disaggregated level than national level. Until 2010, the Danish emission inventory was available on the 50 km x 50 km EMEP grid for reporting of air pollutants to CLRTAP every fifth year. The methodology is described in a Danish-language report (Jensen et al., 2008).

In 2011, the new spatial high-resolution distribution model for emissions to air, SPREAD, was developed at ENVS (Plejdrup & Gyldenkærne, 2011). SPREAD enables distribution of the Danish emissions for all air pollutants and all sectors in the national emission database on a 1 km x 1 km grid covering Denmark and its exclusive economic zone. The model does not include Greenland and the Faroe Islands. The model is set up in Microsoft Access databases and the spatial distribution keys (GeoKeys) are set up in GIS (ArcMAP). Output tables are transformed to shape files for visualisation in GIS. SPREAD uses the datum ETRS89 and the projection is UTM zone 32N.

In 2018 an updated version of SPREAD was prepared, SPREAD 2.0 (Plejdrup et al., 2018). The model setup was changed to improve the system and performance, and besides MS Acces, use of an MS SQL database was implemented.

Besides the restructuring of the model system, part of the GeoKeys were updated with new or updated data.

Since the second version, further improvements have been made to the SPREAD model system. GeoKeys have been updated, new GeoKeys have been prepared and new emission sources in the national emission inventory have been included in SPREAD. Minor changes have been made to the model setup focussing on performance optimisation. All improvements are documented in this report, providing SPREAD 3.0.

This report presents the methodologies in the updated version of SPREAD set up for spatial distribution of the Danish emission inventory on the 1 km x 1 km Danish Grid Net.

The model includes emissions of the following pollutants:

- **Main pollutants:** sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), ammonia (NH_3)
- **Particulate matter:** 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 ($PM_{2.5}$), black carbon (BC)
- **Heavy metals:** arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn)
- **Persistent organic pollutants:** dioxins and furans (PCDD/F), hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs) and the polycyclic aromatic hydrocarbons (PAHs): benzo(b)flouranthene (BbF), benzo(k)flouranthene (BkF), benzo(a)pyrene (BaP) and indeno(1,2,3-c,d)pyrene (IcdP).

Currently, the SPREAD model does not include any greenhouse gases, but it will be possible to extend the model to include greenhouse gases in the future.

The distribution in SPREAD is in general made on SNAP (Selected Nomenclature for Air Pollution) category level in correspondence with the Danish inventory system to assure the most detailed distribution of the emissions. The SNAP categorisation follows a six digit code system, where the first two digits indicates the main sector (e.g. 07 = road transport), the next two digits provides a further subdivision (e.g. 0701 = road transport, passenger cars) and the final two digits provide a further disaggregation (e.g. 070101 = road transport, passenger cars, highway driving).

For the reporting other less detailed categorisations are used, i.e. the Nomenclature for reporting (NFR) for the inventories and the Gridded Nomenclature for Reporting (GNFR) for the gridded inventories. See Annex 1 for a list of SNAP codes and corresponding NFR categories and Annex 2 for a list of GNFR codes and corresponding NFR codes.

It has been aimed to use the most disaggregated SNAP level (SNAP 3 level) but for some categories and for some sectors SNAP 2 level has been applied in the distribution model due to lack of detailed information. 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 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 four years of gridded emissions to CLRTAP and the NECD.

This report documents the SPREAD model used for the reporting in 2021 covering the emission year 2019. The next reporting is due in 2025 covering the emission year 2024. The CLRTAP reporting is based on GNFR categories and the distributions in SPREAD are made on a more disaggregated level than the GNFR level.

In general, emission inventories distinguish between point sources and area sources. Point sources are single facilities where the exact location is known and detailed data are available, e.g. large power plants, refineries or waste incineration plants. Area sources are typically diffuse sources, e.g. without knowledge of the exact location, e.g. road transport, or a very large number of small point sources, e.g. residential wood stoves or animal housing.

For the purposes of the SPREAD model, an additional distinction is made, so that the model operates with three terms, i.e. Large Point Sources (LPS), Point Sources (PS) and Area Sources (AS). At present (2021 inventory), the number of facilities treated as LPS in the Danish emission database is 101 of which 80 was active in 2019. Annex 7 include a list of plants included in the Danish inventories as LPS. For a definition of plants included as LPS in the Danish inventories, see Nielsen et al. (2021a).

The LPSs are characterised by having more detailed data on fuel consumption, emission factors and / or emissions, as plant, installation or process specific data. LPS represent emissions at all SNAP 1 categories except solvents and other product use and road traffic (SNAP 06 and SNAP 07). The Point Sources (PS) cover emissions from stationary combustion and industrial processes from point sources that are smaller and with less information available compared with LPS. PS refers to the large number of plants for which the fuel consumption or the production amounts are known at plant level but emissions are calculated using standard emission factors or process emissions are provided by the company.

The AS are all remaining sources, which are handled as such in the emission inventories. However, in the SPREAD model all available information has been used to develop the GeoKeys. Where available, information on the location has been applied and the resulting GeoKey will utilise point source information. This is for instance the case for residential plants and for animal husbandry. For each GeoKey, the spatial data used have been described including whether point data have been used.

A spatial distribution is more relevant for some pollutants than for others. For example particulate matter, as particles can cause health effects in close proximity to the emission site. The spatial component is less important for components with long lifetimes in the atmosphere, e.g. greenhouse gases, which are more relevant at global scale.

Chapter 2 includes a description of the model system, while Chapter 3 covers the general methodology used to spatially distribute emissions including the guidance provided in the EMEP / EEA Guidebook (EEA, 2019). Chapter 4 describes the major spatial datasets available in Denmark and used in the spatial distribution.

Chapter 5 documents the spatial distribution keys (GeoKeys) for all sources in the Danish emission inventories for air pollutants. Chapter 6 presents the

results of the model, while Chapter 7 describes how the SPREAD model adheres to the requirements established in international agreements. Chapter 8 includes a discussion of the model including a discussion on the uncertainty of the spatial distribution. Finally, Chapter 9 contains a list of planned improvements.

The background data and methodological description applied in the national emission inventory are not included here. For a description of the methodologies, data foundation and emissions in the national emission inventories refer to Denmark's Informative Inventory Report, IIR (Nielsen et al., 2021a) as reported to the UNECE and Denmark's National Inventory Report, NIR (Nielsen et al., 2021b) as reported to the UNFCCC.

2 Model description

The SPREAD model is primarily build in MS Access databases and the setup is illustrated in Figure 2.1.

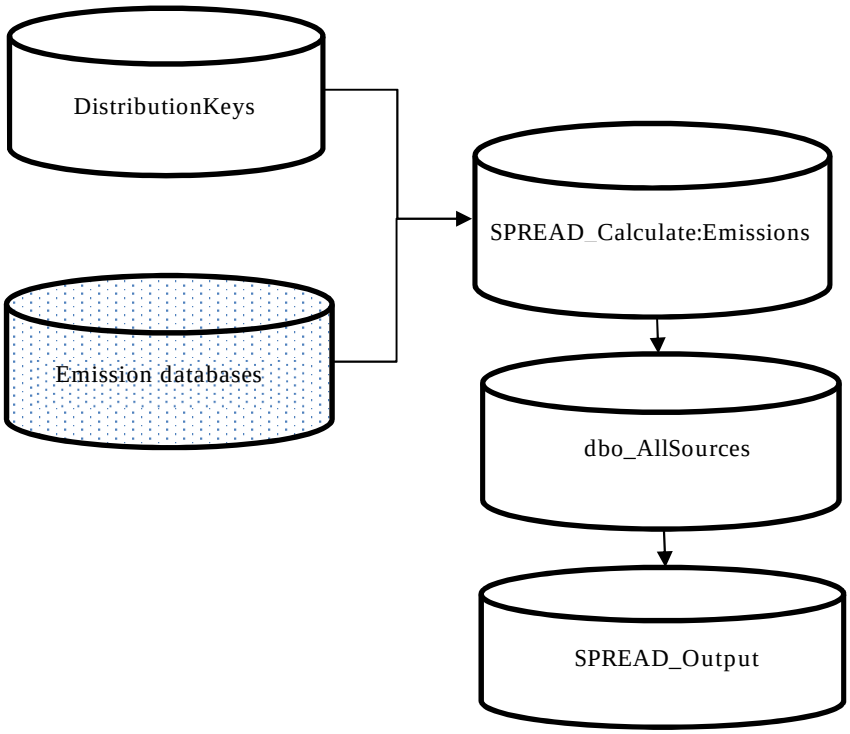


Figure 2.1 Overview of the SPREAD model.

The emission databases are not part of the SPREAD model. The SPREAD model uses as input emission data from the NERIRep database, which is the main emission database in the Danish emission inventories and from the IDA database, which is the Danish emission database for agricultural emissions.

The main components of the SPREAD model are:

- The GeoKeys, which are stored in the MS Access database 'DistributionKeys';
- The calculation of gridded emissions, which is done in the MS Access database 'SPREAD_Calculate_Emissions';
- The storage of the resulting gridded emissions, which is done in the sql server database 'dbo_AllSources';
- The outputs from the model, which consist of a number of MS Access databases.

These elements of the model will be described in more detail in the following.

2.1 GeoKeys

GeoKeys are normalised tables holding information on how emissions are distributed spatially in the SPREAD model, including shares of emissions to be allocated to the individual cells in the 1 km x 1 km grid. Spatial distribution keys are prepared from various data sources including a spatial component in GIS or Excel, and the requisite information is exported and stored in

GeoKey tables in the 'DistributionKeys' database. The GeoKey tables include reference to the grid cells, year and share.

Table 2.1 shows the general design of a GeoKey table. In total, there is currently 94 GeoKeys in use in SPREAD. Improvements to the model, when more detailed spatial data become available will for some sources result in the number of GeoKeys to increase.

Table 2.1 Parameters used in the definition tables of GeoKeys.

Field name	Description	Data type
Year	Year (where relevant)	Number (Long integer)
KN1kmDK	Grid cell name	Text (Short text)
Share	Share of sectoral emission	Number (Double)

The general methodology for developing GeoKeys is described in Chapter 3. A comprehensive description of the GeoKeys included in the SPREAD model, including the methodology and underlying data, is given in Chapter 5.

2.2 Calculation of gridded emissions

The calculation of gridded emissions is done through queries that combines the national emissions with the assigned GeoKey. Source sectors using the same GeoKey are in some cases calculated in the same query.

Figure 2.2 shows an example of a query calculating gridded emissions from coal storage (SNAP 050103).

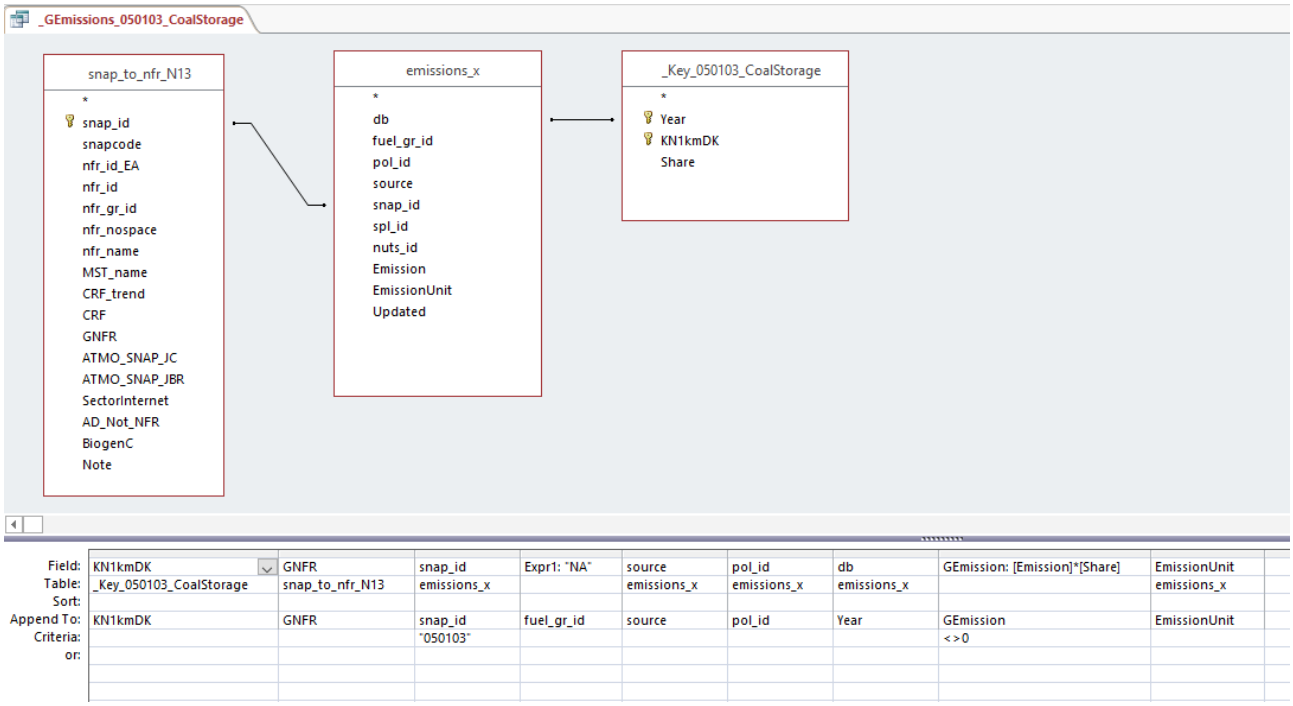


Figure 2.2 Example of a query calculating gridded emissions.

The standard output from each query consists of eight fields as shown in Table 2.2.

Table 2.2 Fields used in the calculation queries.

Field name	Description
KN1kmDK	ID for the 1 km x 1 km grid cell
GNFR	The international nomenclature for gridded emissions
snap_id	The detailed level where emissions are calculated
fuel_gr_id	Fuel type
source	Indication of whether the source is a LPS or AS
pol_id	ID for the relevant pollutant
Year	The year of emission
GEmission	The gridded emission
EmissionUnit	The unit of the gridded emission

Currently, there are 118 calculation queries and additional 30 intermediate queries in the database. Each calculation query appends the output to one result table. All queries are run consecutively through a macro.

In principle, the system can calculate gridded emissions for all years where there are emission data available. In practice, the model is run for 1990, 1995, 2000, 2005, 2010 and every year hereafter.

2.3 Outputs

Calculated emission data are stored in an MS SQL Database due to the size of the output. There are predefined outputs (views) for yearly reporting to the Danish air quality modelling group (ATMO) and for the international reporting to the UNECE in the SQL database.

2.3.1 Reporting to UNECE

Reporting to UNECE is an Excel spreadsheet made from a spreadsheet template called "ANNEX V: Template file for gridded sector data for each of the relevant aggregated Gridding NFR sectors (GNFR)".

In SQL server there is a view for the excel template called dbo.GNFR_report (Table 2.3).

Table 2.3 Example output from SPREAD for the international reporting to the UNECE.

EmissionUnit	Long_c	Lat_c	GNFR	pol_abbr	Emission
kg	9.85	57.05	J_Waste	As	0.00934815317166611
kg	6.95	56.65	I_Offroad	Benzo(b)	0.00324086355898796
Mg	11.55	55.75	J_Waste	$PM_{2.5}$	0.165425387117366
kg	3.65	55.95	I_Offroad	Zn	0.0603840064847959
Mg	12.55	55.45	I_Offroad	BC	0.0587095876988362

Longitude and Latitude indicate the centre of the 0.1° x 0.1° grid cell.

This view is linked in the MS Access database Spread_Output and from there the data are filed in the template.

2.3.2 Reporting for air quality modelling

The output for the reporting to air quality modelling (ATMO) is a big text file used as input for the modelling. For the reporting to ATMO there are three views; one for LPS only, one for area sources only, and one for all sources (area sources and point sources (LPS) combined). The outputs are named:

ATMO_AllSources.csv (all sources)
ATMO_AreaSources.csv (area sources)
qATMO_LPS_ATMOSNAP.xlsx (LPS)

All views are run directly from the sql server and exported as text files.

2.3.3 Quality control

Based on the main output file storing of all data in MS SQL Server, a QC query is made in MS Access. The purpose of the query is to ensure that the total emissions as distributed by SPREAD matches the totals reported in the Danish inventories. The query is exported to MS Excel, where a comparison is made for every SPREAD year and at the GNFR level.

2.3.4 Ad hoc reporting

It is also possible to make ad hoc outputs via MS SQL Server Studio or MS Access written in sql.

In MS SQL server studio, it is possible to export sql and views as text files for further analysis in e.g. MS Excel. In MS Access, it is possible to link to tables and views in sql server for further analysis.

3 General methodology

Gridded emissions are prepared by adding a spatial parameter to the national total emissions. Gridding is made on a disaggregated sectoral level to be able to reflect as many details in the spatial pattern as possible. Part of the emissions are known at plant or site level and can be allocated to the exact location. These are referred to as point sources (PS) or large point sources (LPS), the latter being plants with large emissions that are treated separately in the national emission inventory system. Point sources refer to all sources for which emission allocation is made separately in the spatial emission inventory, but which are treated as an area sources in the national emission inventory system. Area sources are defined as being groups of numerous emission sources with similar characteristics, but being too large in number to be treated separately or without details on individual level and thereby not possible to handle as point sources.

A spatial component is added to the emissions via GeoKeys, which are spatial distribution keys holding information on the share of the national emission from a specific source to be allocated to each spatial unit. The SPREAD model use an orthogonal grid with a spatial resolution of 1 km x 1 km covering the Danish area defined by the national border on land and the exclusive economic zone (EEZ) on sea. GeoKeys are prepared in a geographical information system (GIS) or MS Excel spreadsheet and the resulting tables are stored in an MS Access database.

GeoKeys are prepared from a number of different spatial data with different characteristics. GeoKeys for point sources are prepared from data, where the spatial component is XY coordinates. In some cases, only plant names and / or addresses are available, and the XY coordinates must be added before the GeoKey can be prepared. This is done either by looking up the address in a national address database or via visual identification in e.g. ortho photos, Google maps. XY coordinates can easily be linked to the grid as grid cell names can be generated from the XY coordinates;

KN1kmDK: "1km_" & Left([Y];4) & "_" & Left([X];3)

where Y and X are coordinates expressed as meter north and east, respectively using the datum ETRS89 and the projection is UTM zone 32N. A point with the coordinates Y = 6 175 844 m and X = 724 407 m will be allocated to the grid cell 1km_6175_724. The grid cell name refers to the coordinate of the lower left corner of the grid cell expressed in km as integer.

GeoKeys for area sources are created from data where the spatial component is points, lines or polygons, or a combination of different spatial data with the same or different type of spatial component. The emission shares to be allocated to each grid cell are calculated using spatial analysis methodologies in GIS.

Some spatial data include a source specific parameter, e.g. miles driven for the road network, which can be used to allocate the emissions. Other data only include the spatial component, e.g. the rail network has no information on mileage or number of train passages, and emissions can be allocated only according to the shape of the rail network.

The most common spatial analysis used to prepare GeoKeys is intersection of one or more relevant spatial dataset with the grid, thereby cutting the feature layer by the grid cells, giving the possibility to calculate number of points, length of lines or area of polygons for each grid cell. Following, the share of the total number, length or area is calculated by grid cell. The GeoKey is created as a normalised table holding the share by grid cell and following the formats outlined in Chapter 2.1. Figure 3.1 show the intersection workflow.

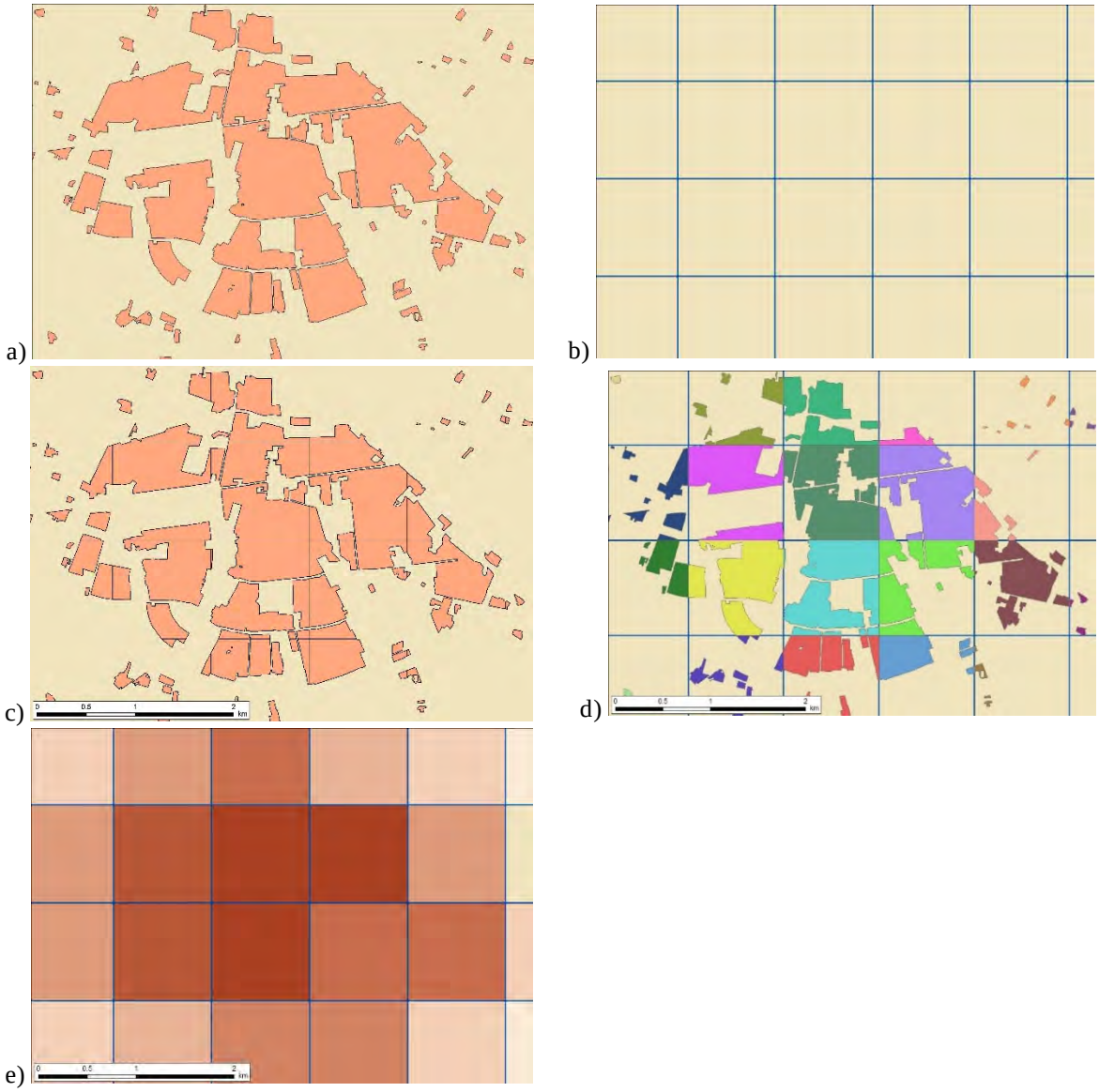


Figure 3.1 Intersection workflow for one-storey settlement.
Input layers:

a) polygon layer of areas with one-storey settlement, and
b) the 1 km x 1 km grid. Result of intersection:
c) polygon layer of areas with one-storey settlement intersected by the 1 km x 1 km grid,
d) the intersected polygons dissolved by the grid cells for calculation of area by grid cell and
e) the resulting GeoKey showing the share by 1 km x 1 km grid cell.

4 Spatial data

A number of general spatial datasets are used in the SPREAD model. These general datasets are documented in this chapter. Some are used for defining the Danish area, while other registries are used as basic data sources and therefore described in general terms in this chapter.

For the individual GeoKeys, the spatial datasets used are described in Chapter 5.

4.1 Exclusive economic zone

The exclusive economic zone (EEZ) is defined in the United Nations Convention on the Law of the Sea (UN, 1982). The EEZ is an area beyond and adjacent to the territorial sea over which a state has special rights regarding the exploration and use of marine resources, including energy production. The EEZ extends at most 200 nautical miles from the coast (Figure 4.1).

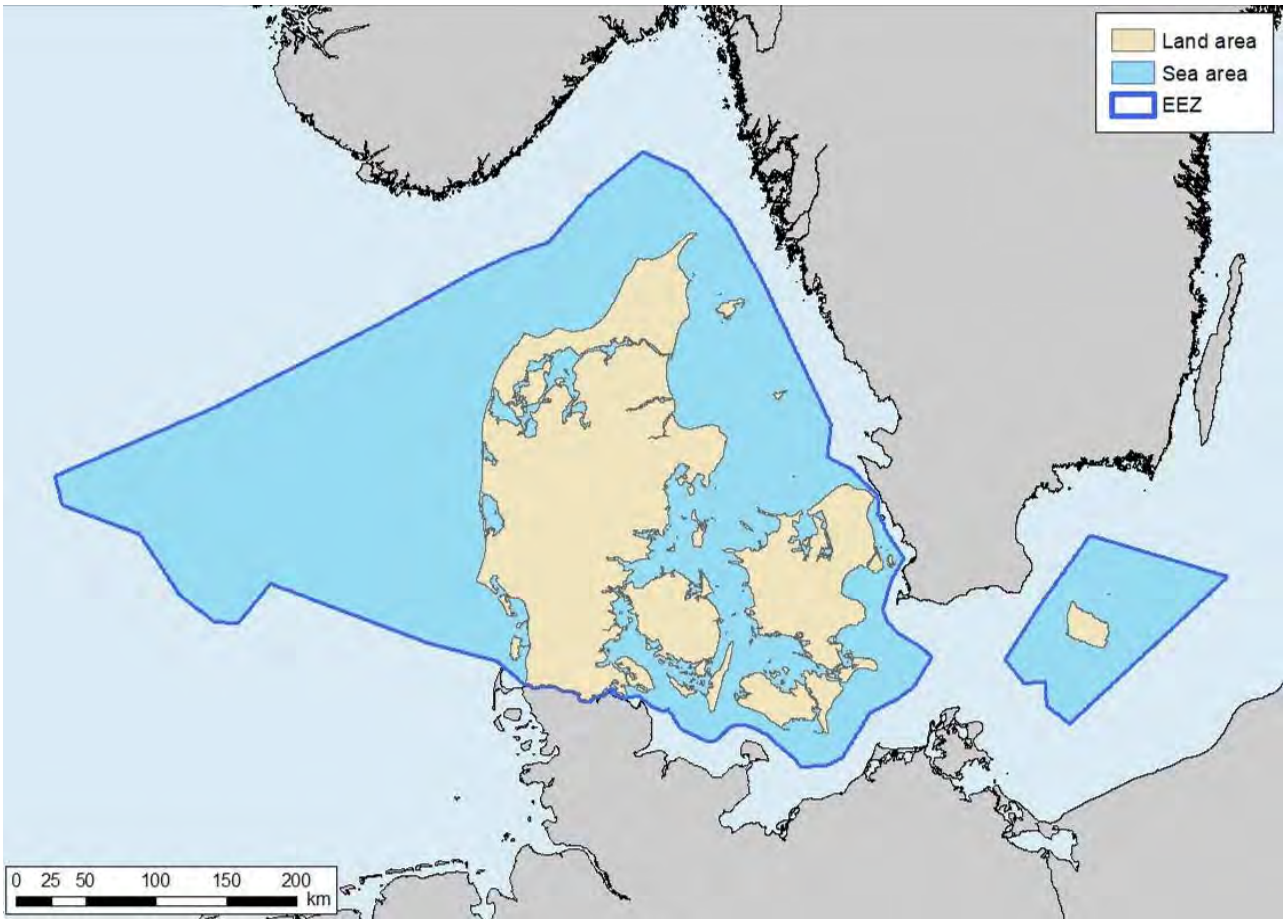


Figure 4.1 The Danish exclusive economic zone and coastline.

4.2 Coastline

The coastline is based on DAGI (Danmarks Administrative Geografiske Inddelinger – Denmarks Administrative Geographical Divisions) data from 2011 (Figure 4.1). Changes to the coastline will normally be minor and without activities causing emissions. Therefore, it has been decided not to update the coastline unless new manmade areas are constructed, e.g. bridges.

4.3 Kort10

Kort10 is a national topographic object oriented map in vector format in scale 1:10 000. Kort10 is based on GeoDenmark data, which is established in a mapping collaboration between the municipalities, the Local Government Denmark, and the Danish Geodata Agency. The Danish Agency for Data Supply and Effeciency host the download portal "The Danish Map Supply", where data are publicly available. Object types are divided into seven classes: buildings, built-up area, traffic, infrastructure, nature, hydrology and administrative units. The data set is supplemented with cartographic information, and with names of roads and places, administrative boundaries and contour lines.

4.4 Building and dwelling register

The building and dwelling register (BBR) is a national register holding data for all buildings and dwellings. The register was created in 1977, based on survey data from all Danish building owners, and is frequently updated by municipalities in connection with building projects. Further, the building owners are obligated to update the register with changes made without involving the municipality. The latter is the main reason for large uncertainties in the register, e.g. regarding heating information, as many changes does not require approval by the municipality. Further, many building owners are not aware that they should update the register themselves, and neglecting it does not lead to consequences. The BBR includes information on e.g. location, building use, heating installation, and heating fuel.

4.5 Agricultural registries

In Denmark, a large number of registries exist with relevant agricultural information. These registries are used in the emission inventory process but several datasets have a geographical component that enables them to be used to give an accurate representation of agricultural activities in Denmark. Below is a short description of the most important agricultural datasets.

4.5.1 Central husbandry register

The Central Husbandry Register (CHR) is used to estimate the number of animals with the exception of horses (Chapter 4.5.2). CHR was established in 1993 with the purpose of being able to track animals quickly in case of outbreaks of deceases such as BSE (Bovine Spongiform Encephalopathy) and foot and mouth disease. The first year of the register is 1996 and no data at farm level exist prior to this. The register includes information on the number of animals per farm for a number of animal types, i.e. cattle, swine, sheep, goats, poultry, deer, foxes, polecats, chinchillas and mink. Some types of animals, e.g. cattle and sheep, are registered individually and the updates are therefore frequent. For other animal types, the number is accounted for a certain date of the year. Ten percent of the farmers are surveyed every month with the exception of July and December. All animal herds are registered with a CHR identification number and the geographical location of the farm. Approximately 45 000 herds are registered. Herds with horses are not included in CHR.

4.5.2 Fertiliser accounts

To protect groundwater, rivers, streams and coastal waters, legislation has been enacted on how much fertiliser can be applied to soils. The fertiliser accounts include information on nitrogen allowances and nitrogen use on farm level. Farmers exceeding a given number of animals or amount of animal manure are obligated to report the number of animals and housing type, the use of nitrogen (N), including both animal manure, inorganic fertilizer and other N containing materials, e.g. sludge. The N quota, which is the amount of N that is allowed to be applied to the fields, and information on catch crops are also reported. The minimum size is approximately a farm turnover of 7 000 EUR which normally is less than three cows. Currently, approximately 35 500 farmers are reporting their fertiliser accounts annually. The difference to CHR is among other things that a large number of sheep and goat holders, which are included in CHR, does not have a size, which exceeds the lower limit in the fertilizer accounts. Based on the fertilizer accounts is it possible to locate approximately 40 % of an estimated 170 000 horses.

4.5.3 General agricultural register

The General Agricultural Register (GLR) was established in 1993 for holding documentation for the area subsidies. The register contains information on the applicant, the fields that are applied for subsidies, the location and size of the fields, and the crops grown on the specific field. Other information is also included such as whether the field is organically cultivated and if afforestation takes place. In total, the location of 600 000 fields is available with an average size of 0.2 km x 0.2 km (4 hectares).

4.6 Chimneysweeper data

The Danish Association of Chimneysweepers (SFL) has provided information on the location and types of small combustion appliances in Denmark. The data consist of information on the address and the type of appliance registered on the address. An example of the format is illustrated in Table 4.1.

Table 4.1 Format for SFL data.

Road	Number	Postal code	Type of appliance

In total, the number of appliances was counted as 1 052 742. The data from SFL was geocoded using the official Danish registry of addresses. However, due to misspelling of road names, or inconsistencies between the road name, number and postal code, it was only possible to geocode 1 046 182 appliances.

The SFL data do not cover the entire country as some chimneysweepers have chosen not to be a member of SFL and a few members did not provide data. The coverage of the SFL data is illustrated in Figure 4.2. For the areas of the country where SFL data were not available, data from BBR have been used for gap filling. The BBR registry is described in Chapter 4.4.

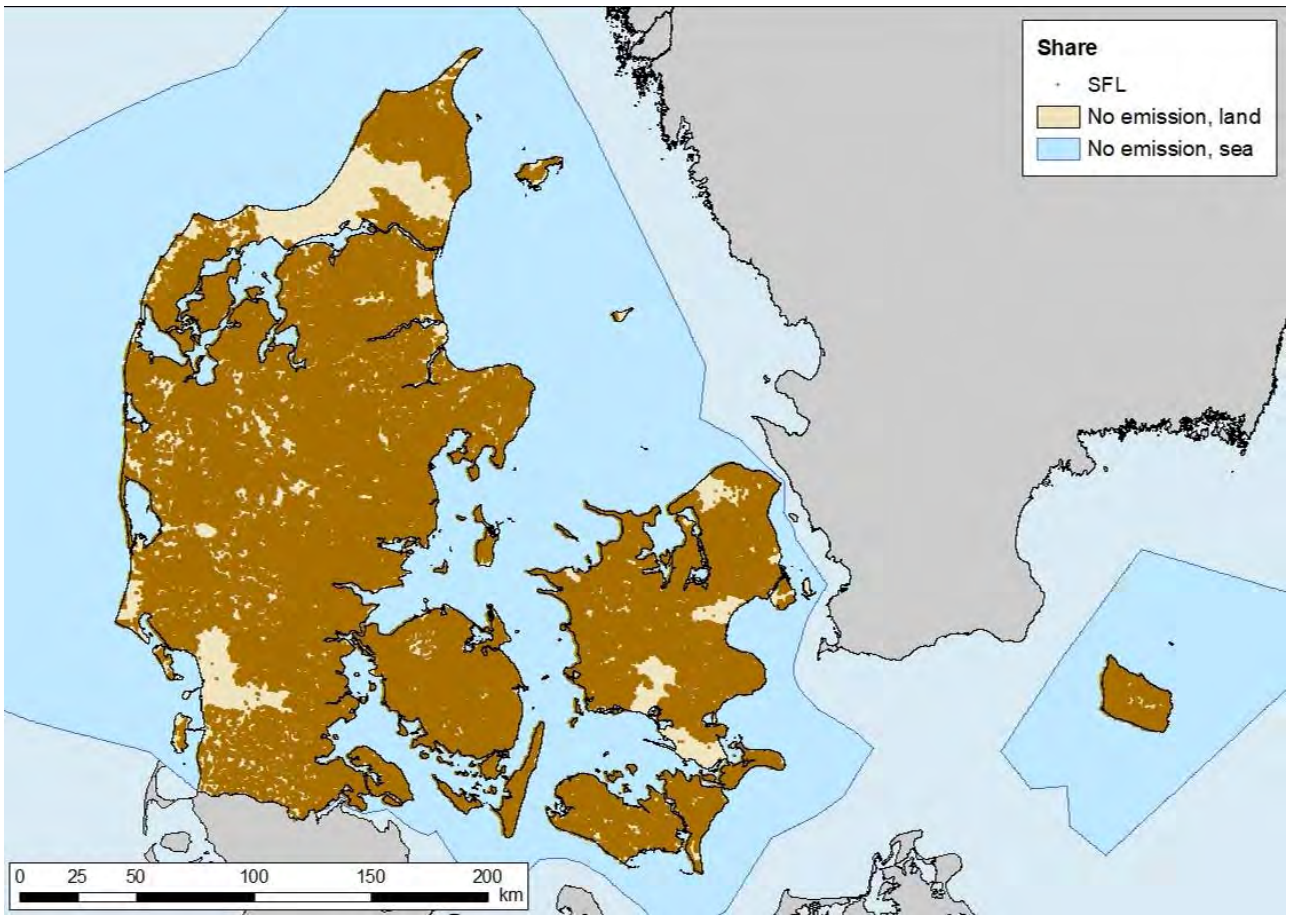


Figure 4.2 Geocoded addresses from SFL.

More information on the data from SFL as well as the data processing done by DCE, can be found in Nielsen & Plejdrup (2018).

5 Spatial distribution keys

The SPREAD model includes a large number (>90) of spatial distribution keys (GeoKeys). Some are used for one emission source only, while others are used for spatial allocation of emissions from different sources. The latter is the case for emission sources where good spatial data are not available, and where less accurate allocations are made based on spatial proxy data. Generally, there is a lack of information on sources in industrial processes, except for the few plants that are treated as LPS or PS, and a considerable part of the emissions are allocated according to the area categorised as “Industrial area” in Kort10. Another example of the very general distribution for industry is emissions from asphalt roofing and from dry cleaning, which are allocated according to the location of buildings in Denmark.

Some emission sources cover both point sources (PS or LPS) and area sources. In these cases, emissions from PS and LPS are allocated to the exact location and GeoKeys are prepared for the residual emissions. This combination is mainly found in the stationary combustion sector, but also some cases are found in the industrial process sector. In general, point source data are used to develop GeoKeys for sources that are handled as area sources in the emission inventories (Chpater 1).

In order to assess the uncertainty of the spatial distribution of emissions, it is necessary to both evaluate the quality of the spatial dataset that is the basis for the GeoKey and to assess the applicability of the selected GeoKey for the specific emission source.

In this report, the quality of the spatial dataset and the applicability as spatial proxy for the specific emission source are both rated according to a five-step system. The quality of the spatial dataset is rated from A to E (Table 5.1) and the applicability as spatial proxy is rated from 1 to 5 (Table 5.2).

That means that the best possible combined rating for a GeoKey is A1, while the worst possible rating would be E5. There are examples of a high quality spatial proxy, e.g. population density, which is not a good representation of the spatial emission pattern, and should be used with caution. Population density is often seen used as proxy for residential wood combustion, but this will most likely lead to large overestimation in densely populated areas. The opposite is the case for the building and dwelling register, which is a good proxy for e.g. heating in commercial and institutional buildings, but where the quality of the spatial data set is lower due to large uncertainties in the register.

Table 5.1 Rating system for the quality of the spatial dataset.

Quality rating	Description	Example
A	Very low uncertainty	Geographical coordinates or address
		Location of animals by type
		Location of agricultural fields including information on crop types
		Population density
B	Low uncertainty	Location of buildings
		Quality A data that need gap filling, e.g. data from the chimney sweeper association
C	Medium uncertainty	Spatial parameters generated from different input data, data analysis and assumptions, e.g. mileage data based on road map and traffic counts
D	High uncertainty	Roughly generalised Land use maps
		Land use that is very difficult to identify, e.g. industrial areas
E	Very high uncertainty	Outdated spatial data
		Spatial data missing full coverage

Table 5.2 Rating system for the applicability as spatial proxy.

Applicability rating	Description	Example
1	Very good correlated proxy	GeoKeys for point sources based on emissions measured or calculated from activity data and corresponding technology information or emission factors
		GeoKeys for area source emissions that occur evenly from a well-defined land-use class, similar to evaporation from a waterbody
2	Good correlated proxy	GeoKeys based on address points including activity data, e.g. process emissions
		GeoKeys for area source emissions based on very detailed spatial and statistical data, e.g. emissions from fertilisers applied to agricultural soils
3	Fair correlated proxy	GeoKeys based on address points without activity data, e.g. residential wood combustion
		GeoKeys for area source emissions based on spatial data that reflect the emission source features, but without indication of activity level, e.g. rail network
4	Poor correlated proxy	GeoKeys distributing point source emissions evenly to areas based on land-use class(es)
		GeoKeys for area source emissions based on spatial parameters not well correlated with the emission activity, e.g. emissions from industrial processes distributed to the industrial areas
5	Very poor correlated proxy	GeoKeys for emissions not limited to the EEZ area, e.g. fishery
		GeoKeys for emissions occurring at unknown locations, e.g. military aviation

The EMEP/EEA Guidebook uses the concept of methodological tiers to distinguish between the varying levels of sophistication. However, as the tier levels are not well defined in the Guidebook, they will not be used in this report. For more discussion on this, see Chapter 7.2.

The following chapters describe the GeoKeys used for the different emission sectors, including information on the spatial data behind the GeoKeys, calculations and assumptions. For each GeoKey, the share of national total emissions distributed using the key is listed and an assessment of the quality and applicability of the GeoKey is made.

The GeoKey descriptions include maps visualising the shares for the 1 km x 1 km grid cells. The sum of all shares for a given GeoKey is 1, and the emissions can be calculated for a 1 km x 1 km grid cell by multiplying the share with the corresponding national sectoral emission.

5.1 General GeoKeys

In this chapter, some of the general GeoKeys are described. These GeoKeys are generally used for more than one emission source and often they are used due to lack of more detailed spatial information being available.

5.1.1 Population

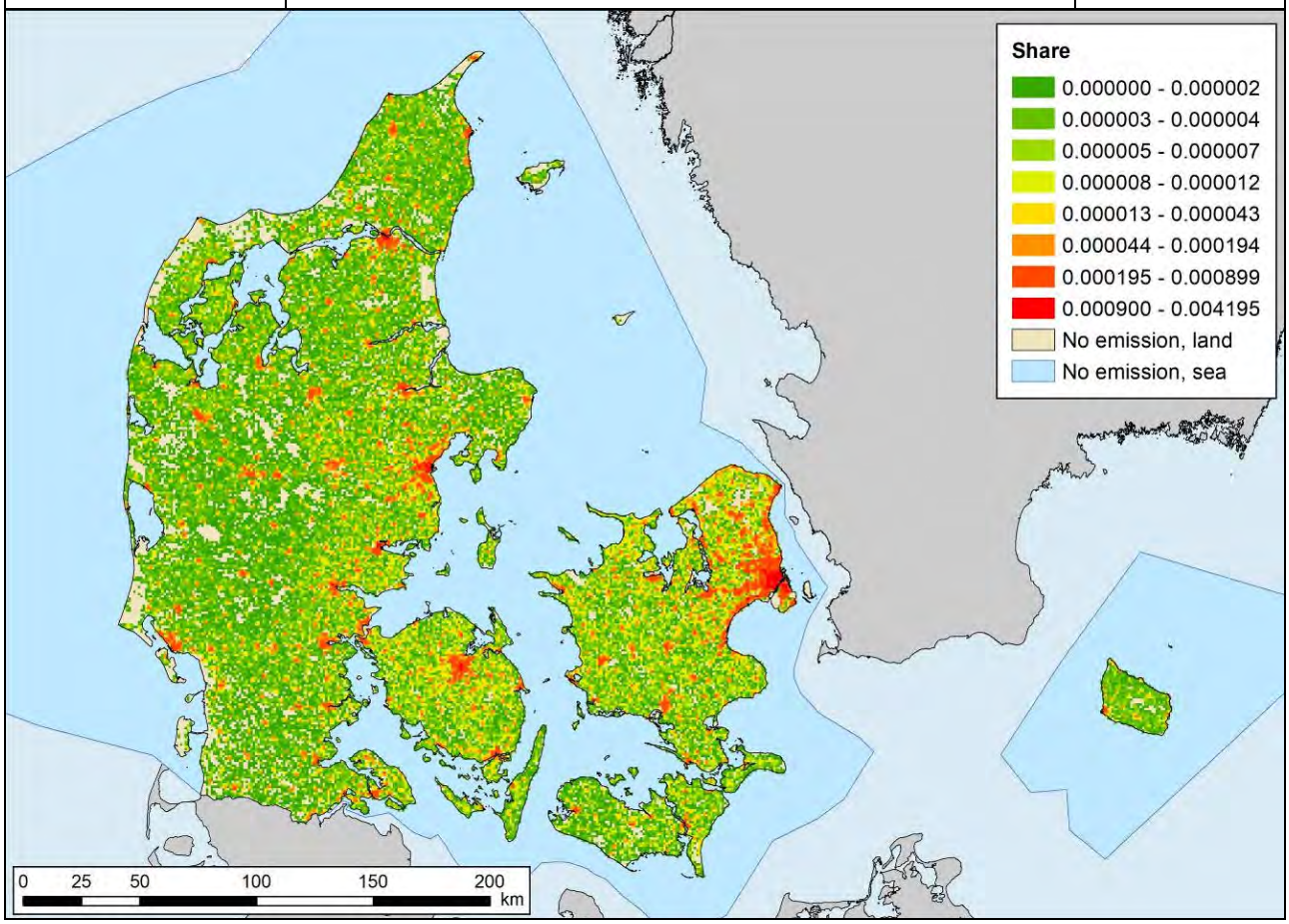
The population GeoKey is based on the Danish Civil Registration System (CPR). The CPR, which was established in 1968, includes information for all persons living in Denmark and having a unique personal identification number. The information include e.g. gender, date of birth, and place of residence. CPR data are confidential, and the use in SPREAD is approved by the Researcher Service, Health Data Authority. Data has been provided as gridded data, including the counts of persons registered by 1 km x 1 km grid cell.

The data set is considered very accurate and therefore it has been assigned a high quality rating. Generally, population as a spatial proxy is uncertain and in many cases chosen due to a lack of a better spatial proxy. For some product uses, such as candles, the population density is considered a good proxy.

Table 5.3 GeoKey for population.

Source data	The Danish Civil Registration System			
Data provider	CIRRAU			
Projection	ETRS89 UTM zone 32N			
Data description	Counts of persons 1 January in 1 km x 1 km squares in the Danish grid net (det danske kvadratnet, DKN1km), based on all person's registered residence in Denmark from the Danish Civil Registration System and the associated geographical coordinates. Further documentation can be found on www.cirrau.au.dk/data-resources/data-documentation and https://sundhedsdatastyrelsen.dk/da/registre-og-services/om-de-nationale-sundhedsregistre/personoplysninger-og-sundhedsfaglig-beskaeftigelse/cpr-registeret (in Danish)			
Workflow	Due to confidentiality, grid cells with 0-1 persons are given the value "<2" in the data set. These are all replaced by 1 when calculating the GeoKey as share of total population by grid cell.			
GeoKey name	_Key_Population			
Year dependent	Yes, GeoKeys are available for every five years 1990-2005 and every single year from 2010 onwards			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	NMVOC, Cu, Pb, Zn	NMVOC, $PM_{2.5}$, As, Cr, Cu, Ni, Pb, Zn	NMVOC, PM_{10}, $PM_{2.5}$, As, Cr, Cu, Ni, Pb, Zn
	5-10 %	PM_{10}, $PM_{2.5}$	PM_{10}	IcdP
	1-5 %	CO, TSP, As, Cd, Cr, Ni, BbF, BkF, BaP, IcdP	CO, TSP, Cd, BbF, BkF, BaP, IcdP	SO_2, CO, TSP, Cd, BbF, BkF, BaP
	< 1 %	SO_2, NO_x, NH_3, BC, Hg, Se, PCDD/F	SO_2, NO_x, NH_3, BC, Hg, Se, PCDD/F	NO_x, NH_3, BC, Hg, Se, PCDD/F
Quality of spatial dataset	A			
Applicability as spatial proxy	060100 Paint application			4
	060400 Other use of solvents and related activities			3
	060408 Domestic solvent use			3
	060502 Refrigeration and air conditioning equipments using halocarbons			4
	060506 Aerosol cans			3
	060507 Electrical equipments			3
	060508 Other use of HFC, N_2O, NH_3, PFC and SF_6			4
	060601 Use of fireworks			4
	060602 Use of tobacco (smoking)			3
	060603 Use of shoes			3
	060606 Use of candles			2
	091201 Accidental fires – Vehicles			4
	091202 Accidental fires – Containers			4

	091203 Accidental fires – Detached houses	4
	091204 Accidental fires – Undetached houses	4
	091205 Accidental fires – Apartment buildings	4
	091207 Accidental fires – Other buildings	4



5.1.2 Industrial area

The general GeoKey for industrial areas is very generic and quite uncertain, and therefore it has been assigned the low quality rating of D. As a spatial proxy, the dataset is also very uncertain and therefore has been assigned ratings of fair to very poor. The majority of the emission sources are very specific production processes, e.g. brick and tiles manufacturing that only occurs on a limited number of sites. The use of this GeoKey will therefore tend to overestimate emissions around the population centres where there is a high proportion of industrial areas, but the industries are not producing emissions as they use electricity or district heating for their processes.

Table 5.4 GeoKey for industrial areas.

Source data	Kort10 version 2011
Data provider	The Danish Agency for Data Supply and Effeciency
Projection	EUREF89 UTM zone 32N
Data description	The layer include areas with buildings categorised as industrial buildings. The 2011 version of Kort10 is used. The choice of dataset version is verified by visual comparison with World Imagery in ArcMap (Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).
Workflow	The industrial building layer is intersected with the 1 km x 1 km Danish grid net and the share of the total industrial building area is calculated by grid cell.
GeoKey name	_Key_Industry
Year dependent	No
Pollutant dependent	No

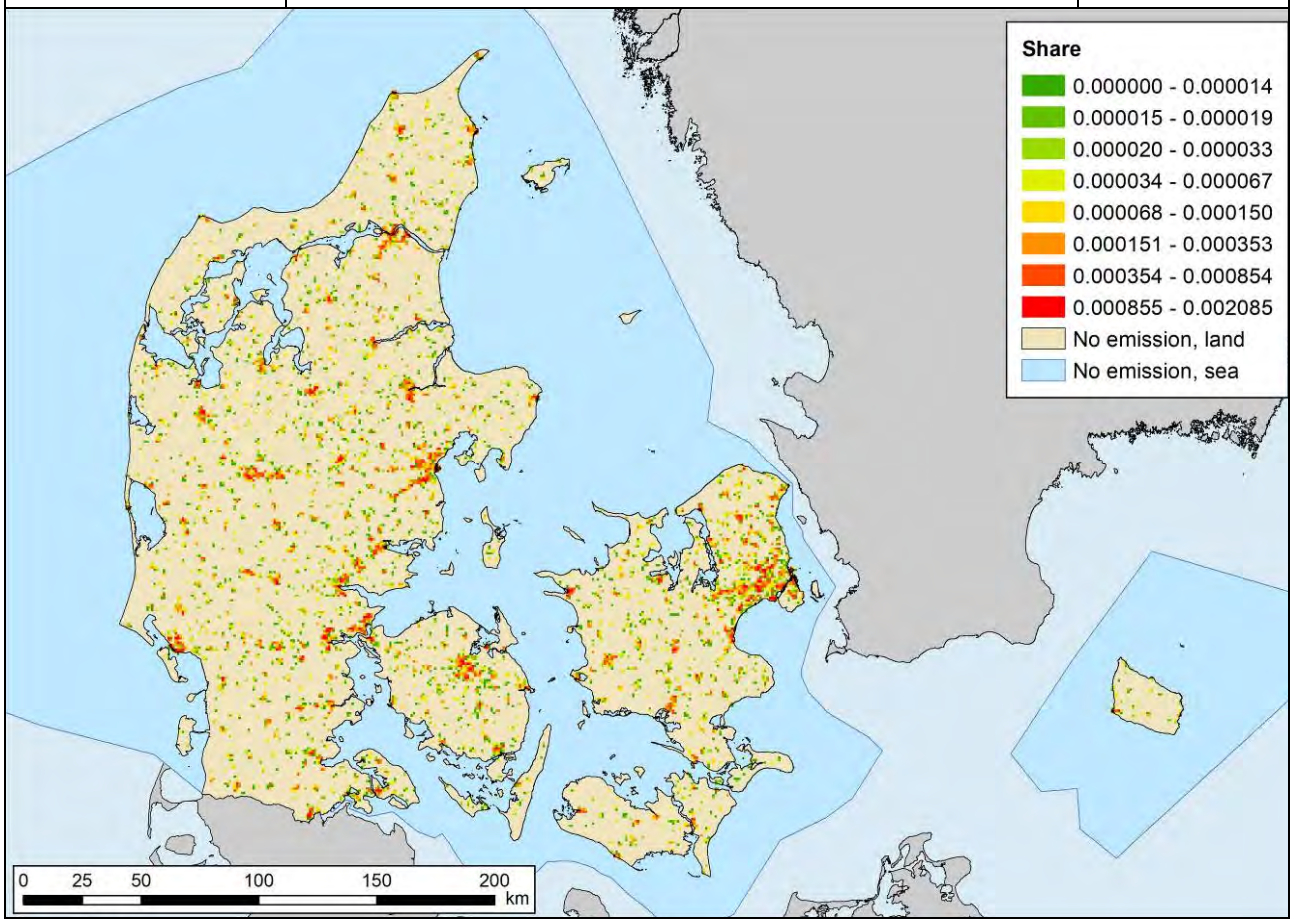
Share of national emission

	1990	2005	2019
> 10 %		HCB, PCBs	As, Pb, PCBs
5-10 %	As, Ni, PCBs	As, Cr, PCDD/F	SO_2, PCDD/F
1-5 %	SO_2, TSP, PM_{10}, Cd, Cr, Pb, Se, Zn, HCB, PCDD/F	SO_2, TSP, PM_{10}, Cd, Hg, Pb, Se, Zn	TSP, PM_{10}, Cd, Cr, Hg, Ni
< 1 %	NO_x, NMVOC, CO, NH_3, $PM_{2.5}$, BC, Cu, Hg, BbF, BkF, BaP, IcdP	NO_x, NMVOC, CO, NH_3, $PM_{2.5}$, BC, Cu, Ni, BbF, BkF, BaP, IcdP	NO_x, NMVOC, CO, NH_3, $PM_{2.5}$, BC, Cu, Se, Zn, HCB, BbF, BkF, BaP, IcdP

Quality of spatial dataset	D

Applicability as spatial proxy

0301 Combustion in manufacturing industry (excl. PS)	4
0303 Processes with contact	4
0307 Non-Metallic Minerals	4
0308 Mining and Quarrying	5
0315 Construction	4
0320 Other manufacturing industry	4
040633 Construction of non-residential buildings	5
040690 Storage, handling and transport of mineral products	4
091206 Industrial building fires	3

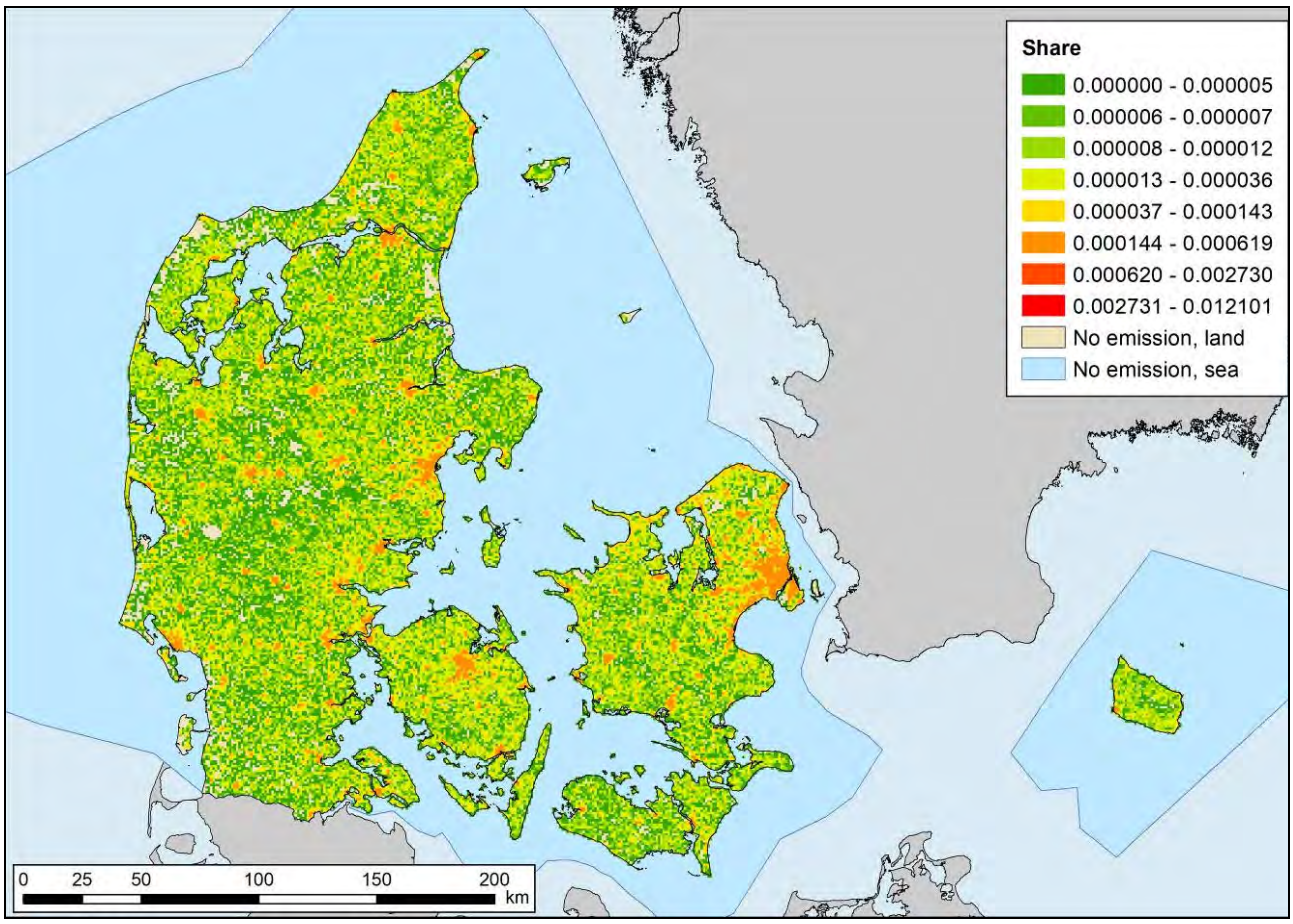


5.1.3 Buildings

The spatial theme for buildings are considered relatively accurate with a rating of B. Uncertainties relate to the fact that it is currently not year dependent and therefore, it is a snapshot of the status in 2011. The GeoKey is only used for a few smaller emission sources, e.g. “dry cleaning” and “other building fires”. Emissions will not occur evenly from all buildings and the applicability is considered poor to fair.

Table 5.5 GeoKey for buildings.

Source data	Kort10 version 2011			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	EUREF89 UTM zone 32N			
Data description	The layer include buildings as polygons. The 2011 version of Kort10 is used. The choise of dataset version is verified by visual comparison with World Imagery in ArcMap (Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).			
Workflow	The building layer is intersected with the 1 km x 1 km Danish grid net and the share of the total building area is calculated by grid cell.			
GeoKey name	_Key_Building			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		PCDD/F	PCDD/F
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, BbF, BkF, BaP, IcdP
Quality of spatial dataset	B			
Applicability as spatial proxy	040610 Asphalt roofing			3
	060202 Dry cleaning			4
	091202 Container fires			4
	091207 Other building fires			3



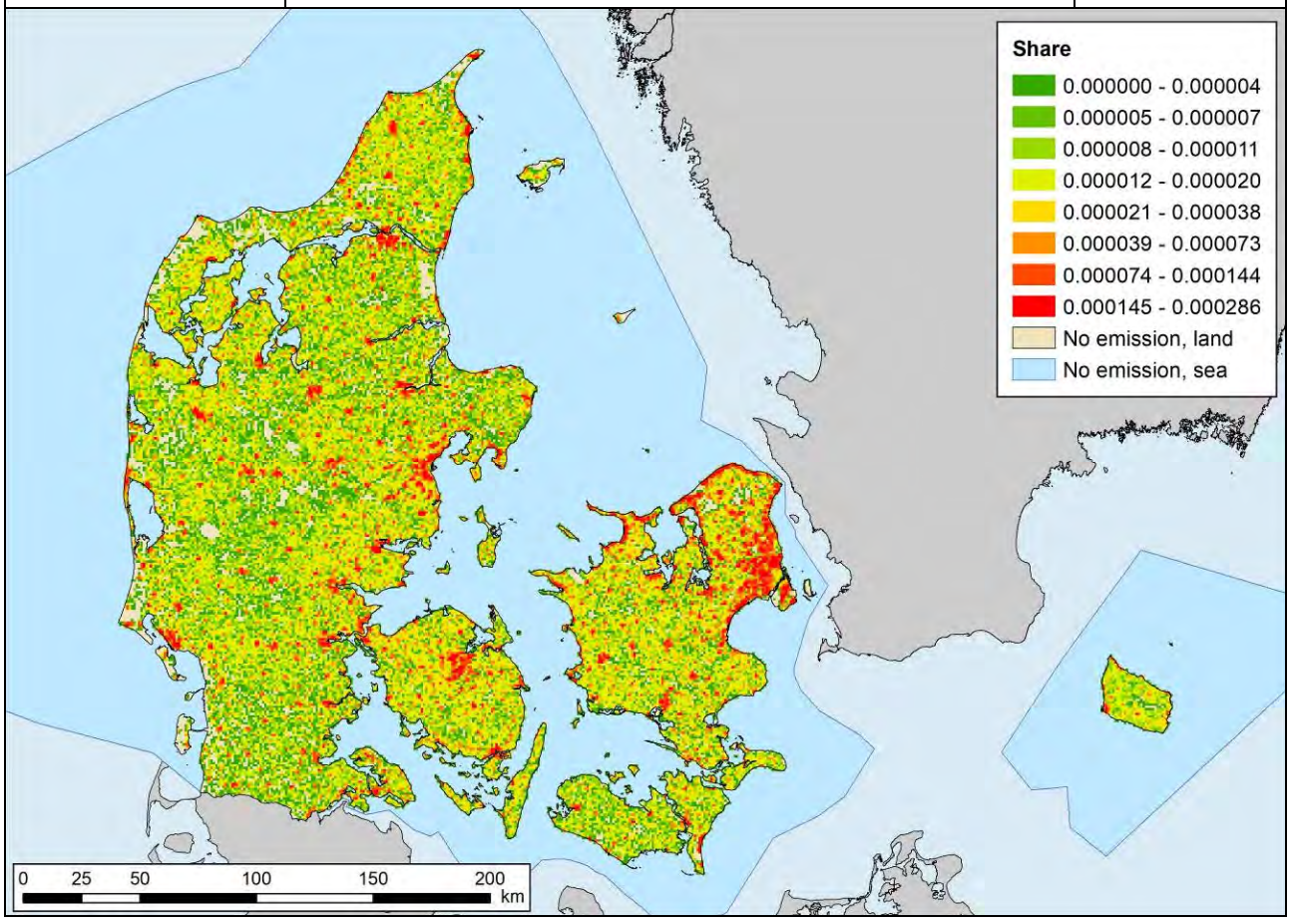
5.1.4 One-storey settlement

The GeoKey is based on the theme “one-storey settlement” in Kort10. The 2011 version is used as this includes more areas than the other available versions. Unfortunately, a visual check of the data set against orthophotos shows that the theme also include some fur animal farms and lakes, but this is found to be only a minor error. The GeoKey is based on the distribution of the area of one-storey settlements, as no information is available to differentiate the activity or emissions between the individual polygons in the theme.

The GeoKey for one-storey settlement is considered to have a medium uncertainty. The applicability as a spatial proxy is considered poor to fair for the few emission sources, where it is used.

Table 5.6 GeoKey for one-storey settlement.

Source data	Kort10 version 2011			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	EUREF89 UTM zone 32N			
Data description	The layer include areas with buildings categorised as one-storey settlement ("lav bebyggelse"). The 2011 version of Kort10 is used. The choice of dataset version is verified by visual comparison with World Imagery in ArcMap (Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).			
Workflow	The one-storey settlement layer is intersected with the 1 km x 1 km Danish grid net and the share of the total one-storey settlement area is calculated by grid cell.			
GeoKey name	_Key_Building_OneStorey			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %		PCDD/F	PCDD/F
	5-10 %	PCDD/F		CO
	1-5 %	CO, BbF	SO_2, CO, BbF, BkF, BaP, IcdP	SO_2, $PM_{2.5}$, Se, BbF, BkF, BaP, IcdP
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, BkF, BaP, IcdP, PCBs	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCBs	NO_x, NMVOC, NH_3, TSP, PM_{10}, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, HCB, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	040631 Construction of Houses			4
	060605 Use of charcoal (barbequing)			3
	0809 Non-road machinery – residential (household and gardening)			3
	091104 Home composting			3
	091203 Detached house fires			3
	091204 Undetached house fires			3



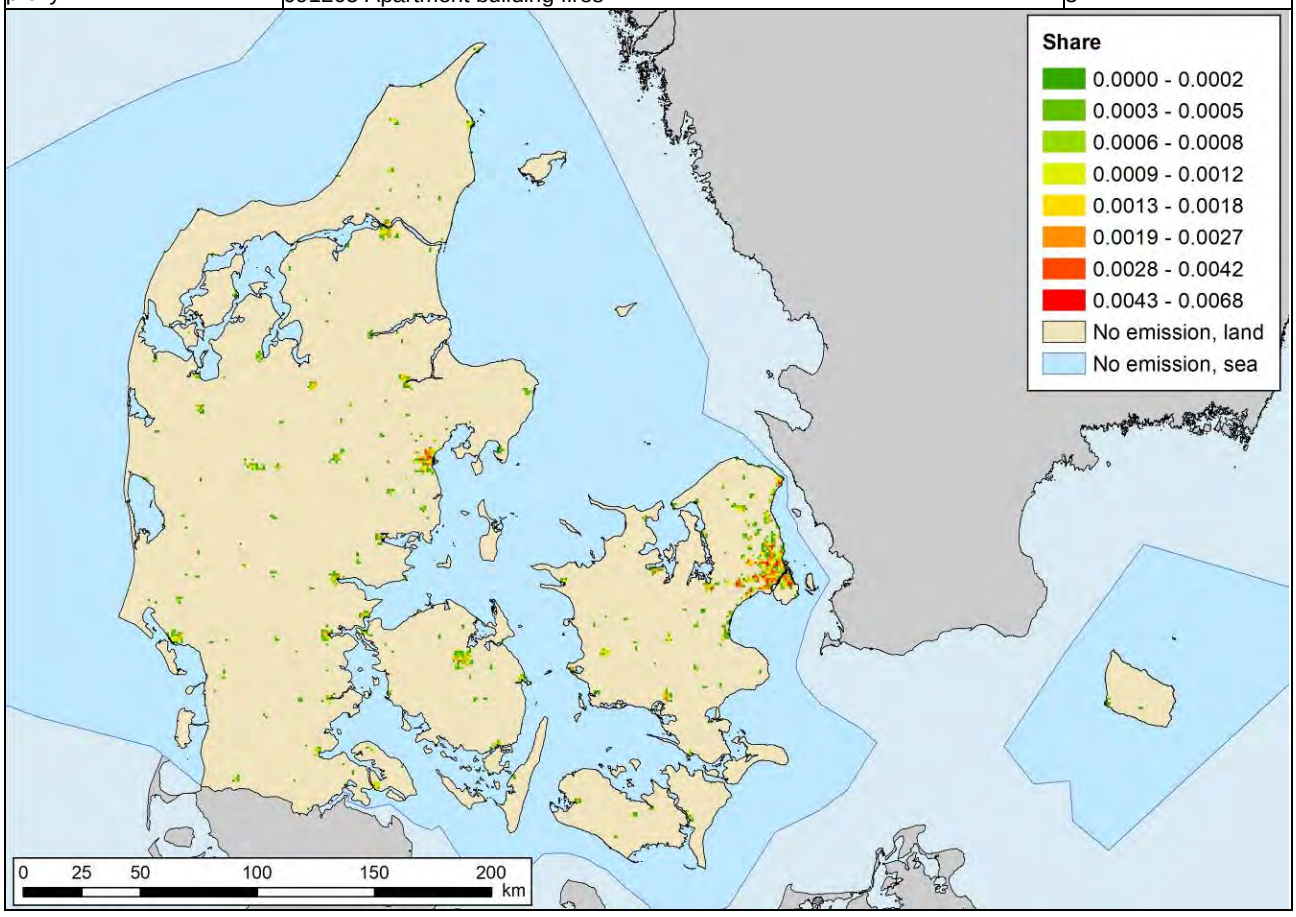
5.1.5 Appartment buildings

The GeoKey is based on the theme "apartment buildings" in Kort10. The 2019 version is used. The GeoKey is based on the distribution of the area of apartment buildings, as no information is available to differentiate the activity or emissions between the individual polygons in the theme.

The GeoKey for apartment buildings is considered to have a medium uncertainty. The applicability as a spatial proxy is considered fair for the few emission sources, where it is used.

Table 5.7 GeoKey for apartment buildings.

Source data	Kort10 version 2019			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	EUREF89 UTM zone 32N			
Data description	The layer include areas with buildings categorised as apartment buildings ("høj bebyggelse"). The 2011 version of Kort10 is used. The choice of dataset version is verified by visual comparison with World Imagery in ArcMap (Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).			
Workflow	The apartment building layer is intersected with the 1 km x 1 km Danish grid net and the share of the total apartment building area is calculated by grid cell.			
GeoKey name	_Key_Building_Appartment			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	PCDD/F	PCDD/F	PCDD/F
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, BbF, BkF, BaP, IcdP
Quality of spatial dataset	C			
Applicability as spatial proxy	040632 Construction of apartment buildings			3
	091205 Apartment building fires			3



5.1.6 Agricultural area

The GeoKey is based on the Danish land use matrix (LUM) covering the six land use classes Forestry, Cropland, Grassland, Wetlands, Settlement and Other Land (Gyldenkærne et al., 2015).

The LUM is based on a number of data sets including:

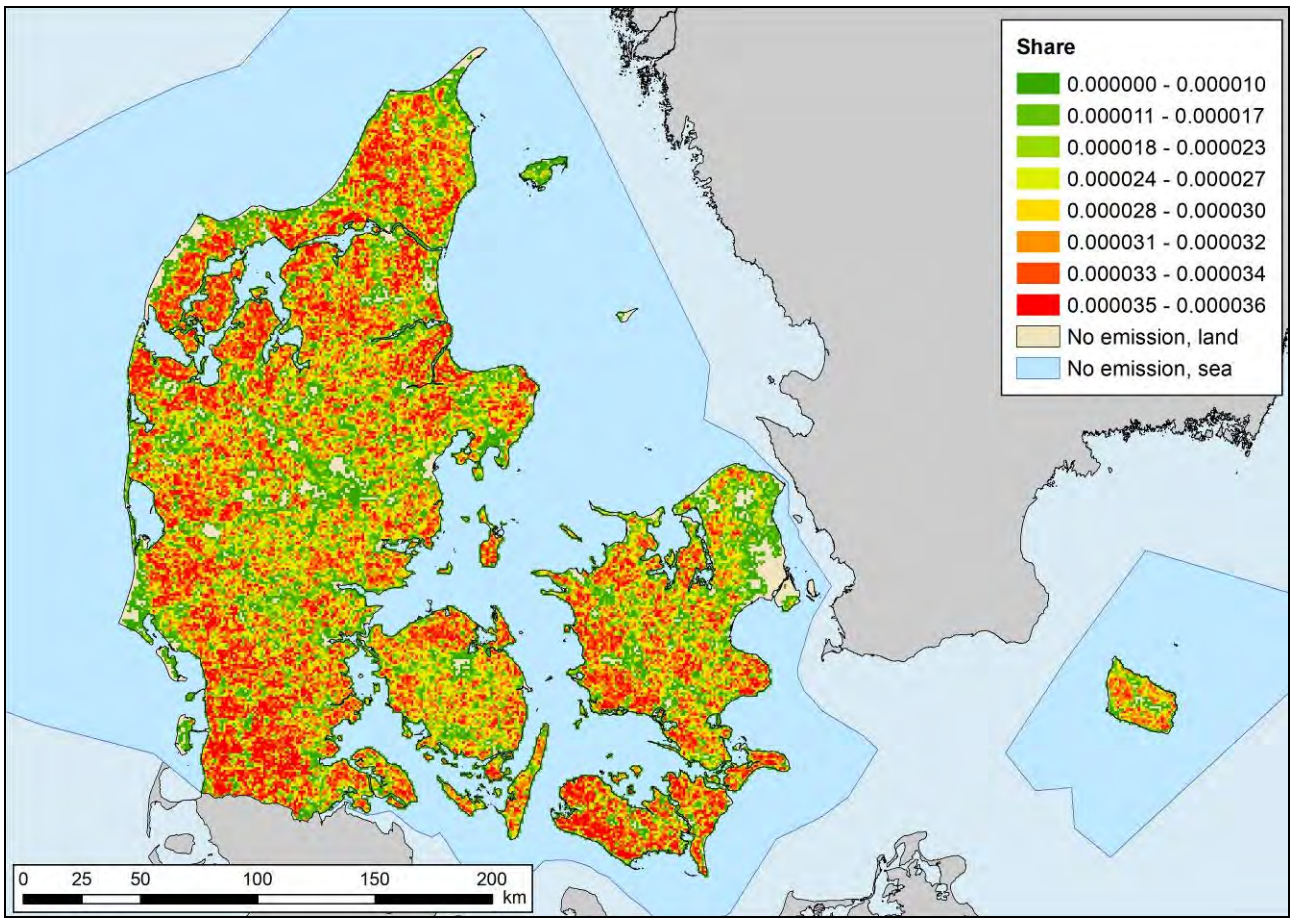
- Agricultural land use based on the European Union subsidy system for agriculture, which includes information on the crops grown by the individual farmers on each land parcel and covers more than 270 different crop types.
- Natura2000 dataset of protected habitats.
- FOT, which includes data related to traffic, technical elements, hydrology, natural areas etc. as well as topographical information.

The GeoKey is based on areas categorised as cropland (gridcode 15) in the LUM.

The spatial data set used for the GeoKey is considered to have a very low uncertainty, as the dataset is based on a combination of detailed spatial data sets. The applicability as a spatial proxy is considered fair for the few emission sources, where it is used. The only exception is field burning of agricultural residues, which occur on a limited part of the agricultural areas, and therefore is considered a very poor proxy.

Table 5.8 GeoKey for agricultural land.

Source data	The Danish land use matrix (LUM)			
Data provider	Aarhus University			
Projection	ETRS89 UTM32N			
Data description	The Danish land use matrix covers the six land use classes Forestry, Cropland, Grassland, Wetlands, Settlement and Other Land and is based on detailed spatial data sets. The land use matrix is updated annually.			
Workflow	The land use class Cropland (grid code 15) is selected and the polygons are intersected with the 1 km x 1 km grid. The GeoKey is calculated as the share of the total agricultural area by grid cell.			
GeoKey name	_Key_AgriculturalArea			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	TSP, PM_{10}, $PM_{2.5}$, BC, HCB	TSP, PM_{10}, BC	TSP, PM_{10}, HCB
	5-10 %	CO	NO_x, NH_3, $PM_{2.5}$, Cd, HCB	CO, NH_3, $PM_{2.5}$, BC, Cd
	1-5 %	NO_x, NMVOC, NH_3, Cd, BbF, BkF	CO, Hg, BbF, BkF, IcdP	NO_x, Hg, BbF, BkF, BaP, IcdP
	< 1 %	SO_2, As, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BaP, IcdP, PCBs	SO_2, NMVOC, As, Cr, Cu, Ni, Pb, Se, Zn, PCDD/F, BaP, PCBs	SO_2, NMVOC, As, Cr, Cu, Ni, Pb, Se, Zn, PCDD/F, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0806 Agricultural machinery			3
	3Dc Farm-level agricultural operations			3
	3De Cultivated crops			3
	3Df Use of pesticides			4
	3F Field burning of agricultural residues			5



5.2 Stationary combustion

As mentioned, a large part of the emissions from stationary combustion is available in the national emission inventory system on plant level (LPS) and is allocated to the exact location of e.g. heat and power plants. Further, fuel consumptions are available for a large number of plants (PS) in the database on plants producing heat and/or electricity to the public grid, provided annually by the DEA, including fuel consumption by fuel on facility level.

Table 5.9 shows the share of emissions from stationary combustion of the national total emissions for the pollutants covered by the SPREAD model. It can be seen that the share for almost all pollutants have remained over 10 % of the national total throughout the time series.

For many pollutants, the share has decreased. This is particularly the case for pollutants, where the main emission comes from LPS, and where abatement has reduced emissions of e.g. SO_2, NO_x and most of the heavy metals substantially. For other pollutants, where small combustion is the main source, e.g. NMVOC, NH_3, $PM_{2.5}$, BC and CO, the emission share has been increasing, due to the increased use of fuel wood in the residential sector.

Table 5.9 Share of emissions from stationary combustion of the national total.

Share	1990	2005	2019
> 10 %	NO_x, SO_2, TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs	NO_x, NMVOC, SO_2, TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Ni, Se, Zn, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs	NO_x, NMVOC, SO_2, TSP, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cd, Hg, As, Cr, Ni, Se, Zn, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs
5-10 %	NMVOC		
1-5 %		NH_3, Cu	NH_3, Cu
< 1 %	NH_3		

An overview of the different activities within stationary combustion is provided together with the GeoKey for the individual activities in Table 5.10.

Table 5.10 Activities (excl. LPS) within stationary combustion and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Public electricity and heat production	0101 & 0102	_Key_EPT
Petroleum refining plants	010306	_Key_010306_AS
Offshore combustion	0105	_Key_010504_OffshoreGasturbines
Commercial and institutional plants – gaseous fuels	0201	_Key_0201_Gas
Commercial and institutional plants – liquid fuels	0201	_Key_0201_Liquid
Commercial and institutional plants – solid fuels	0201	_Key_0201_Solid
Residential plants – gaseous fuels	0202	_Key_0202_Gas
Residential plants – liquid fuels	0202	_Key_0202_Liquid
Residential plants – solid fuels	0202	_Key_0202_Solid
Residential plants – straw	0202	_Key_02_Straw
Agricultural plants – gaseous fuels	0203	_Key_0203_Gas
Agricultural plants – liquid fuels	0203	_Key_0203_Liquid
Agricultural plants – solid fuels	0203	_Key_0203_Solid
Agricultural plants – straw	0203	_Key_02_Straw
Manufacturing plants - Processes with contact	0303	_Key_Industry
Manufacturing plants – Iron and steel	0304	_Key_Metal
Manufacturing plants – Chemical and petrochemical	0306	_Key_ChemicalIndustry
Manufacturing plants – Non-metallic minerals	0307	_Key_Industry
Manufacturing plants – Mining and quarrying	0308	_Key_Quarrying
Manufacturing plants – Food and tobacco	0309	_Key_Food_Drinks_Tobacco
Manufacturing plants – Textile and leather	0310	_Key_Textile_Leather
Manufacturing plants – Paper, pulp and print	0311	_Key_Wood_Paper_Print
Manufacturing plants – Transport equipment	0312	_Key_MeansOfTransportIndustry
Manufacturing plants – Machinery	0313	_Key_MachineryIndustry
Manufacturing plants – Wood and woodproducts	0314	_Key_Wood_Paper_Print
Manufacturing plants – Construction	0315	_Key_Industry
Manufacturing plants – Cement production	0316	_Key_Industry
Manufacturing plants – Non-specified	0320	_Key_Industry

The subsectors within stationary combustion are described in more detail in the following chapters.

5.2.1 Large point sources

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 major power plant operators). Further, a number of companies and plants contribute additional data annually or on request. LPS cover the largest heat and power plants, some major industrial plants, e.g. refineries and cement production, and natural gas storage and treatment plants.

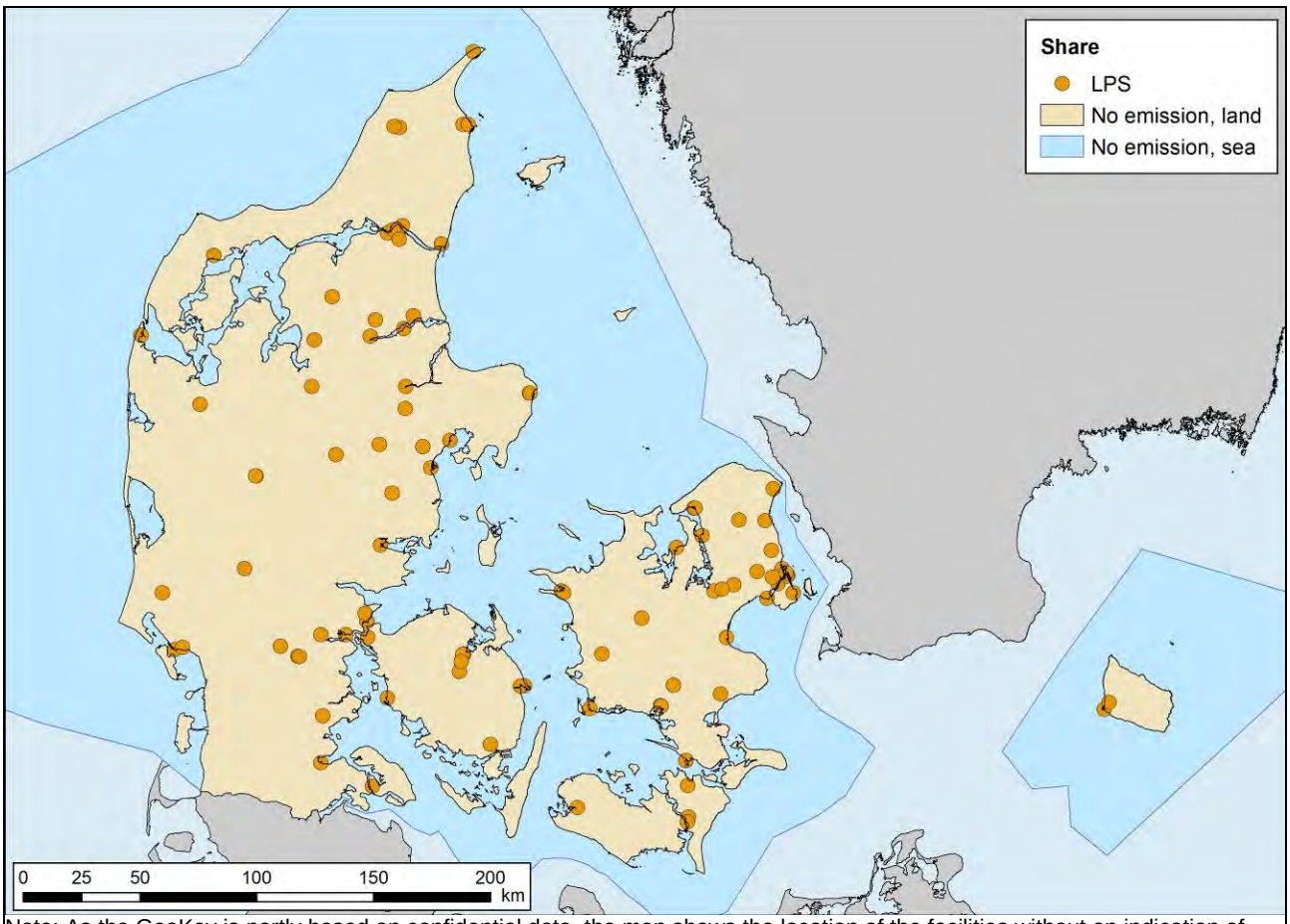
Results from SPREAD can be generated both including and excluding LPS emissions in order to comply with the demand to input emission data in different dispersion and air quality models like the Danish Eulerian Hemispheric Model, DEHM (Christensen, 1997; Brandt et al., 2012) and the Urban Background Model, UBM (Brandt et al., 2001; Brandt et al., 2003). The inventory system include stack heights for all LPS, which is used in air quality modelling together with the spatial emissions.

As shown in Table 5.11, LPS accounts for a significant share of emissions for many pollutants. However, the share of national total emissions have generally been decreasing by the introduction of stricter emission limit values and hence the installation of abatement equipment.

A list of the plants included as LPS in the Danish inventory and their coordinates are included in Annex 4.

Table 5.11 GeoKey for large point source (LPS).

Source data	Inventory data			
Data provider	Relevant agencies and companies			
Projection	ETRS89 UTM zone 32N			
Data description	Detailed data are gathered from LPS facilities for use in the Danish emission inventories. Data include address, activity data and/or emissions/emission factors by facility.			
Workflow	Emissions are allocated to the exact position of the emission source.			
GeoKey name	No GeoKeys are produced, as the LPS emissions are stored in the inventory database system on facility level in a format that is useful in SPREAD. The LPS emissions are treated separately in order to enable generation on outputs both including LPS emissions and with LPS emissions separately, the latter being used as input in air quality modelling.			
Year dependent	Yes. LPS emissions are available annually from 1994 in the inventory database			
Pollutant dependent	Yes			
Share of national emission		1990	2005	2019
	> 10 %	SO_2, NO_x, As, Cd, Cr, Hg, Ni, Se, Zn, HCB, PCDD/F, PCBs	SO_2, NO_x, As, Cd, Cr, Hg, Ni, Se, HCB, PCDD/F, PCBs	SO_2, NO_x, As, Cd, Cr, Hg, Ni, Se, HCB, PCBs
	5-10 %		Pb	CO, PCDD/F
	1-5 %	CO, TSP, PM_{10}, $PM_{2.5}$, Cu, Pb, BbF, BkF, BaP, IcdP	NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, Zn, BbF, BkF, BaP, IcdP	NMVOC, PM_{10}, $PM_{2.5}$, BC, Pb, Zn, BbF, BkF, BaP, IcdP
	< 1 %	NMVOC, NH_3, BC	NH_3, BC, Cu	NH_3, TSP, Cu
Quality of spatial dataset	A			
Applicability as spatial proxy	LPS		1	



Note: As the GeoKey is partly based on confidential data, the map shows the location of the facilities without an indication of emission shares.

5.2.2 Point sources

Data on FC and combustion technology are based on the annual database from the Danish Energy Agency (DEA), holding data separately for each district heating or power producing plant ("Energiproducenttællingen", EPT). Emissions are estimated per plant and using the geographical coordinates for the plants, annual GeoKeys are prepared. EPT is available for the years 1994 onwards.

Some LPS are included in the EPT and are therefore removed from the dataset to avoid double accounting.

The EPT includes PS in several sectors, i.e. public electricity and heat production, manufacturing industries, commercial/institutional and agricultural. The workflow in preparing the data is the same for all sectors. The explanation of the workflow has therefore only been included under 'Public electricity and heat production'.

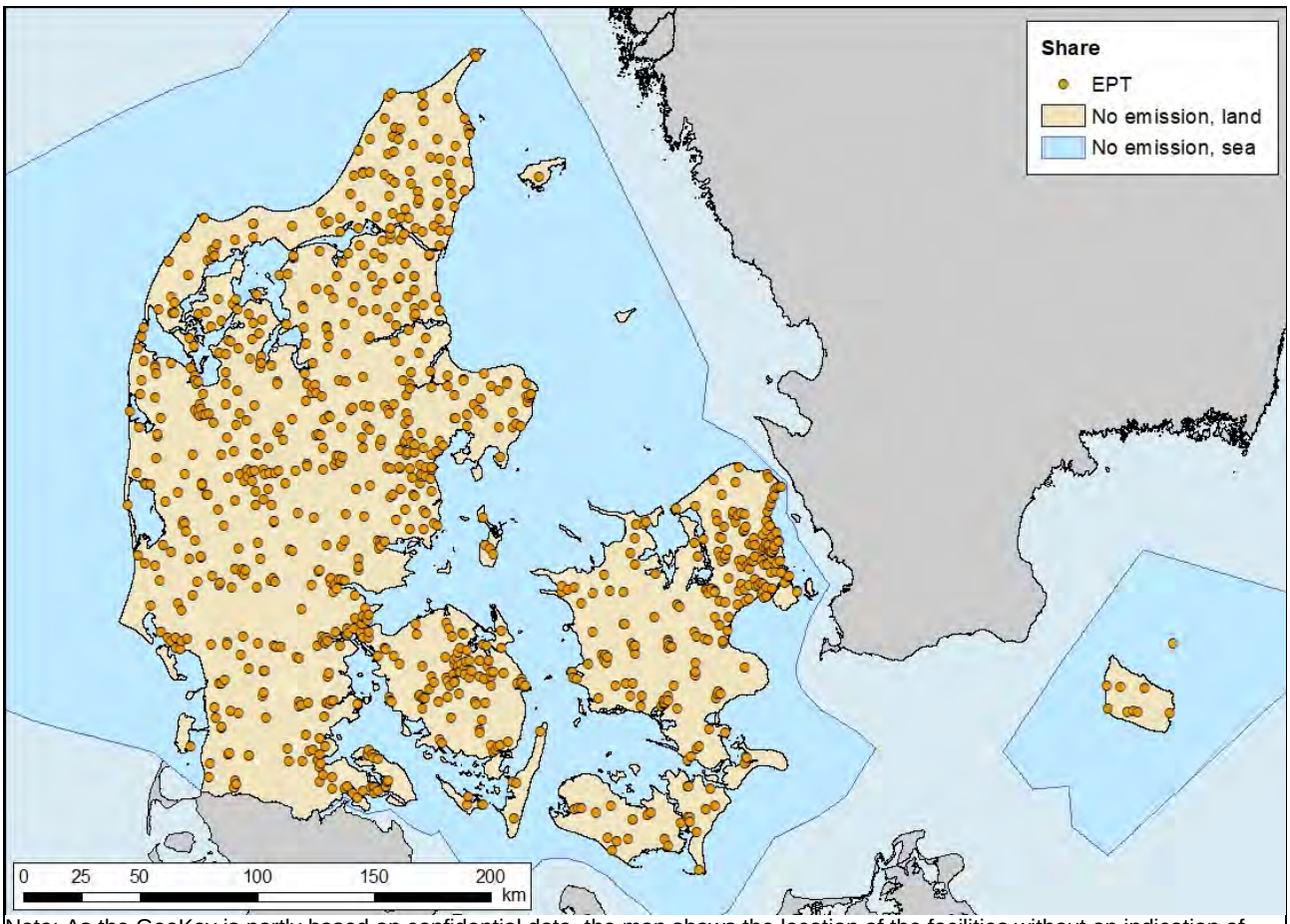
Public electricity and heat production

The part of the public electricity and heat production sector not covered by LPS (Chapter 5.2.1) is distributed using the EPT GeoKey. The number of LPS in the Danish inventories has increased over the years and in 1990 only very few plants were included as LPS. This means that the EPT GeoKey is used for a very large share of the emissions in 1990.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the EPT include addresses and coordinates. The spatial applicability is considered very good, as it is based on plant level fuel consumption in the EPT.

Table 5.12 GeoKey for point sources – public electricity and heat production.

Source data	EPT (see description above)			
Data provider	Danish Energy Agency (DEA)			
Projection	ETRS89 UTM zone 32N			
Data description	(see description above)			
Workflow	The EPT data include some LPS, which are all identified and excluded from the data processing to avoid double counting. Further, PS without any fuel consumption are excluded from the data processing (e.g. facilities with solar power). Geographical coordinates are missing for few facilities, and these are added manually based on the address. Fuel consumption is aggregated to the fuel categories in the inventory system (e.g., wood chips, wood waste, and wood pellets are combined in the fuel category "Wood and similar wood wastes"). The EPT fuel consumption are combined with emission factors for area sources from the inventory system. A few snap-fuel combinations do not occur in the inventory, and applicable emission factors are selected for emission calculations. Emissions calculated from the EPT fuel consumption and the corresponding emission factors from the inventory system are summarised by 1 km x 1 km grid cell, and the GeoKey is calculated as the share of the annual total EPT emission by grid cell.			
GeoKey name	_Key_EPT			
Year dependent	Yes. EPT data are available annually from 1994. 1995 data are used for 1990.			
Pollutant dependent	Yes			
Share of national emission		1990	2005	2019
	> 10 %	As, Cd, Cr, Hg, Ni, Se, Zn, HCB, PCDD/F, PCBs		PCBs
	5-10 %	SO_2, Pb		SO_2
	1-5 %	NO_x, Cu	SO_2, NO_x, CO, As, Cr, Hg, Ni, HCB, PCBs	NO_x, CO, PM_{10}, $PM_{2.5}$, Cr, Hg, Ni, BbF, BkF
	< 1 %	NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, BbF, BkF, BaP, IcdP	NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cu, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	NMVOC, NH_3, TSP, BC, Cd, Cu, Pb, Zn, PCDD/F, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	0101 Public power (not covered by LPS)			1
	0102 District heating plants (not covered by LPS)			1
	0201 Commercial and institutional plants (not covered by LPS)			1
	0203 Plants in agriculture, forestry and aquaculture (not covered by LPS)			1
	03 Combustion in manufacturing industry (not covered by LPS)			1



Note: As the GeoKey is partly based on confidential data, the map shows the location of the facilities without an indication of emission shares.

Other sectors

As mentioned, the EPT also includes information for plants in industry, the commercial/institutional sector and in agriculture. However, the number of plants and their fuel consumption is limited and the contribution to the national total is for all pollutants less than 1 %.

The workflow for preparing the GeoKey has been described under 'Public electricity and heat production' and is not repeated here.

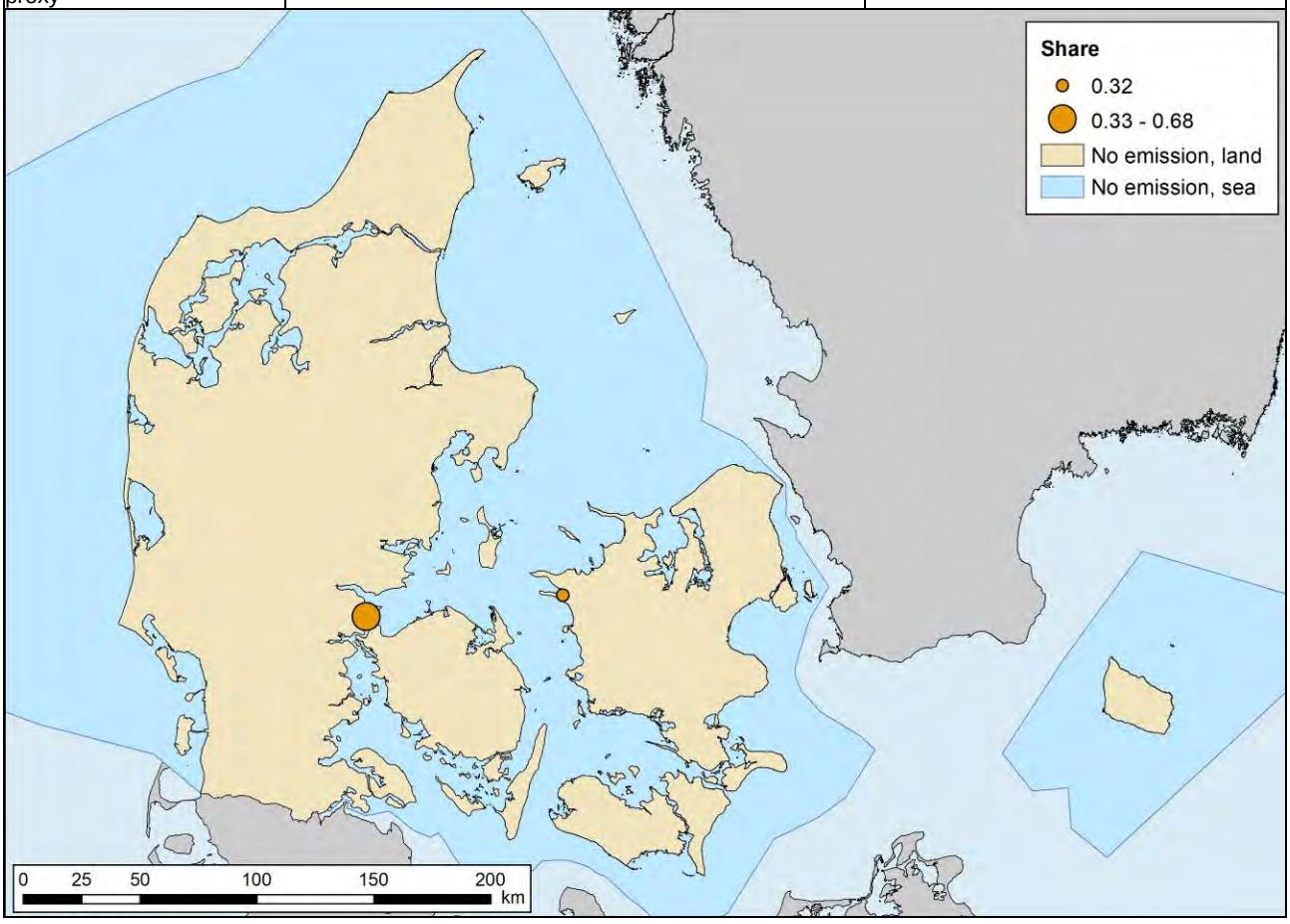
5.2.3 Petroleum refining plants

The Danish refineries are treated as LPS in the Danish emission inventories, but in some years, the fuel consumption included in the energy statistics exceeds the fuel consumption provided by the refineries. The residual fuel consumption is for theses years included as area source, and the emission are distributed according to the LPS distribution. Until 1996, there were three refineries in Denmark, and two in the years 1997 onwards. The refineries are not included as LPS before 1994 in the inventory system, and the LPS distribution for 1995 is applied for 1990 for area source emissions.

The spatial dataset used for the GeoKey is considered to have very low uncertainty and the spatial applicability is considered good, as the GeoKey is based on plant level data. For 1990, the applicability is considered fair.

Table 5.13 GeoKey for petroleum refining plants (area source emissions).

Source data	Location of refineries			
Data provider				
Projection	ETRS89 UTM zone 32N			
Data description	Location of refineries			
Workflow	Denmark has two refineries (three until 1996). Emissions are allocated to the exact position of the emission source. Area source emissions from petroleum refining plants are equally distributed between the two (three) sites, each having a share of 0.5 (0.33) in the GeoKey. For 1990, the LPS distribution key for 1994 is applied.			
GeoKey name	_Key_010306_AS			
Year dependent	Yes			
Pollutant dependent	Yes			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	SO_2, Cd, Cr, Ni		
	< 1 %	NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	
Quality of spatial dataset	A			
Applicability as spatial proxy	010306 Petroleum refining plants - Process furnaces		2 (3 for 1990)	



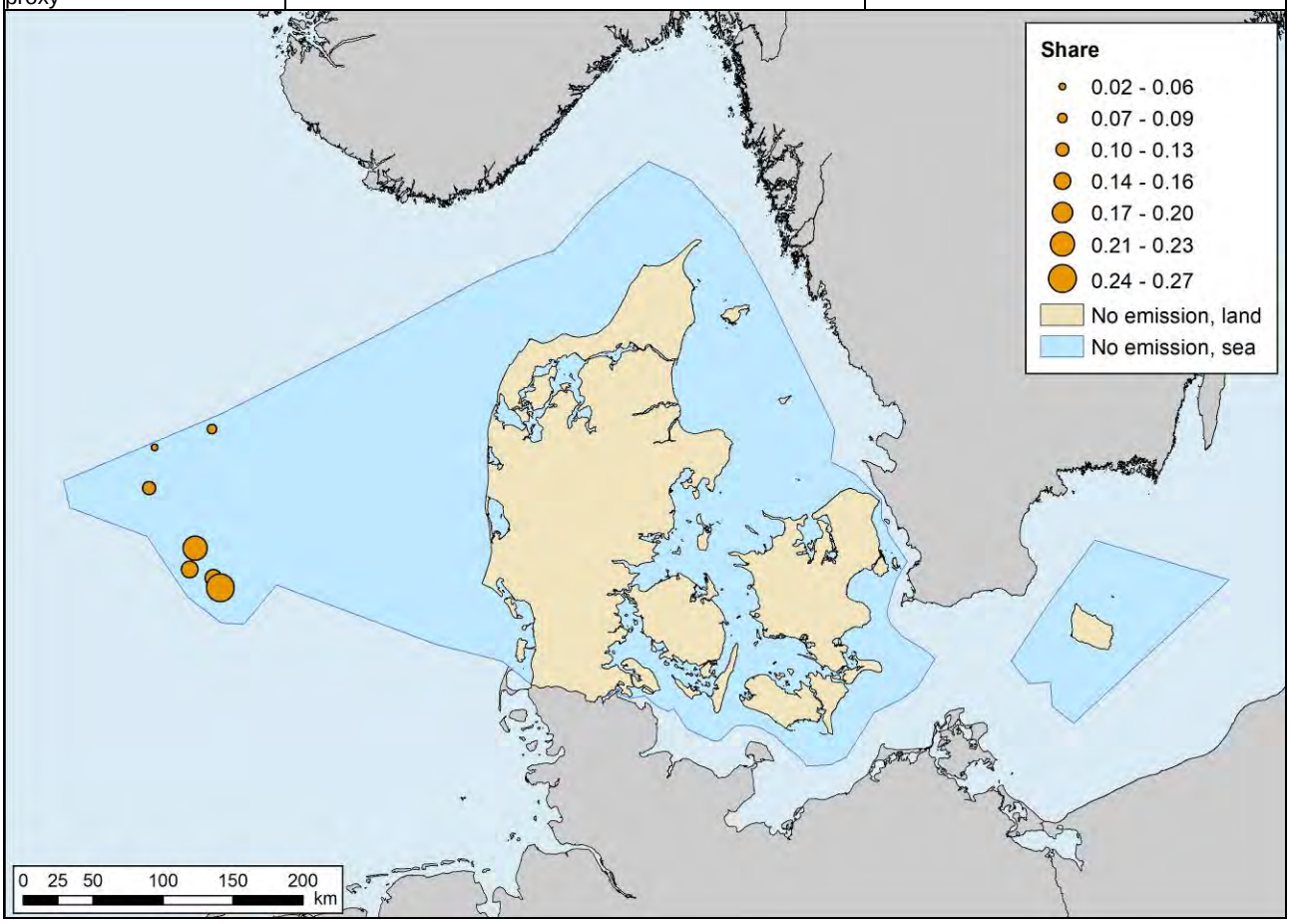
5.2.4 Offshore combustion

Denmark has offshore oil and gas extraction in the Danish part of the North Sea. The extraction process is energy demanding and the energy is produced on site by combustion of gas in gas turbines.

The spatial dataset used for the GeoKey is considered to have very low uncertainty and the spatial applicability is considered very good, as the GeoKey is based on detailed data on installation level.

Table 5.14 GeoKey for offshore combustion.

Source data	Yearly data on oil and gas production in Denmark			
Data provider	The Danish Energy Agency			
Projection	ETRS89 UTM zone 32N			
Data description	Oil and gas production statistics for the years 1972 onwards. Data is available by offshore facility. The data set include data for oil production, gas production, fuel consumption and flaring rates. Detailed information on location and activities for offshore installations in oil and gas production.			
Workflow	The share of the total fuel consumption is calculated by offshore facility and by year.			
GeoKey name	_Key_010504_OffshoreGasturbines			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		NO_x	NO_x
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	010504 Offshore gas turbines		1	



5.2.5 Commercial and institutional plants

The national building and dwelling register (BBR) is used to identify commercial and institutional buildings based on building use information. Further, information on primary and supplementary heating is used to prepare separate GeoKeys for commercial and institutional plants using gaseous, liquid and solid fuels.

The BBR does not hold detailed information on installation technology, which would make it possible to differentiate emissions between the identified

plants. Therefore, the GeoKey is set up to distribute emissions evenly between the identified plants. For buildings with both primary and supplementary heating relevant for a given GeoKey, both are included. Due to the limitations in the structure of the BBR, a building can have only one primary heating and one supplementary heating, regardless that it might have two or more supplementary heating installations of the same or of different types.

Table 5.15, Table 5.16, Table 5.17 and Table 5.18 list the building use, heating installation, fuel, and supplementary heating categories, respectively, which are included in the GeoKeys for emissions from commercial and institutional plants.

Table 5.15 BBR building use categories included in the GeoKeys for commercial and institutional plants.

Building use
150 Dormitory
160 24-hour care centre
300-399 Buildings for retailer, transport, office, liberal profession, service etc.
400-499 Buildings for cultural purpose and institutions
520-521 Holiday resort
529-535 Building related to sport exercise

Table 5.16 BBR heating installation categories included in the GeoKeys for commercial and institutional plants.

Heating installation
2 Boiler, one unit
3 Stove
6 Boiler, two units
8 Gas appliance

Table 5.17 BBR fuel categories included in the GeoKeys for commercial and institutional plants.

Fuel
2 Town gas
3 Liquid
4 Solid
7 Natural gas

Table 5.18 BBR supplementary heating categories included in the GeoKeys for commercial and institutional plants.

Supplementary heating
2 Stove, solid fuel
3 Stove, liquid fuel
5 Open fireplace, solid fuel
6 Gas
10 Biogas

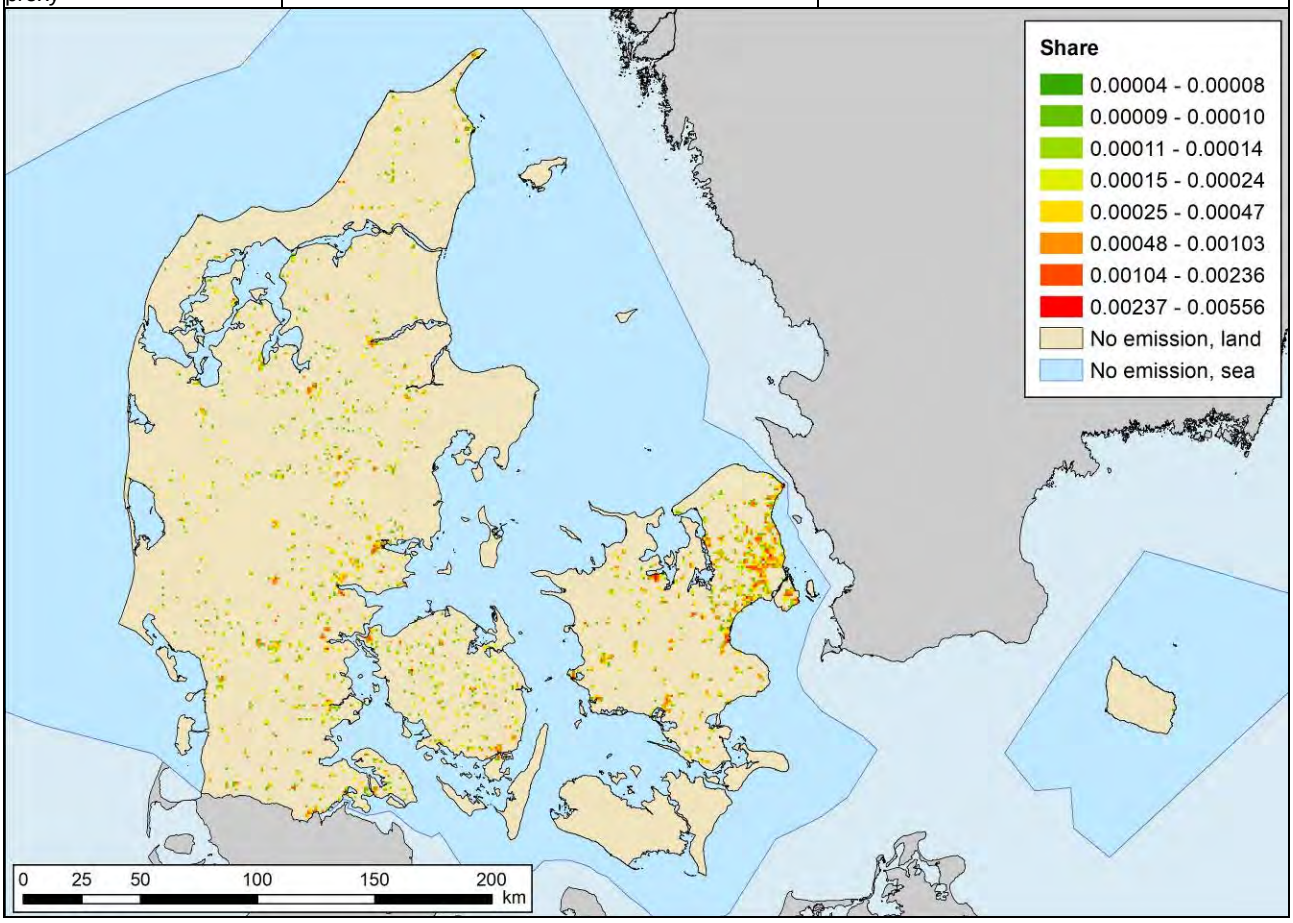
Gaseous fuels

The spatial dataset used for the GeoKey for gaseous fuels is considered to have medium uncertainty as the BBR register generally have uncertainties regarding heating installation. Due to legislation for gas-fired appliances, the

registration is assumed more accurate than for liquid and solid fuel installations. The spatial applicability is considered fair as the data is a snapshot from 2017 and does not include any time series data. Further, the data set does not include any activity data.

Table 5.19 GeoKey for commercial and institutional plants – gaseous fuels.

Source data	The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4			
Workflow	The buildings that fulfil the criteria regarding building use and heating installation in Table 5.15 and where the fuel type is 2 (town gas) or 7 (natural gas), and/or where the supplementary heating type is 6 (gas) or 10 (biogas), are selected. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0201_Gas			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0201 - Commercial and institutional plants - Gas	3		



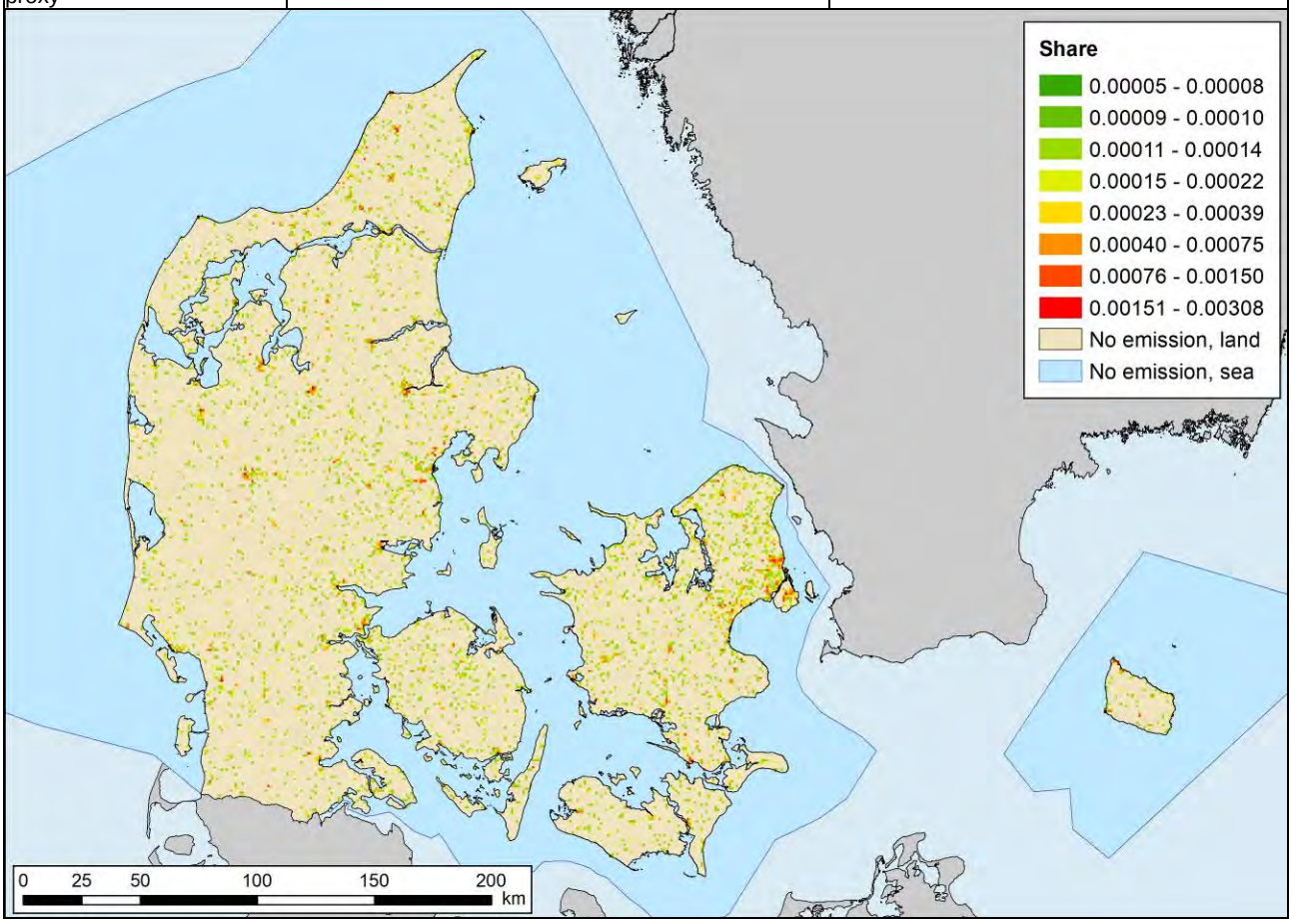
Liquid fuels

The spatial dataset used for the GeoKey for liquid fuels is considered to have high uncertainty as the BBR register generally have uncertainties regarding heating installation, and the number of liquid fuel appliances is overestimated, as many have been taken out of use without being removed or

changed in the register. The spatial applicability is considered fair as the data is a snapshot from 2017 and does not include any time series data. Further, the data set does not include any activity data.

Table 5.20 GeoKey for commercial and institutional plants – liquid fuels.

Source data	The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4			
Workflow	The buildings that fulfil the criteria regarding building use and heating installation in Table 5.15 and where the fuel type is 3 (liquid), and/or where the supplementary heating type is 3 (liquid), are selected. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0201_ Liquid			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	Ni		
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	D			
Applicability as spatial proxy	0201 - Commercial and institutional plants - Liquid	3		



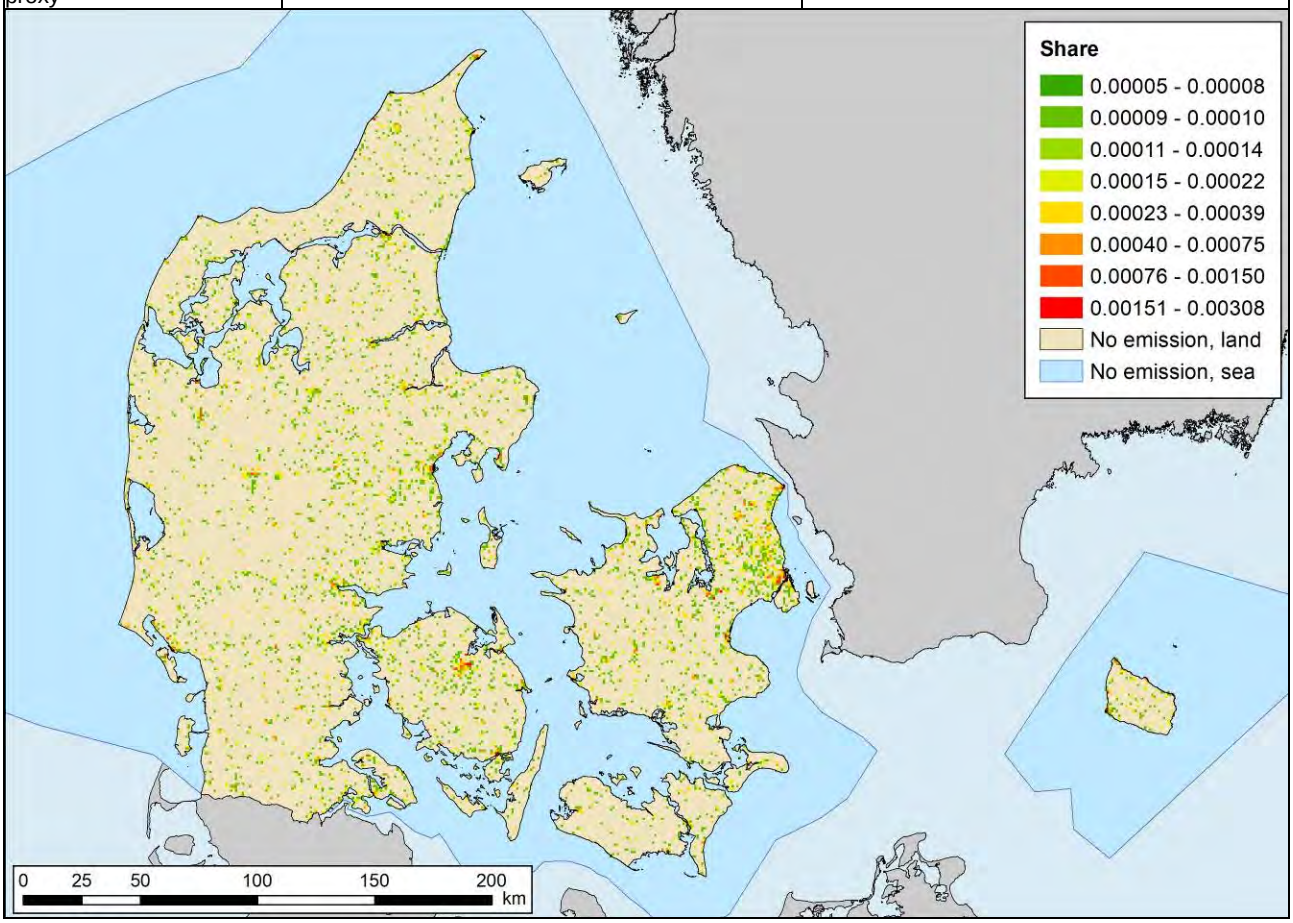
Solid fuels

The spatial dataset used for the GeoKey for solid fuels is considered to have high uncertainty as the BBR register generally have uncertainties regarding heating installation. The number of solid fuel appliances is largely underestimated in BBR. The house owners have the responsibility to register installa-

tion of new appliances and dismantling of old appliances. The spatial applicability is considered fair as the data is a snapshot from 2017 and does not include any time series data. Further, the data set does not include any activity data.

Table 5.21 GeoKey for commercial and institutional plants – solid fuels.

Source data	The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4			
Workflow	The buildings that fulfil the criteria regarding building use and heating installation in Table 5.15 Table 5.15and where the fuel type is 4 (solid fuel), and/or where the supplementary heating type is 2 (stove, solid fuel) or 5 (open fireplace, solid fuel), are selected. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0201_ Solid			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	Cd, Cr, Hg, Ni, Zn, HCB, PCDD/F, BbF, PCBs	BbF	PCDD/F, BbF, BkF, BaP, IcdP
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cu, Pb, Se, Zn, HCB, PCDD/F, BbF, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCBs
Quality of spatial dataset	D			
Applicability as spatial proxy	0201 - Commercial and institutional plants - Solid	3		



5.2.6 Residential plants

The GeoKeys for residential plants are based on detailed data from The Danish Association of Chimneysweepers (SFL) (Chapter 4.6), and data from the BBR. The SFL data holds the address and the type of appliance, but no information of the building use. A spatial join is run in GIS to join the building use from the nearest BBR address point to each of the SFL address points. Data from the BBR is used for gap filling for the areas not included in the SFL data (Figure 4.2), so that these areas are based entirely on BBR data.

The BBR holds data on building level while the SFL data are on address level, and therefore one address in the SFL data can be associated with different building use types in the BBR after the spatial join of the two data sets. To assign only one building use type to each SFL address, ranking of building use types is introduced (Table 5.22 and Table 5.23).

Table 5.22 Ranking of building use in the BBR associated to the SFL for appliances fired with liquid or solid fuels.

Ranking	Building use
1	Residential, Permanent residence
2	Agricultural
3	Residential, Holiday house
4	Residential, Apartment
5	Commercial & Institutional

Table 5.23 Ranking of building use in the BBR associated to the SFL for appliances fired with straw.

Ranking	Building use
1	Agricultural
2	Residential, Permanent residence
3	Residential, Holiday house
4	Residential, Apartment
5	Commercial & Institutional

The straw-fired boilers are allocated very differently in SFL and BBR between residential and agricultural buildings, which makes it problematic to use BBR for gap filling. To overcome this issue, a common GeoKey is prepared for straw-fired boilers, including all straw-fired appliances in SFL and BBR regardless of building use (commercial and institutional, residential, or agricultural).

Appliances on addresses, which have been assigned specific building uses, heating installations, fuels, and supplementary heating categories, are included in the GeoKey for emissions from residential plants (Table 5.24, Table 5.25, Table 5.26 and Table 5.27.

Table 5.24 BBR building use categories included in the GeoKeys for residential plants.

Building use	Building categories
110 Farmhouse	Permanent residence
120, 130-132 Detached house	Permanent residence
140 Apartment building	Apartment
185 Annex to permanent residence	Permanent residence
190 Other permanent residence	Permanent residence
510 Holiday house	Holiday house
522, 523 Holiday apartment	Holiday house
539 Other holiday building	Holiday house
540 Allotment	Holiday house
585 Annex to holiday house	Holiday house
590 Other leisure building	Holiday house

Table 5.25 BBR heating installation categories included in the GeoKeys for residential plants.

Heating installation
2 Boiler, one unit
3 Stove
6 Boiler, two units
8 Gas appliance

Table 5.26 BBR fuel categories included in the GeoKeys for residential plants.

Fuel
2 Town gas
3 Liquid
4 Solid
6 Straw
7 Natural gas

Table 5.27 BBR supplementary heating categories included in the GeoKeys for residential plants.

Supplementary heating
2 Stove, solid fuel
3 Stove, liquid fuel
5 Open fireplace, solid fuel
6 Gas
10 Biogas

Separate GeoKeys are prepared for gaseous fuels, liquid fuels, straw and solid fuels (wood). Only a very limited number of gas-fired appliances are included in the SFL data, as they do not require chimney sweeping unless they are connected to a chimney together with an appliance, for which chimney sweeping is compulsory. Accordingly, the GeoKey for gas-fired appliances are based solely on data from the BBR.

The GeoKeys for gaseous fuels, liquid fuels and straw are based on the location of the relevant appliances, i.e. the share of the total number of relevant appliances in the grid cells. A more detailed approach is made for solid fuels (wood being by far the dominant fuel), as residential wood combustion is a large emission source in Denmark with large impact on air quality and exposure, as emissions occur in low heights in areas where people live. The detailed methodology developed for residential wood combustion contribute a more precise reflection of the spatial emission pattern and thereby ensure the

best possible input to the air quality models. The detailed methodology introduce weighting factors for the appliances based on appliance information in the SFL data, and building use information and heating type in the BBR. The residential buildings are subdivided into the categories "permanent residence", "apartment" and "holiday house" (Table 5.28). Further, the appliances are categorised as "boiler" or "stove", and as "primary" or "supplementary" heating installation.

Table 5.28 Categorisation of appliances in SFL based on SFL appliance group and BBR primary heating type.

SFL appliance	BBR primary	SPREAD categorisation		
group	heating type	Fuel	Technology	Primary/supplementary
Other		Wood	Stove	Supplementary
Other, wood		Wood	Stove	Supplementary
Wood boiler		Wood	Boiler	Primary
Wood stove	Gas	Wood	Stove	Supplementary
Wood stove	Boiler, solid	Wood	Stove	Supplementary
Wood stove	Boiler, liquid	Wood	Stove	Supplementary
Wood stove	Boiler, straw	Wood	Stove	Supplementary
Wood stove	Stove, solid	Wood	Stove	Primary
Wood stove	Stove, liquid	Wood	Stove	Supplementary
Wood stove	Other	Wood	Stove	Supplementary
Gas		Gas	Boiler	Primary
Straw boiler		Straw	Boiler	Primary
Oil boiler		Liquid	Boiler	Primary
Wood pellet boiler		Wood	Boiler	Primary

For wood boilers, which are all assumed to be used as primary heating installations, a weighting factor of 1 is applied for permanent residences and apartments, while holiday houses have a weighting factor of 0.8 (Table 5.29).

The relatively high factor allocated to holiday houses is assumed because the economic cost of installing a boiler and corresponding heat distribution system indicate that the holiday house will be used for the majority of the year or even be permanently inhabited, which is possible for retired people in Denmark. The corresponding weighting factor for primary stoves are 0.8 for permanent residences and apartments, and 0.2 for holiday houses. The factor for holiday houses is lower as they are generally smaller and occupied only part of the year mainly in warmer periods.

For supplementary appliances (only stoves) in permanent residences, a weighting factor of 0.4 is applied, based on the assumption, that the wood consumption for supplementary heating is half the amount of primary heating with wood stoves (Table 5.29).

The wood consumption in apartments are assumed to be one tenth for supplementary heating (0.08) compared to primary heating, as the space for wood storage is limited, and access to and transport of the stored wood is often inconvenient. For holiday houses, the same weighting factor is applied for supplementary stove as for primary stove. A more thorough description of the weighting factors for spatial emission modelling for residential wood combustion in Denmark are available in Plejdrup et al. (2016).

Table 5.29 Weighting factors for residential wood appliances.

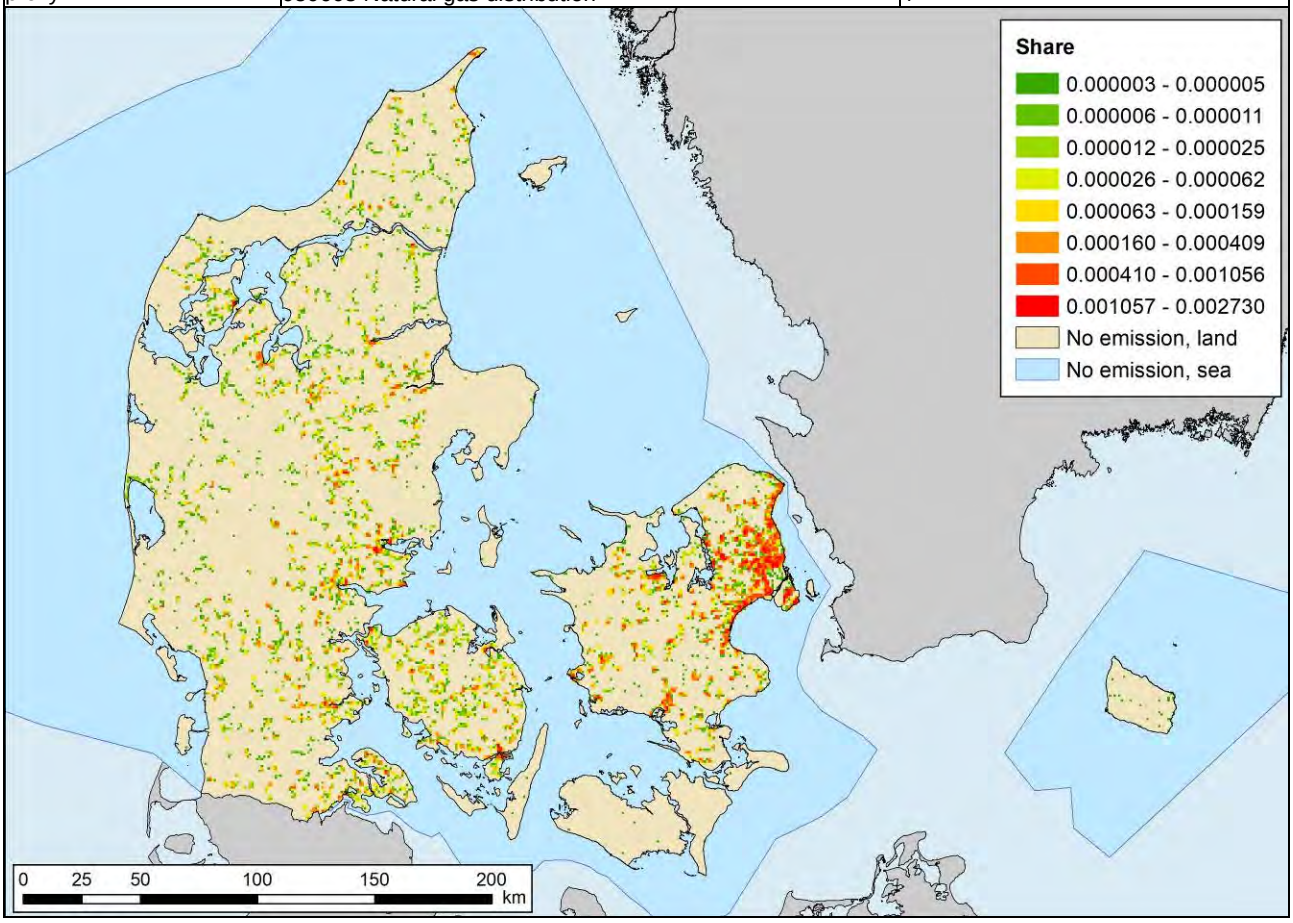
Heating installation		Building categories	Weighting factor
Primary heating	Boiler	Permanent residence	1
		Apartment	1
		Holiday house	0,8
	Stove	Permanent residence	0,8
		Apartment	0,8
		Holiday house	0,2
Supplementary heating	Stove	Permanent residence	0,4
		Apartment	0,08
		Holiday house	0,2

Gaseous fuels

The spatial dataset used for the GeoKey for gas-fired residential plants is considered to have medium uncertainty as the BBR register generally have some uncertainties regarding heating installation. Due to legislation for gas-fired appliances, the registration is assumed more accurate than for liquid and solid fuel installations. The spatial applicability is considered fair as the data is a snapshot from 2017 and does not include any time series data. Further, the data set does not include any activity data.

Table 5.30 GeoKey for residential plants – gaseous fuels.

Source data	The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4			
Workflow	The buildings that fulfil the criteria regarding building use and heating installation in Table 5.24 and Table 5.25, and where the fuel type is 2 (town gas) or 7 (natural gas), and/or where the supplementary heating type is 6 (gas) or 10 (biogas), are selected. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0202_Gas			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			As, Hg
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cr, Cu, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0202 Residential plants - Gsa		3	
	050603 Natural gas distribution		4	

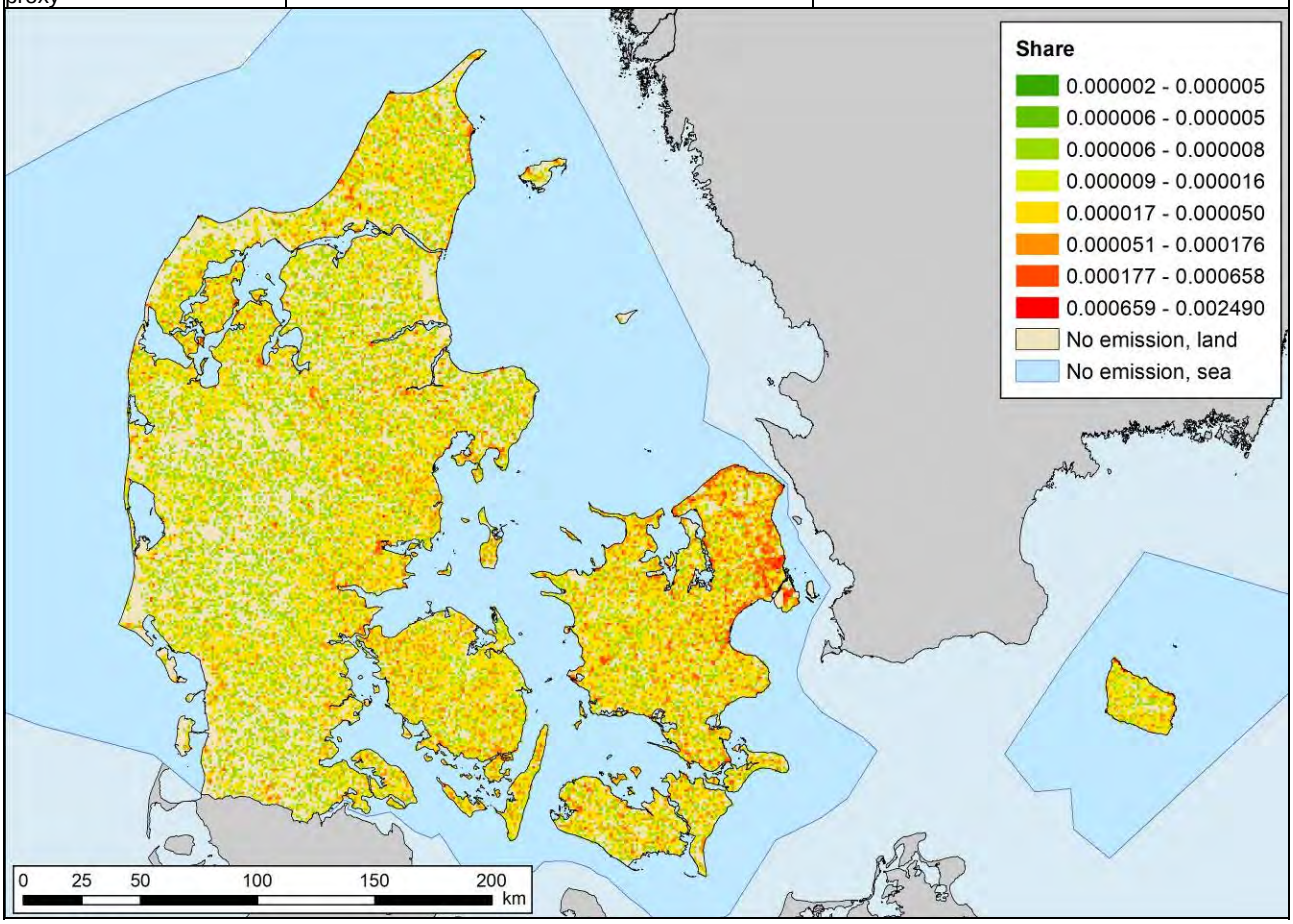


Liquid fuels

The spatial data used for the GeoKey for residential plants using liquid fuels is considered to have medium uncertainty as the number of appliances is overestimated in the SFL data as appliances not in use but still connected to a chimney require chimney sweep, and therefore occur in the SFL data (Nielsen & Plejdrup, 2018). The BBR register generally have uncertainties regarding heating installation and the number of liquid-fired appliances is largely over-estimated. The spatial applicability is considered fair as neither the SFL nor the BBR data include time series or activity data.

Table 5.31 GeoKey for residential plants – liquid fuels.

Source data	SFL data The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Association of Danish Chimney sweepers (SFL) The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4 and Chapter 4.6			
Workflow	Appliances from the SFL data that are categorised as using liquid fuels are include in the GeoKey, and for areas not covered by SFL, the buildings that fulfil the criteria in Table 5.24 and Table 5.25, and where the fuel is 3 (liquid) are used. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0202_ Liquid			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	SO_2	SO_2	
	< 1 %	NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0202 – Residential plants – Liquid	3		



Solid fuels

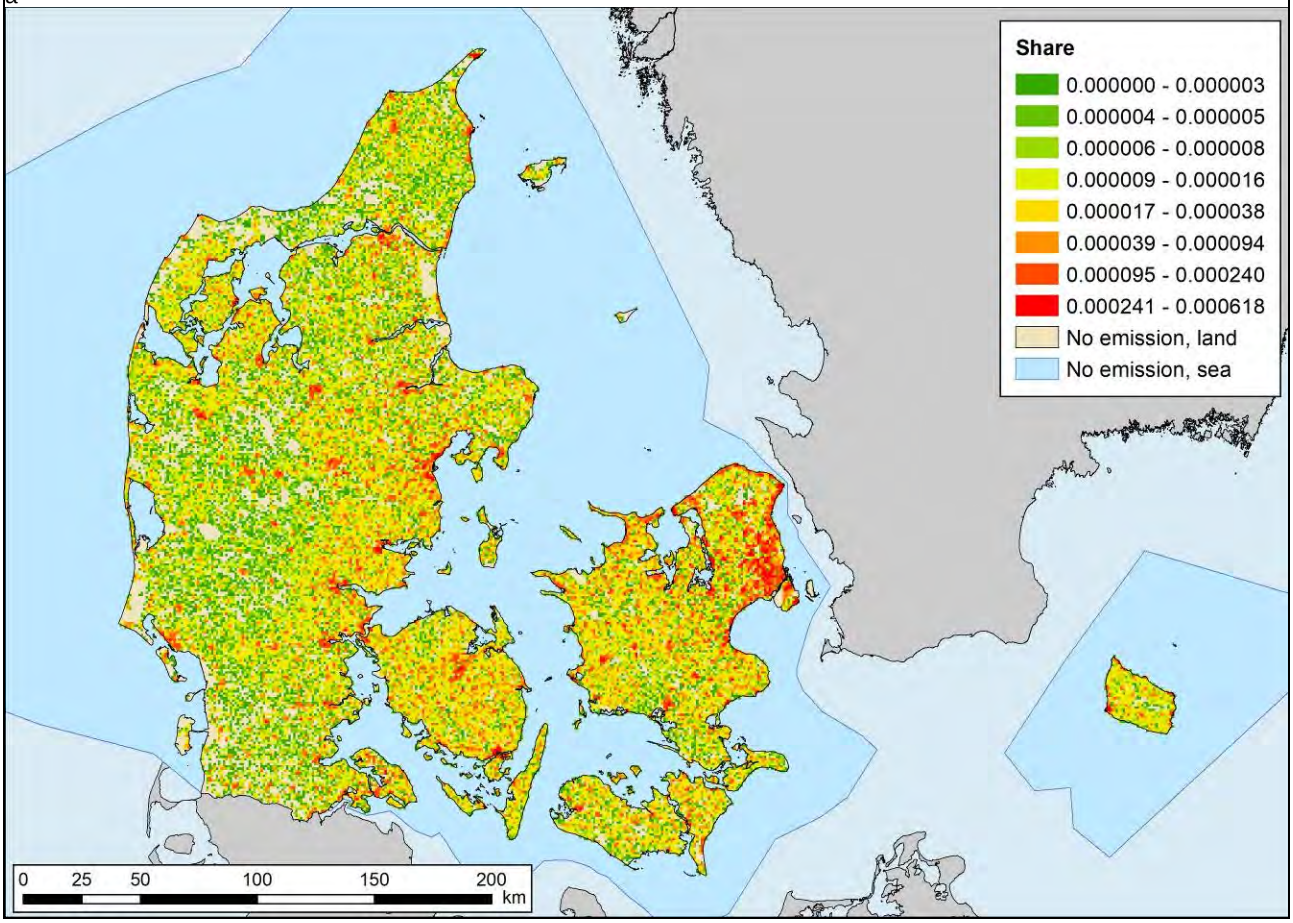
The spatial data used for the GeoKey for residential plants using solid fuels is considered to have low uncertainty. The SFL data has a very low uncertainty but as it is not of full coverage, gap filling with BBR data with a medium uncertainty is made for smaller areas. The BBR register generally have uncertainties regarding heating installation and the number of appliances using solid fuels is largely underestimated. The spatial applicability is considered

good. The dataset could be more applicable if the SFL or the BBR data included a time series. The weighting factors serve as proxy for actual activity data.

Table 5.32 GeoKey for residential plants – solid fuels.

Source data	SFL data The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Association of Danish Chimney sweepers (SFL) The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4 and Chapter 4.6			
Workflow	Appliances from the SFL data that are categorised as using solid fuels are include in the GeoKey, and for areas not covered by SFL, the buildings that fulfil the criteria in Table 5.24 and Table 5.25, and where the fuel is 4 (solid) are used. The GeoKey is calculated using the weighting factors in Table 5.29. Further description is found in Chapter 5.2.6 and in Plejdrup et al. (2016).			
GeoKey name	_Key_0202_Solid			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	PM_{10}, $PM_{2.5}$, PCDD/F, BbF, BkF, BaP, IcdP	CO, TSP, PM_{10}, $PM_{2.5}$, Cd, Cr, Zn, PCDD/F, BbF, BkF, BaP, IcdP	CO, PM_{10}, $PM_{2.5}$, BC, Cd, Cr, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
	5-10 %	CO, TSP, Zn, HCB	BC, PCBs	TSP, Hg, Pb, HCB
	1-5 %	NMVOC, BC, Ni, PCBs	SO_2, NMVOC, NH_3, Hg, Pb, HCB	SO_2, NO_x, NMVOC, NH_3, As, Ni, Se
	< 1 %	SO_2, NO_x, NH_3, As, Cu, Hg, Pb, Se	NO_x, As, Cu, Ni, Se	Cu
Quality of spatial dataset	B			
Applicability as spatial proxy	0202 – Residential plants – Solid		2	

a

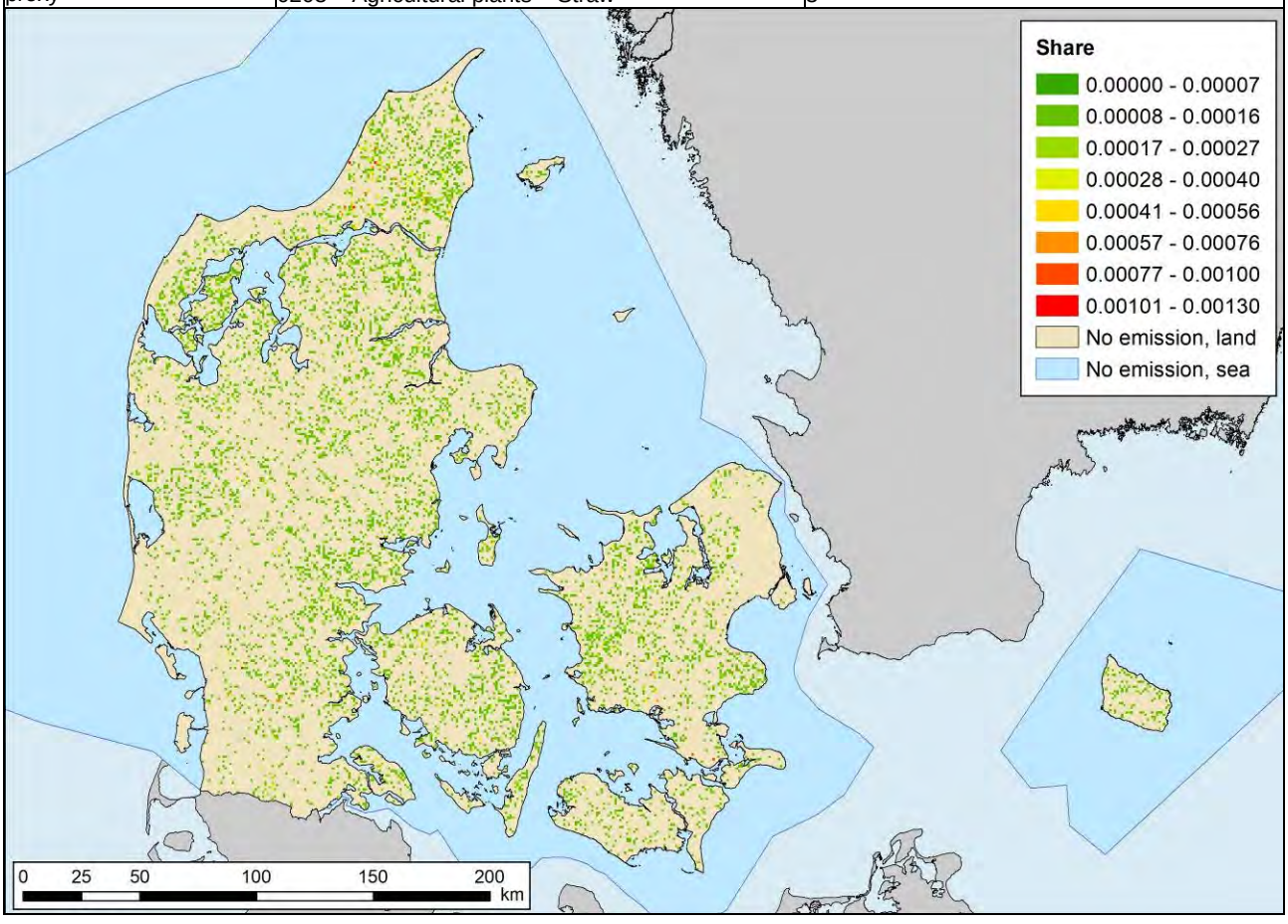


Straw

The spatial data used for the GeoKey for straw-fired residential plants is considered to have low uncertainty. The SFL data has a very low uncertainty but as it is not of full coverage, gap filling with BBR data with a medium uncertainty is made for smaller areas. The BBR register generally have uncertainties regarding heating installation and the number of straw-fired appliances is largely overestimated. The spatial applicability is considered fair as the data is a snapshot from 2017 and does not include any time series data. Further, the data set does not include any activity data.

Table 5.33 GeoKey for residential and agricultural plants – straw.

Source data	SFL data The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Association of Danish Chimney sweepers (SFL) The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4 and Chapter 4.6			
Workflow	Appliances from the SFL data that are categorised as straw-fired are included in the GeoKey, and for areas not covered by SFL, the buildings from the BBR where the fuel is 6 (straw) are used. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_02_Straw			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	$PM_{2.5}$, BC	BC	$PM_{2.5}$, BC
	5-10 %	CO, PM_{10}, Cd, Zn, PCDD/F	PM_{10}, $PM_{2.5}$, Cd, PCDD/F	SO_2, PM_{10}, Cd, PCDD/F
	1-5 %	TSP, Cr, BbF, BkF, BaP, IcdP	SO_2, CO, TSP, Cr, Zn, BbF, BkF, BaP, PCBs	CO, TSP, Cr, Hg, Pb, Zn, HCB, BbF, BkF, BaP, IcdP, PCBs
	< 1 %	SO_2, NO_x, NMVOC, NH_3, As, Cu, Hg, Ni, Pb, Se, HCB, PCBs	NO_x, NMVOC, NH_3, As, Cu, Hg, Ni, Pb, Se, HCB, IcdP	NO_x, NMVOC, NH_3, As, Cu, Ni, Se
Quality of spatial dataset	B			
Applicability as spatial proxy	0202 – Residential plants – Straw	3		
	0203 – Agricultural plants – Straw	3		



5.2.7 Agricultural plants

The national building and dwelling register (BBR) is used to identify agricultural buildings from information on building use. Further, information on primary heating and fuel is used to identify agricultural plants. BBR does not hold detailed information on installation technology making it possible to differentiate emissions between the identified plants, and therefore the GeoKey is set up to distribute emissions evenly between the identified plants, i.e. all plants using a specific fuel is assumed to have the same fuel consumption.

Table 5.34, Table 5.35, Table 5.36 and Table 5.37 list the building use, heating installation, fuel, and supplementary heating categories, respectively, which are included in the GeoKeys for emissions from agricultural plants.

Table 5.34 BBR building use categories included in the GeoKeys for agricultural plants.

Building use
210 Production building in agriculture, horticulture etc.
211, 212, 213,214 Animal housing
215 Greenhouse
216, 217, 218 Barn
219 Other building in agriculture, forestry or fishery
290 Other building in agriculture, industry etc.

Table 5.35 BBR heating installation categories included in the GeoKeys for agricultural plants.

Heating installation
2 Boiler, one unit
3 Stove
6 Boiler, two units
8 Gas appliance

Table 5.36 BBR fuel categories included in the GeoKeys for agricultural plants.

Fuel
2 Town gas
3 Liquid
4 Solid
6 Straw
7 Natural gas

Table 5.37 BBR supplementary heating categories included in the GeoKeys for agricultural plants.

Supplementary heating
2 Stove, solid fuel
3 Stove, liquid fuel
5 Open fireplace, solid fuel
6 Gas
10 Biogas

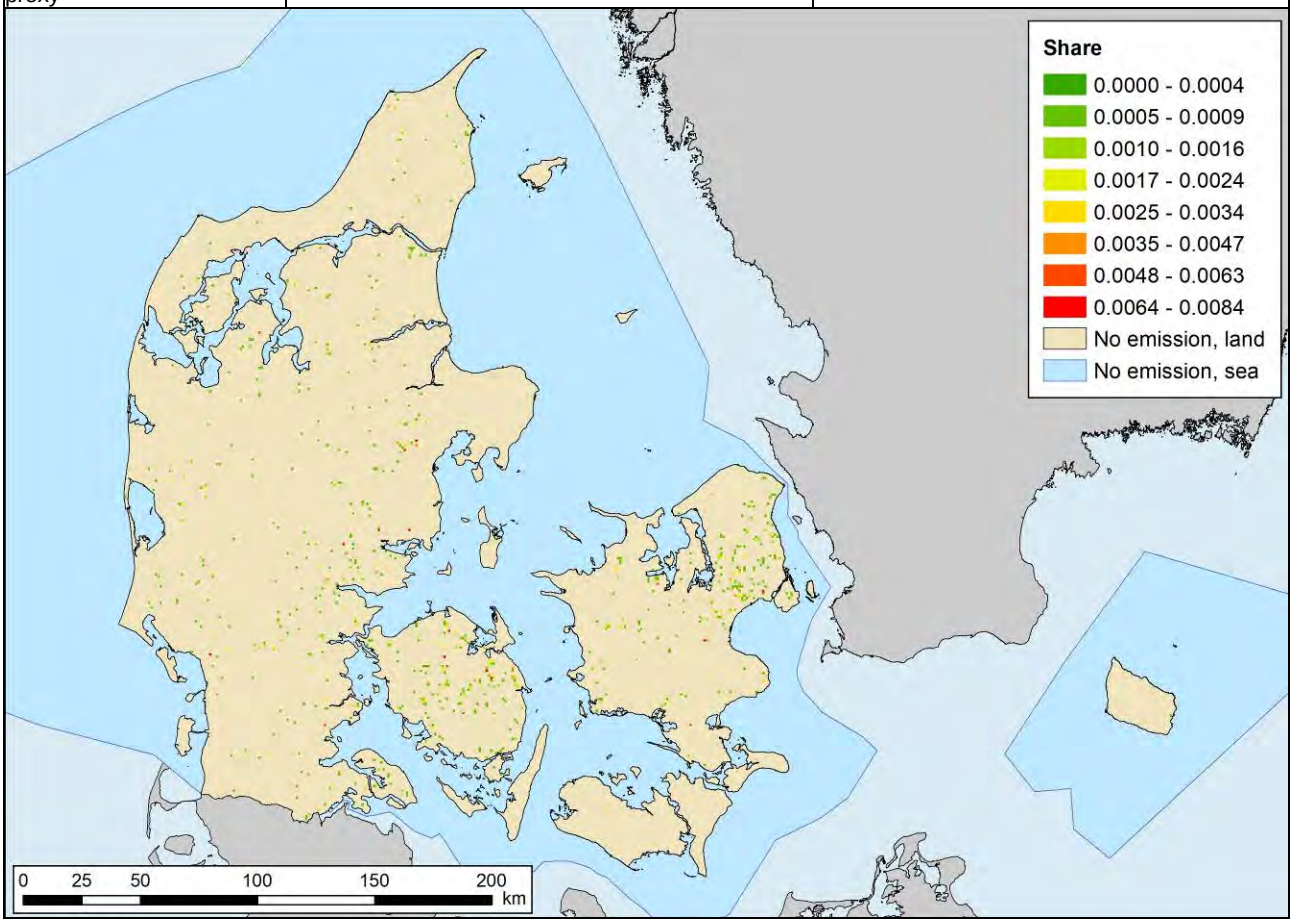
Gaseous fuels

The spatial dataset used for the GeoKey for gas-fired agricultural plants is considered to have medium uncertainty as the BBR register generally have some uncertainties regarding heating installation. Due to legislation for gas-fired appliances, the registration is assumed more accurate than for liquid and solid fuel installations. The spatial applicability is considered fair as the data

is a snapshot from 2017 and does not include any time series data. Further, the data set does not include any activity data.

Table 5.38 GeoKey for agricultural plants – gaseous fuels.

Source data	The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4			
Workflow	The buildings that fulfil the criteria regarding building use and heating installation in Table 5.34 and Table 5.35 and where the fuel type is 2 (town gas) or 7 (natural gas), and/or where the supplementary heating type is 6 (gas) or 10 (biogas), are selected. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0203_Gas			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0203 – Agricultural plants – Gas		3	



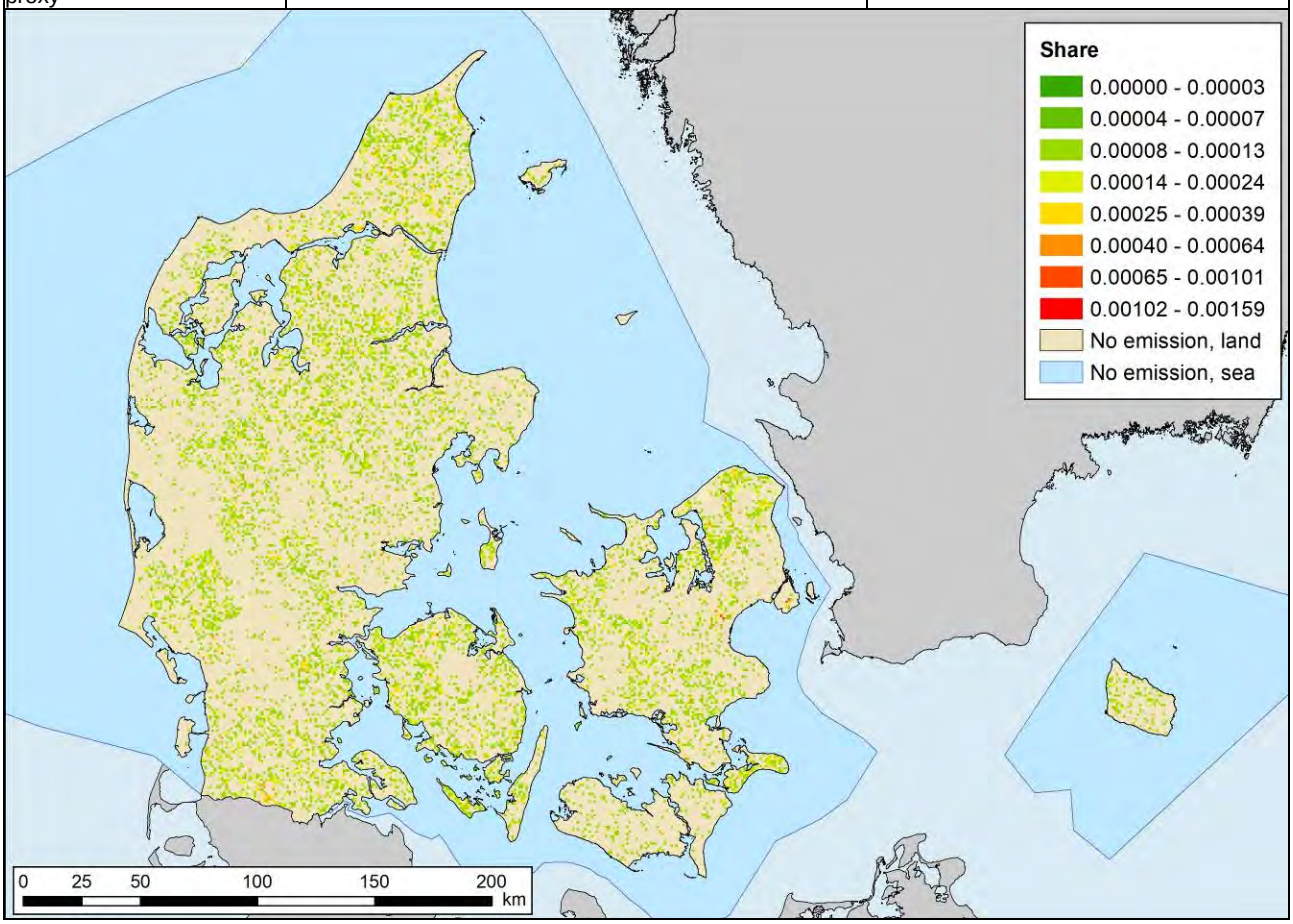
Liquid fuels

The spatial data used for the GeoKey for agricultural plants using liquid fuels is considered to have medium uncertainty as the number of appliances is overestimated in the SFL data as appliances not in use but still connected to a chimney still require chimney sweep, and therefore occur in the SFL data (Nielsen & Plejdrup, 2018). The BBR register generally have uncertainties regarding heating installation and the number of liquid-fired appliances is

largely overestimated. The spatial applicability is considered fair as neither the SFL nor the BBR data include time series or activity data.

Table 5.39 GeoKey for agricultural plants – liquid fuels.

Source data	The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4			
Workflow	The buildings that fulfil the criteria regarding building use and heating installation in Table 5.34 and Table 5.35 and where the fuel type is 3 (liquid), and/or where the supplementary heating type is 3 (liquid), are selected. The GeoKey is calculated as the share of the total selected number of buildings by grid cell.			
GeoKey name	_Key_0203_Liquid			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	Ni	SO_2, Ni	
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb Se, Zn, HCB, PCDD/F, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0203 – Agricultural plants – Liquid		3	



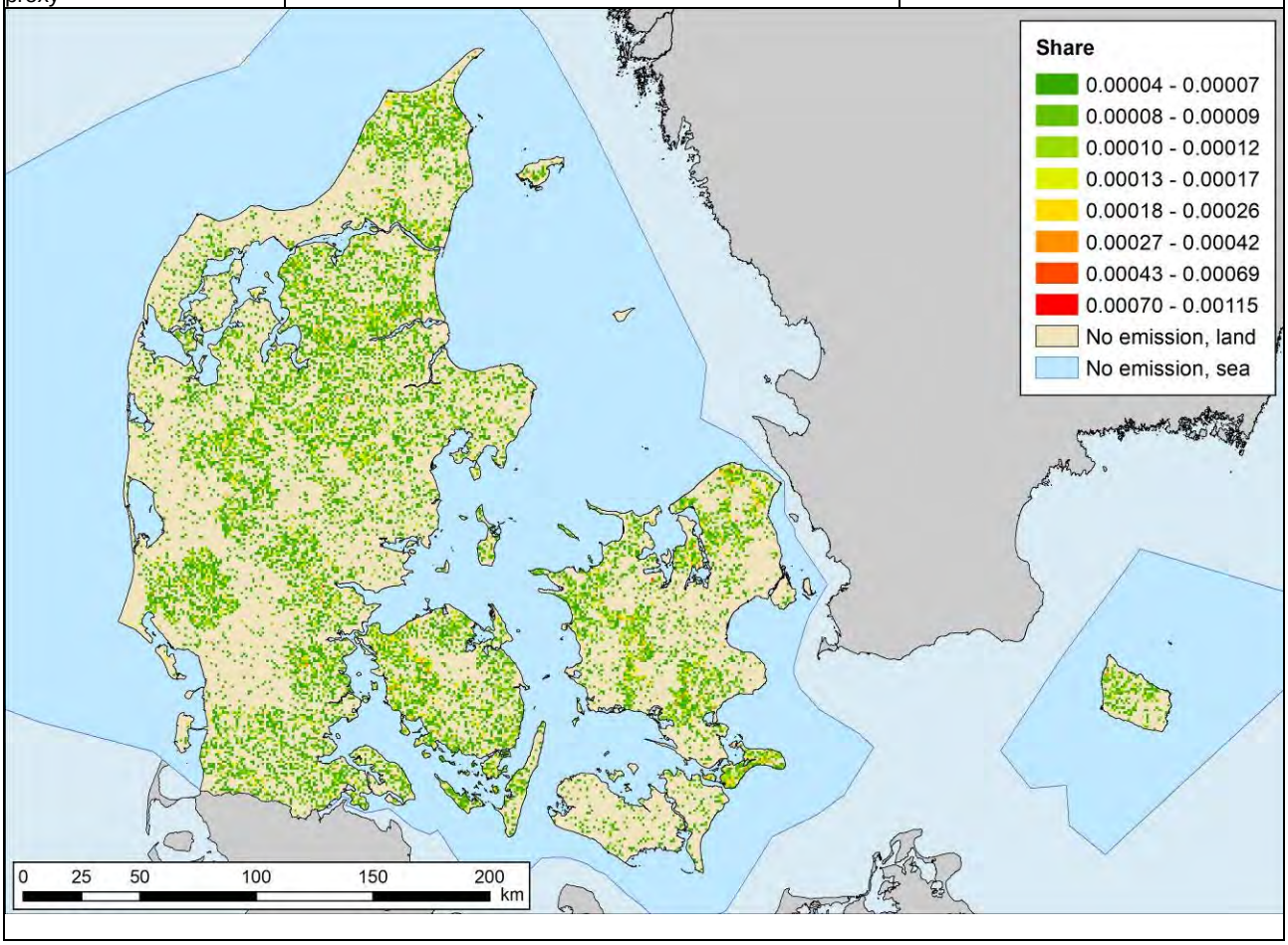
Solid fuels

The spatial data used for the GeoKey for agricultural plants using solid fuels is considered to have low uncertainty. The SFL data has a very low uncertainty but as it is not of full coverage, gap filling with BBR data with a medium uncertainty is made for smaller areas. The BBR register generally have uncertainties regarding heating installation and the number of appliances using

solid fuels is largely underestimated. The spatial applicability is considered good. The dataset could be more applicable if the SFL or the BBR data included a time series. The weighting factors serve as proxy for actual activity data.

Table 5.40 GeoKey for agricultural plants – solid fuels.

Source data	SFL data The Building and Dwelling Register (BBR), version November 2017			
Data provider	The Association of Danish Chimney sweepers (SFL) The Danish Customs and Tax Administration (SKAT)			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 4.4 and Chapter 4.6			
Workflow	Appliances from the SFL data that are categorised as using solid fuels are include in the GeoKey, and for areas not covered by SFL, the buildings that fulfil the criteria in Table 5.34 and Table 5.35 and where the fuel is 4 (solid) are used. The GeoKey is calculated using the weighting factors in Table 5.29.			
GeoKey name	_Key_0203_Solid			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %	BbF, IcdP	IcdP	IcdP
	1-5 %	SO_2, As, Ni, Se, PCDD/F, BaP	SO_2, As, Cr, Hg, Se, HCB, PCDD/F, BbF, BaP, PCBs	Se, BbF, BkF, BaP
	< 1 %	NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cr, Cu, Hg, Pb, Zn, HCB, BkF, PCBs	NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cu, Ni, Pb, Zn, BkF	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, HCB, PCDD/F, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	0203 – Agricultural plants – Solid			2



Straw

Straw-fired agricultural plants are distributed using the same GeoKey as for residential straw-fired appliances (Table 5.33).

The spatial data used for the GeoKey for straw-fired agricultural plants is considered to have low uncertainty. The SFL data has a very low uncertainty but as it is not of full coverage, gap filling with BBR data with a medium uncertainty is made for smaller areas. The BBR register generally have uncertainties regarding heating installation and the number of straw-fired appliances is largely overestimated. The spatial applicability is considered poor as the data is a snapshot from 2017 and does not include any time series data or activity data. Further, the GeoKey is prepared for residential buildings, but applied also for agricultural buildings.

5.2.8 Manufacturing plants

Emissions from manufacturing plants are largely covered by LPS and PS (Chapter 5.2.1 and 5.2.2). The part of emissions that are not covered by LPS and PS is distributed using GeoKeys based on employment statistics for Chemical industry, Machinery industry, Means of transport industry, Metal industry, Textile and leather industry, or Wood, paper and print industry, or using the general GeoKey for industry as described in Chapter 5.1.2. The share of emissions from manufacturing industry to the national total not covered by LPS and PS is shown in Table 5.41.

Table 5.41 Share of emissions from manufacturing plants (excl. LPS and PS) of the national total.

Share	1990	2005	2016
> 10 %	As, Ni	SO_2, As, Ni, HCB	As
5-10 %	SO_2, Cr, Se, Zn	Cr, Se, Pb	SO_2, Cr, Hg, Ni, Pb
1-5 %	NO_x, $PM_{2.5}$, Cd, Cu, Hg, Pb, HCB, PCDD/F, BbF, BkF	NO_x, Cd, Hg, Zn, PCDD/F	NO_x, Cd, Se, Zn, HCB
< 1 %	NMVOC, CO, NH_3, TSP, PM_{10}, BC, BaP, IcdP, PCBs	NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Cu, PAH, PCBs	NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Cu, PCDD/F, PAH, PCBs

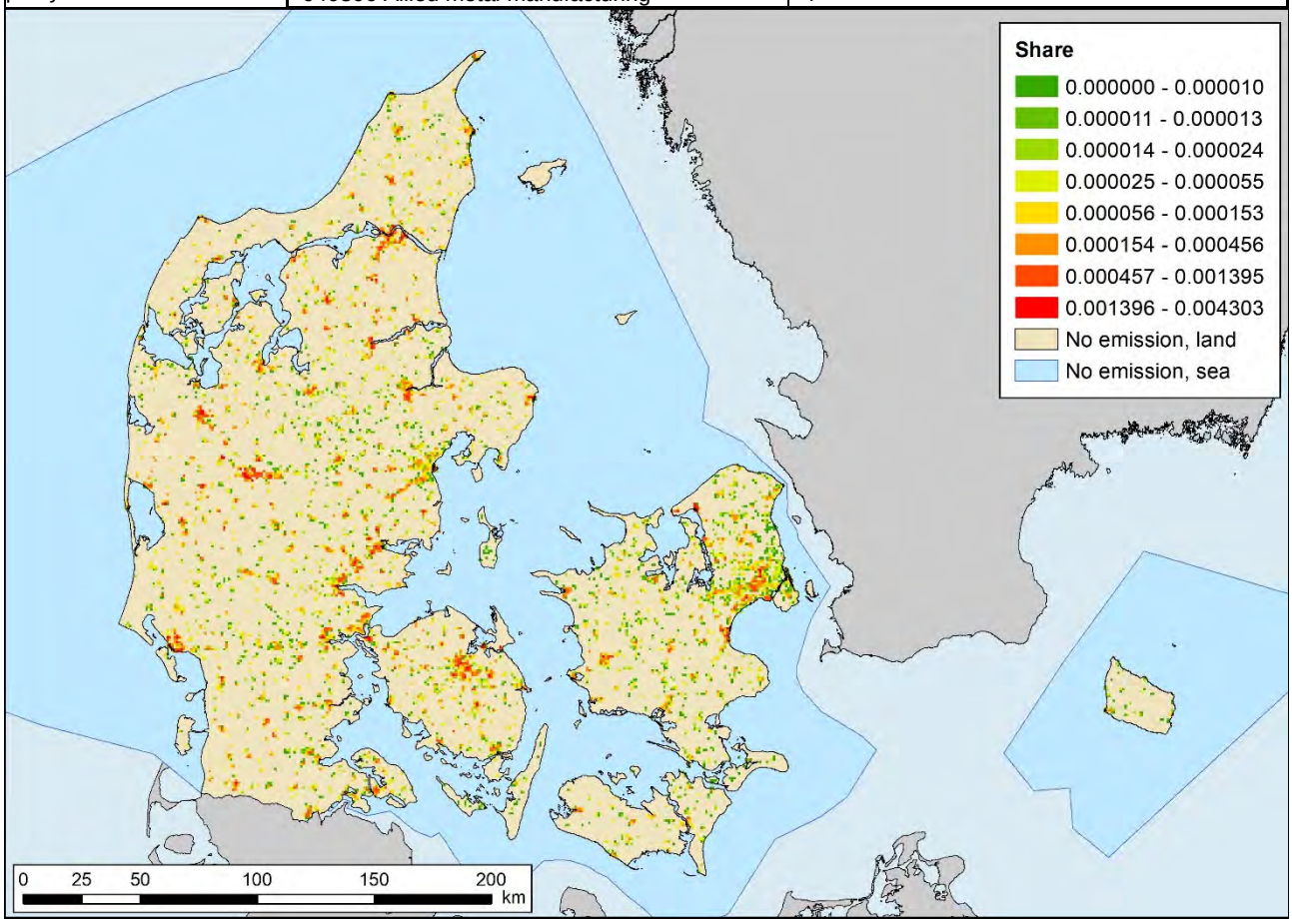
Metal industry

The GeoKey is based on employment statistics from Statistics Denmark. Data for metal industry (CH Metalindustri) are selected from the statistic data set KAS301 (“Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period”). Data are applied as annual numbers of emlpoyees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements. The spatial applicability is considered poor as the number of emlpoyees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.42 GeoKey for metal industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period			
Data provider	Statistics Denmark			
Projection				
Data description	The statistic table KAS301 holds the annual numbers of emlpoyees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CH Metalindustri" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_Metal			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		Zn	
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F,
Quality of spatial dataset	A			
Applicability as spatial proxy	0304 Manufacturing plants - Iron and Steel	4		
	040306 Allied metal manufacturing	4		



Chemical industry

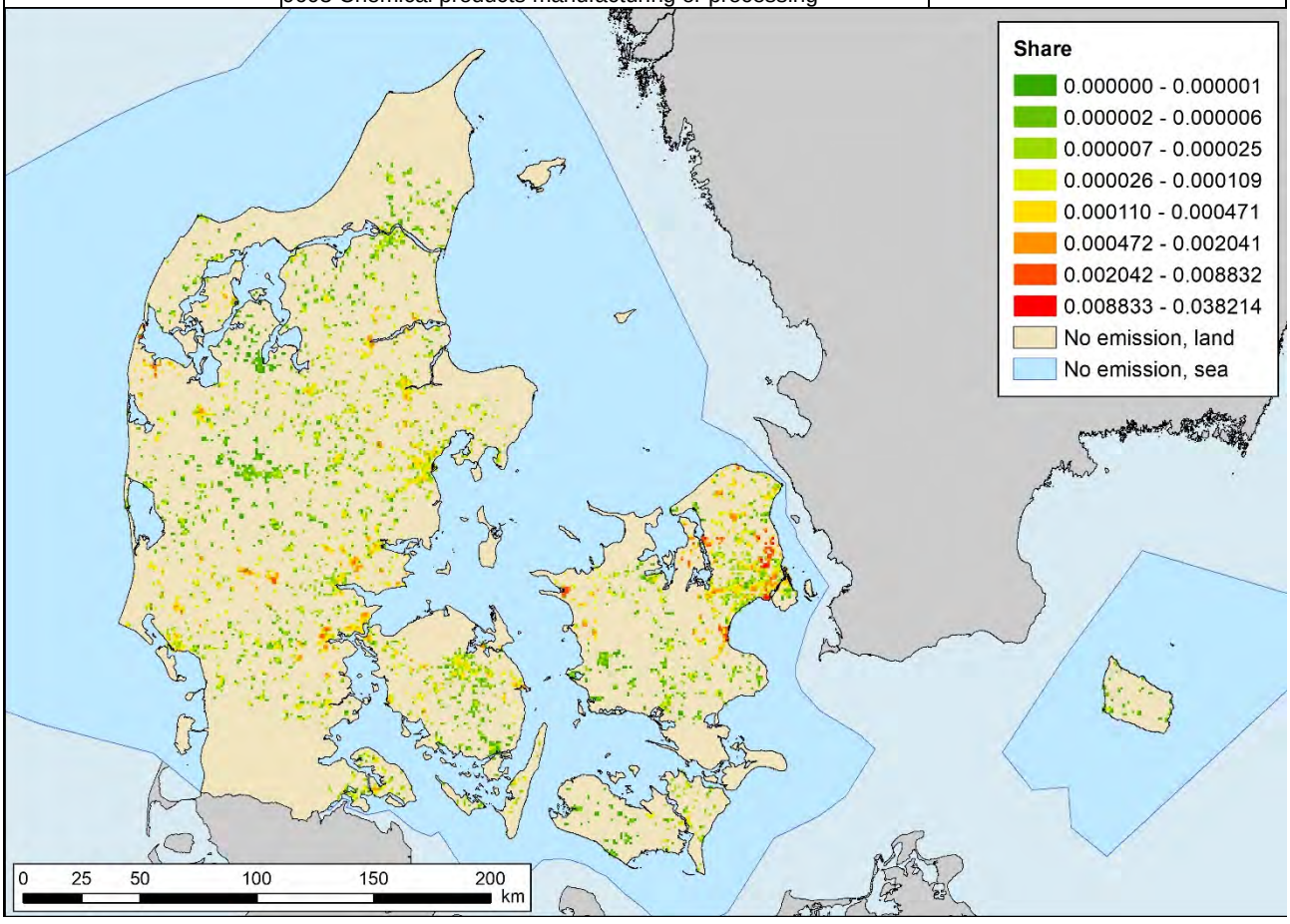
The GeoKey is based on employment statistics from Statistics Denmark. Data for chemical industry (CE Kemisk industri) are selected from the statistic data set KAS301 ("Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period"). Data are applied as annual numbers of emlpoyees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements.

The spatial applicability is considered poor as the number of emlpoyees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.43 GeoKey for chemical industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period Denmark's Administrative Boundaries (DAGI), municipalities			
Data provider	Statistics Denmark Agency for Data Supply and Efficiency			
Projection	UTM32_EUREF89			
Data description	The statistic table KAS301 holds the annual numbers of emlpoyees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CE Kemisk industri" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_ChemicalIndustry			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NMVOC, Ni	SO_2, NMVOC, Ni	NMVOC, Se
	< 1 %	SO_2, NO_x, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NO_x, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0306 Manufacturing plants - Chemical and Petrochemical	4		
	0603 Chemical products manufacturing or processing	4		



Mining and quarrying

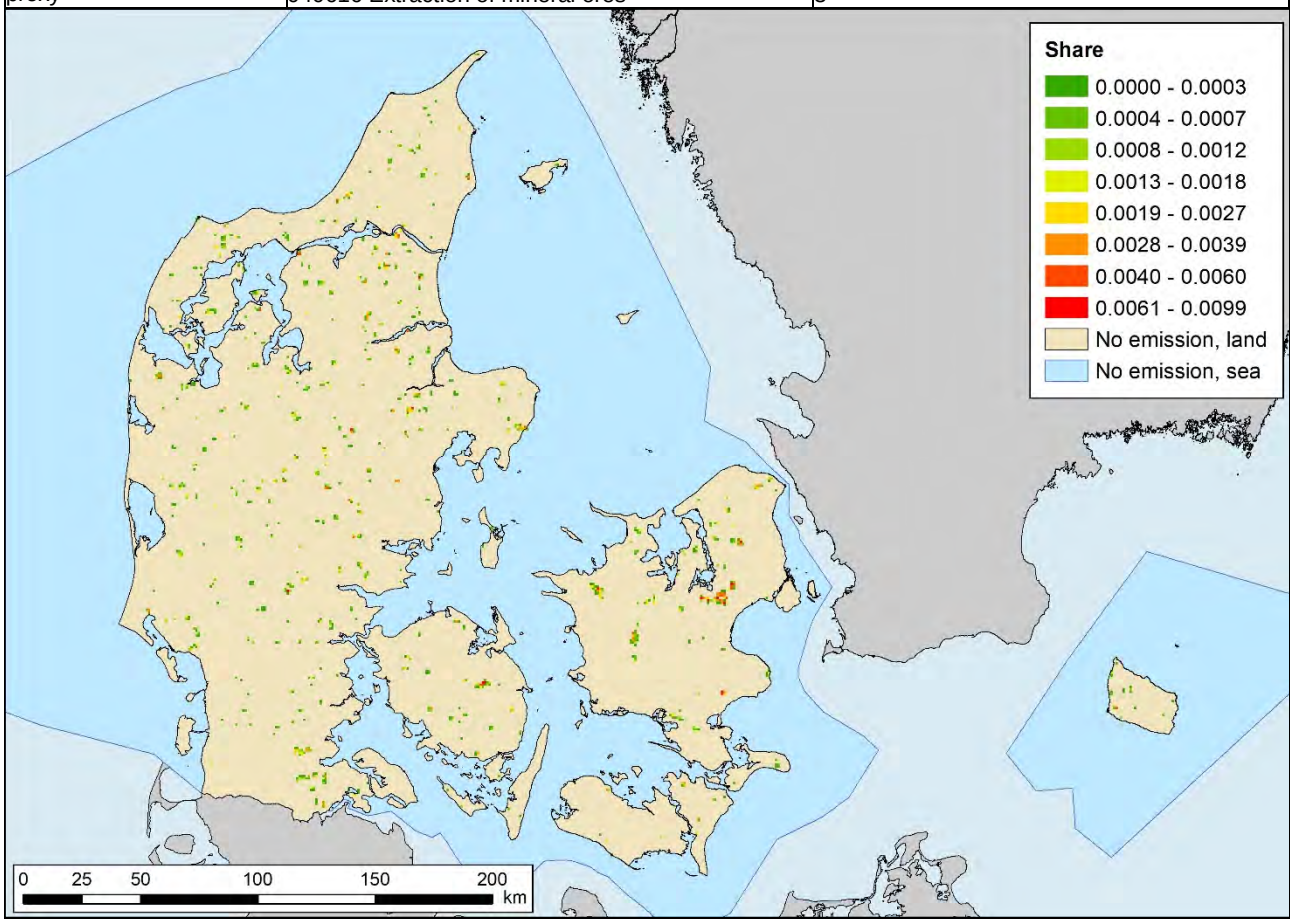
Many different minerals are quarried in Denmark leading to emissions of particulate matter. Emissions from the quarrying of minerals contributes with

some significance to the national total emissions. In later years, the share of emissions has been between 1 and 5 %.

The spatial dataset used for the GeoKey is considered to have a low uncertainty based on data from the municipalities. The spatial applicability is considered fair as activity data are not available.

Table 5.44 GeoKey for quarrying and mining.

Source data	Kort10 version 2015			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	UTM32_EUREF89			
Data description	Raw material extraction sites			
Workflow	The raw material layer is intersected with the 1 km x 1 km Danish grid net and the share of the total extraction area is calculated by grid cell.			
GeoKey name	_Key_Quarrying			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		TSP, PM_{10}	TSP, PM_{10}
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	0308 Manufacturing plants - Mining and quarrying			
	040616 Extraction of mineral ores		3	



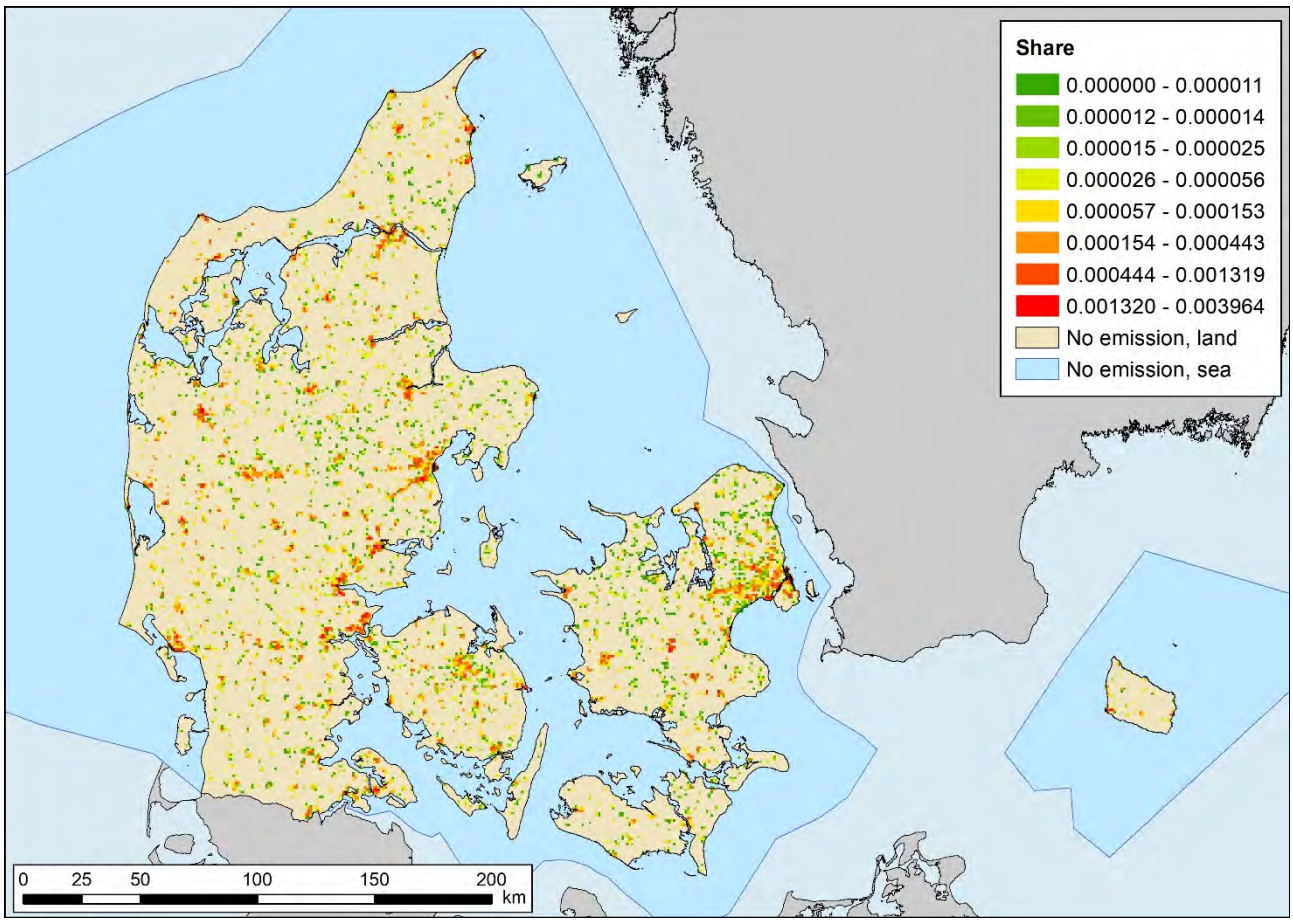
Food, drinks and tobacco industry

The GeoKey is based on employment statistics from Statistics Denmark. Data for food, drinks and tobacco industry ("CA Føde-, drikke- og tobaksvareindustri") are selected from the statistic data set KAS301 ("Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period"). Data are applied as annual numbers of emlpoyees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements. The spatial applicability is considered poor as the number of emlpoyees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.45 GeoKey for food, drinks and tobacco industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period			
Data provider	Statistics Denmark			
Projection				
Data description	The statistic table KAS301 holds the annual numbers of emlpoyees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CA Føde-, drikke- og tobaksvareindustri" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_Food_Drinks_Tobacco			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	Ni		
	5-10 %		Ni	
	1-5 %	SO_2, As, Cd, Cr, Hg, Se, Zn, PCBs	SO_2, As, Se	Hg, Se
	< 1 %	NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, Cu, Pb, HCB, PCDD/F, BbF, BkF, BaP, IcdP	NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cr, Cu, Hg, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Ni, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0309 Food and tobacco	4		
	040605 Bread	4		
	040607 Beer	4		
	040608 Spirits	4		
	040626 Flour production	4		
	040627 Meat curing	4		
	040698 Margarine and solid cooking fats	4		
	040699 Coffee roasting	4		



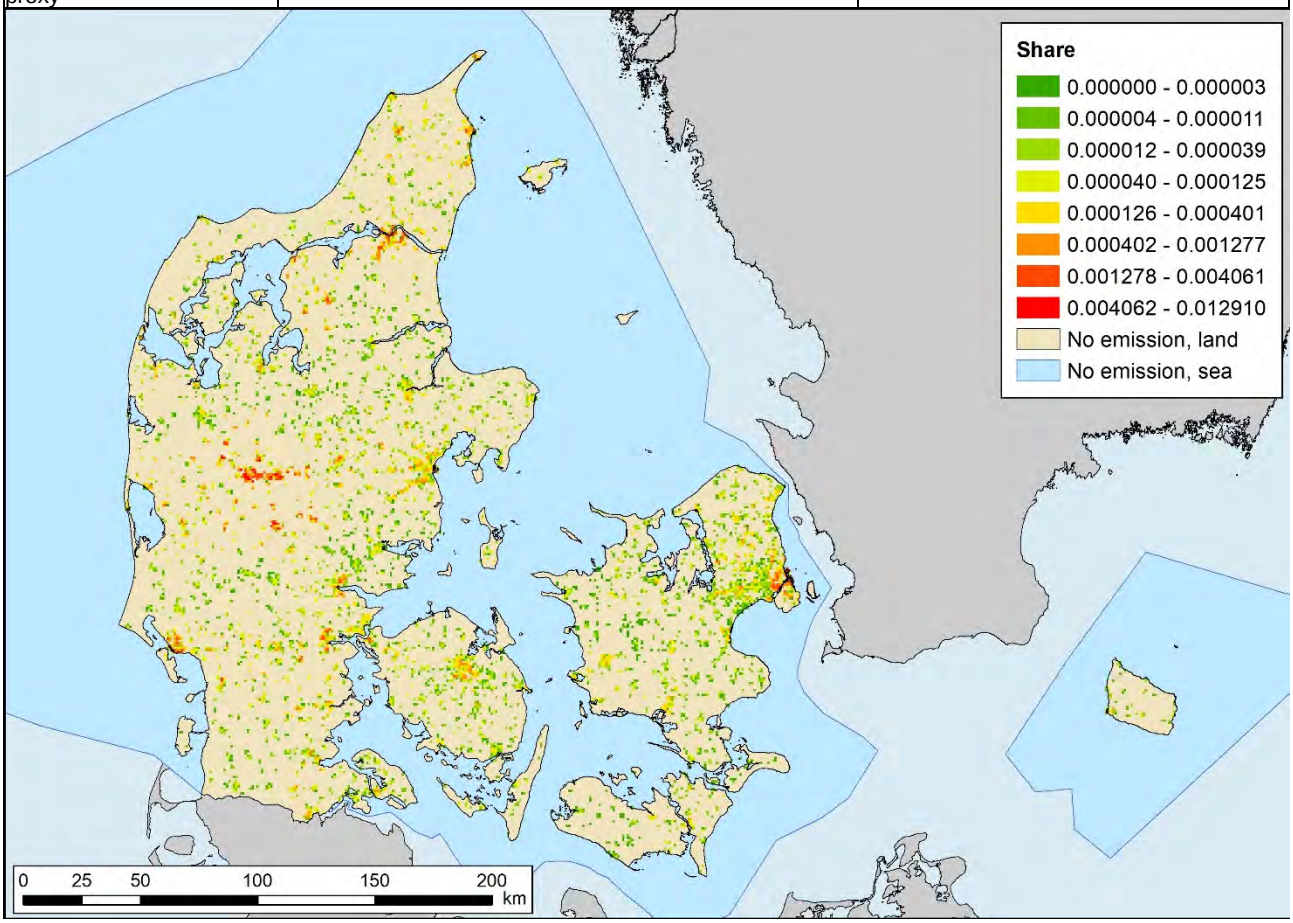
Textile and leather industry

The GeoKey is based on employment statistics from Statistics Denmark. Data for textile and leather industry (CB Tekstil- og læderindustri) are selected from the statistic data set KAS301 ("Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period"). Data are applied as annual numbers of emlpoyees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements. The spatial applicability is considered poor as the number of employees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.46 GeoKey for textile and leather industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period Denmark's Administrative Boundaries (DAGI), municipalities			
Data provider	Statistics Denmark Agency for Data Supply and Efficiency			
Projection	UTM32_EUREF89			
Data description	The statistic table KAS301 holds the annual numbers of employees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CB Tekstil- og læderindustri" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_Textile_Leather			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0310 Manufacturing plants - Textile and leather		4	



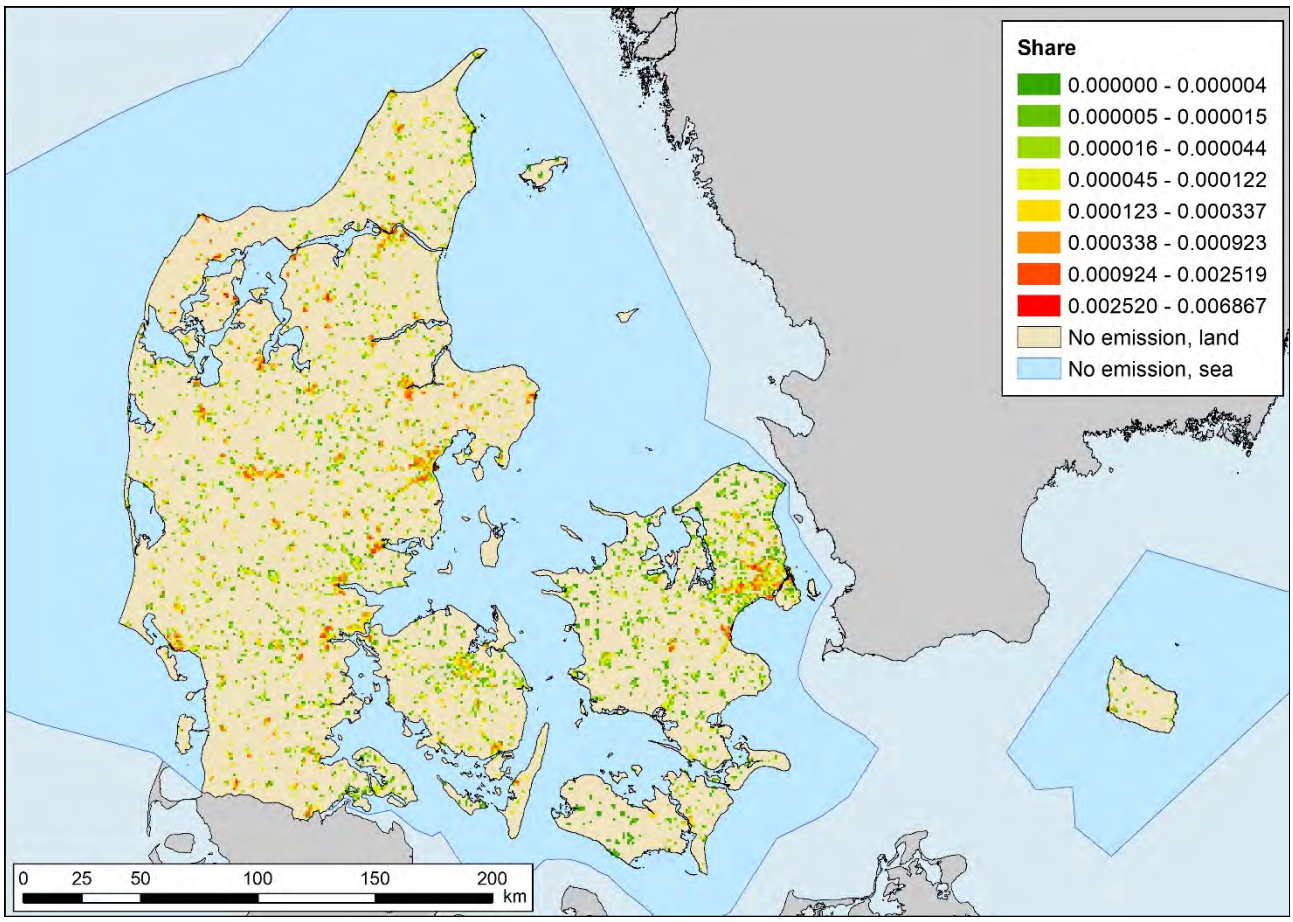
Wood, paper and print industry

The GeoKey is based on employment statistics from Statistics Denmark. Data for wood, paper and print industry (CC Træ- og papirindustri, trykkerier) are selected from the statistic data set KAS301 ("Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period"). Data are applied as annual numbers of employees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements. The spatial applicability is considered poor as the number of employees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.47 GeoKey for wood, paper and print industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period Denmark's Administrative Boundaries (DAGI), municipalities			
Data provider	Statistics Denmark Agency for Data Supply and Efficiency			
Projection	UTM32_EUREF89			
Data description	The statistic table KAS301 holds the annual numbers of employees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CC Træ- og papirindustri, trykkerier" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_Wood_Paper_Print			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	Ni		PCBs
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	0311 Manufacturing plants - Paper, pulp and print			4
	0314 Manufacturing plants - Wood and wood products			4
	040620 Wood manufacturing			4
	060403 Other use of solvents and related activities – printing industry			4



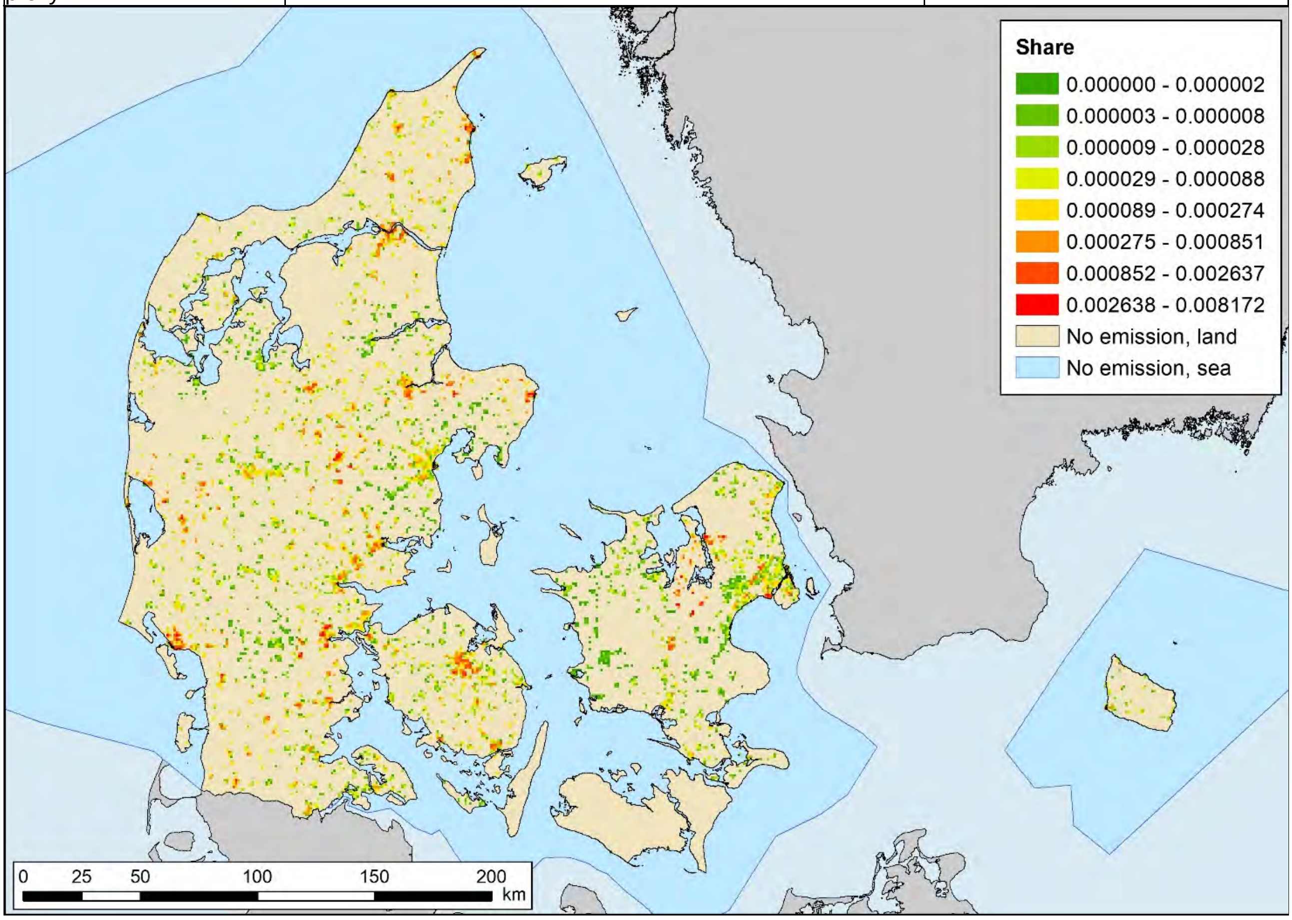
Means of transport industry

The GeoKey is based on employment statistics from Statistics Denmark. Data for means of means of transport industry (CL Transportmiddelindustri) are selected from the statistic data set KAS301 ("Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period"). Data are applied as annual numbers of emlpoyees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements. The spatial applicability is considered poor as the number of employees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.48 GeoKey for means of transport industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period Denmark's Administrative Boundaries (DAGI), municipalities			
Data provider	Statistics Denmark Agency for Data Supply and Efficiency			
Projection	UTM32_EUREF89			
Data description	The statistic table KAS301 holds the annual numbers of employees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CL Transportmiddelindustri" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_MeansOfTransportIndustry			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0312 Manufacturing plants - Transport equipment	4		



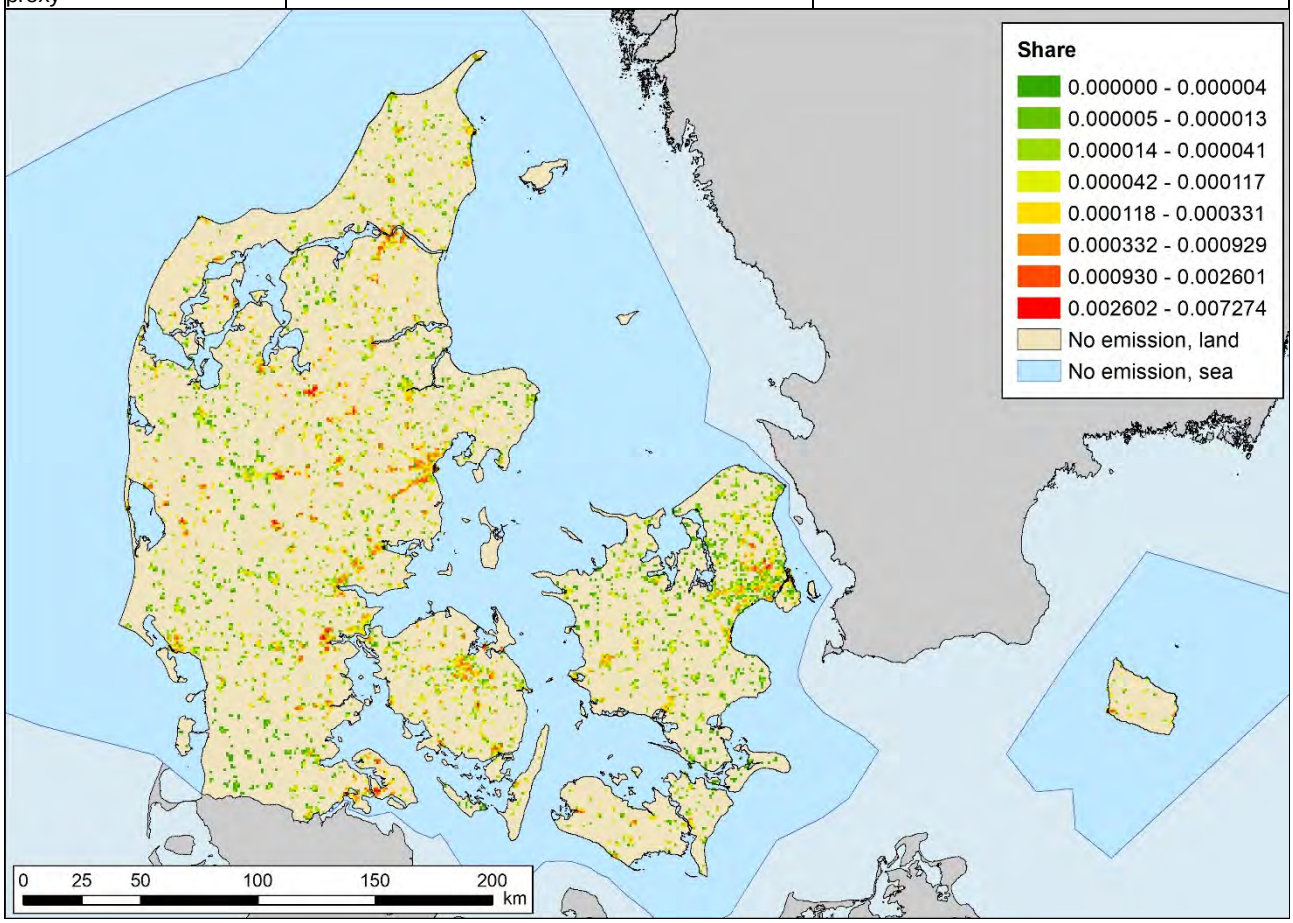
Machinery industry

The GeoKey is based on employment statistics from Statistics Denmark. Data for machinery industry (CK Maskinindustri) are selected from the statistic data set KAS301 ("Average number of employed by region (work place), industry (DB07 36-grouping), socioeconomic status, age, sex and period"). Data are applied as annual numbers of employees per industrial sector per municipality.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as the statistics are based on the occupational financial statements. The spatial applicability is considered poor as the number of employees does not nessecarily correspond with emission amounts and as the spatial resolution is only municipality level.

Table 5.49 GeoKey for machinery industry.

Source data	KAS301: Average number of employed by region (work place), industry (DB07 36-grouping), socio-economic status, age, sex and period Denmark's Administrative Boundaries (DAGI), municipalities			
Data provider	Statistics Denmark Agency for Data Supply and Efficiency			
Projection	UTM32_EUREF89			
Data description	The statistic table KAS301 holds the annual numbers of emlpoyees per industrial sector per municipality.			
Workflow	The GeoKey is based on data for the industrial sector "CK Maskinindustri" and calculated as the share of the total number of employees per municipality evenly distributed on the municipality area.			
GeoKey name	_Key_MachineryIndustry			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	Ni		
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0313 Manufacturing plants - Machinery		4	



5.3 Mobile combustion

Mobile combustion covers both transport (aviation, road, railways and navigation) as well as non-road machinery in industry, service, households, agriculture, forestry and fishing.

Table 5.50 shows the share of emissions from mobile combustion of the national total emissions for the pollutants covered by the SPREAD model. It can be seen that the share for many pollutants have remained over 10 % of the national total throughout the time series.

For some pollutants, the share has decreased mainly due to effective regulation of emissions. This is the case for e.g. NMVOC and CO. In other cases, the share has actually increased even if emissions have been substantially reduced. This is for instance the case for NO_x and PM where emissions have greatly decreased, but since emissions from stationary combustion have decreased even more, the share for mobile combustion has increased.

For heavy metals (except Pb), the share of emissions has increased as the abatement measures in stationary combustion has reduced emissions from this source.

Table 5.50 Share of emissions from mobile combustion of the national total.

Share	1990	2005	2019
> 10 %	NO_x, NMVOC, SO_2, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Cu, Ni, Zn	NO_x, NMVOC, SO_2, PM_{10}, $PM_{2.5}$, BC, CO, Pb, As, Cr, Cu, Ni, Zn, HCB	NO_x, NMVOC, PM_{10}, $PM_{2.5}$, BC, CO, Pb, Hg, As, Cr, Cu, Ni, Se, Zn, HCB, BkF
5-10 %	TSP, As, Se	TSP, Cd, Hg, Se	SO_2, Cd, BbF, IcdP
1-5 %	Cd, Hg, Cr, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs	NH_3, PCDD/F, BaP, BbF, IcdP, BkF	NH_3, TSP, BaP, PCBs
< 1 %	NH_3	PCBs	PCDD/F

An overview of the different activities within mobile combustion is provided together with the GeoKey for the individual activities in Table 5.51.

Table 5.51 Activities within mobile combustion and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Aviation – landing and take-off, national	080501	_Key_080501_DomLTO
Aviation – landing and take-off, international	080502	_Key_080502_IntLTO
Aviation – cruise, national	080503	_Key_080503_DomCruise
Road transport – passenger cars, highway	070101	_Key_070101_Road_PC_Highway
Road transport – passenger cars, rural	070102	_Key_070102_Road_PC_Rural
Road transport – passenger cars, urban	070103	_Key_070103_Road_PC_Urban
Road transport – light-duty vehicles, highway	070201	_Key_070201_Road_LD_Highway
Road transport – light-duty vehicles, rural	070202	_Key_070202_Road_LD_Rural
Road transport – light-duty vehicles, urban	070203	_Key_070203_Road_LD_Urban
Road transport – heavy-duty vehicles, highway	070301	_Key_070301_Road_HD_Highway
Road transport – heavy-duty vehicles, rural	070302	_Key_070302_Road_HD_Rural
Road transport – heavy-duty vehicles, urban	070303	_Key_070303_Road_HD_Urban
Road transport – mopeds	070400	_Key_0704_Mopeds
Road transport – motorcycles, highway	070501	_Key_070101_Road_PC_Highway
Road transport – motorcycles, rural	070502	_Key_070102_Road_PC_Rural
Road transport – motorcycles, urban	070503	_Key_070103_Road_PC_Urban
Road transport – non-exhaust[1]	070600, 070700 & 070800	_Key_0706_0707_0708_NonExhaust
Railways	080200	_Key_0802_Railways
National navigation	080402	_Key_080402_Ferry
Non-road machinery – industrial	080800	_Key_0808_IndustrialMachinery
Non-road machinery – commercial & institutional	081100	_Key_0811_CommInstMachinery
Non-road machinery – residential	080900	_Key_Building_OneStorey
Non-road machinery – agriculture	080600	_Key_AgriculturalArea
Non-road machinery – forestry	080700	_Key_Forest
Fishing	080403	_Key_080403_Fishing
Recreational crafts (small boats)	080300	_Key_Buffer_15km
Military, aviation	080100	_Key_Area_EEZ
Military, landbased	080100	_Key_0801_Military

[1] Non-exhaust emissions are comprised of emissions from gasoline evaporation, tyre & brake wear and road abrasion.

The subsectors within mobile combustion are described in more detail in the following chapters.

5.3.1 Aviation

Emissions from aviation are estimated for two distinct phases of the flight: the landing and take-off phase (LTO) and the cruise phases. The LTO phase is defined as below 1 000 feet. A 5 km buffer zone is applied as an assumption for the 1 000 feet phase zone. Additionally, for reporting of national inventories, emissions are estimated separately for national and international aviation.

The GeoKeys for LTO are based on LTO data for the 11 largest airports in Denmark (Table 5.52). The GeoKey for domestic cruise is based on cruise data for routes between Copenhange (CPH) and the remaining 10 largest airports, respectively.

Table 5.52 The largest airports in Denmark used to prepare the GeoKeys for aviation.

ICAO	Name
EKCH	Copenhagen
EKBI	Billund
EKYT	Aalborg
EKAH	Aarhus
EKRN	Roenne
EKKA	Karup
EKEB	Esbjerg
EKSB	Soenderborg
EKOD	Odense
EKRK	Roskilde
EKTS	Thisted
EKSP	Vojens

Landing and take-off (LTO)

The location of the airports is well defined, so the uncertainty of the spatial dataset is very low. The applicability as a spatial proxy is only rated to be good, as there are flight fields outside of major airports that are not included and as the 5 km buffer zone does not necessarily represent the actual emission location.

Emissions from LTO are for most pollutants minor; however, since the aviation gasoline still contains lead, the share of the total lead emissions has increased. As the SO_2 and NO_x emissions from other sources have decreased and the number of international LTOs have increased, the share of the national total has increased.

Table 5.53 GeoKey for domestic LTO (landing and take-off).

Source data	Activity data statistics for domestic LTO.			
Data provider	The Transport and Construction Agency, and Copenhagen Airport DEA			
Projection	ETRS89 UTM zone 32N			
Data description	Location of airports Fuel consumption data for domestic LTO for the major airports			
Workflow	The 12 main airports in Denmark are located and 5 km buffer zones are generated in GIS. The buffer zones are intersected with the 1 km x 1 km grid and the share of buffer zone area is calculated by grid cell for each airport. Emissions are allocated to the main airports according to the activity data for domestic LTO. The GeoKey is calculated as the share of the domestic LTO activity data multiplied by the share of buffer zone area by grid cell.			
GeoKey name	_Key_080501_DomLTO			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		Pb	Pb
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	080501 Domestic LTO		2	

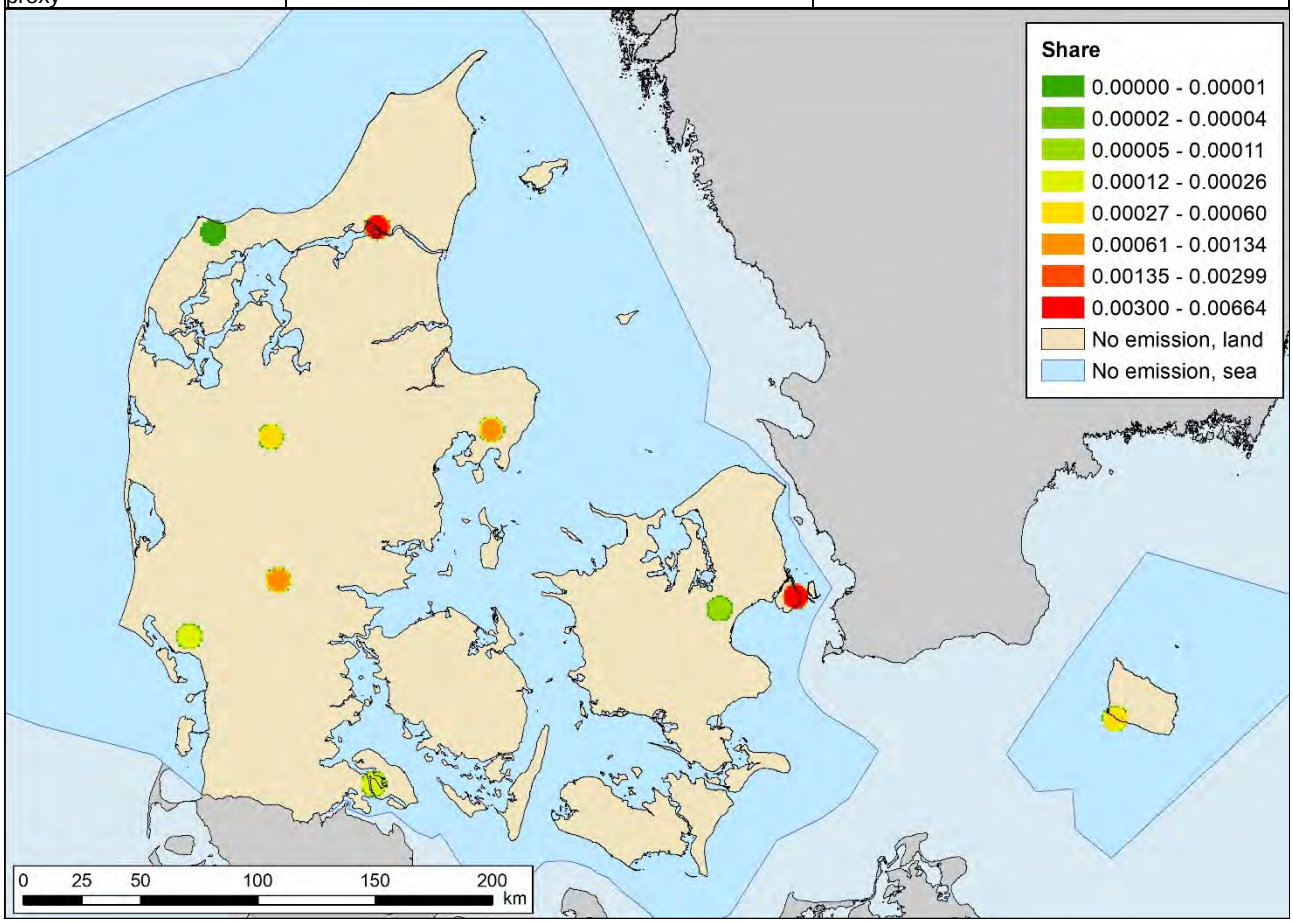
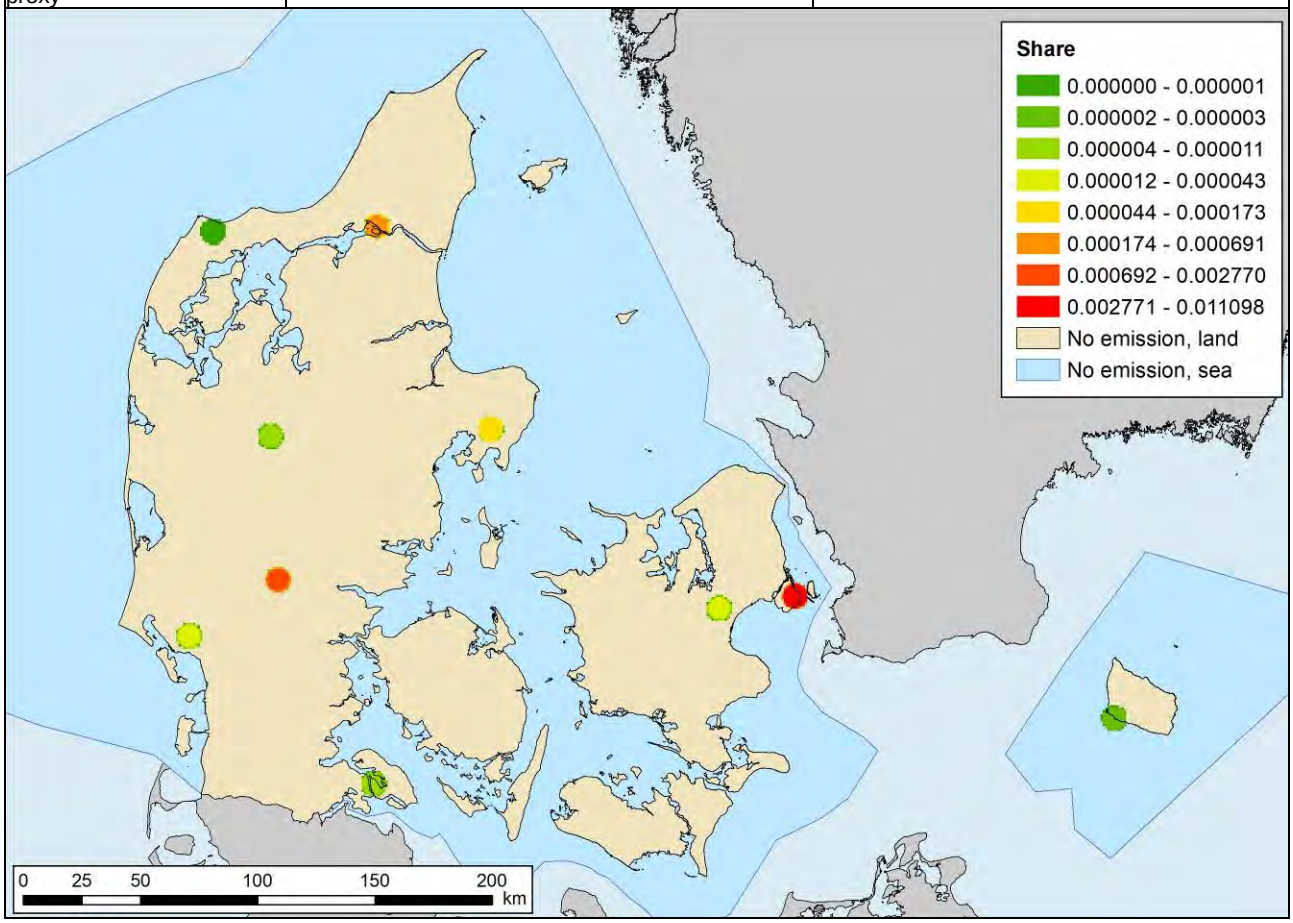


Table 5.54 GeoKey for international LTO (landing and take-off).

Source data	Activity data statistics for international LTO.			
Data provider	The Transport and Construction Agency, and Copenhagen Airport DEA			
Projection	ETRS89 UTM zone 32N			
Data description	Location of airports Fuel consumption data for international LTO for the major airports			
Workflow	The 12 main airports in Denmark are located and 5 km buffer zones are generated in GIS. The buffer zones are intersected with the 1 km x 1 km grid and the share of buffer zone area is calculated by grid cell for each airport. Emissions are allocated to the main airports according to the activity data for international LTO. The GeoKey is calculated as the share of the international LTO activity data multiplied by the share of buffer zone area by grid cell.			
GeoKey name	_Key_080502_IntLTO			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			SO_2, NO_x
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC
Quality of spatial dataset	A			
Applicability as spatial proxy	080502 International LTO		2	



Cruise

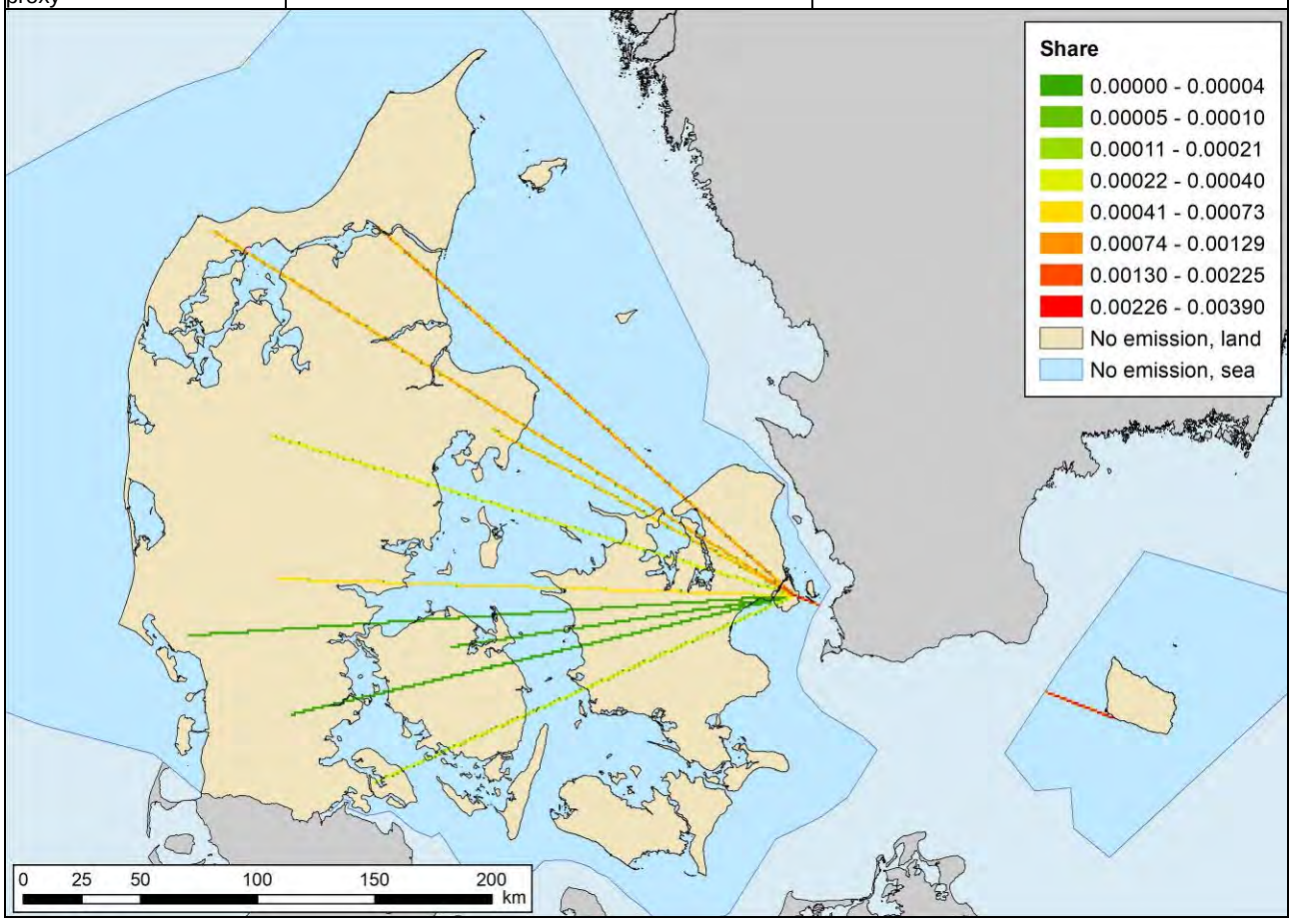
Only domestic aviation is considered for the cruise phase of the flight. In the Danish inventories, flights to the Faroe Islands and to Greenland are also considered domestic. However, per international guidelines emissions should be allocated within the Danish EEZ. Therefore, the total emissions are allocated to the part of domestic flight routes located within the EEZ.

The share of the national total is low, for all years it is below 1 %.

The location of the airports is well defined and the flight routes generated as great circle lines between airports are assumed to be close to the actual routes, so the uncertainty of the spatial dataset is low. The applicability as a spatial proxy is determined to be good, as there are flight fields outside of major airports that are not included.

Table 5.55 GeoKey for aviation (cruise).

Source data	Activity data statistics for domestic cruise based on data for each flight			
Data provider	The Transport and Construction Agency, and Copenhagen Airport DEA			
Projection	ETRS 1989 UTM Zone 32N			
Data description	Location of airports Fuel consumption for domestic cruise			
Workflow	Route lines are generated as great circle lines between Copenhagen Airport and the 11 largest airports. Parts of the routes that fall outside the Danish EEZ are excluded from the GeoKey, which is calculated as the share of the activity data by route multiplied by the share of the route length by 1 km x 1 km grid cell.			
GeoKey name	Key_080503_DomCruise			
Year dependent	Yes, the GeoKey is based on annual activity data for domestic cruise.			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC
Quality of spatial dataset	B			
Applicability as spatial proxy	080503 Domestic cruise	3		



5.3.2 Road transport

The emission modelling for the road transport sector is very detailed. For the purpose of the spatial emission modelling, the level of detail is restricted to the vehicle type and road type. Vehicles are categorised as passenger cars, light-duty vehicles, heavy-duty vehicles, motorcycles and mopeds. For the spatial modelling passenger cars and motorcycles are distributed in the same way. For the road types, a distinction is made between urban roads, rural roads and highways. The GeoKeys are based on the GIS-based National Road and Traffic Database 1960-2020 (Jensen et al., 2019), prepared by Aarhus University. The database holds annual average daily traffic (AADT) for every fifth year. For the years not included in the the GIS-based National Road and Traffic Database 1960-2020 but included in the SPREAD model, AADT for the nearest year is applied.

Table 5.56 Correspondance list for SPREAD years and years in the GIS-based National Road and Traffic Database 1960-2020 (AADT years).

SPREAD year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AADT year	1990	1995	2000	2005	2010	2010	2010	2015	2015	2015	2015	2015	2020	2020

AADT is split into five road classes (motorways, express ways, road width > 6 m, road width 3 – 6 m and road width < 3 m) and four vehicle classes (passenger cars, vans, trucks and busses). The road and vehicle classes are aggregated into categories that correspond to the categorisation in the national emission inventory (Table 5.57 and Table 5.58). 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 1 km x 1 km.

Table 5.57 Road types in the national road and traffic database.

Road class	SPREAD road type
Road width < 3 m	Urban road (inside urban zone) / Rural road (outside urban zone)
Road width 3 – 6 m	
Road width > 6 m	
Expressways	
Motorways	Highway

Table 5.58 Vehicle types in the national road and traffic database.

Vehicle class	SPREAD vehicle type
Passenger cars	Passenger cars, PC
Vans	Light-duty vehicles, LD
Trucks	Heavy-duty vehicles, HD
Busses	

Passenger cars and motorcycles

Passenger cars are defined as vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.

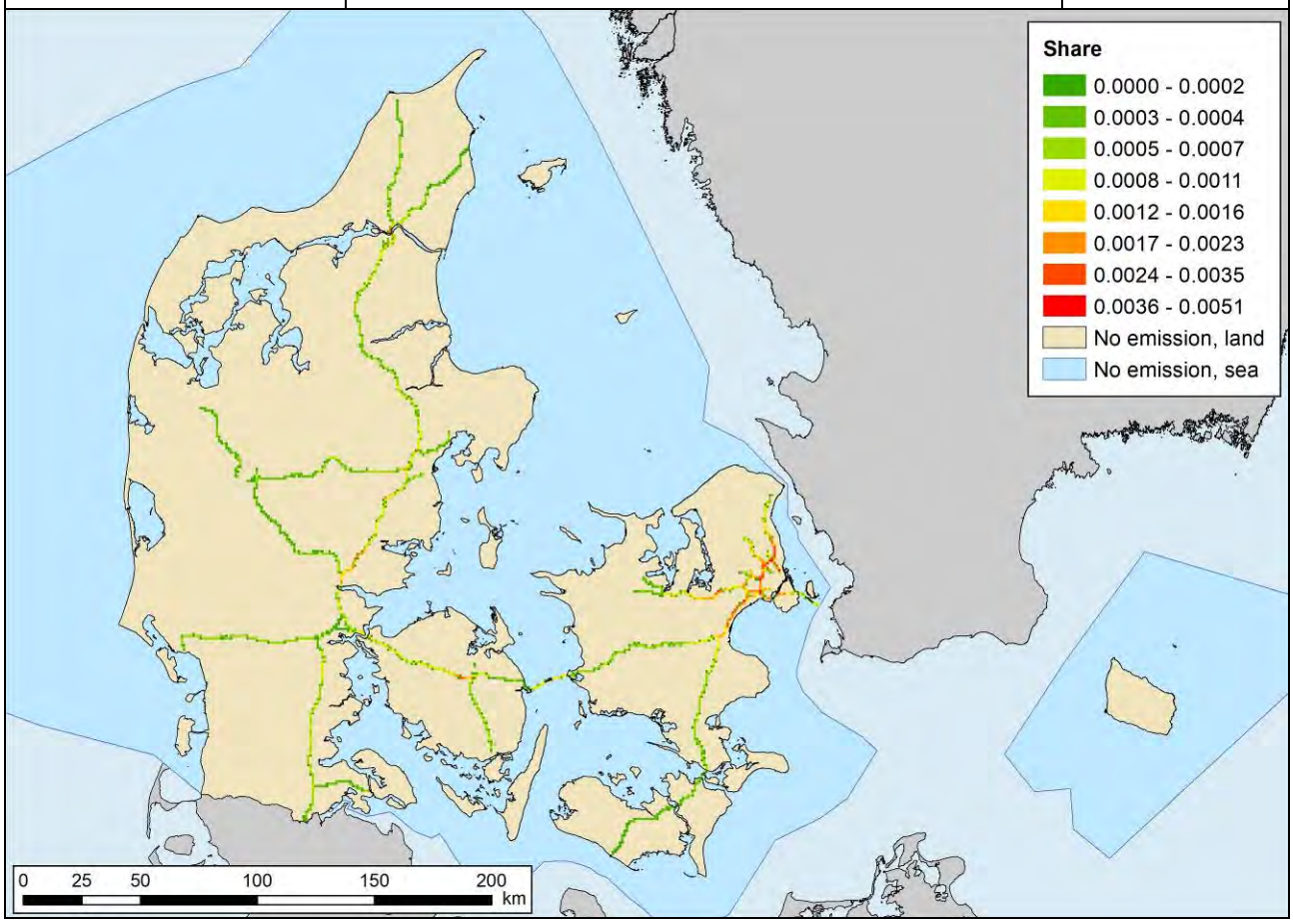
Highways

The spatial dataset used for the GeoKey for passenger cars and motorcycles on highways is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The highway network has been updated in 2019 (Jensen et al., 2019). The GeoKey is based on traffic data for every fifth year 1990-2020, and AADT

data for the closest year are applied for years in between. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation.

Table 5.59 GeoKey for passenger cars and motorcycles on highways.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles.			
Workflow	Mileage data for passenger cars on highways are used to calculate the GeoKey, regardless if the highways are located in urban or rural zones. The GeoKey is calculated as the share of the total mileage for passenger cars on highways by 1 km x 1 km grid cell.			
GeoKey name	_Key_070101_Road_PC_Highway			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	Pb		
	5-10 %	NO_x, CO		
	1-5 %	Zn, BC	NO_x, CO, BC, Zn	NO_x, CO, BC, Cd, Hg, Zn, HCB, BbF, BkF, BaP, IcdP
	< 1 %	SO_2, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Se, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cr, Cu, Ni, Pb, Se, PCDD/F, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070101 Road transport – Passenger cars – Highway driving			2
	070501 Road transport – Passenger cars – Highway driving			2

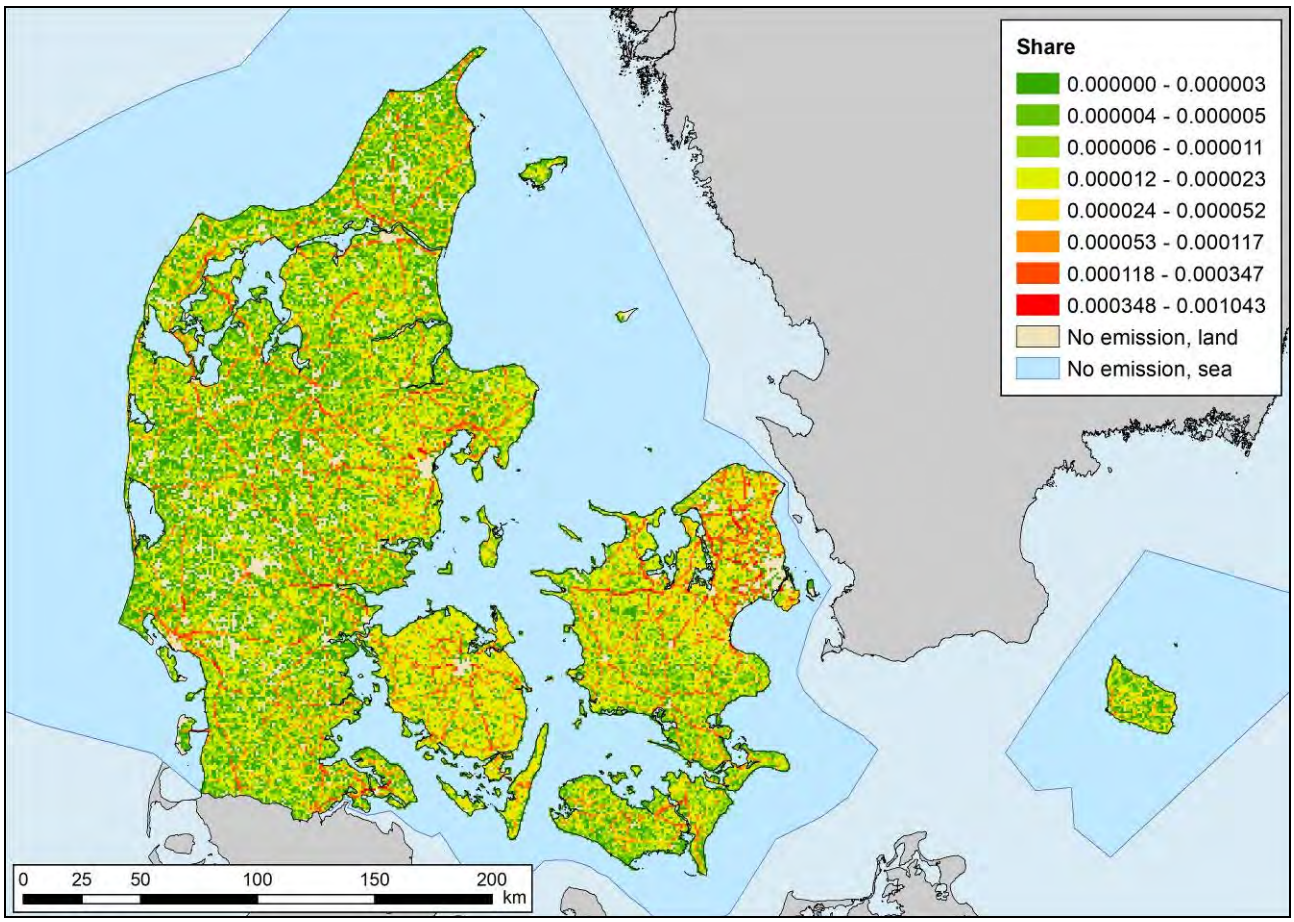


Rural roads

The spatial dataset used for the GeoKey for passenger cars and motorcycles on rural roads is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation. The rural road network is assumed to show roughly the same pattern over time. Urban development will affect the road network, but this has impact on relatively small areas compared to the national total land area.

Table 5.60 GeoKey for passenger cars and motorcycles on rural roads.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 KORT 10 Urban zones (bypolygon)			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are sub-urban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	The mileage data for passenger cars is intersected with the urban zones and allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for passenger cars on rural roads, regardless if part of the highways are located in rural zones. The GeoKey is calculated as the share of the total mileage for passenger cars on rural roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_070102_Road_PC_Rural			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	NO_x, CO, Pb		
	5-10 %		NO_x, CO	NO_x
	1-5 %	NMVOC, BC, Zn	NH_3, BC, Cd, Hg, Zn, HCB	CO, BC, Cd, Cr, Hg, Zn, HCB, BbF, BkF, BaP, IcdP
	< 1 %	SO_2, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Se, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, TSP, PM_{10}, $PM_{2.5}$, As, Cr, Cu, Ni, Pb, Se, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cu, Ni, Pb, Se, PCDD/F, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070102 Road transport – Passenger cars – Rural driving	2		
	070502 Road transport – Motor cycles – Rural driving	2		

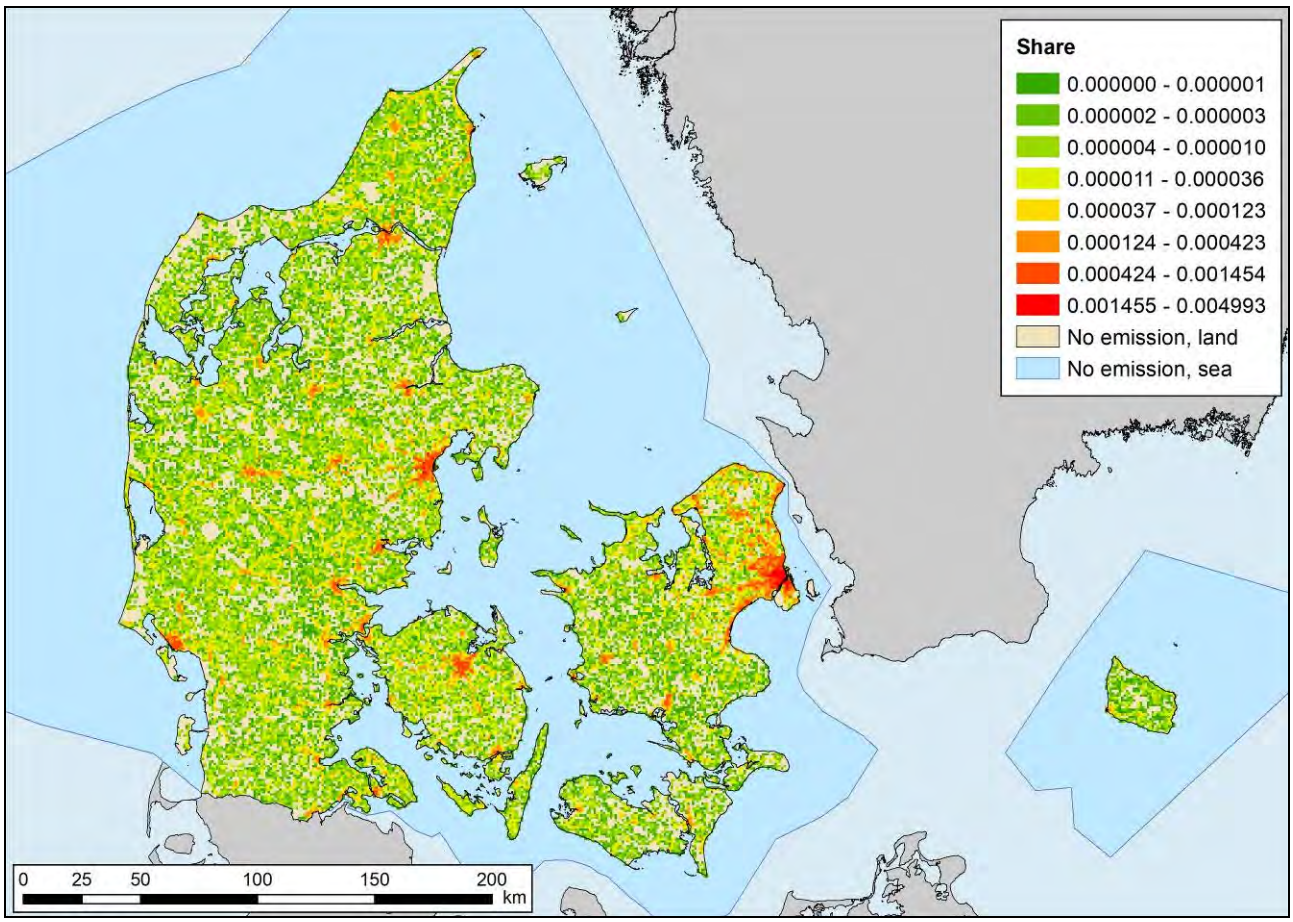


Urban roads

The spatial dataset used for the GeoKey for passenger cars and motorcycles on urban roads is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation. Only minor changes of the road network is assumed to have occurred in urban areas, while urban development have caused expansion of the urban road network, which is not reflected in the GeoKey.

Table 5.61 GeoKey for passenger cars and motorcycles on urban roads.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 KORT 10 Urban zones (bypolygon)			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	Mileage data is received as gridded data on the 1 km x 1 km Danish grid net, including mileage data by road and vehicle type. The mileage data is intersected with the urban zones, and the mileage data are allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for passenger cars on urban roads, regardless if part of the highways are located in urban zones. The GeoKey is calculated as the share of the national total mileage for passenger cars on urban roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_070103_Road_PC_Urban			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	CO, Pb	CO	CO
	5-10 %			
	1-5 %	NO_x, NMVOC, $PM_{2.5}$, BC, Zn	NO_x, NMVOC, BC, Zn	NO_x, BC, Hg, Zn, HCB
	< 1 %	SO_2, NH_3, TSP, PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Se, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070103 Road transport – Passenger cars – Rural driving			2
	070503 Road transport – Motor cycles – Rural driving			2



Light-duty vehicles

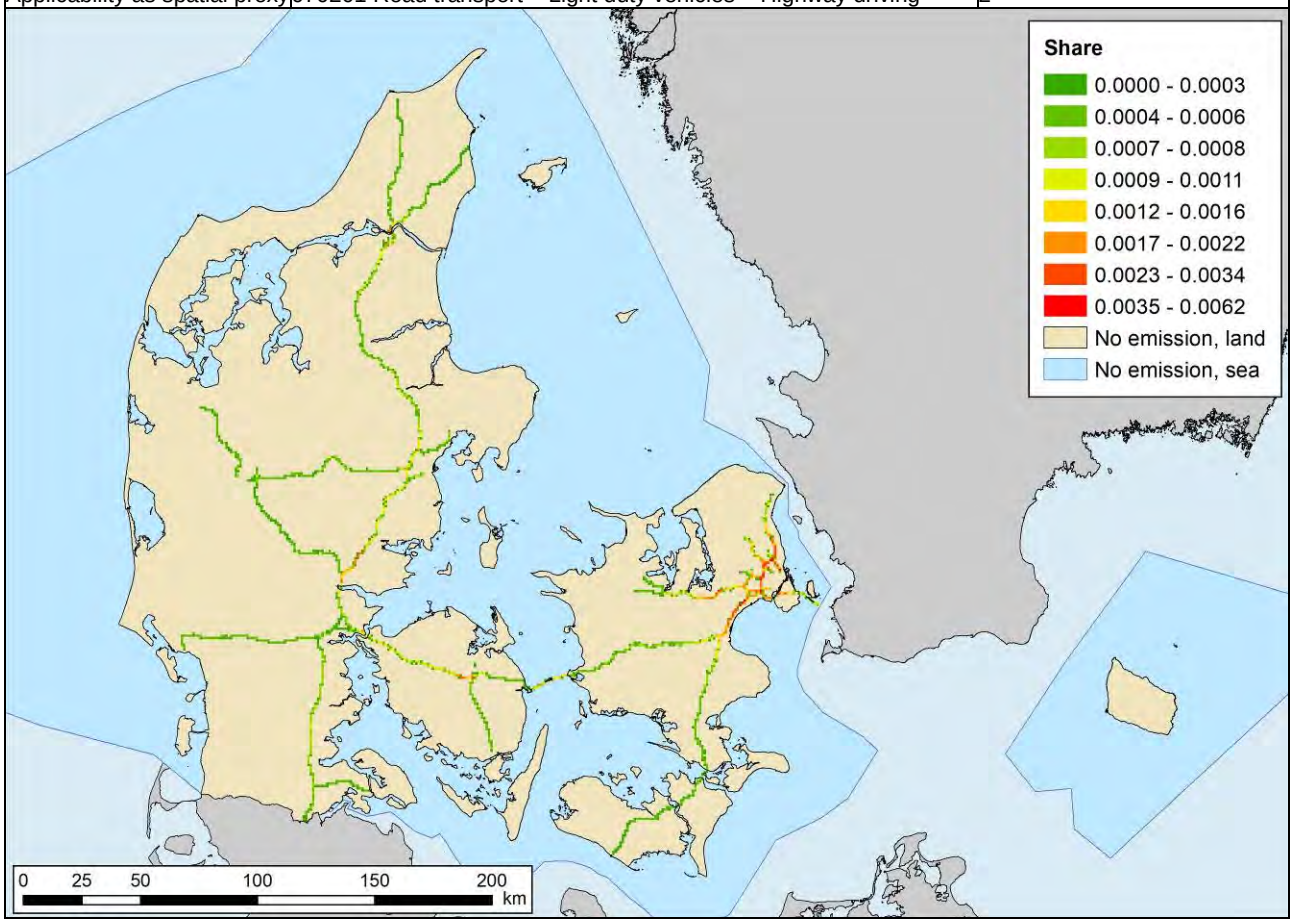
Light-duty vehicles are defined as vehicles used for the carriage of goods and having a maximum weight not exceeding 3.5 tonnes.

Highways

The spatial dataset used for the GeoKey light-duty vehicles on highways is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The highway network has been updated in 2019 (Jensen et al., 2019). The GeoKey is based on traffic data for every fifth year 1990-2020, and AADT data for the closest year are applied for years in between.The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation.

Table 5.62 GeoKey light-duty vehicles on highways.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles.			
Workflow	Mileage data for light-duty vehicles on highways are used to calculate the GeoKey, regardless if the highways are located in urban or rural zones. The GeoKey is calculated as the share of the total mileage for light-duty vehicles on highways by 1 km x 1 km grid cell.			
GeoKey name	_Key_070201_Road_LD_Highway			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	$PM_{2.5}$, BC	NO_x, BC	NO_x, BC, HCB
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070201 Road transport – Light duty vehicles – Highway driving			2



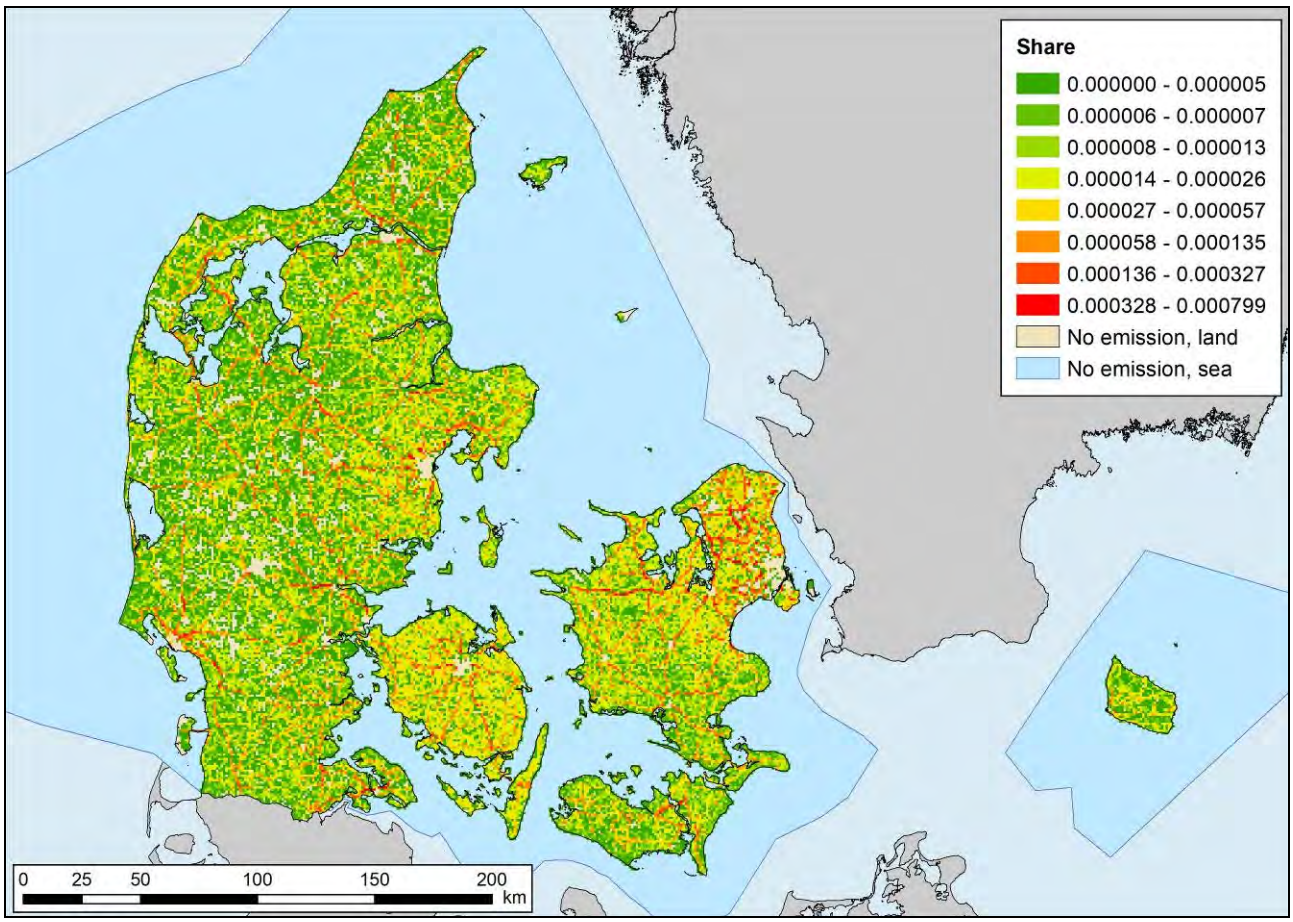
Rural roads

The spatial dataset used for the GeoKey for light-duty vehicles on rural roads is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation. The rural road network is assumed to show roughly the same pattern over time. Urban development will affect the road network, but

this has impact on relatively small areas compared to the national total land area.

Table 5.63 GeoKey for light-duty vehicles on rural roads.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 KORT10			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	The mileage data for light-duty vehicles is intersected with the urban zones and allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for passenger cars on rural roads, regardless if part of the highways are located in rural zones. The GeoKey is calculated as the share of the total mileage for light-duty vehicles on rural roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_070202_Road_LD_Rural			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %	BC	BC	
	1-5 %	NO_x, CO, PM_{10}, $PM_{2.5}$, Pb	NO_x, PM_{10}, $PM_{2.5}$, HCB	NO_x, BC, HCB
	< 1 %	SO_2, NMVOC, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070202 Road transport – Light duty vehicles – Rural driving			2

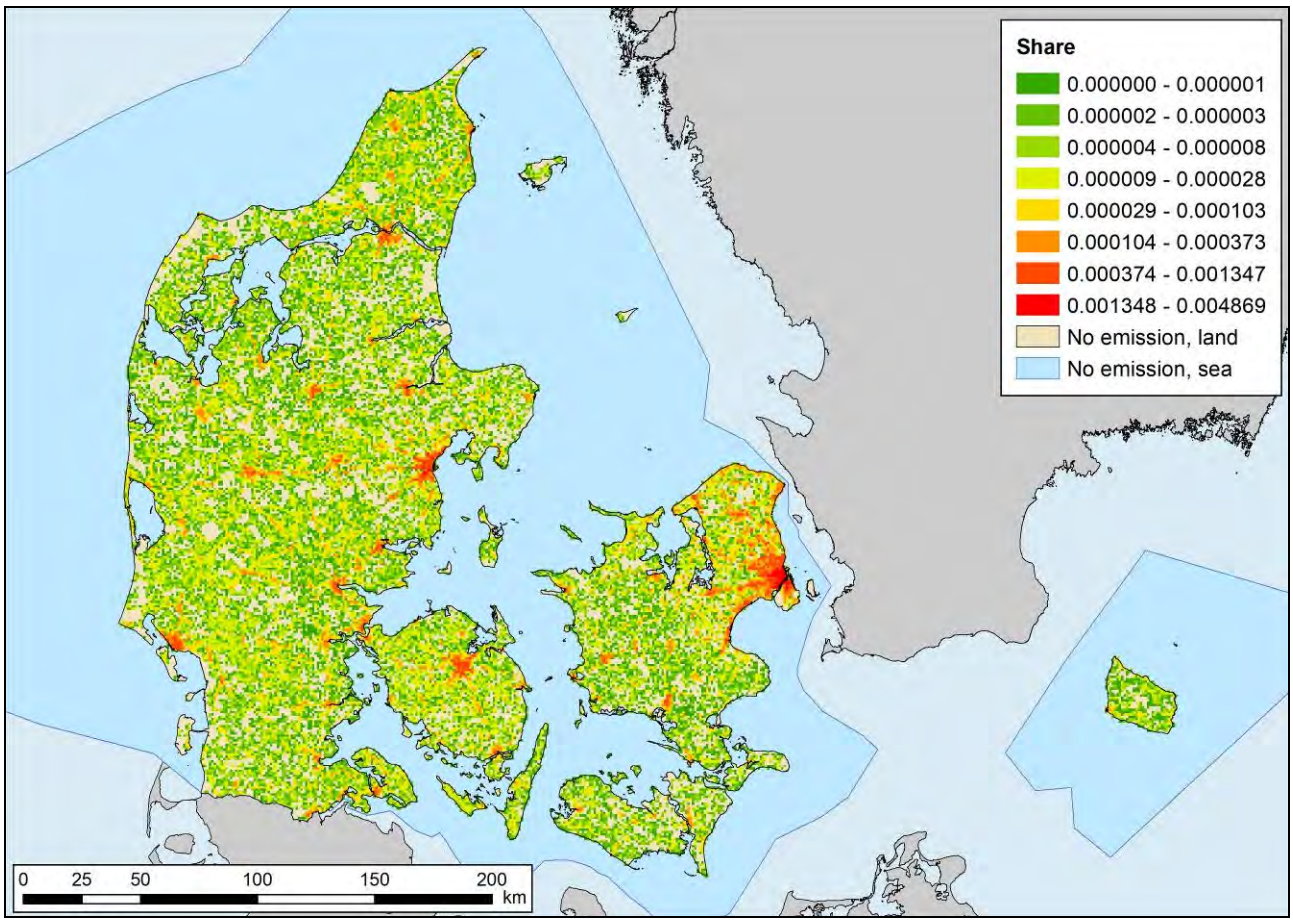


Urban roads

The spatial dataset used for the GeoKey for light-duty vehicles on urban roads is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation. Only minor changes of the road network is assumed to have occurred in urban areas, while urban development have caused expansion of the urban road network, which is not reflected in the GeoKey.

Table 5.64 GeoKey for light-duty vehicles on urban roads.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 Urban zones			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	Mileage data is received as gridded data on the 1 km x 1 km Danish grid net, including mileage data by road and vehicle type. The mileage data is intersected with the urban zones, and the mileage data are allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for light-duty vehicles on urban roads, regardless if part of the highways are located in urban zones. The GeoKey is calculated as the share of the national total mileage for light-duty vehicles on urban roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_070203_Road_LD_Urban			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %	BC	BC	
	1-5 %	CO, PM_{10}, $PM_{2.5}$, Pb	NO_x, CO, $PM_{2.5}$, HCB	NO_x, BC, HCB
	< 1 %	SO_2, NO_x, NMVOC, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070203 Road transport – Light duty vehicles – Urban driving			2



Heavy-duty vehicles

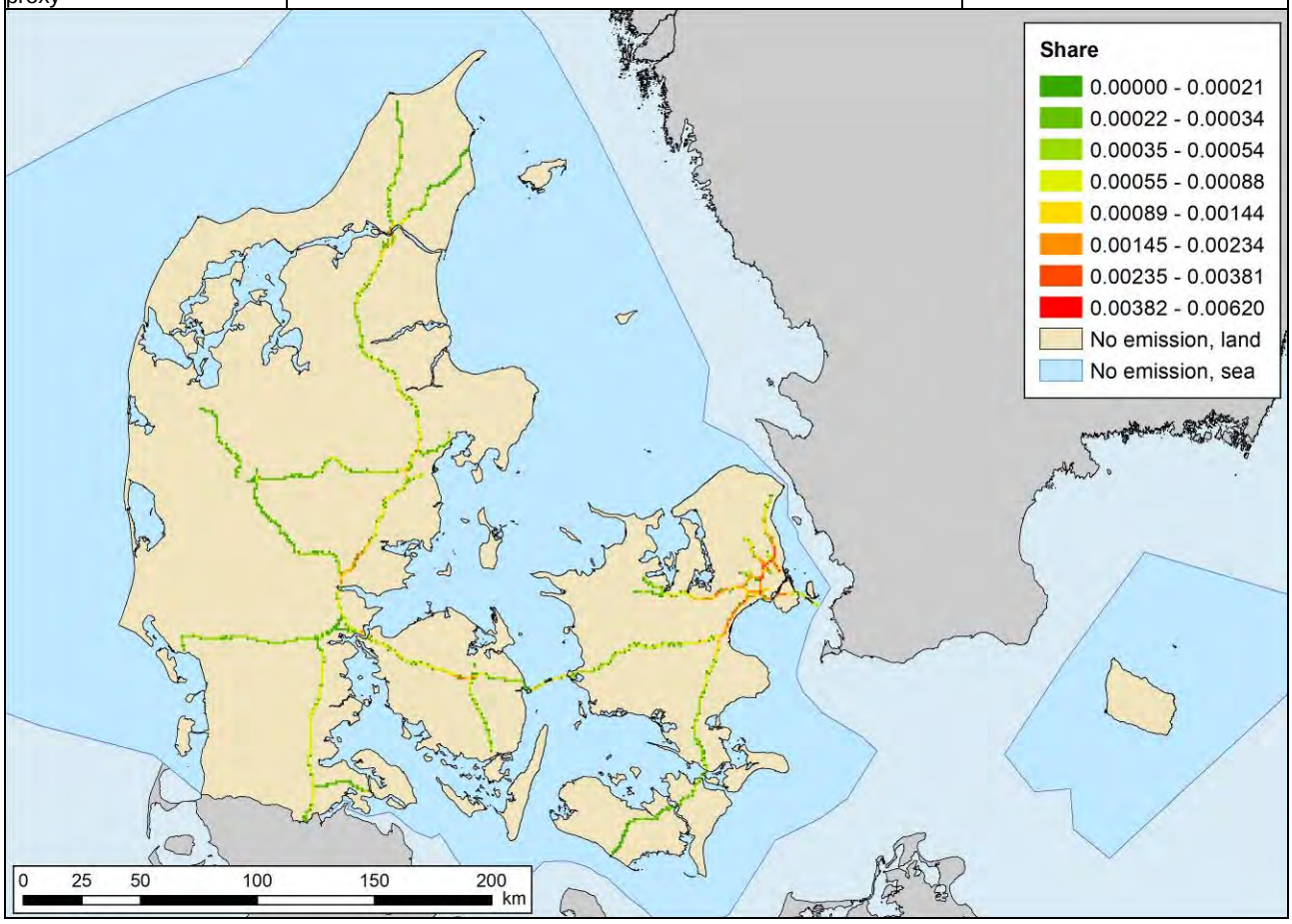
Heavy-duty vehicles are defined as either vehicles used for the carriage of goods and having a maximum weight exceeding 3.5 tonnes or vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat.

Highways

The spatial dataset used for the GeoKey for heavy-duty vehicles on highways is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the highway network has been updated in 2019 (Jensen et al., 2019). The GeoKey is based on traffic data for every fifth year 1990-2020, and AADT data for the closest year are applied for years in between.

Table 5.65 GeoKey for heavy-duty vehicles on highways.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles.			
Workflow	Mileage data for heavy-duty vehicles on highways are used to calculate the GeoKey, regardless if the highways are located in urban or rural zones. The GeoKey is calculated as the share of the total mileage for heavy-duty vehicles on highways by 1 km x 1 km grid cell.			
GeoKey name	_Key_070301_Road_HD_Highway			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %		NO_x	HCB
	1-5 %	NO_x, $PM_{2.5}$, BC	$PM_{2.5}$, BC, HCB	NO_x, BC, Hg, Zn, BkF
	< 1 %	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, PCDD/F, BbF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070301 Road transport – Heavy duty vehicles – Highway driving			2



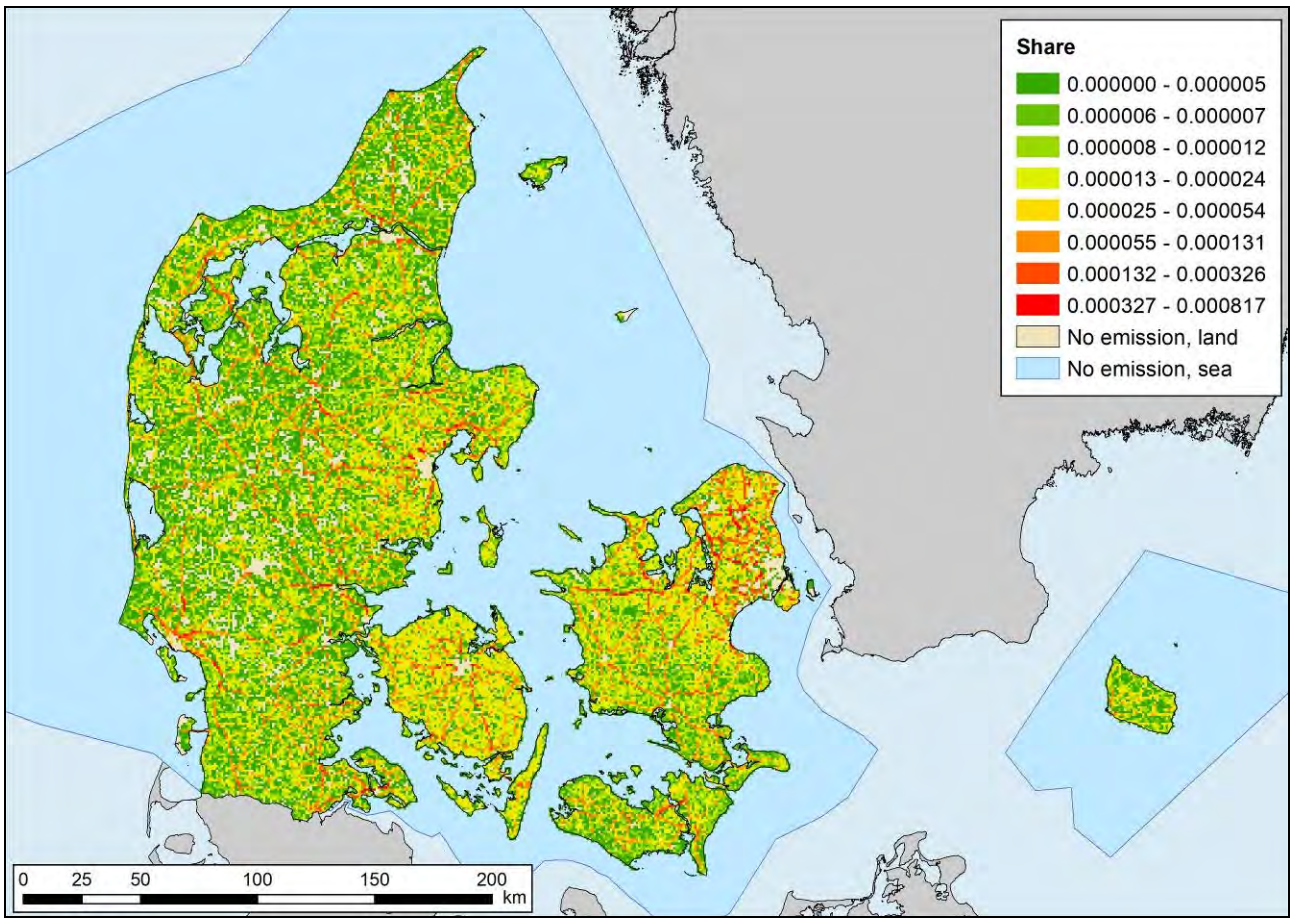
Rural roads

The spatial dataset used for the GeoKey for heavy-duty vehicles on rural roads is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation. The rural road network is assumed to show roughly the same pattern over time. Urban development will affect the road

network, but this has impact on relatively small areas compared to the national total land area.

Table 5.66 GeoKey for heavy-duty vehicles on rural roads.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 KORT10			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	The mileage data for heavy-duty vehicles is intersected with the urban zones and allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for passenger cars on rural roads, regardless if part of the highways are located in rural zones. The GeoKey is calculated as the share of the total mileage for heavy-duty vehicles on rural roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_070302_Road_HD_Rural			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %	NO_x, BC	NO_x, BC	HCB
	1-5 %	PM_{10}, $PM_{2.5}$	PM_{10}, $PM_{2.5}$, HCB	NO_x, BC, Hg, BkF
	< 1 %	SO_2, NMVOC, CO, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, Zn, PCDD/F, BbF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070302 Road transport – Heavy duty vehicles – Rural driving			2

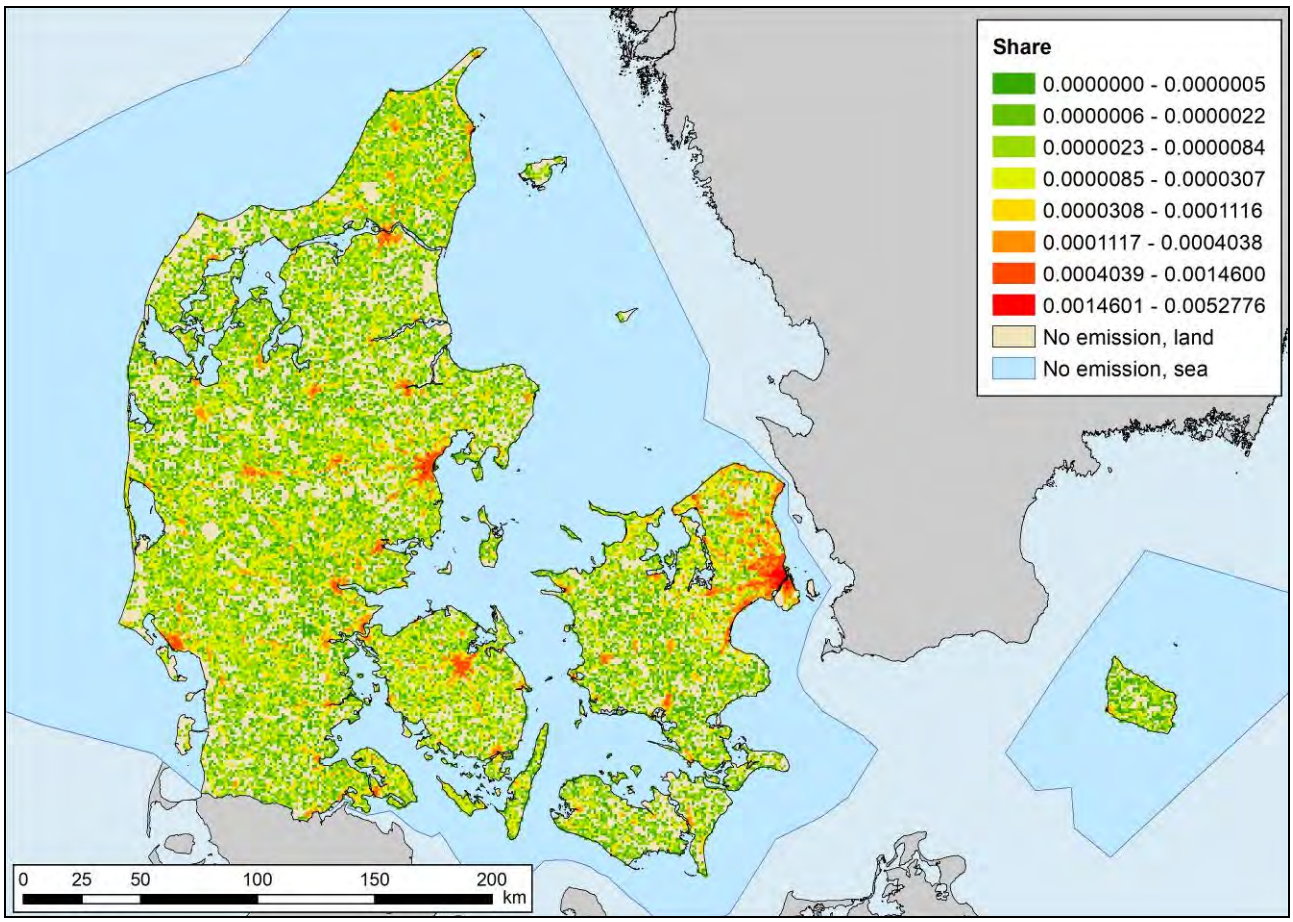


Urban roads

The spatial dataset used for the GeoKey for heavy-duty vehicles on urban roads is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as the GeoKey reflects both spatial pattern and annual variation. Only minor changes of the road network is assumed to have occurred in urban areas, while urban development have caused expansion of the urban road network, which is not reflected in the GeoKey.

Table 5.67 GeoKey for heavy-duty vehicles on urban roads.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 Urban zones			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	Mileage data is received as gridded data on the 1 km x 1 km Danish grid net, including mileage data by road and vehicle type. The mileage data is intersected with the urban zones, and the mileage data are allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for heavy-duty vehicles on urban roads, regardless if part of the highways are located in urban zones. The GeoKey is calculated as the share of the national total mileage for heavy-duty vehicles on urban roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_070303_Road_HD_Urban			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NO_x, PM_{10}, $PM_{2.5}$, BC	NO_x, BC, HCB	NO_x, HCB
	< 1 %	SO_2, NMVOC, CO, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	070303 Road transport – Heavy duty vehicles – Urban driving			2

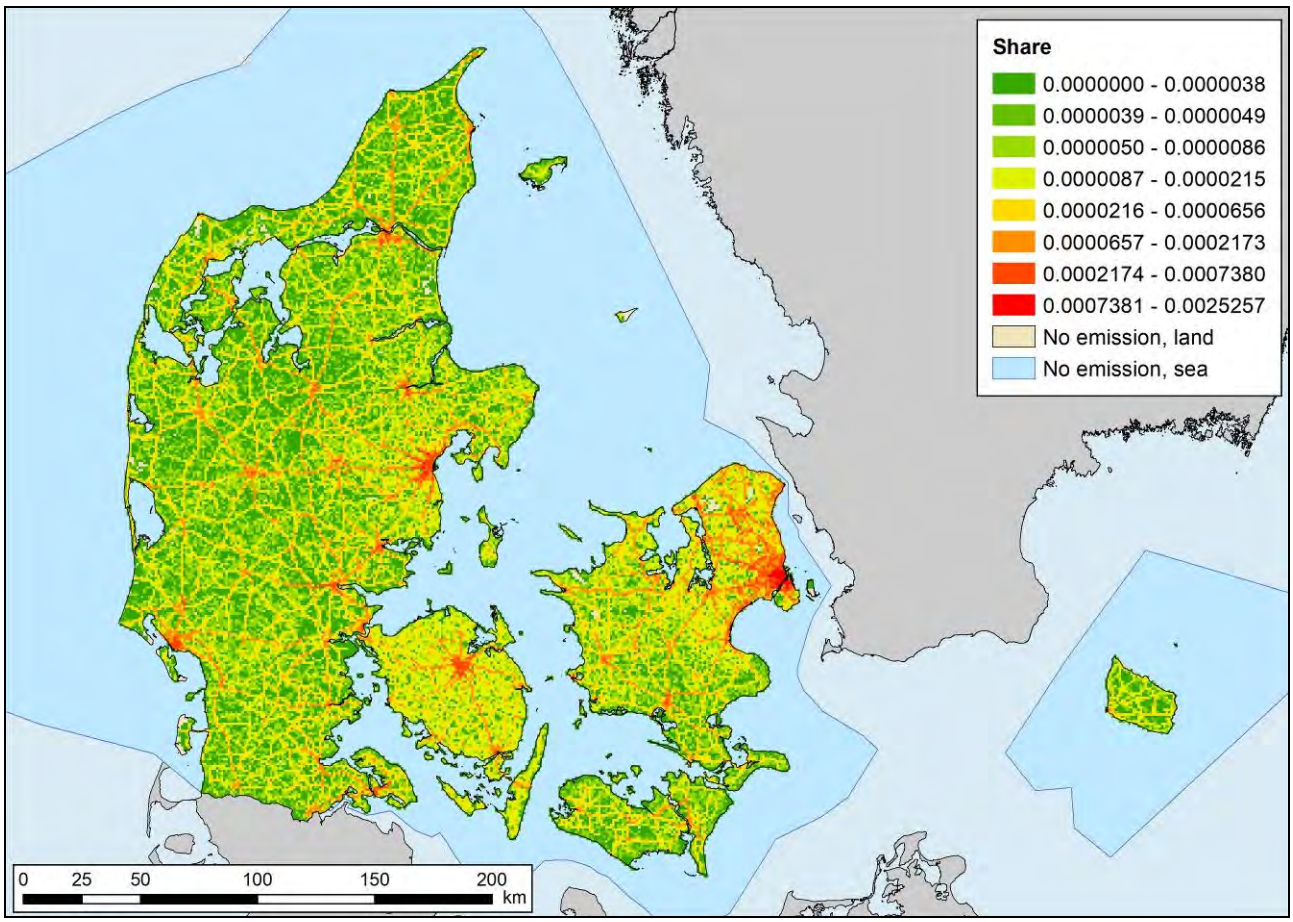


Mopeds

The Danish national GIS-based road network and traffic database does not include mopeds as a separate category. As mopeds are not allowed on highways, the GeoKey is based on mileage data for passenger cars on urban and rural roads assuming that mopeds follow this spatial trend. The spatial dataset used for the GeoKey is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered poor as data for passenger cars are used as proxy for mopeds.

Table 5.68 GeoKey for mopeds.

Source data	The GeoKey is based on mileage data the GIS-based National Road and Traffic Database 1960-2020 KORT10			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS-based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS-based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	Mileage data is received as gridded data on the 1 km x 1 km Danish grid net, including mileage data by road and vehicle type. The mileage data is intersected with the urban zones, and the mileage data are allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. Mileage data for highways are excluded from the calculation of GeoKeys for mopeds, as they are not allowed to drive on highways. The GeoKey is calculated as the share of the national total mileage for passenger cars on urban and rural roads by 1 km x 1 km grid cell.			
GeoKey name	_Key_0704_Mopeds			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	0704 Road transport – Mopeds			4



Non-exhaust

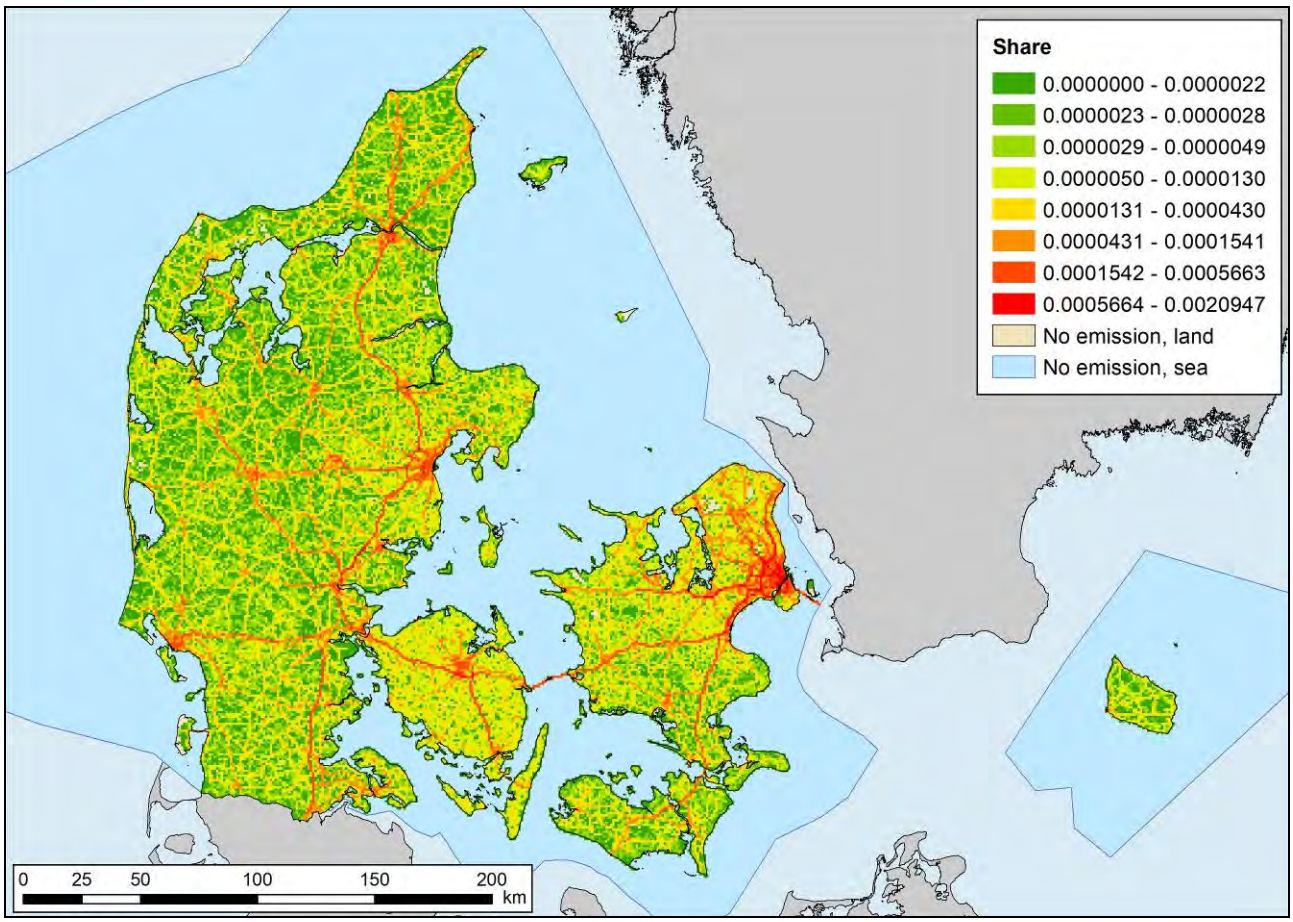
The non-exhaust emissions are evaporative emissions (NMVOC) from gasoline vehicles and particle emissions and heavy metal emissions from tyre and brake wear and road abrasion.

The spatial dataset used for the GeoKey is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The spatial applicability is considered good as mileage data is a good proxy for non-exhaust emissions, and as the GeoKey reflects the variation over time for the road network and the mileage pattern.

The sector is a large source of emissions for some heavy metals and particulate matter.

Table 5.69 GeoKey for non-exhaust.

Source data	The GeoKey is based on mileage data the GIS based National Road and Traffic Database 1960-2020 KORT10			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles. AADT for minor roads are not available and following it is assumed in the Danish national GIS based road network and traffic database for 1960-2020 that all minor roads without AADT data have AADT=200. This has shown to be an overestimation for most of these roads, of which most are suburban streets and byways. To avoid allocating too large a share of the emissions to the minor roads, an adjustment of the AADT has been included in the GeoKey calculation. The adjustment is based on comparison between distances travelled based on data from the Danish Road Directorate (DRD) and the road and traffic database (RTD). The AADT for minor roads has following been adjusted from 200 to 10. Urban zones are based on KORT 10 (bypolygon).			
Workflow	Mileage data is received as gridded data on the 1 km x 1 km Danish grid net, including mileage data by road and vehicle type. The mileage data is intersected with the urban zones, and the mileage data are allocated to urban and rural zones depending on the share of the grid cell area in urban and rural zones, respectively. The GeoKey is calculated as the share of the national total mileage for all vehicle types on all road types by 1 km x 1 km grid cell.			
GeoKey name	_Key_0706_0707_0708_NonExhaust			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	Cu, Zn	Cu, Pb, Zn	Cu, Pb, Zn
	5-10 %			PM_{10}, $PM_{2.5}$, BC, Se
	1-5 %	NMVOC, TSP, PM_{10}, $PM_{2.5}$, BC, Pb	TSP, PM_{10}, $PM_{2.5}$, BC, As, As, Cr, Ni, Se	TSP, As, Cr, Ni
	< 1 %	As, Cd, Cr, Hg, Ni, Se, BbF, BkF, BaP	NMVOC, Cd, Hg, BbF, BkF, BaP	NMVOC, Cd, Hg, BbF, BkF, BaP
Quality of spatial dataset	B			
Applicability as spatial proxy	0706 Gasoline evaporation from vehicles		2	
	0707 Automobile tyre and brake wear		2	
	0708 Automobile road abrasion		2	



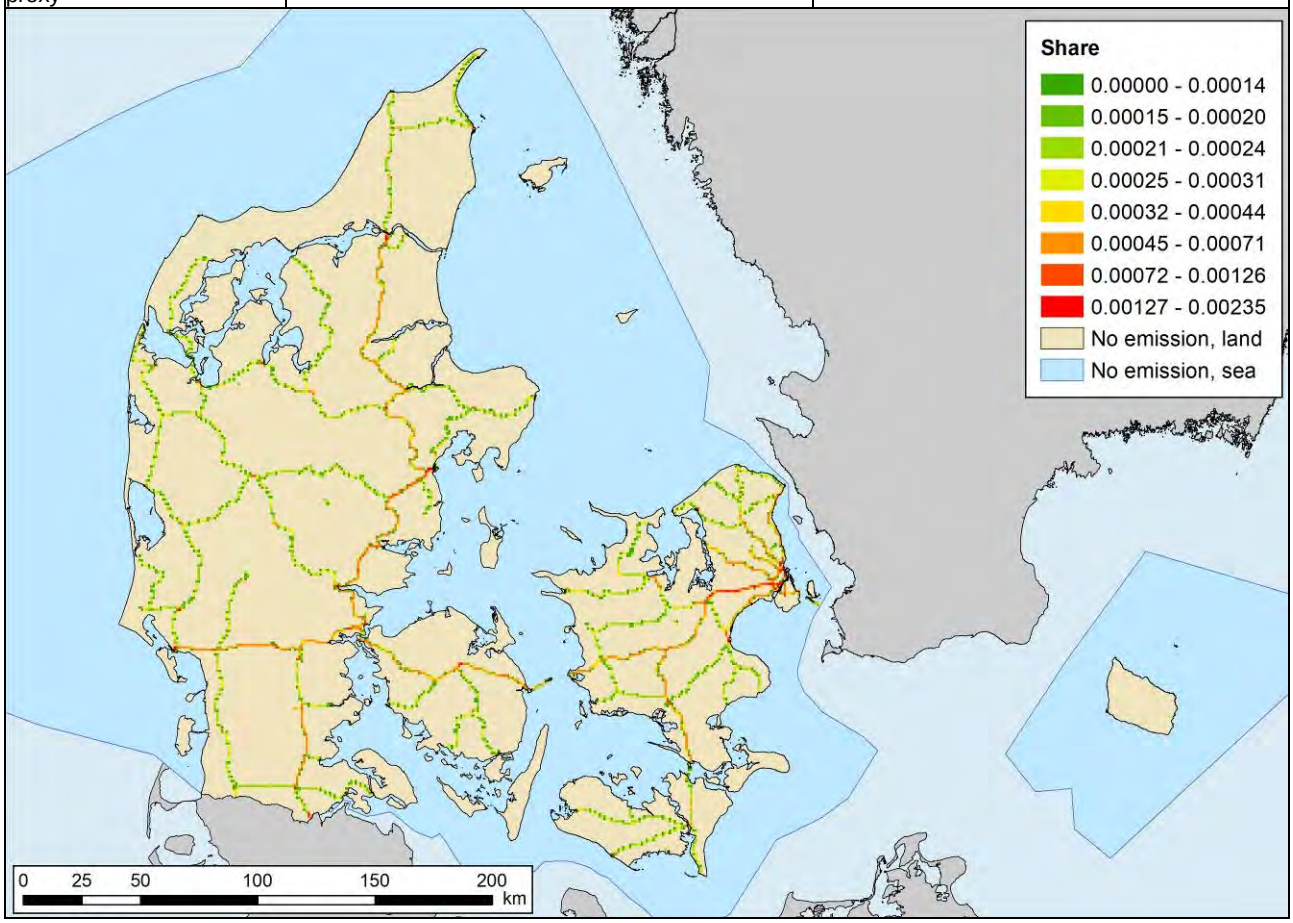
5.3.3 Railways

The GeoKey for railways is based on the railway theme in Kort10. The 2005 version of the map is used as this includes underground parts of the railway network, which is not the case for the 2009 version. Activity data is not included in the digital railway network map and following the emissions is distributed evenly on the network lines.

The spatial dataset used for the GeoKey is considered to have low uncertainty. The spatial applicability is considered poor, as no activity data are included in the dataset, as the dataset does not reflect the extent of electrification, and as the GeoKey does not reflect the variation over time.

Table 5.70 GeoKey for railways.

Source data	Kort10 version 2005			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection.	UTM32_EUREF89			
Data description	Railway network			
Workflow	The railway network is intersected with the 1 km x 1 km grid and the GeoKey is calculated as the share of the total railway network length by grid cell.			
GeoKey name	_Key_0802_Railways			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NO_x, BC	NO_x, BC	NO_x
	< 1 %	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	0802 Railways		4	



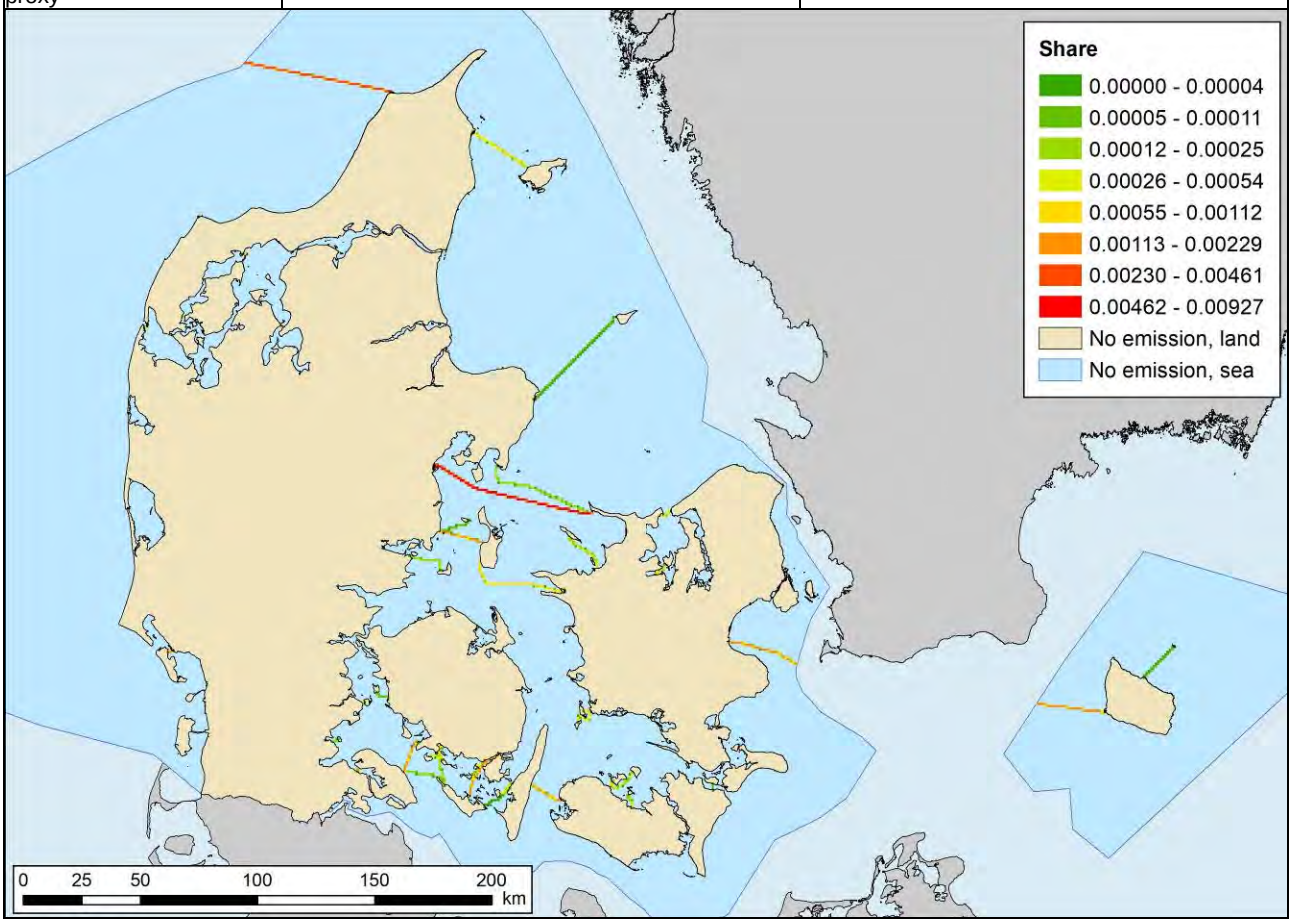
5.3.4 Navigation

Navigation includes only sea transport defined as ferries and other vessels sailing between two Danish harbours. Fishing vessels and recreational boats are described in Chapter 5.3.10 and Chapter 5.3.11, respectively. Part of the sea transport occur outside the Danish sea territory (EEZ), e.g. ferries to Greenland and Bornholm. However, per international guidelines emissions should be allocated within the Danish EEZ. Therefore, the total emissions are allocated to the part of navigation routes located within the EEZ.

The spatial dataset used for the GeoKey is considered to have low uncertainty as it include all ferry routes included in the emission inventory. The spatial applicability is considered fair as the GeoKey is based on annual fuel consumption data by ferry route, but limited to the EEZ area.

Table 5.71 GeoKey for national navigation.

Source data	Kort10 version 2011 Open Street Map, gis.osm_traffic_free_1 (marina)			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	EUREF89 UTM zone 32N			
Data description	The ferry theme in Kort10 include lines for ferry routes in operation. Missing ferry lines and ferry routes that are no longer in operation have been added manually to the spatial data set.			
Workflow	Lines for ferry routes that are no longer in operation has been added manually to the spatial data set using the editing tool in ArcMap. The routes has been intersected with the 1 km x 1 km grid covering the sea area in the Danish EEZ, and the share of the total line length is calculated by route. For each year in the time series as the share of the fuel consumption is calculated by route, and the GeoKey is calculated as [share of FC by route]*[Share of route line length by 1 km x 1 km grid cell].			
GeoKey name	_Key_080402_Ferry			
Year dependent	Yes, based on fuel consumption data for the major ferry routes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	Ni	SO_2, Ni	Ni
	5-10 %		NO_x, As	NO_x, As, Se
	1-5 %	SO_2, NO_x, PM_{10}, $PM_{2.5}$, As, Se	PM_{10}, $PM_{2.5}$, Se	SO_2, $PM_{2.5}$, BC, Hg
	< 1 %	NMVOC, CO, NH_3, TSP, BC, Cd, Cr, Cu, Hg, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NMVOC, CO, TSP, BC, Cd, Cr, Cu, Hg, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NMVOC, CO, TSP, PM_{10}, Cd, Cr, Cu, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	080402 National sea traffic		3	



5.3.5 Building and construction machinery

Emissions from building and construction machinery are estimated from the number of machines per type and related emission factors in the national emission inventory. Information on where the activities take place is not available, and the location of the activities will change from year to year. The largest machinery, and thereby the major part of the emissions, is used in road and building construction, while smaller machinery are used in smaller maintenance works. It is not possible to separate the machinery between different use, as the same machine types are used in different building and construction works, e.g. large soil haulage vehicle are used both in building construction, and road and rail construction project. A comprehensive survey of available data related to the activity has been carried out and three data sets have been selected for creating the GeoKey:

First, building construction activity from statistics Denmark including the number of new-built square meters on municipality level. From this data, a key is created which holds the share of total new-built square meters per 1 km x 1 km grid cell.

Second, information on larger road construction projects is available from the Danish Road Directorate. The data are available as a digital map showing the road segments that are affected by construction work and information if it is a major or minor construction project. From this data, two keys are created for major and minor road construction, respectively, including share of the construction road length per 1 km x 1 km grid cell.

Third, the railway network GeoKey is included. A GeoKey for building & construction machinery is created from these four keys and corresponding weighting factors, the latter being based on expert judgement on the share of the emissions from each of the four sources (Table 5.72). Data on building construction and road construction reflect time variations, while rail construction does not reflect a time variation.

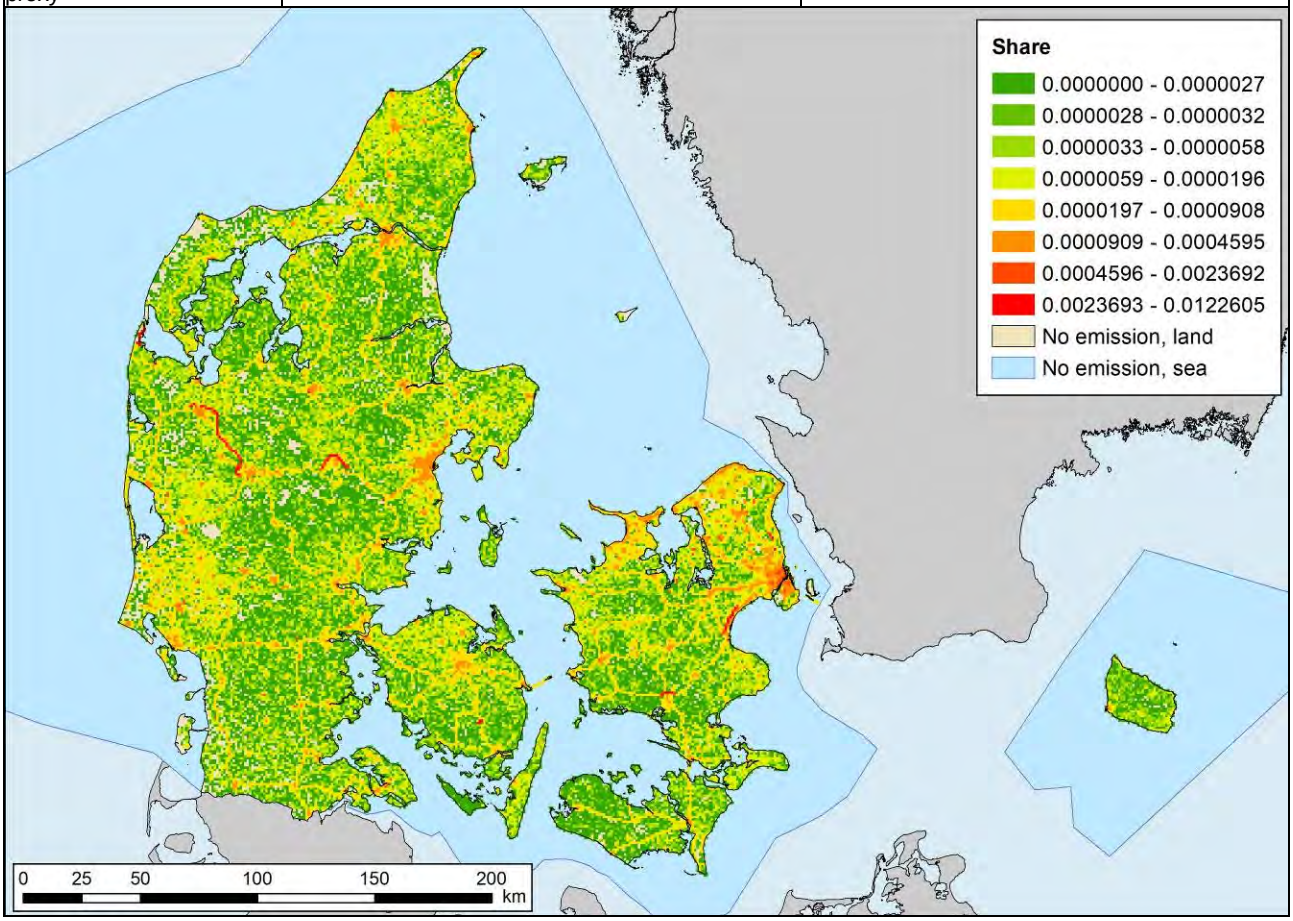
Table 5.72 Weighting factors for building & construction GeoKey.

Key	Weighting factor
Building construction	0.5
Major road construction	0.25
Minor road construction	0.15
Rail construction	0.1

The spatial datasets used for the GeoKey are all considered to have low uncertainty levels. The spatial applicability is considered fair as the GeoKey use weighting fastors for the distribution keys reflecting different activities, but does only include time variations to some degree.

Table 5.73 GeoKey for machinery used in building and construction.

Source data	Building construction activity Larger road construction projects			
Data provider	Statistics Denmark The Danish Road Directorate			
Projection	ETRS89 UTM zone 32N			
Data description	New-built square meters on municipality level Road segments that is affected by construction work and information if it is a major or minor construction project			
Workflow	The GeoKey is created as a combination of four different distribution keys which hold 1) the share of total new-built square meters per 1 km x 1 km grid cell, 2) the share of the construction road length for major road construction projects per 1 km x 1 km grid cell, 3) the share of the construction road length for major road construction projects per 1 km x 1 km grid cell, and 4) the share of the railway network (Chapter 5.3.3). The four distribution keys are combined using the weighting factors listed in Table 5.72			
GeoKey name	_ Key_0808_IndustrialMachinery			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	BC		
	5-10 %		BC	BC
	1-5 %	NO_x, CO, TSP, PM_{10}, $PM_{2.5}$	NO_x, CO, PM_{10}, $PM_{2.5}$, HCB	NO_x, CO, $PM_{2.5}$, HCB
	< 1 %	SO_2, NMVOC, NH_3, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NMVOC, NH_3, TSP, PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	0808 Mobile sources and machinery - Industry	3		



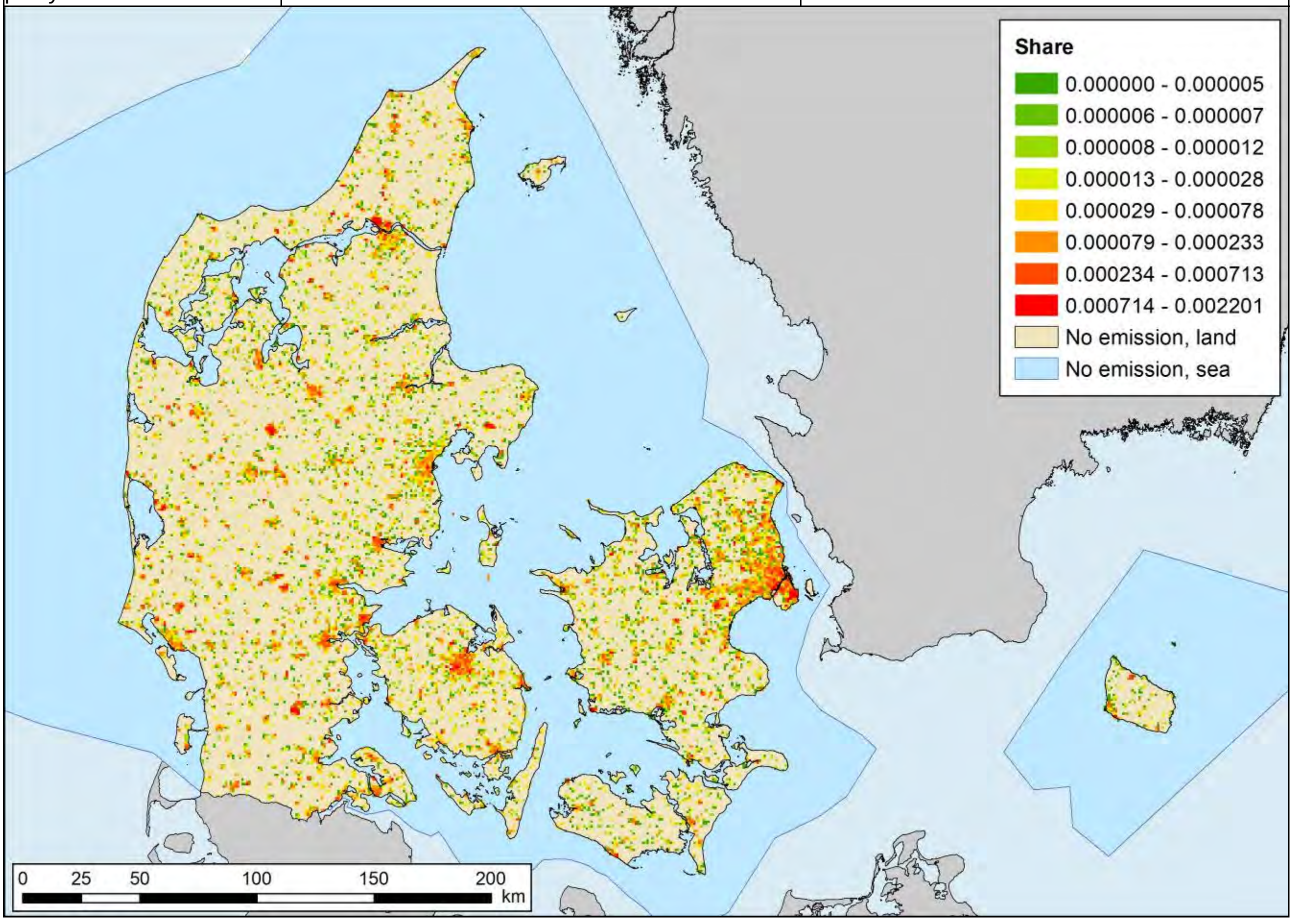
5.3.6 Commercial and institutional machinery

Emissions from commercial and institutional machinery are distributed on technical areas, sport areas, recreational areas, scrub and cemeteries, as defined in Kort10.

The spatial dataset used for the GeoKey is considered to have medium uncertainty. The spatial applicability is considered poor, as it has no time variation and activity data, and does not include all relevant areas.

Table 5.74 GeoKey for machinery used in the commercial and institutional sector.

Source data	Kort10, version 2011			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	EUREF89 UTM zone 32N			
Data description	Areas categorised as the landuse clases technical area, sport area, recreational area, scrub and cemeteries are used.			
Workflow	Areas categorised as technical area, sport area, recreational area, scrub and cemeteries are selected, unioned to a common feature, and intersected with the 1 km x 1 km grid. The GeoKey is calculated as the share of the total selected area by grid cell.			
GeoKey name	_Key_0811_CommInstMachinery			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			CO
	5-10 %		CO	
	1-5 %	CO		
	< 1 %	SO_2, NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0811 Mobile sources and machinery – Commercial and institutional	4		



5.3.7 Residential machinery

Emissoins from residential machinery is spatially allocated using the GeoKey _Key_Building_OneStorey based on the theme “one-storey settlement” in Kort10. The GeoKey is based on the distribution of the area of one-storey settlements, as no information is available to differentiate the activity or emissions between the individual polygons in the theme.

For more information on the GeoKey for one-storey settlement area, see Chapter 5.1.4.

5.3.8 Agricultural machinery

The GeoKeys for agricultural machinery is based on the Danish land use matrix, LUM (Gyldenkærne et al., 2015). The GeoKey is based on the distribution of the agricultural area, as no information is available to differentiate the activity or emissions between the individual agricultural areas.

For more information on the GeoKey for agricultural area, see Chapter 5.1.6.

5.3.9 Forest machinery

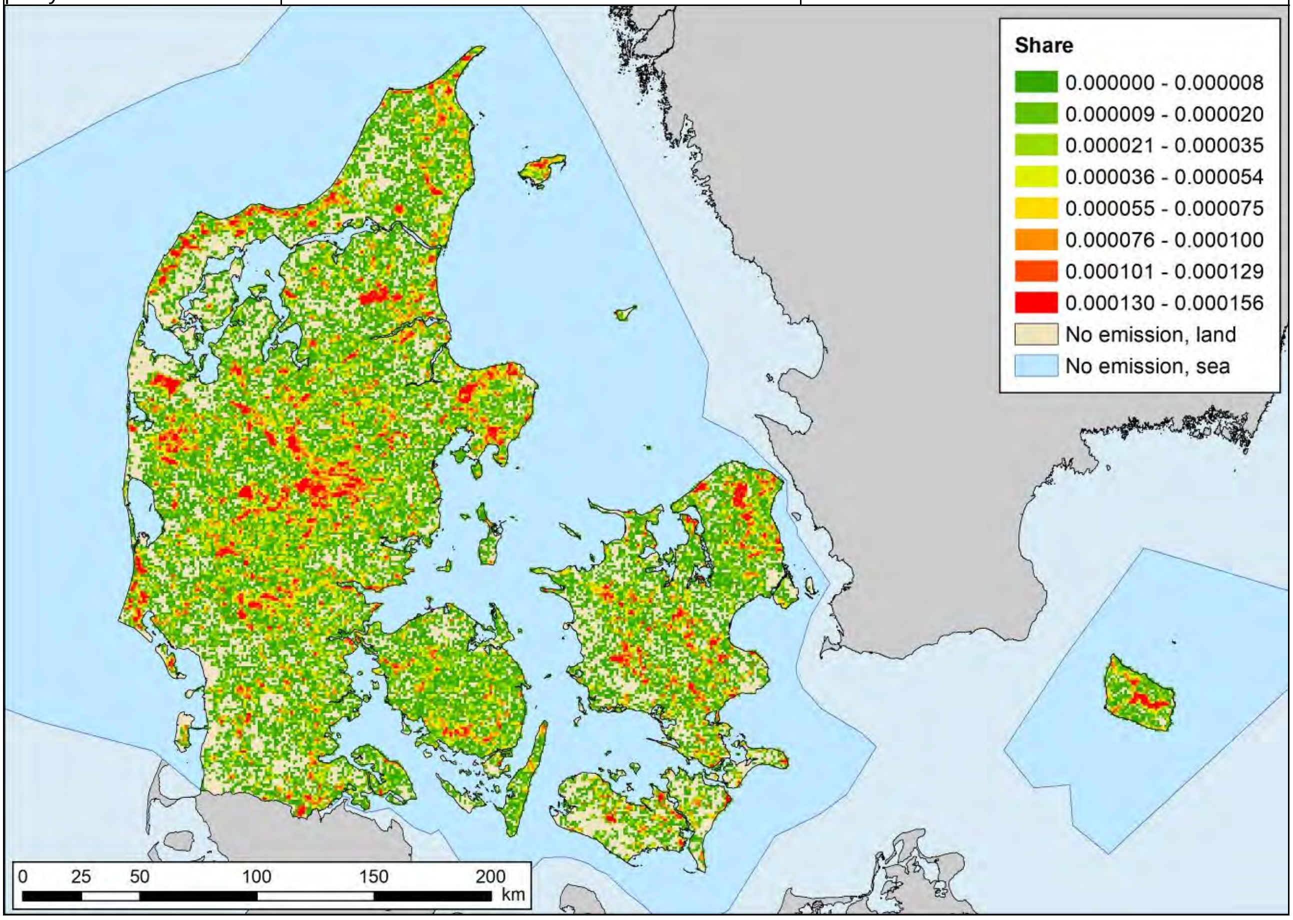
The GeoKey is based on the Danish land use matrix, LUM (Gyldenkærne et al., 2015). The matrix include data on forest based on the National Forest Inventory (NFI). The NFI is a continuous sample based inventory with partial replacement of sample plots based on a 2 x 2 km grid covering the Danish land surface. In each grid, a cluster of four circular plots for measuring forest factors are placed in a 200 x 200 m grid.

The GeoKey is based on areas categorised as Forest (gridcode 13) or Christmas trees (gridcode 14) in the LUM.

The spatial data set used for the GeoKey is considered to have a medium uncertainty, as the dataset is based on a combination of detailed spatial data sets. The applicability as a spatial proxy is considered fair, as no information is available about where the use of forest machinery occur.

Table 5.75 GeoKey for machinery used in the forestry sector.

Source data	The Danish landuse matrix (LUM)			
Data provider	Aarhus University			
Projection	ETRS89 UTM32N			
Data description	The Danish landuse matrix covers the six land use classes Forestry, Cropland, Grassland, Wetlands, Settlement and Other Land and is based on detailed spatial data sets. The land use matrix is updated annually.			
Workflow	The land use classes Forest (gridcode 13) and Christmas trees (gridcode 14) are selected and the polygons are intersected with the 1 km x 1 km grid. The GeoKey is calculated as the share of the total agricultural area by grid cell.			
GeoKey name	_Key_Forest			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	C			
Applicability as spatial proxy	0807 Mobile sources and machinery – Forestry	3		



5.3.10 Fishing

A comprehensive survey of available data related to fishing is carried out and the best available data has been selected for creating the GeoKey. Catch statistics is available from statistics Denmark including amounts per International Council for the Exploration of the Sea (ICES)/shellfish catch area and per species. The catch amounts are grouped into the two categories fish and shellfish. Some of the catch areas extends beyond the Danish EEZ, and according to international guidelines for reporting of gridded emissions, the Danish

emissions from fishing must be allocated only to the Danish area, even if the activity takes place outside the Danish sea area. In these cases, the catch amount in the entire catch area is included in the GeoKey calculation, leading to an accumulation of the activity to a smaller area. From the catch data, two separate fishing distribution keys are prepared for fish and shellfish, respectively. The final GeoKey for fishing is created from the two keys and corresponding weighting factors, the latter being based on expert judgement (Table 5.76).

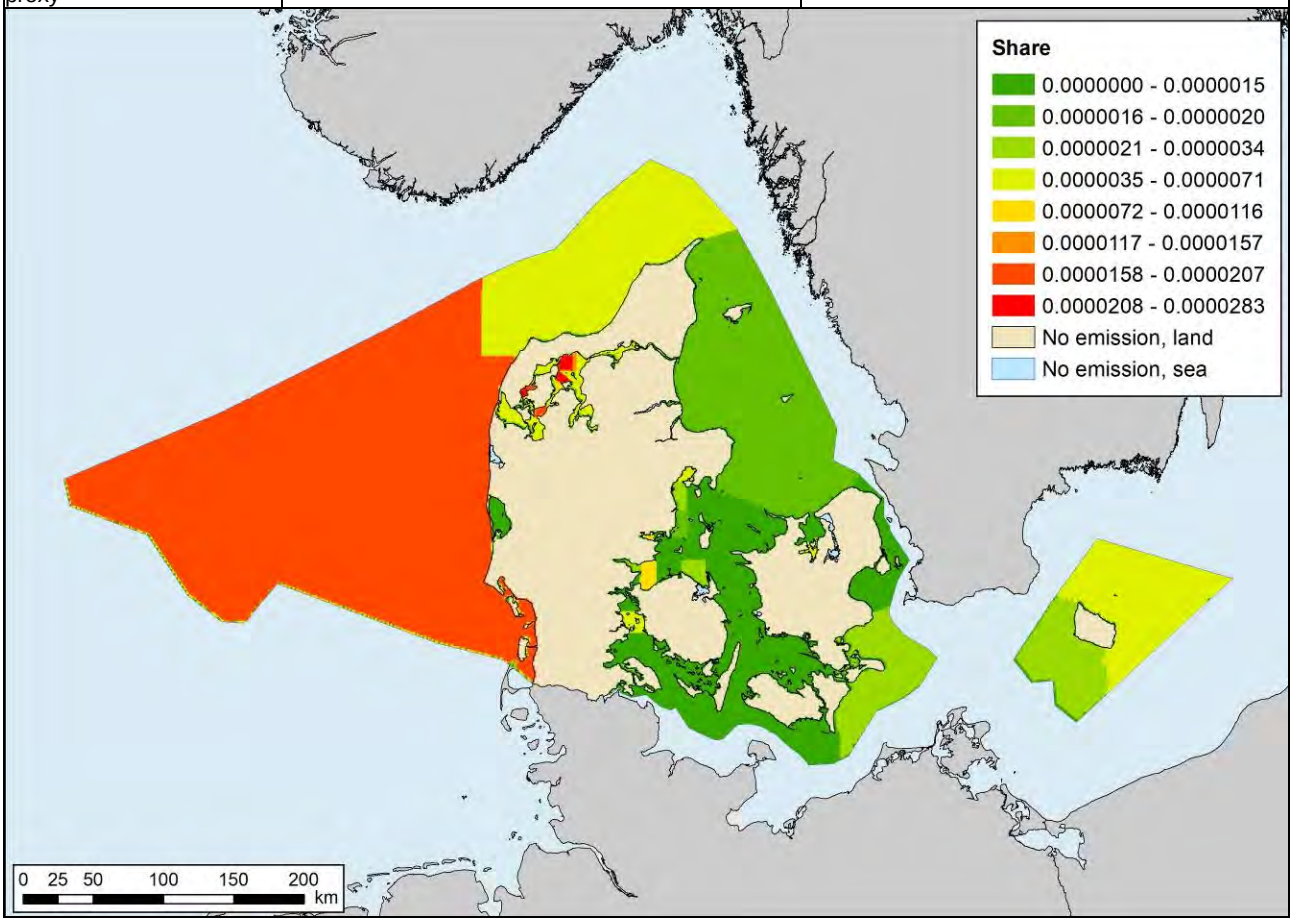
The spatial dataset used for the GeoKey is considered to have low uncertainty due to regulation and registration of catch amounts. The spatial applicability is considered very poor as the catch amounts are not expected to correlate with the emissions and as emissions are allocated to the Danish sea territory even if the catch areas extend beyond the Danish EEZ.

Table 5.76 Weighting factors for fishing.

Key	Weighting factor
Fish	0.5
Shellfish	0.5

Table 5.77 GeoKey for fishing.

Source data	Catch statistics Shell fish catch areas ICES area			
Data provider	Danish Fisheries Agency (catch statistics and shell fish catch areas) International Council for the Exploration of the Sea (ICES)			
Projection	ETRS89 UTM zone 32N			
Data description	Polygon theme covering ICES areas Polygon themes covering Danish shell fish catch areas			
Workflow	Catch statistics from the Danish Fisheries Agency is joined to the attribute data for the relevant catch area polygon theme (shellfish or ICES), depending on the split in the statistics. The polygon layers are intersected with the 1 km x 1 km grid and the share of the total catch area is calculated by grid cell. The shares for spatial distribution is calculated as the share of catch area (ICES and shellfish, respectively) multiplied by the total catch amount in the catch area (ICES and shellfish, respectively). The GeoKey is calculated as a weighted average of the shares for shellfish areas and ICES areas, using a weighting factor of 0.5 for both layers.			
GeoKey name	_Key_080403_Fishing			
Year dependent	Yes, based on annual catch amount data			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NO_x	SO_2, NO_x, As, Se	SO_2, NO_x, As, Hg, Se
	< 1 %	SO_2, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cr, Cu, Hg, Ni, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, Cd, Cr, Cu, Ni, Pb, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	B			
Applicability as spatial proxy	080403 National fishing		5	



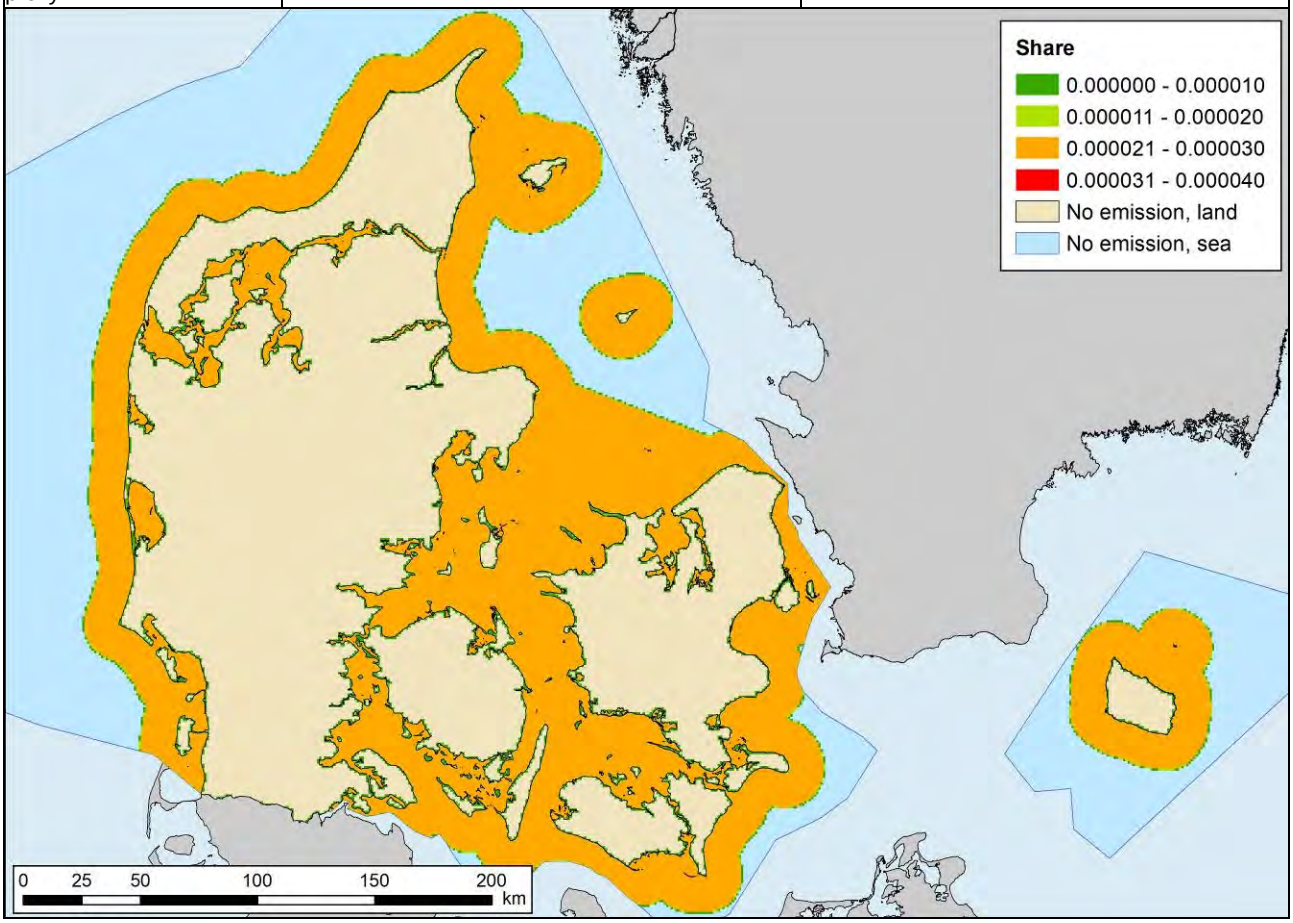
5.3.11 Recreational crafts

Emissions from recreational crafts are distributed evenly within a 15 km buffer zone from the Danish coast.

The spatial dataset used for the GeoKey is considered to have very low uncertainty and the spatial applicability is considered fair based on the assumption the recreational crafts does not sail far from the coastline, but the actual mileage pattern is unknown.

Table 5.78 GeoKey for recreational crafts.

Source data	Coastline			
Data provider	DAGI (Danmarks Administrative Geografiske Inddelinger – Denmarks Ad-ministrative Geographical Divisions), version 2011			
Projection	EUREF89 UTM zone 32N			
Data description	The Danish coastline			
Workflow	A buffer zone of 15 km is generated around the Danish coastline. The buffer zone is adjusted to include the shortest path between the northern part of Zealand and the eastern part of Jutland (Djursland).			
GeoKey name	_Key_Buffer_15km			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		CO, BC	CO, BC
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0803 Inland waterways - recreational crafts	3		



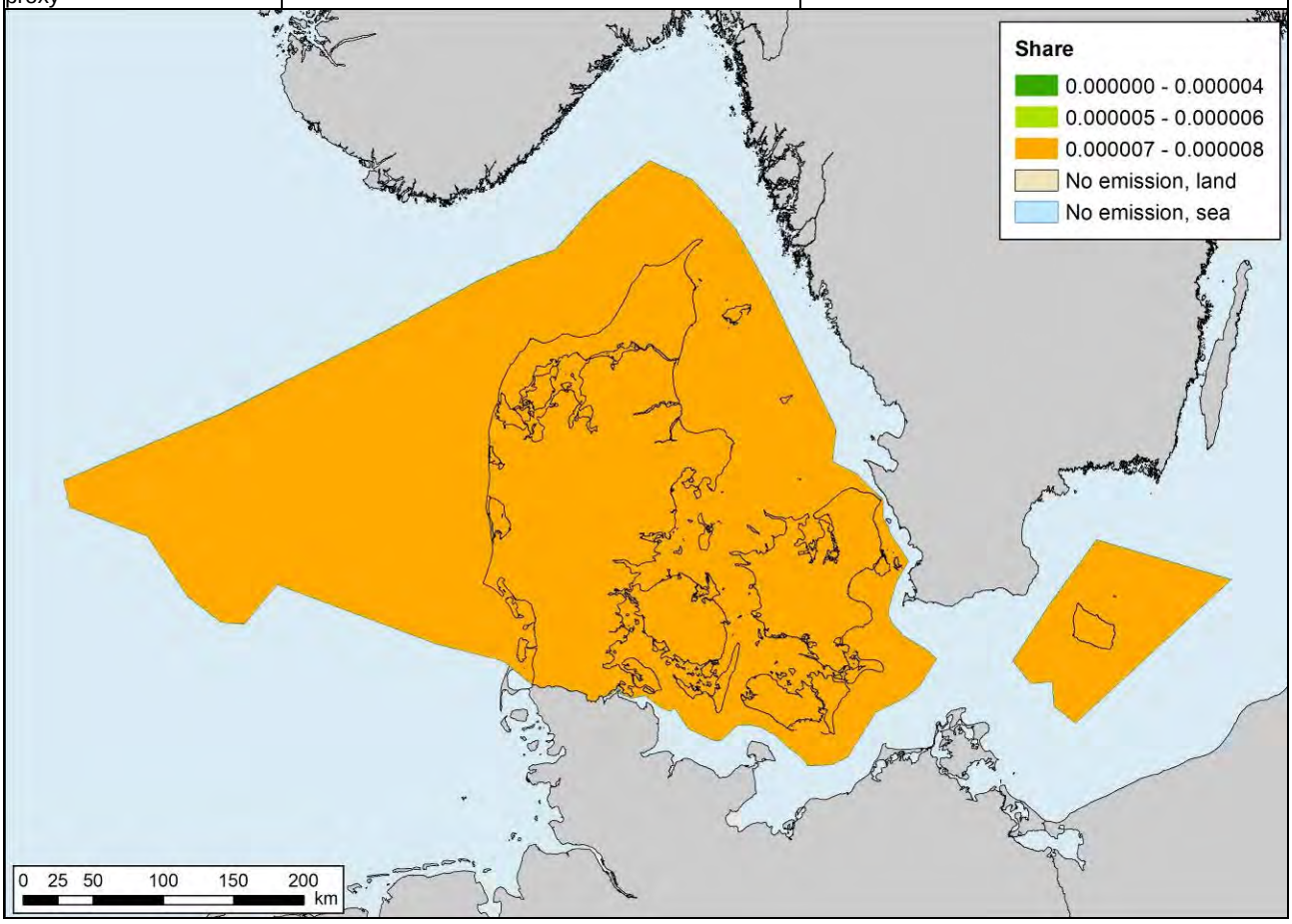
5.3.12 Military

Emissions from military include road and off-road transport, aviation and use of machinery for military purpose. The land-based 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 emissions from military aviation are distributed evenly over the Danish EEZ, as no specific information is available to allow for a more precise spatial distribution.

The spatial dataset used for the GeoKey for military aviation is considered to have low uncertainty as the defined EEZ borders in small areas have been modified especially around the Danish-German border. Geometry errors in the spatial data, e.g. gaps between polylines, is manually adjusted to generate a polygon. Further, adjustments have been made where the Danish EEZ extend into the German land area. The spatial applicability is considered very poor based as the location of activities are not known.

Table 5.79 GeoKey for military aviation.

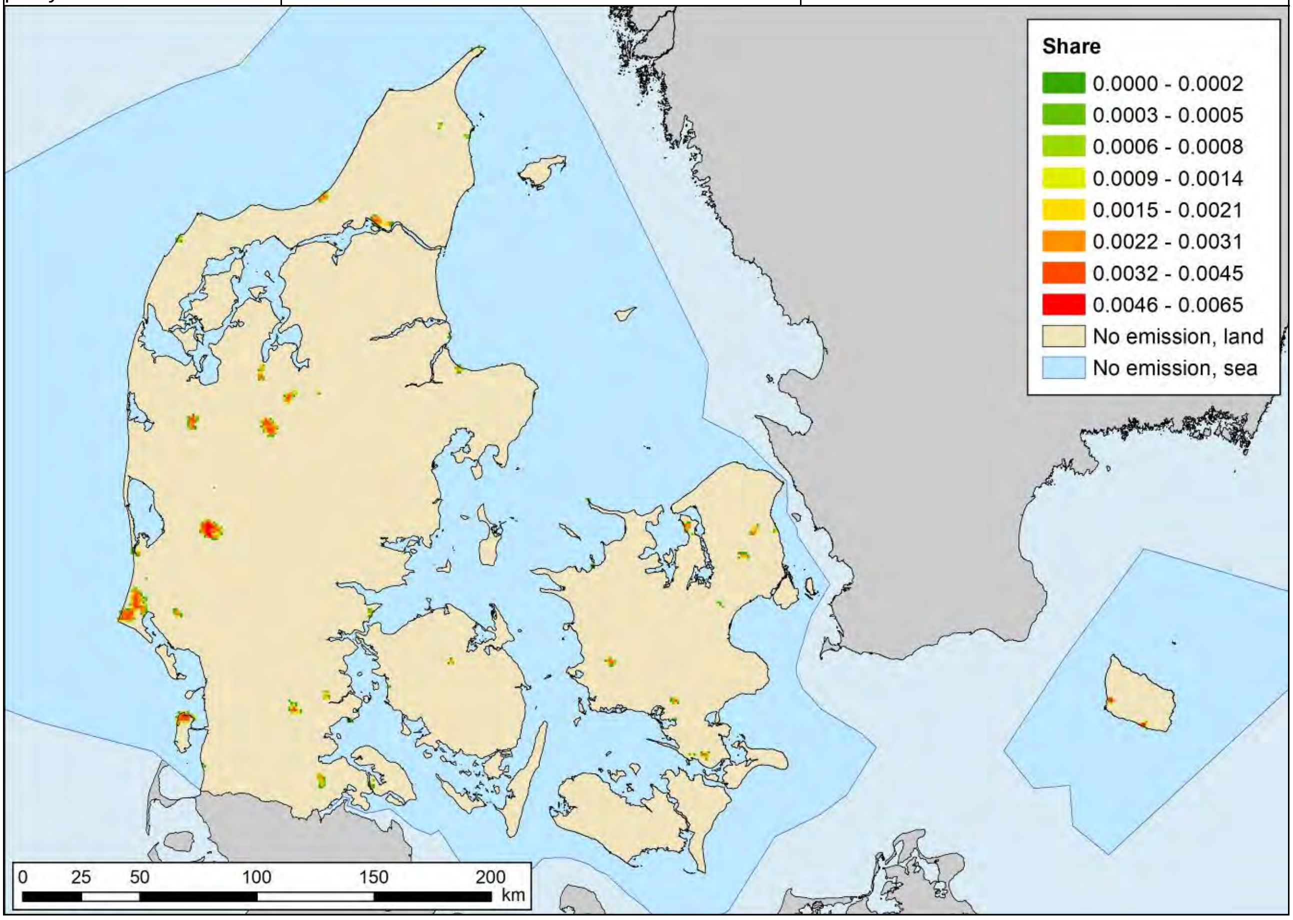
Source data	The exclusive economic zone (EEZ)			
Data provider	Marineregions.org, version 2011			
Projection	GCS_WGS_1984			
Data description	See Chapter 4.1			
Workflow	The GeoKey is calculated as the share of the total EEZ area by grid cell.			
GeoKey name	_Key_Area_EEZ			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC
Quality of spatial dataset	B			
Applicability as spatial proxy	0801 Military - Aviation		5	



The spatial dataset used for the GeoKey for land-based military is considered to have very low uncertainty as the exercise areas are welldefined areas with restricted acces. The spatial applicability is considered fair as most activity is expected to occur in these areas, while the transport on public roads are not possible to outline.

Table 5.80 GeoKey for land based military.

Source data	Military training areas			
Data provider	The Danish Nature Agency			
Projection	ETRS89 UTM zone 32N			
Data description	Spatial data from the Danish Nature Agency holding military training areas			
Workflow	The polygon layer including military training areas is intersected with the 1 km x 1 km grid and the GeoKey is calculated as the share of the total military training area by grid cell.			
GeoKey name	_Key_0801_Military			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs
Quality of spatial dataset	A			
Applicability as spatial proxy	0801 Military – Land based	3		



5.4 Fugitive emissions from fuels

Fugitive emissions from fuels covers dust emissions from coal storage and handling, evaporative emissions from extraction, transport, refining / processing and distribution of crude oil, natural gas and town gas as well as evaporative emissions from the distribution of gasoline. In addition, emissions from flaring and venting are included in this category.

Table 5.81 shows the share of fugitive emissions from fuels of the national total emissions for the pollutants covered by the SPREAD model. It can be seen that the share for most pollutants have remained below 1 % of the national total throughout the time series. For many of the pollutants, e.g. NH_3, CO, heavy metals and POPs, the share is below 0.1 %. In some cases, the emissions are insignificant compared to the national total.

Emissions of SO_2, NMVOC and BC are contributing most to the national total. For SO_2, the emissions are mainly originating from refining and storage of crude oil, for NMVOC, the largest sources are refining and storage of crude oil, loading of ships and service stations. The source accounting for almost the entire fugitive BC emission is coal storage and handling.

The reduction in the share for PM and BC is due to less coal being consumed in Denmark.

Table 5.81 Share of emissions from fugitive emissions from fuels of the national total.

Share	1990	2005	2019
> 10 %		NMVOC	
5-10 %	NMVOC		NMVOC, SO_2
1-5 %	BC, SO_2	BC, SO_2	BC
< 1 %	NO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs	NO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs	NO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP, CO, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, BaP, BbF, BkF, IcdP, HCB, PCBs

An overview of the different activities within fugitive emissions from fuels is provided together with the GeoKey for the individual activities in Table 5.82. Emissions from refining including flaring and natural gas storage are included in LPS (Chapter 5.2.1).

Table 5.82 Activities within fugitive emissions from fuels and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Coal handling and storage	050103	_Key_050103_CoalStorage
Oil exploration	050204	_Key_050204_050304_Exploration
Gas exploration	050304	_Key_050204_050304_Exploration
Oil production	050205	_Key_050205_OilProduction
Offshore loading of crude oil	050206	_Key_050206_LoadingOffshore
Onshore loading of crude oil	050207	_Key_050208_OilTerminal
Storage of crude oil	050208	_Key_050208_OilTerminal
Natural gas production	050305	_Key_050305_GasProduction
Service stations (including refuelling of cars)	050503	_Key_050503_ServiceStations
Natural gas transmission	050601	_Key_050601_GasTransmission
Natural gas distribution	050603	_Key_0202_Gas
Town gas distribution	050604	_Key_050604_TownGas
Flaring in gas and oil extraction	090206	_Key_090206_FlaringOffshore
Flaring in gas transmission and distribution	090299	_Key_050601_GasTransmission

The subsectors within fugitive emissions from fuels are described in more detail in the following chapters.

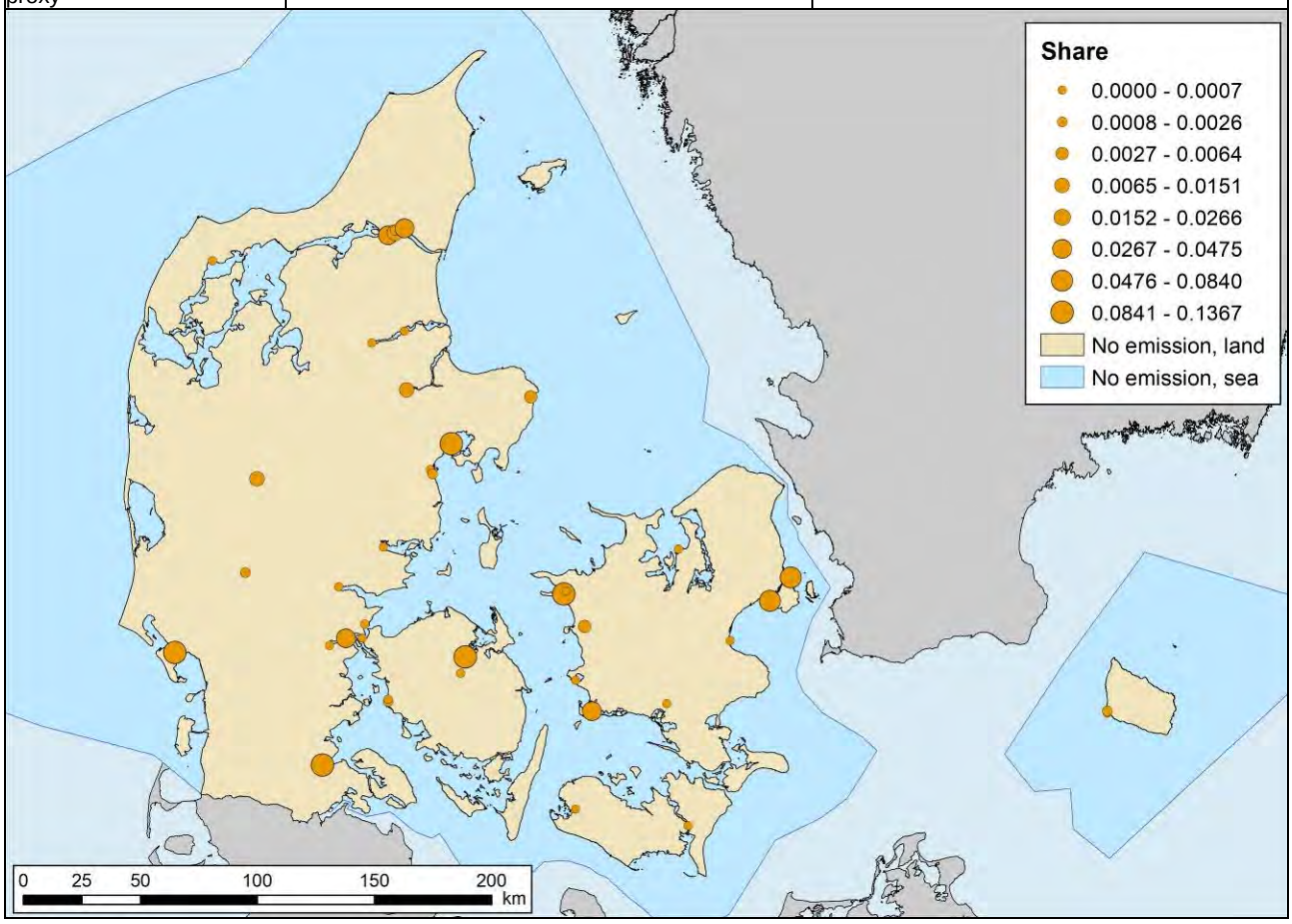
5.4.1 Coal handling and storage

Fugitive emissions from solid fuels in the Danish inventory cover storage of coal in coal piles and include emissions of particulate matter (TSP, PM_{10} and $PM_{2.5}$) and BC. Coal piles occur in connection with harbours and coal fired combined heat power (CHP) plants. Most of the coal fired CHP plants are located at or near the harbours. The GeoKey is based on fuel consumption data for LPSs and on national statistics for import of coal by harbour.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it is based on LPS data and on national import statistics. The spatial applicability is considered good for the years 1997 onwards, where both LPS activity data and coal import statistics by harbour are available. For the years 1990-1996, the import is assumed the same as in 1997. Eventhough the import amounts might vary, this assumption is made to apply the same distribution between the harbours for the years without import data. Acticity data for the coal fired CHP plants are available from 1994/1995. For the years where activity data are missing, data for the earliest year in the time series is applied. The amount of coal used in the LPS plants are distributed according to the coal consumption for the LPS plants. The remaining part of the coal consumption, used in plants not treated as LPS in the inventory system (area sources, AS), are distributed among the harbours according to the coal import. The GeoKey is calculated as an average of the distribution for LPS and AS weighted by the share of the national total coal consumption for LPS and AS, respectively. For the years 1995 onwards, the LPS make up more than 96% of the national total coal consumption.

Table 5.83 GeoKey for coal handling and storage.

Source data	Coal import statistics LPS activity data			
Data provider	Statistics Denmark Inventory data			
Projection	ETRS89 UTM zone 32N			
Data description	Data from Statistics Denmark include coal loading and unloading of ships by harbour for the years 1997-2018. Inventory data include annual coal consumption by power plant.			
Workflow	Coal used in LPS are distributed by annual coal consumption. Coal used in AS are distributed by the annual coal import by harbour. The GeoKey is calculated as an average of the distribution for LPS and AS weighted by the share of the national total coal consumption for LPS and AS, respectively. For years where import statistics and/or LPS coal consumption are missing, the data for the earliest year in the time series is applied.			
GeoKey name	_Key_050103_CoalStorage			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	BC	BC	BC
	< 1 %	TSP, PM_{10}, $PM_{2.5}$	TSP, PM_{10}, $PM_{2.5}$	TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	050103 Coal handling and storage	2		



5.4.2 Oil

Fugitive emissions from oil include emissions from exploration, production, offshore and onshore loading of ships, storage at the oil terminal, and distribution of oil products.

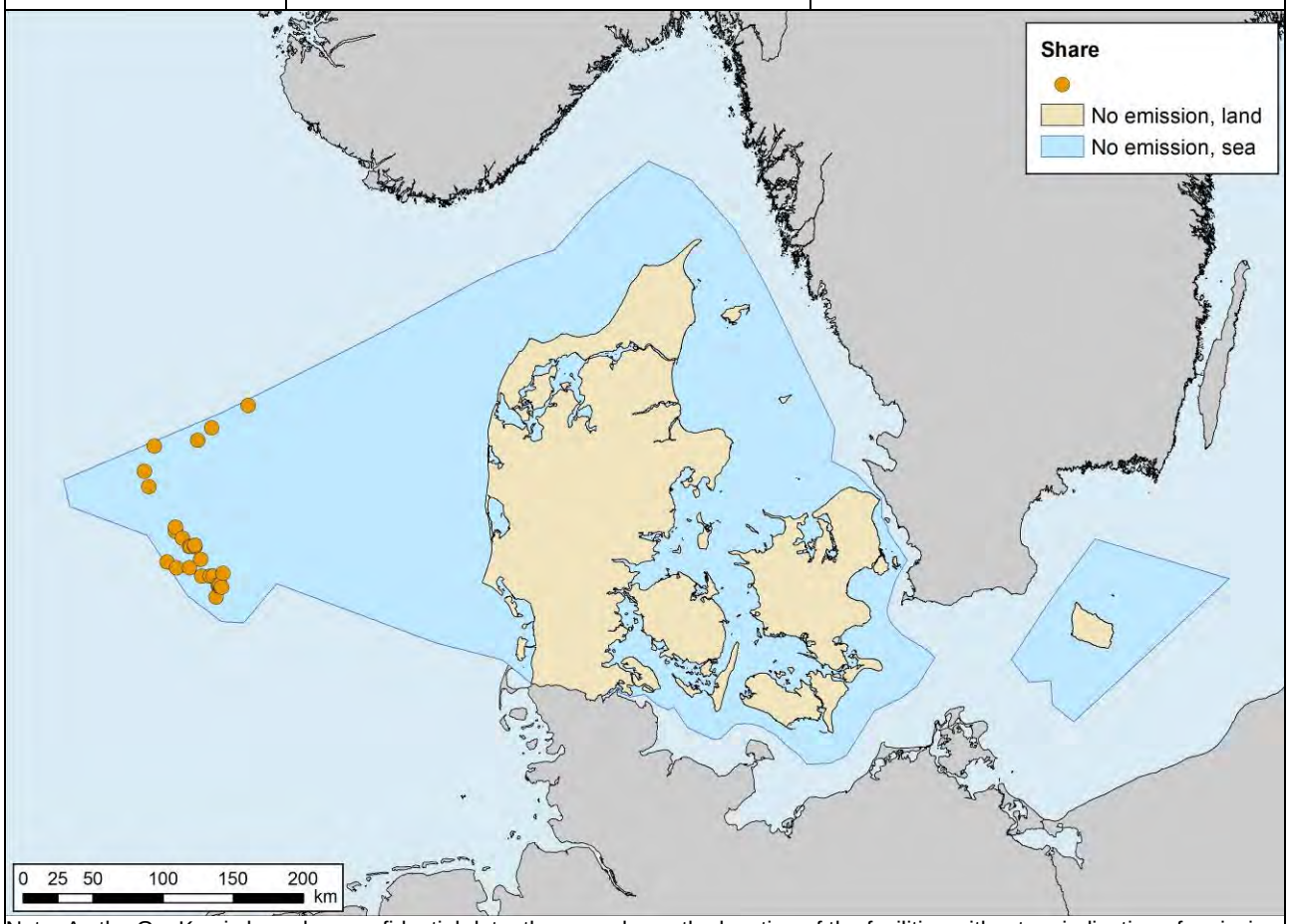
Oil and gas exploration

Detailed data for exploration sites are provided annually by the Danish Energy Agency, including amounts of oil and/or gas explored. Exploration activity only occur in some years, and therefore this source does not occur in the gridded data for all years included in the SPREAD model.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on exact location of the offshore installations. The spatial applicability is considered poor as exploration occur on varying locations and the produced oil/gas is transported to an existing installation, which may vary between exploration drillings.

Table 5.84 GeoKey for oil and gas exploration.

Source data	Location of offshore facilities			
Data provider	The Danish Energy Agency			
Projection	ED1950 UTM zone 32N			
Data description	Location of offshore facilities			
Workflow	The share of the total number of offshore facilities is calculated. All facilities are included in the GeoKey for oil and gas exploration.			
GeoKey name	_Key_050204-050304_Exploration-Oil-Gas			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	
Quality of spatial dataset	A			
Applicability as spatial proxy	050204 Exploration of oil		4	
	050304 Exploration of gas		4	



Note: As the GeoKey is based on confidential data, the map shows the location of the facilities without an indication of emission shares.

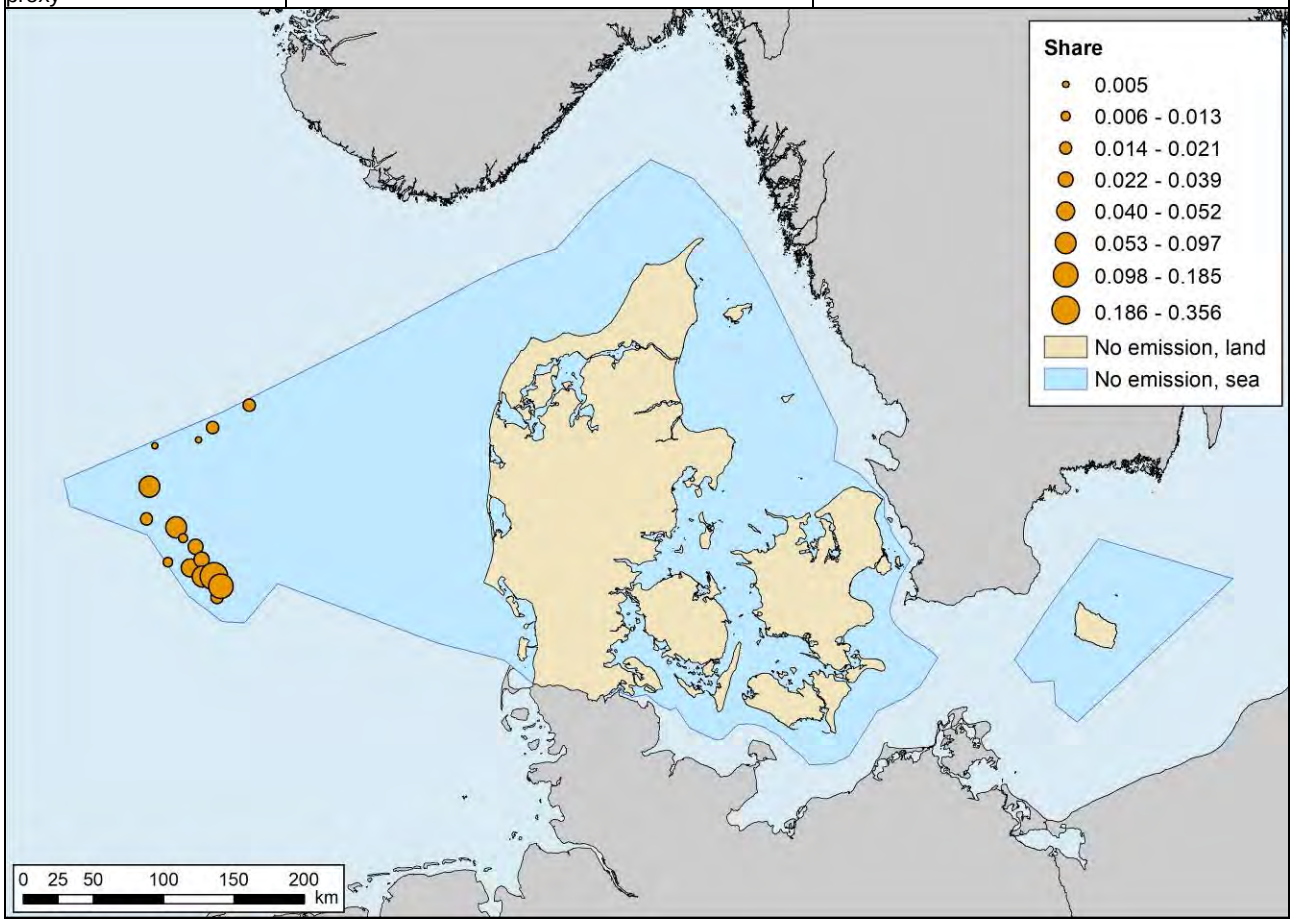
Oil production

Danish oil production only occur at offshore facilities, and annual production data is available from the the Danish Energy Agency on facility level.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it is based on installation specific production amounts. The spatial applicability is considered good as production amounts are assumed to correlate well with the production amounts.

Table 5.85 GeoKey for oil production.

Source data	Yearly data on oil and gas production in Denmark			
Data provider	The Danish Energy Agency			
Projection	ED1950 UTM zone 32N			
Data description	Oil and gas production statistics for the years 1972 onwards. Data is available by offshore facility. The data set include data for oil production, gas production, fuel consumption and flaring rates.			
Workflow	The share of the total oil production is calculated by offshore facility and by year.			
GeoKey name	_Key_050205_OilProduction			
Year dependent	Yes, based on annual production statistics			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	050205 Production of oil		2	



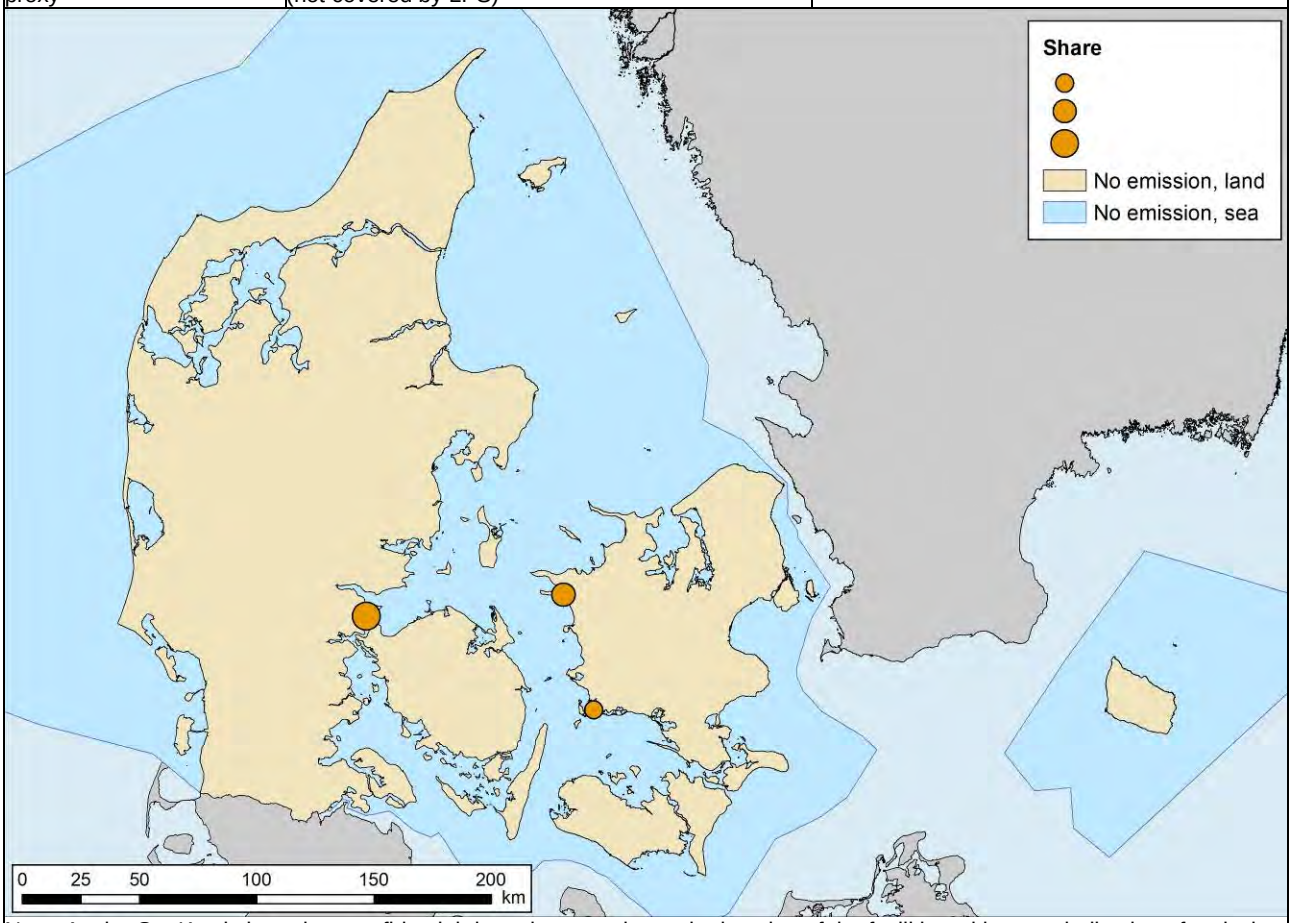
Refining of oil

The two refineries in Denmark are treated as LPS in the inventory system from 1994 onwards. Detailed data are not available for 1990 and following, the emissions are treated as area sources in the inventory system as well as in SPREAD. The GeoKey for 1990 is based on the LPS emissions in 1994, and the emissions distribution follows the shares in 1994.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on LPS emissions. The spatial applicability is considered fair as the GeoKey is based on 1994 conditions. A comparison of the emission distribution in 1994 and in 1995 show only small differences, which support the use of 1994 data for 1990.

Table 5.86 GeoKey for refining of oil.

Source data	LPS activity data			
Data provider	Inventory data			
Projection	ETRS89 UTM zone 32N			
Data description	Inventory data include emissions for the three refineries in 1994			
Workflow	Plant specific emissions for the refineries (snap 0401) in 1994 are used to calculate shares per pollutant per refinery.			
GeoKey name	_Key_0401_Refineries_AS			
Year dependent	Yes			
Pollutant dependent	Yes			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	SO_2		
	< 1 %	NMVOC		
Quality of spatial dataset	A			
Applicability as spatial proxy	0401 Processes in petroleum industries (not covered by LPS)		3	



Note: As the GeoKey is based on confidential data, the map shows the location of the facilities without an indication of emission shares.

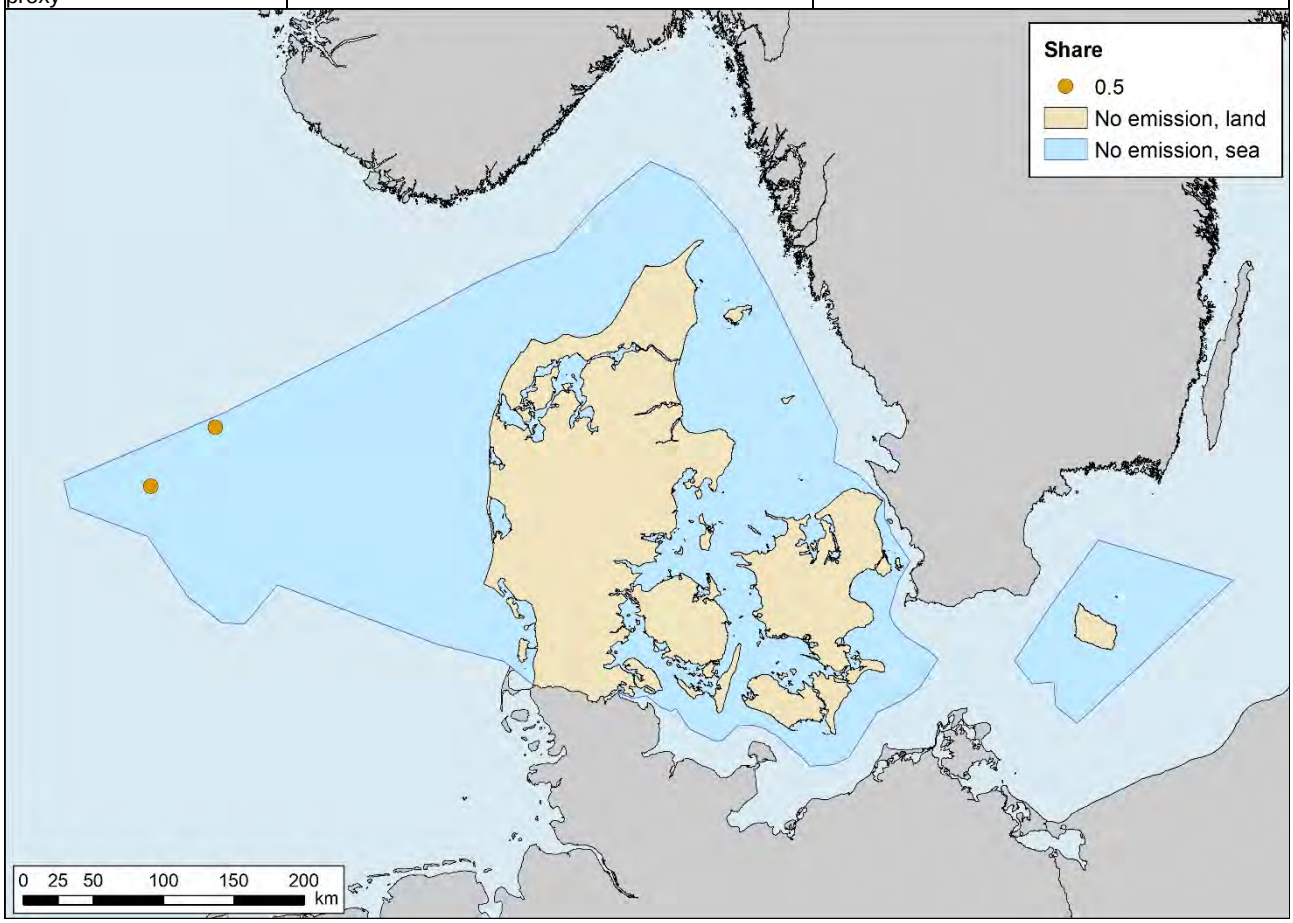
Offshore loading

Offshore loading is taking place at two offshore facilities. Oil from other facilities are either transported to these two facilities for loading to ships or transported to the raw oil terminal via pipeline.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on exact location of the offshore installations. The spatial applicability is considered fair as the GeoKey is based on annual installation specific loading amount but no information about the ships are available, e.g. vapour recovery systems and previous content of the tanks, which both influence the emissions.

Table 5.87 GeoKey for offshore loading.

Source data	Location of offshore facilities			
Data provider	The Danish Energy Agency			
Projection	ED1950 UTM zone 32N			
Data description	Location of offshore facilities			
Workflow	Offshore loading occur at two facilities. As detailed data for offshore loading are not available, emissions are assumed equally distributed between the two sites, each having a share of 0.5 in the GeoKey.			
GeoKey name	_Key_050206_LoadingOffshore			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %		NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	050206 Offshore loading of oil		3	



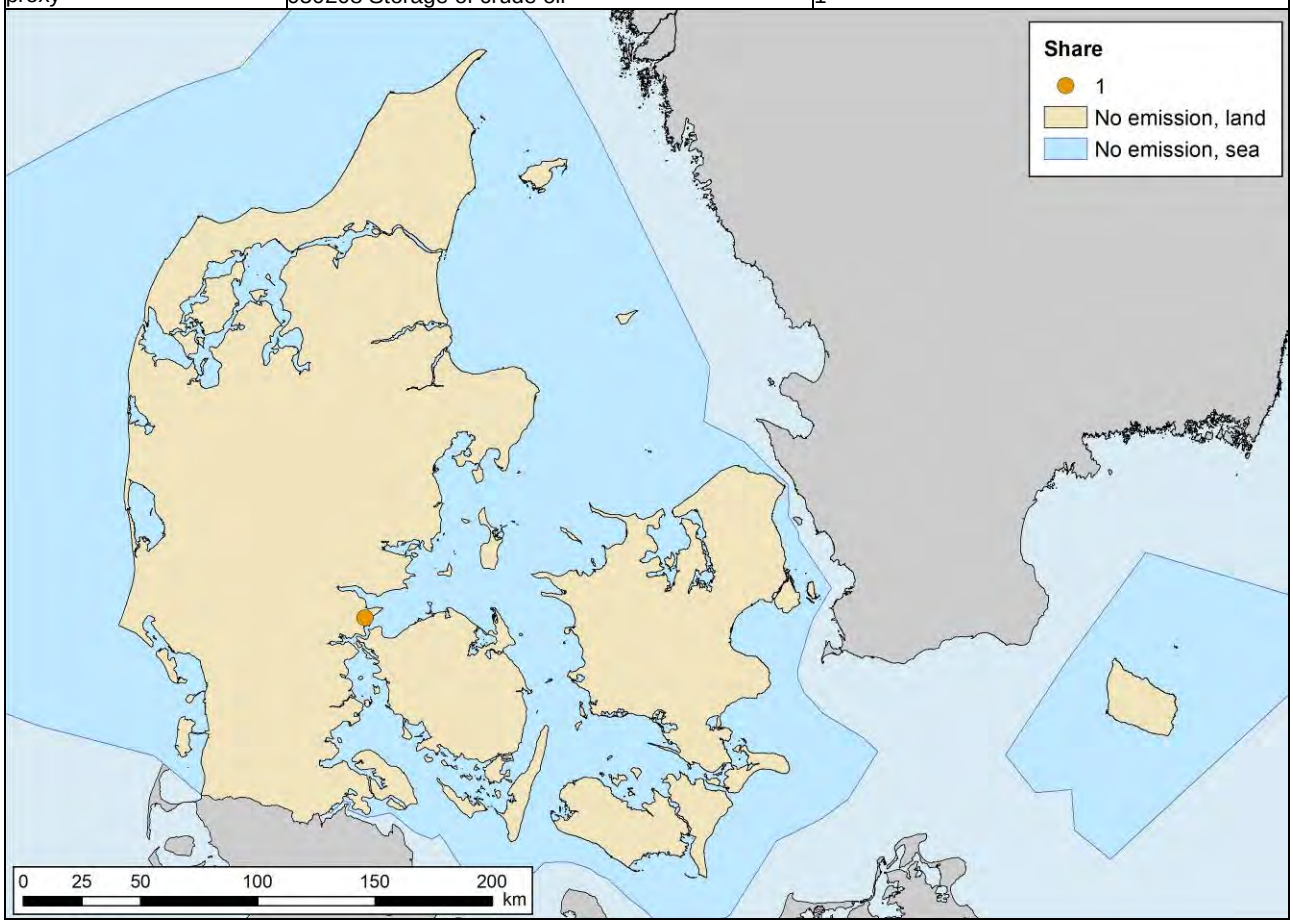
Storage and onshore loading of crude oil

Production of oil and gas in Denmark only occur offshore. Part of the oil and gas produced are transported to the raw oil terminal via an undersea pipeline. Raw oil is stored at the terminal and either transported by pipeline to the nearby refinery or loaded to ships at the oil terminal's harbour.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty and the spatial applicability is considered very good as emissions occur at a single location.

Table 5.88 GeoKey for storage and onshore loading of crude oil.

Source data	Annual Self-regulation Report for the Raw Oil Terminal			
Data provider	DONG Oil Pipe A/S			
Projection	ETRS89 UTM zone 32N			
Data description	The reports include annual amounts of oil transported in pipeline from offshore facilities to the oil terminal, annual amounts for onshore loading, and emissions from the oil terminal.			
Workflow	Emissions from storage and onshore loading of ships is allocated to the location of the oil terminal			
GeoKey name	_Key_050208_OilTerminal			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		NMVOC	
	< 1 %	NMVOC		NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	050207 Onshore loading of crude oil		1	
	050208 Storage of crude oil		1	



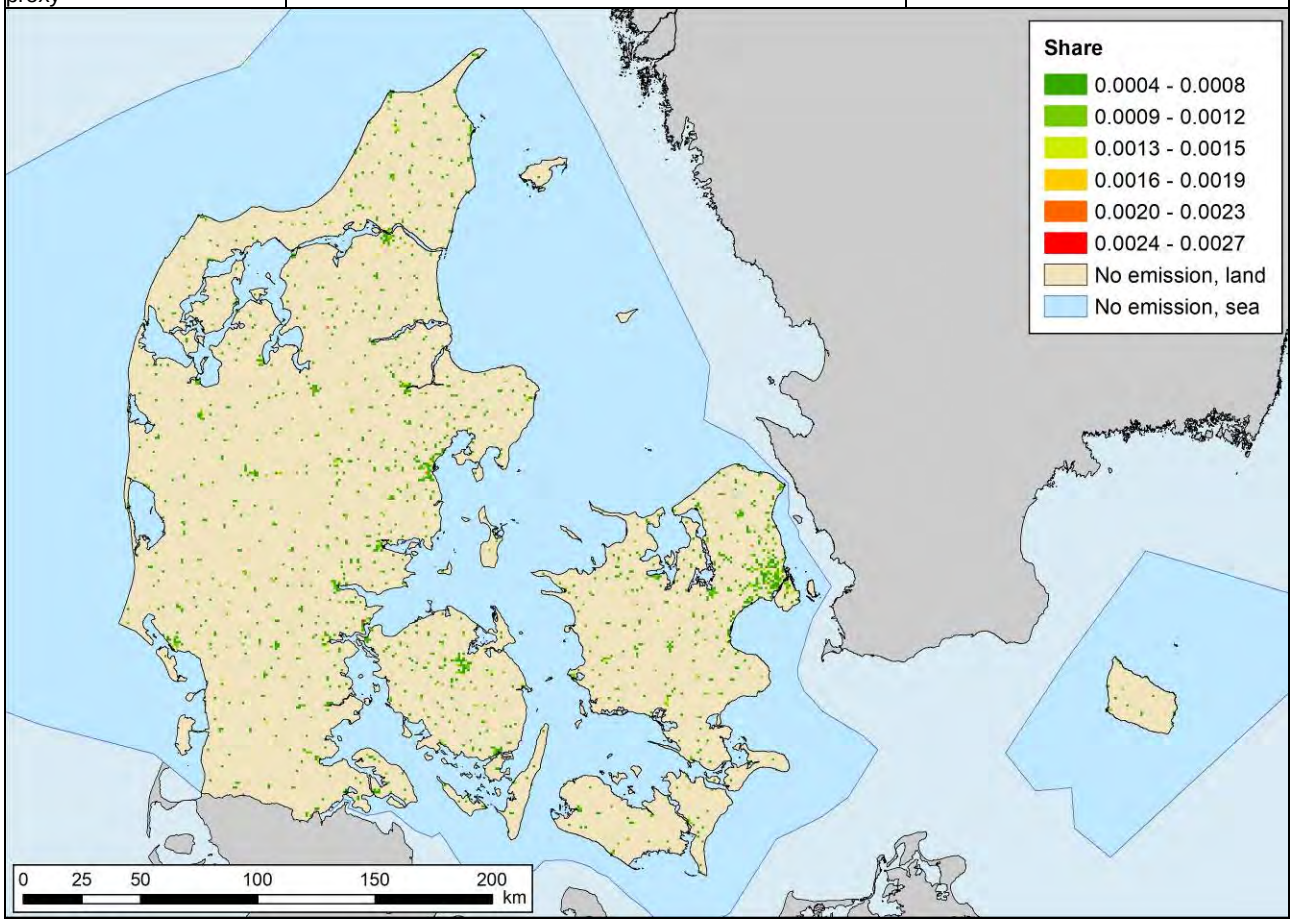
Service stations

Service stations include unloading of tanker trucks, storage in tanks at the service stations and refuelling of vehicles. Sales amounts are not available on service station level, and following the emissions are distributed evenly between the 2260 service stations included in the list provided by the Danish Petroleum Association. Small private and industrial gasoline / diesel tanks are not included in the list. This is assumed to be of minor importance as the main part of fuels for transport are sold from service stations.

The spatial dataset used for the GeoKey is considered to have low uncertainty as the list of Danish service stations is expected to include all active service stations, but no private filling sites. The spatial applicability is considered poor, as the data does not include the changes over time.

Table 5.89 GeoKey for storage and onshore loading of crude oil.

Source data	Address list of Danish service stations			
Data provider	The Danish Petroleum Association			
Projection	ETRS89 UTM zone 32N			
Data description	Address list of Danish service stations from 2001			
Workflow	The service stations are geocoded from the address information and the GeoKey is calculated as the share of the total number of service stations by 1 km x 1 km grid cell			
GeoKey name	_Key_050503_ServiceStations			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	B			
Applicability as spatial proxy	050503 Service stations (including refuelling of cars)		4	



5.4.3 Gas

Fugitive emissions from gas include emissions from exploration, production, transmission and distribution of gas. Distribution of gas covers both natural gas and town gas, the latter being natural gas diluted with ambient air (approximately 50/50).

Table 5.84 includes a description of the GeoKey used for gas exploration.

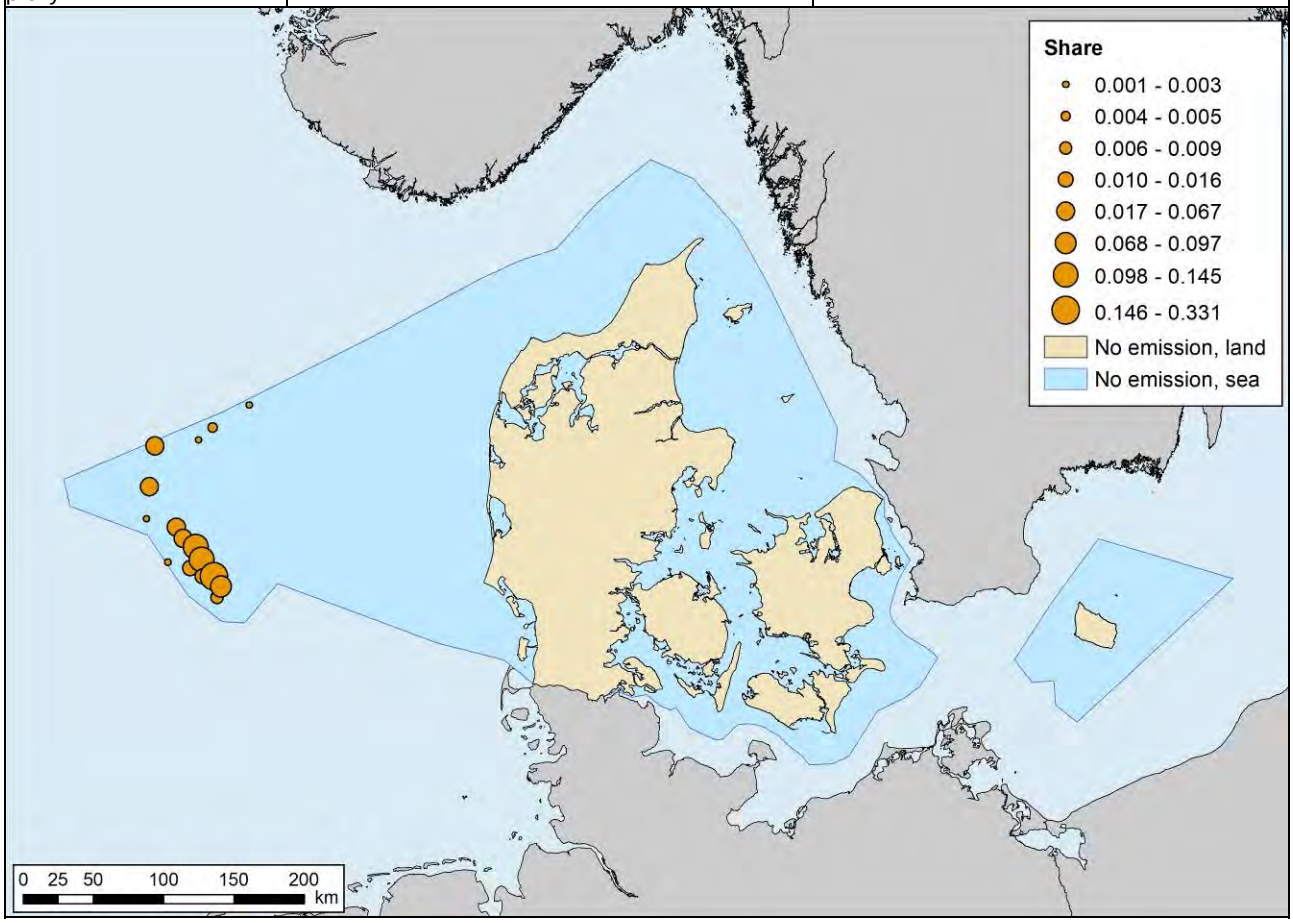
Gas production

Danish gas production only occur at offshore facilities, and annual production data is available from the the Danish Energy Agency on facility level.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it is based on installation specific production amounts. The spatial applicability is considered good as production amounts are assumed to correlate well with the production amounts.

Table 5.90 GeoKey for gas production.

Source data	Yearly data on oil and gas production in Denmark			
Data provider	The Danish Energy Agency			
Projection	ED1950 UTM zone 32N			
Data description	Oil and gas production statistics for the years 1972 onwards. Data is available by offshore facility. The data set include data for oil production, gas production, fuel consumption and flaring rates.			
Workflow	The share of the total gas production is calculated by offshore facility and by year.			
GeoKey name	_Key_050305_GasProduction			
Year dependent	Yes, based on annual production statistics			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	050305 Production of gas		2	



Natural gas transmission

The Danish natural gas pipelines are rather new and made of plastic, and emissions mainly occur due to leaks during construction and maintenance. This leads to large annual fluctuations, regarding both emission amounts and locations. As detailed data for location and size of leaks are not available,

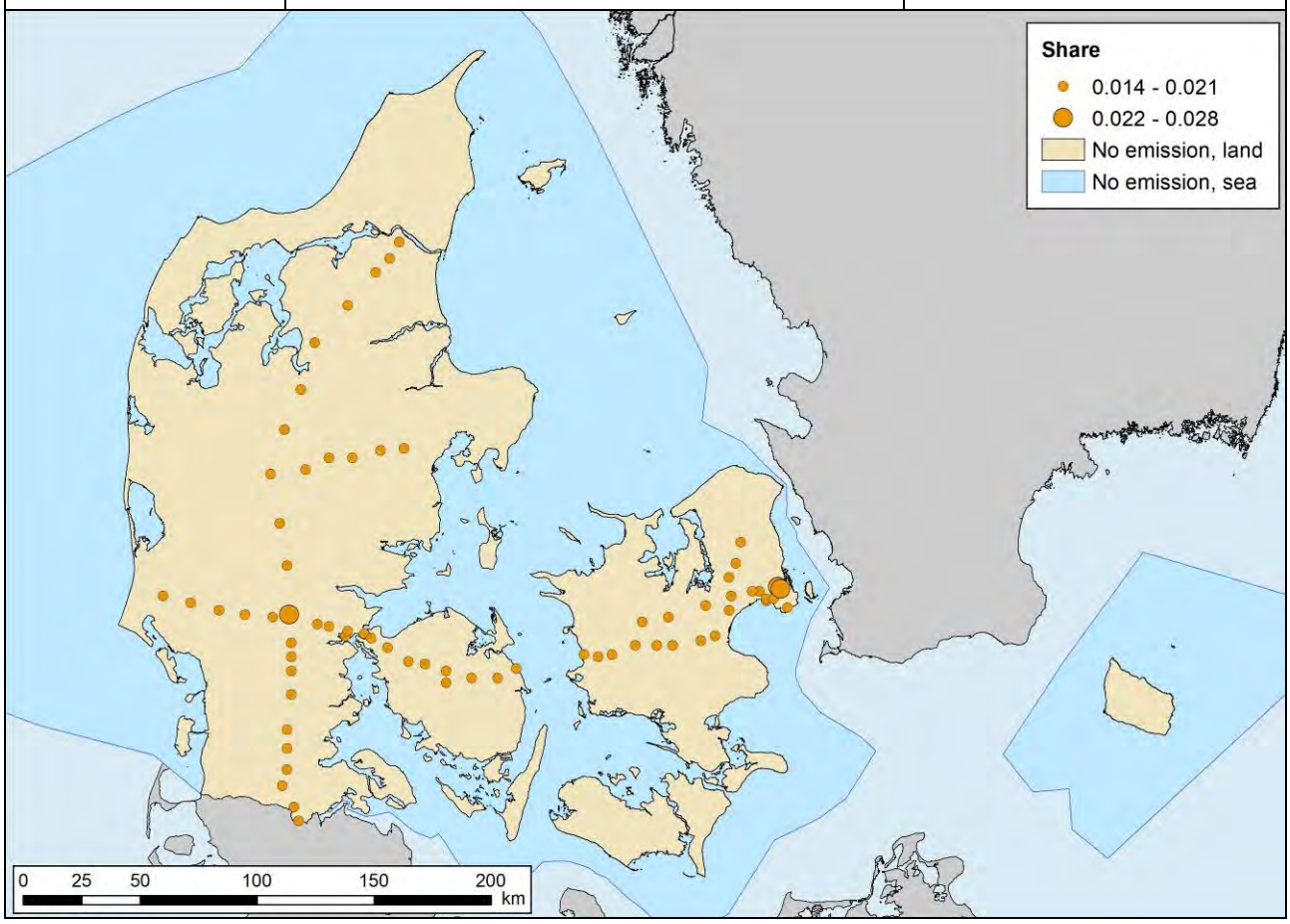
emissions are allocated to the monitoring and regulation (M / R) stations in the gas transmission network.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it include exact location of each M / R station. The spatial applicability is considered very poor, as location of leaks are unknown and vary from year to year.

The GeoKey for gas transmission is also used for flaring in gas transmission and distribution (Chapter 5.4.4).

Table 5.91 GeoKey for gas transmission.

Source data	Location of M/R stations in the gas transmission network			
Data provider	Energinet.dk			
Projection	ETRS89 UTM zone 32N			
Data description	Name address and geographical coordinates for the M/R stations in the gas transmission network			
Workflow	The share of the total number of M/R stations is calculated by 1 km x 1 km and used for distribution of emissions			
GeoKey name	_Key_050601_GasTransmission			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	050601 Natural gas transmission			5
	090299 Flaring in gas transmission and distribution			5



Natural gas distribution

The emissions from natural gas distribution are distributed using information on the location of residential natural gas appliances (Table5.30).

The spatial dataset used for the GeoKey for gas-fired residential plants is considered to have medium uncertainty (see Chapter 5.2.6 for further information). The spatial applicability is considered poor as the GeoKey is based on location of addresses using natural gas for heating and does not include any activity data or time series data.

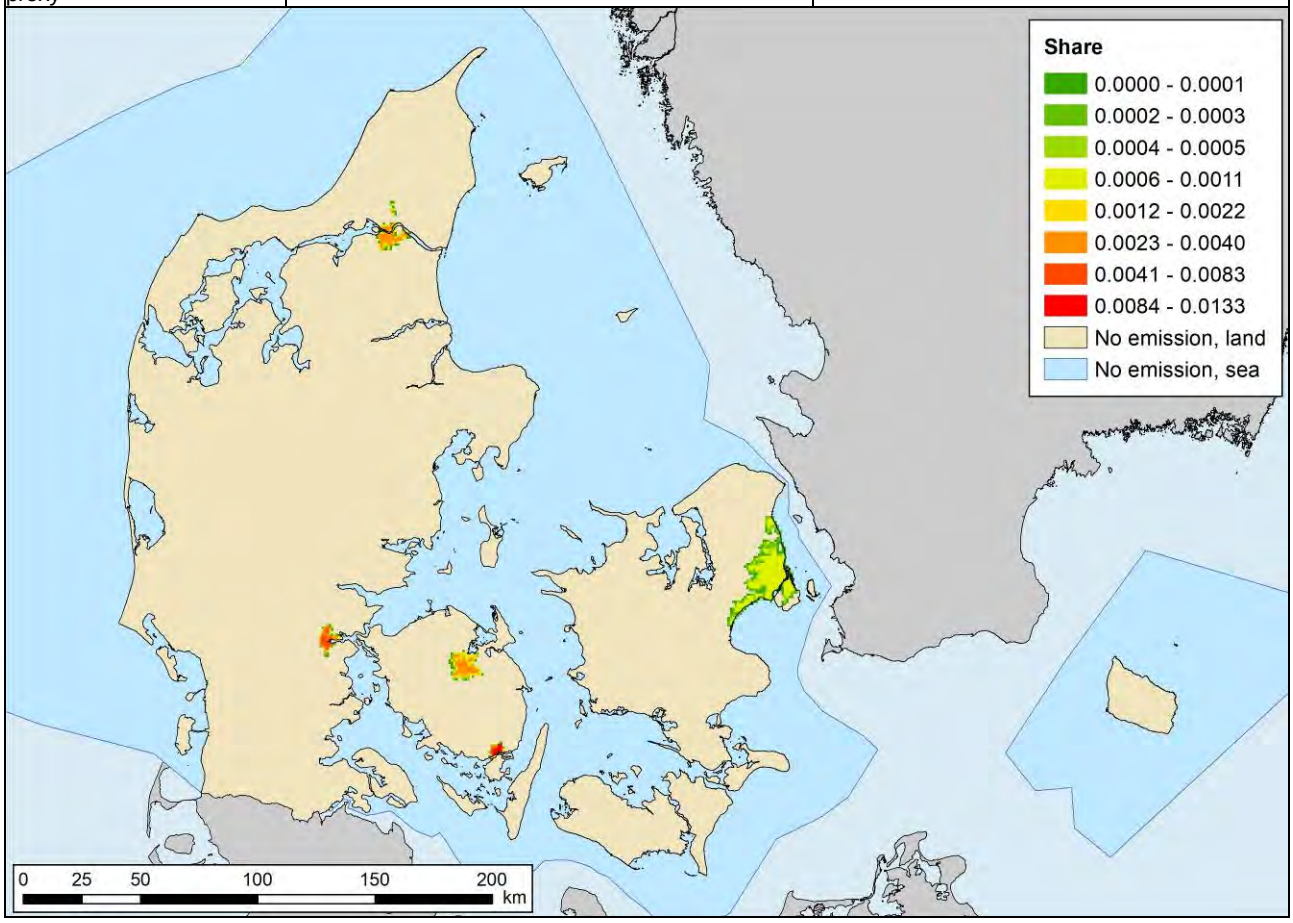
Town gas distribution

Town gas is used in a limited number of urban areas in Denmark. Few companies have been closed down since 1990 and following, town gas distribution has stopped in these areas. Detailed data for the town gas distribution network and consumers are not available for all areas with town gas, and therefore the emissions are allocated to the urban areas in municipalities with town gas.

The spatial dataset used for the GeoKey is considered to have a low uncertainty as administrative borders are well defined. The spatial applicability is considered poor, as it does not reflect the location of the distribution network within the municipalities.

Table 5.92 GeoKey for town gas distribution.

Source data	Kort10 version 2011 Urban zones			
Data provider	The Danish Agency for Data Supply and Effeciency			
Projection	EUREF89 UTM zone 32N ED50 UTM zone 32N			
Data description	Municipalities and urban zones are used. The annual reports include data on production and distribution loss. Estimation of the part of the gas loss that owe to fugitive emissions (fugitive gas loss) are based on detailed information from "Aalborg Forsyning".			
Workflow	The GeoKey is calculated as the annual share of the total fugitive gas loss evenly distributed on urban areas in municipalities with town gas.			
GeoKey name	_Key_050604_TownGas			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	B			
Applicability as spatial proxy	050604 Town gas distribution	4		



5.4.4 Venting and flaring

Fugitive emissions from venting and flaring include emissions from venting in gas storage and treatment facilities (covered as LPS, see Chapter 5.2.1), flaring in offshore oil and gas production, flaring in refineries (covered as LPS), flaring in gas storage (covered as LPS) and flaring in gas transmission and distribution.

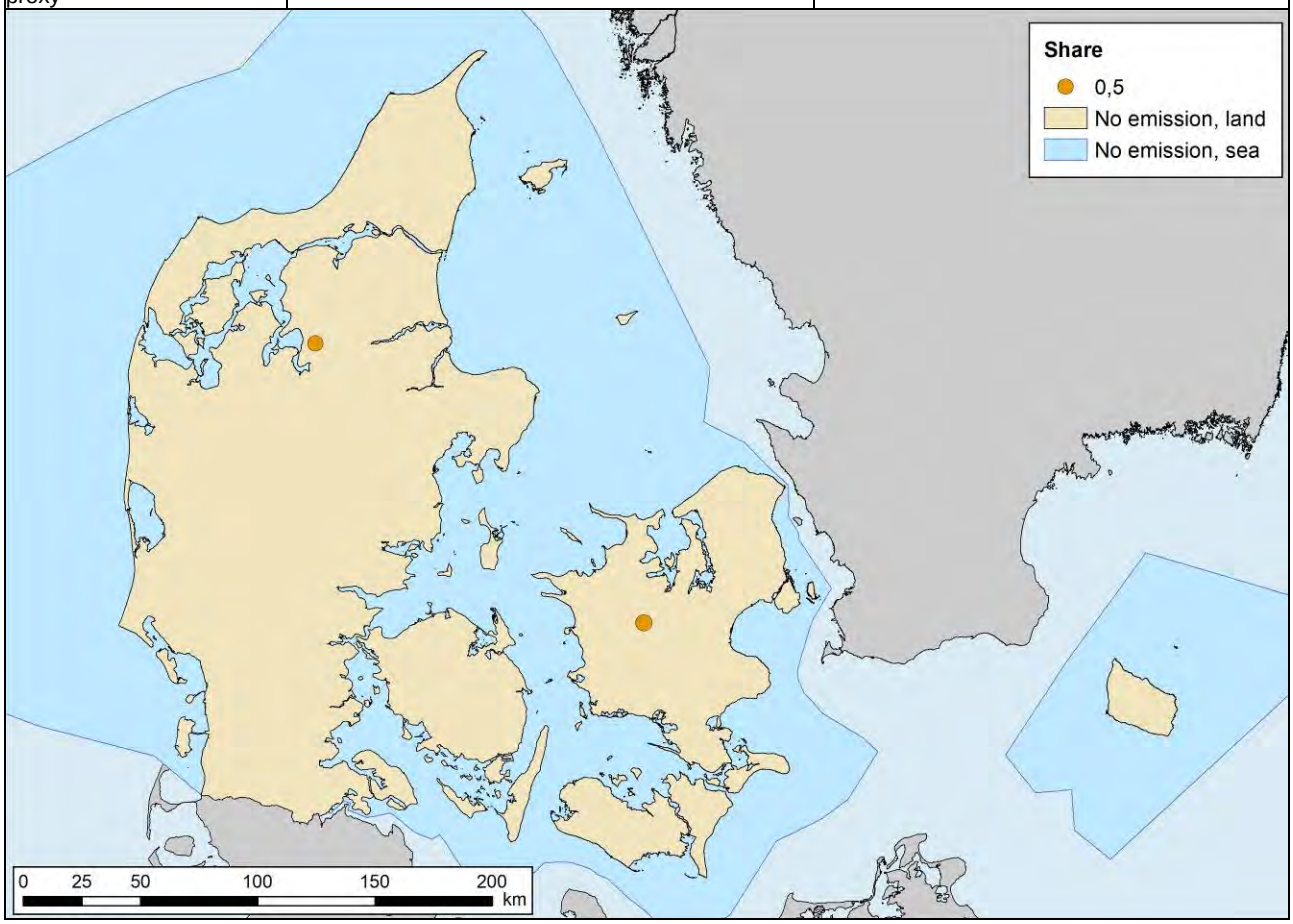
Venting in gas storage

Venting in gas storage is covered by LPS from 1994 onwards. For 1990, it is assumed the emissions from venting are distributed equally between the two gas storage facilities.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty, as it include the location of all (two) gas storage facilities. The spatial applicability is considered fair, as activity data are not available but the distribution for the two facilities are around 50 / 50 for the years 1994-1997 (58 / 42, 44 / 56, 63 / 37, 55 / 45, respectively).

Table 5.93 GeoKey for venting in gas storage.

Source data	LPS location data			
Data provider	Inventory data			
Projection	ETRS89 UTM zone 32N			
Data description	Location of the two Danish gas storage facilities			
Workflow	The GeoKey is prepared for the years prior to 1994 when emissions from venting was treated as an area source in the inventory system. Emissions are allocated evenly to the two facilities.			
GeoKey name	_Key_050699_Venting			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC		
Quality of spatial dataset	A			
Applicability as spatial proxy	050699 Venting in gas storage		3	



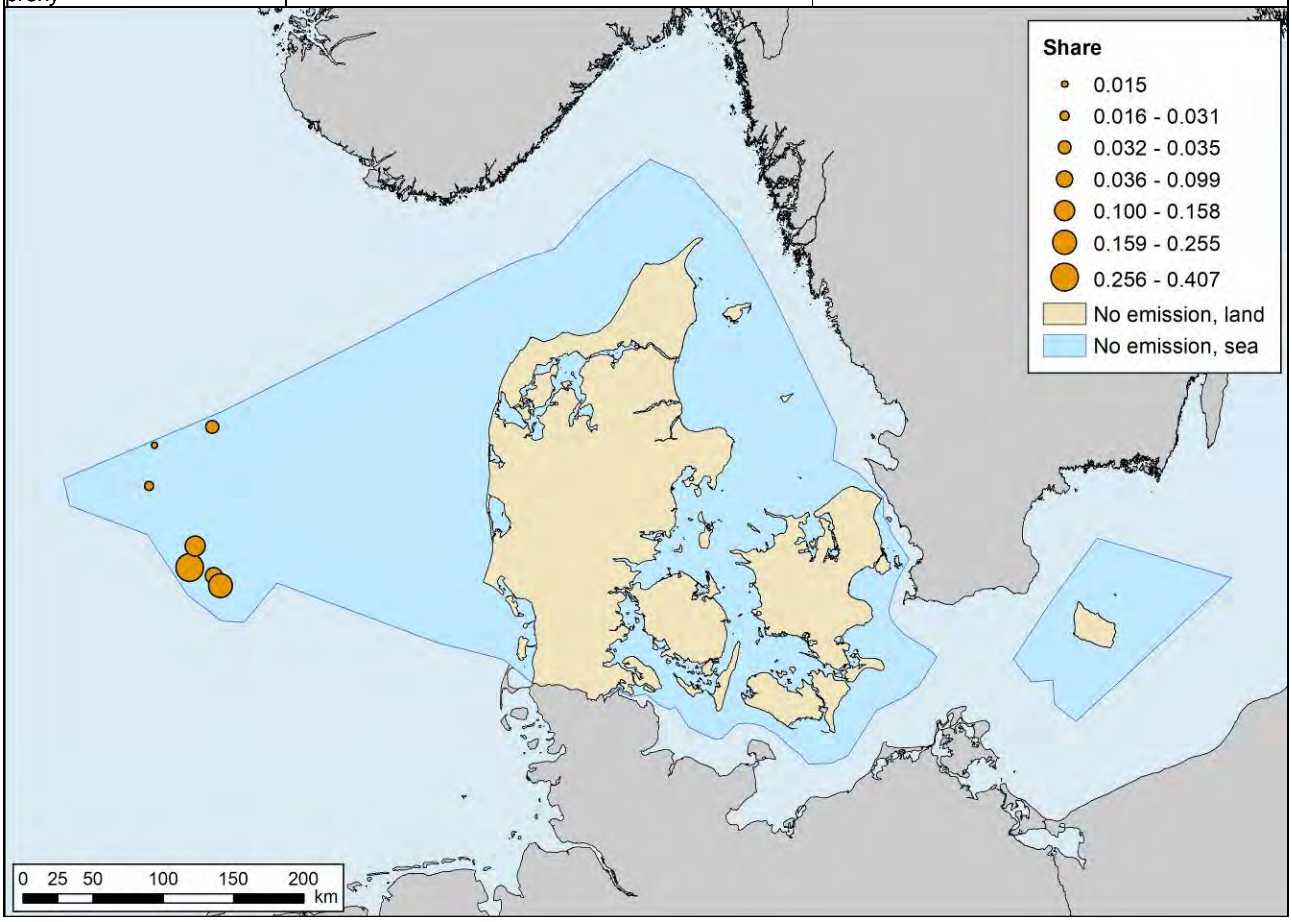
Flaring in gas and oil extraction

Flaring in oil and gas extraction emits most pollutants covered by the SPREAD model. However, the contribution to the national total emissions is very limited for all pollutants. For all years and all pollutants, the contribution to the national total is less than 1 %.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty, since the actual location of the platforms with flaring is known. The spatial applicability is considered good, as the flaring rates are known for each platform.

Table 5.94 GeoKey for flaring in gas and oil extraction.

Source data	Yearly data on oil and gas production in Denmark			
Data provider	The Danish Energy Agency			
Projection	ED1950 UTM zone 32N			
Data description	Oil and gas production statistics for the years 1972 onwards. Data is available by offshore facility. The data set include data for oil production, gas production, fuel consumption and flaring rates.			
Workflow	The annual share of the total flaring is calculated by offshore facility and by year.			
GeoKey name	_Key_090206_FlaringOffshore			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	090206 Flaring in gas and oil extraction (offshore)	2		



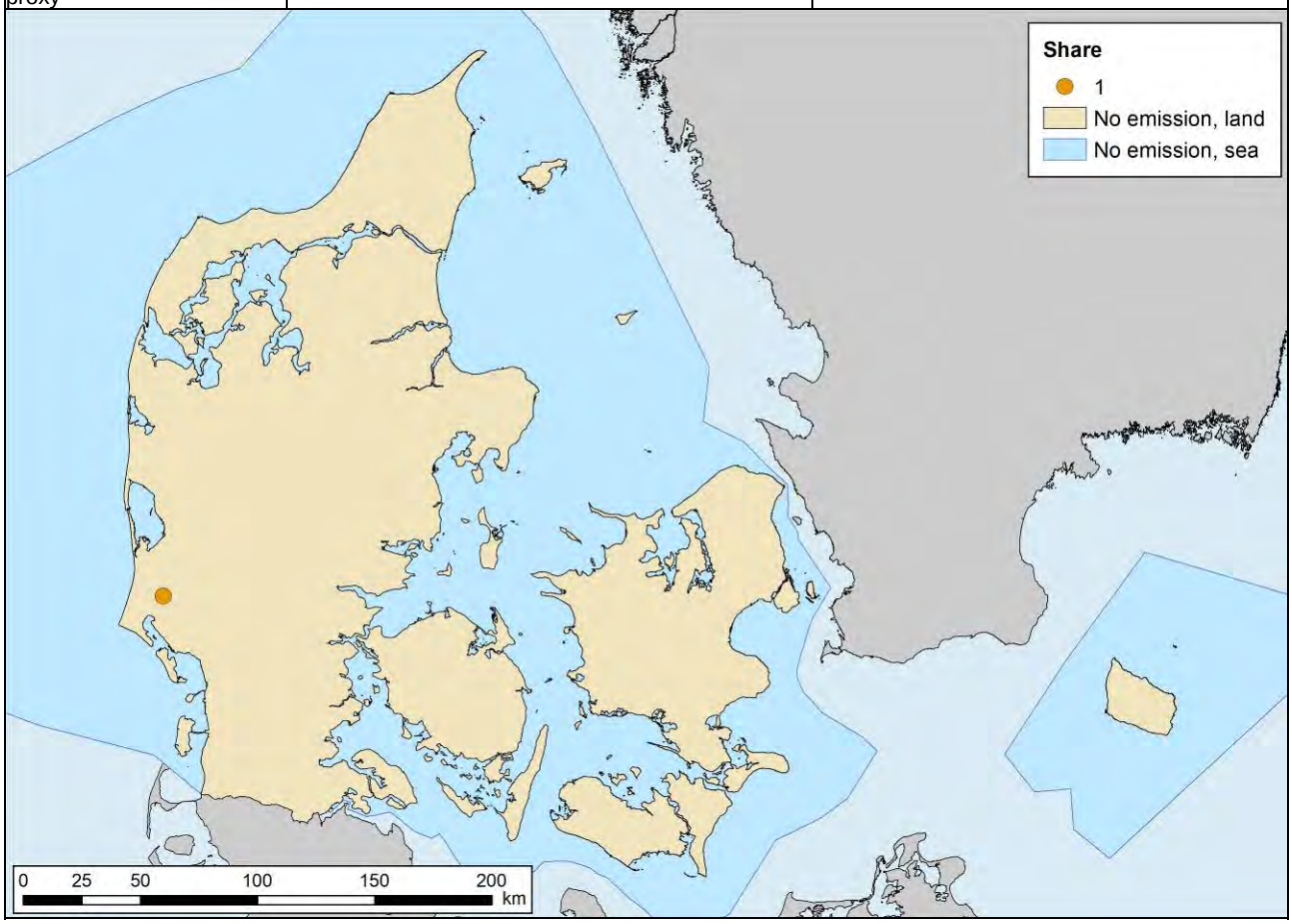
Flaring in gas treatment and storage

Flaring in gas treatment and storage is covered by LPS from 1994 onwards. In 1990, flaring only occurred at the single Danish natural gas treatment plant.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty and the spatial applicability is considered very good as emissions occur at a single location.

Table 5.95 GeoKey for flaring in gas treatment and storage.

Source data	LPS location data			
Data provider	Inventory data			
Projection	ETRS89 UTM zone 32N			
Data description	Location of the Danish gas treatment plant			
Workflow	Emissions from flaring in gas treatment and stoarage is allocated to the location of the single Danish natural gas treatment plant			
GeoKey name	_Key_090298_Flaring_GasStorage			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, BC, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F, BbF, BkF, BaP, IcdP		
Quality of spatial dataset	A			
Applicability as spatial proxy	090298 Flaring in gas treatment and storage		1	



Flaring in gas transmission and distribution

There is no information available on the precise location of the flaring in the transmission and distribution of natural gas. These emissions typically occur in connection with maintenance work. The emissions have been distributed, using the same GeoKey as for natural gas transmission (Table 5.91).

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it include exact location of each M/R station. The spatial applicability is considered very poor, as location of leaks are unknown and vary from year to year.

5.5 Industrial processes and product use (IPPU)

Industrial processes cover a wide range of processes from a limited amount of facilities such as production of bricks and tiles to more diffuse processes, such as emissions from baking of bread or construction and demolition.

The IPPU sector covers both LPS, point sources and area sources. Emissions from LPS are allocated to the individual plants. Emissions from point sources are based on the annual database from the Danish Energy Agency (Chapter 5.2.2) and emissions are allocacted to the location of the plants. Due to the emission calculation methodology in the national emission inventory system, it is not possible to estimate the area source emissions on snap 3 level, but it is nesecary to aggregate the emissions to snap 2 level before subtracting the LPS emissions and the point source emissions from the national total emissions. Consequently, GeoKeys can only be applied for all sources in a given snap 2 level category.

For some industrial sectors, the distribution keys are based on activity data or emissions data. This is the case for Wine industry, Treatment of slaughterhouse waste, Production of bricks and tile, and Production of expanded clay products (Chapter 5.5.6).

For other industrial sectors, the distribution keys are based on employment statistics. This is the case for Chemical industry, Metal industry, and Food, drinks and tobacco industry (Chapter 5.5.2, 5.5.3 and 5.5.6).

For the remaining activities under this sector, different general GeoKeys are used, mainly the GeoKey for Industrial area, but also Population, One-storey building, Building, and Road network (Chapter 5.1).

Table 5.96 shows the share of emissions from IPPU of the national total emissions for the pollutants covered by the SPREAD model. It can be seen that the share for many pollutants change during the years. This is due to the closure of some industries in Denmark, e.g. the electro steelworks in Frederiksværk, but also due to flue gas abatement installed in some industrial branches. For some pollutants, the shares change because of increasing or decreasing emissions from other sectors.

In 2019, the IPPU sector accounts for more than 10 % of the national emissions for NMVOC, SO_2, Pb, As, Cr and PCBs. For NMVOC, the major source is solvent use, in both industry and households, but a significant contribution also comes from the food and drink industry. For SO_2, the major source is production of bricks, tiles and expanded clay products. As the raw material (clay) in

some cases contain sulphur, this is released as SO_2 during the production process. Emissions of As, Cr and PCBs mainly originates from metal production and more specifically from steel production and emissions of Pb mainly come from lead production. Another contribution comes from product use, more specifically from the use of fireworks.

Table 5.96 Share of emissions from industrial processes and product use of the national total.

Share	1990	2005	2019
> 10 %	NMVOC, PM_{10}, Zn, PCDD/F, HCB, PCBs	NMVOC, SO_2, PM_{10}, TSP, Pb, As, Cr, HCB, PCBs	NMVOC, SO_2, Pb, As, Cr, PCBs
5-10 %	TSP, Pb, $PM_{2.5}$, Cd, Hg, As, Se	Se, Cd, Zn, PCDD/F	$PM_{2.5}$, PM_{10}, TSP, Cu, Ni, Se
1-5 %	SO_2, CO, Cr, Cu, Ni, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene	$PM_{2.5}$, CO, Hg, Cu, Ni, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene	CO, Cd, Hg, Zn, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene
< 1 %	NO_x, NH_3, BC	NO_x, NH_3, BC , HCB	NO_x, NH_3, BC , PCDD/F, HCB

An overview of the different activities within the IPPU sector is provided together with the GeoKey for the individual activities in Table 5.97.

Table 5.97 Activities within mineral industries and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Cast iron production	030303	_Industry
Secondary lead production	030307	_Industry
Secondary aluminium production	030310	_Industry
Lime production	030312	_Key_Industry
Iron and steel	030400	_Key_Metal
Chemical and petrochemical industry	030600	_Key_ChemicalIndustry
Food and Tobacco	030900	_Key_Food_Drinks_Tobacco
Manufacturing plants - Paper, pulp and print	0311	_Key_Wood_Paper_Print
Manufacturing plants - Wood and wood products	0314	_Key_Wood_Paper_Print
Allied metal manufacturing	040306	_Key_Metal
Bread production	040605	_Key_Food_Drinks_Tobacco
Wine production	040606	_Key_Wine
Beer production	040607	_Key_Food_Drinks_Tobacco
Spirits production	040608	_Key_Food_Drinks_Tobacco
Asphalt roofing	040610	_Key_Building
Road paving with asphalt	040611	_Key_RoadNetwork
Quarrying and mining of minerals other than coal	040616	_Key_Quarrying
Treatment of slaughterhouse waste	040617	_Key_040617_SlaughterhouseWaste
Wood manufacturing	040620	_Key_Wood_Paper_Print
Sugar production	040625	LPS
Flour production	040626	_Key_Food_Drinks_Tobacco
Meat curing	040627	_Key_Food_Drinks_Tobacco
Construction of house	040631	_Key_Building_OneStorey
Construction of apartment buildings	040632	_Key_Building_Appartment
Construction of non-residential buildings	040633	_Key_Industry
Construction of road	040634	_Key_RoadNetwork
Storage, handling and transport of mineral products	040690	_Key_Industry
Production of bricks and tiles	040691	_Key_040691_Brickworks
Production of expanded clay products	040692	_Key_040692_ExpandedClayProducts
Margarine and solid cooking fat production	040698	_Key_Food_Drinks_Tobacco
Coffee roasting	040699	_Key_Food_Drinks_Tobacco
Paint application	060100	_Key_Population
Dry cleaning	060202	_Key_Building
Chemical products	060300	_Key_ChemicalIndustry
Domestic solvent use	060400	_Key_Population
Other use of solvents and related activities – printing industry	060403	_Key_Wood_Paper_Print
Use of fireworks	060601	_Key_Population
Use of tobacco (smoking)	060602	_Key_Population
Use of shoes	060603	_Key_Population
Use of charcoal (barbequing)	060605	_Key_Building_OneStorey
Paraffin wax use (candles)	060606	_Key_Population

The subsectors within IPPU is described in more detail in the following chapters.

5.5.1 Mineral industry

Mineral industry covers many different activities, e.g. production of cement, bricks and tiles. Emissions from cement production in Denmark is solely estimated by LPS data from the one cement plant in Denmark and hence described in Chapter 5.2.1. The list of activities and corresponding GeoKeys are shown in Table 5.98.

Table 5.98 Activities within mineral industries and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Lime production	030312	_Key_Industry
Quarrying and mining of minerals other than coal	040616	_Key_Quarrying
Construction of house	040631	_Key_Building_OneStorey
Construction of apartment buildings	040632	_Key_Building_Appartment
Construction of non-residential buildings	040633	_Key_Industry
Construction of road	040634	_Key_RoadNetwork
Storage, handling and transport of mineral products	040690	_Key_Industry
Production of bricks and tiles	040691	_Key_040691_Brickworks
Production of expanded clay products	040692	_Key_040692_ExpandedClayProducts

For production of lime (non-LPS) the default GeoKey for industry is used. This general GeoKey is described in Chapter 5.1.2. The GeoKey for buildings used for emissions from construction and demolition is described in Chapter 5.1.3. Emissions from mining and quarrying are distributed using the GeoKey _Key_Quarrying, described in Chapter 5.2.8. The GeoKey for bricks and tiles, and expanded clay products are described in the following chapter.

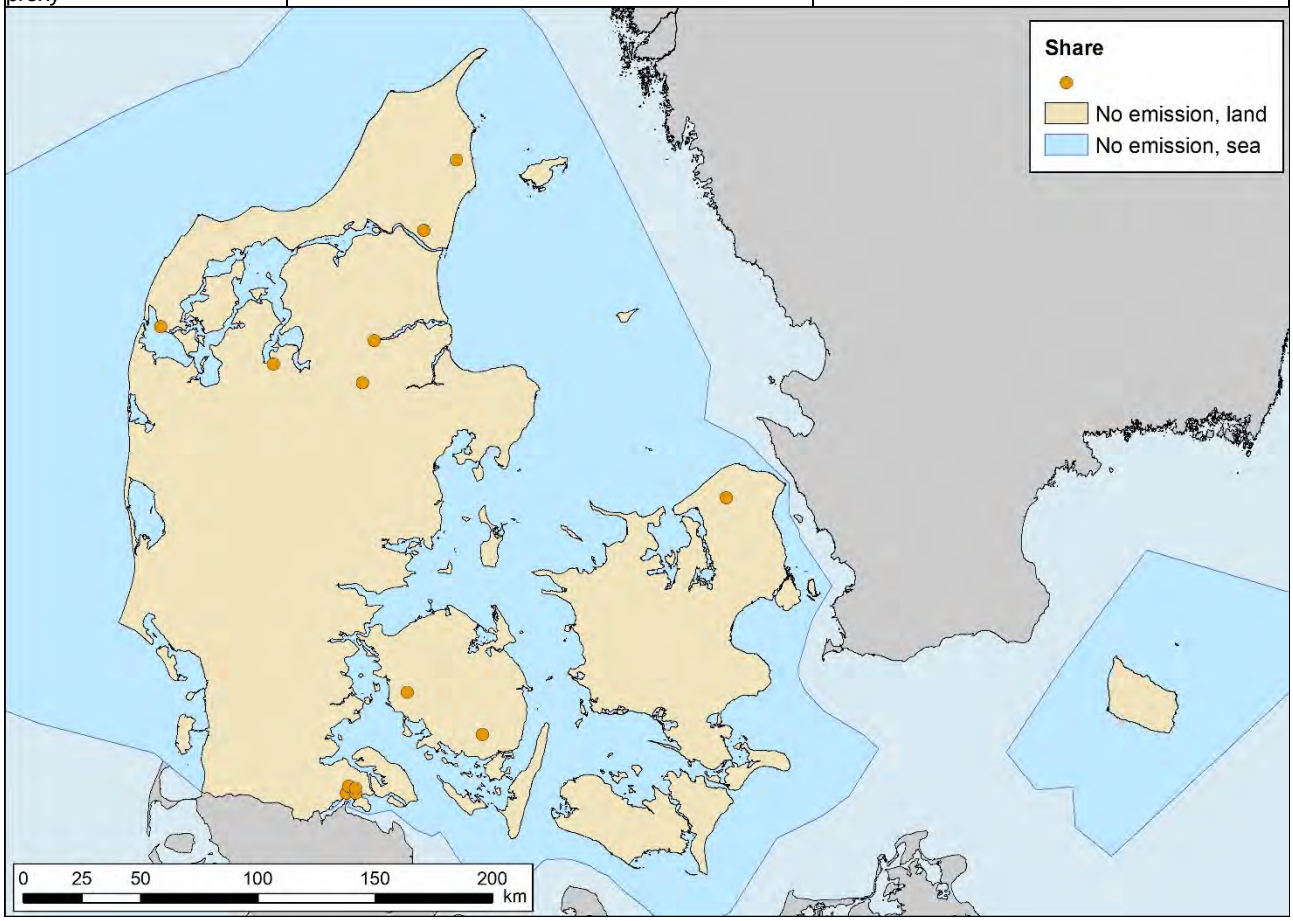
Bricks and tiles

The distribution of emissions from brickworks industry is based on activity data for the plants, which are available in the EU Emission Trading Scheme (EU ETS) reportings. Activity data are collected to the extend that the data are available both regarding coverage of plants and years. Data are mainly available for the largest plants and in the later part of the time series.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it is based on EU-ETS data. The spatial applicability is considered fair, as the data set is not full coverage neither regarding number of plants nor all years in the SPREAD model.

Table 5.99 GeoKey for production of bricks and tiles.

Source data	EU Emission Trading Scheme (EU ETS)			
Data provider	The Danish Energy Agency.			
Projection	ETRS89 UTM zone 32N			
Data description	Activity data for the largest brickworks plants			
Workflow	The annual activity data is intersected with the 1 km x 1 km Danish grid net and the share of the total annual activity data is calculated by grid cell			
GeoKey name	_Key_040691_Brickworks			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		SO_2	SO_2
	< 1 %	SO_2, PCDD/F	PCDD/F	PCDD/F
Quality of spatial dataset	A			
Applicability as spatial proxy	040691 Production of yellow bricks		3	



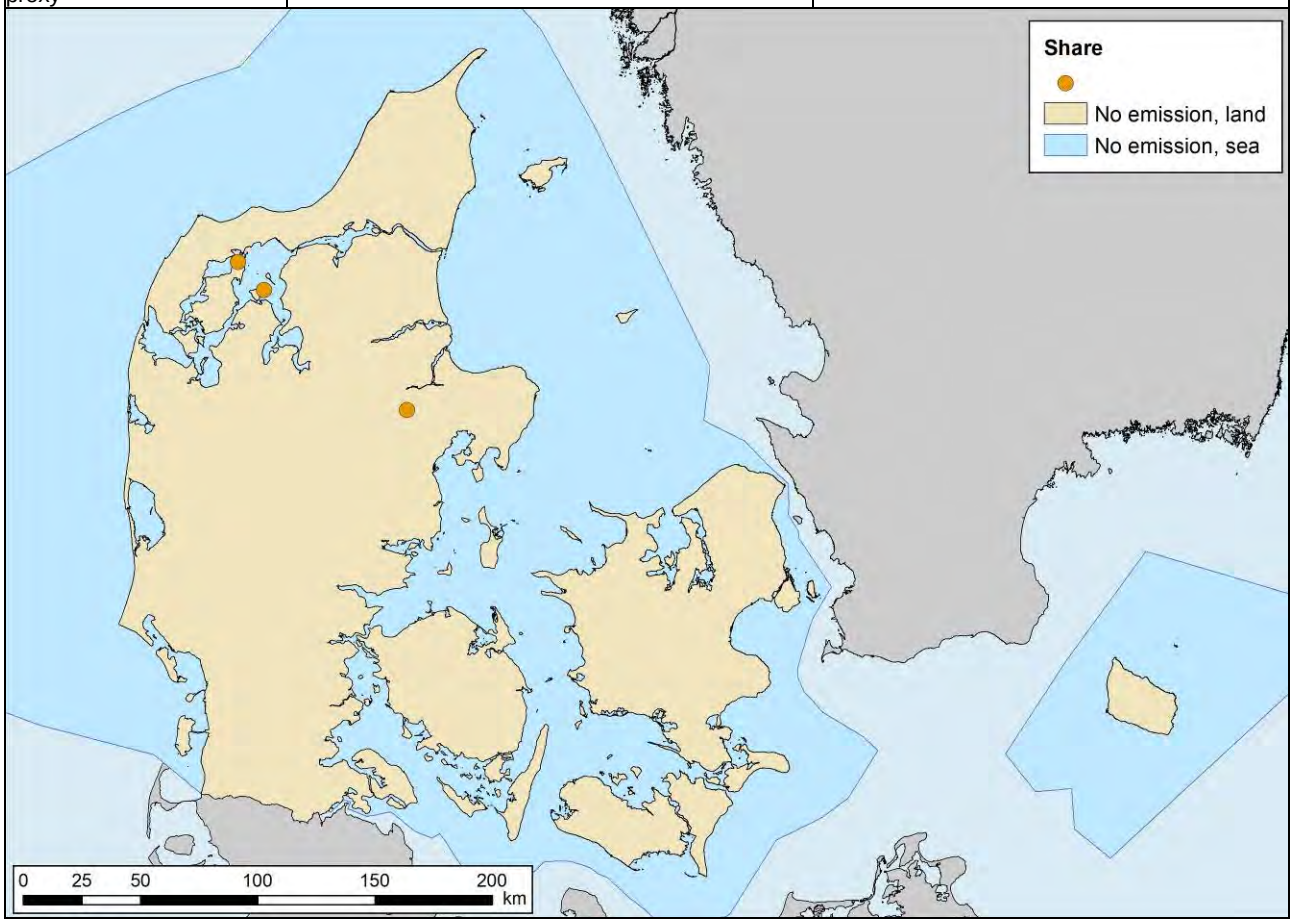
Expanded clay products

The distribution of emissions from expanded clay products is based on SO_2 emission data and EU ETS data for the plants to the extent that the data are available both regarding coverage of plants and years. Data are mainly available for the largest plants and in the later part of the time series.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it is based on plant specific data. The spatial applicability is considered fair, as the data set is not full coverage neither regarding number of plants nor all years in the SPREAD model.

Table 5.100 GeoKey for expanded clay products.

Source data	Plant specific activity data Location of plants (address) EU ETS data			
Data provider	Individual plants and the Danish Energy Agency			
Projection	ETRS89 UTM zone 32N			
Data description	Activity data for the largest brickworks plants			
Workflow	The annual activity data is intersected with the 1 km x 1 km Danish grid net and the share of the total total annual activity data is calculated by grid cell			
GeoKey name	_Key_040692_ExpandedClayProducts			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %		SO_2	
	1-5 %	SO_2		
	< 1 %	PCDD/F	PCDD/F	SO_2, PCDD/F
Quality of spatial dataset	A			
Applicability as spatial proxy	040692 Expanded clay products		3	



5.5.2 Chemical industry

Chemical industry in Denmark is very limited and is mainly covered by LPS. Emissions are from a relatively small number of plants involved in the production of catalysts, pesticides, chemical ingredients, tar products and previously, until 2004, nitric and sulphuric acid. The list of activities and corresponding GeoKeys are shown in Table 5.101

Table 5.101 Activities within chemical industries and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Chemical and Petrochemical Industry	0306	Key_ChemicalIndustry
Chemical products manufacturing or processing	0603	Key_ChemicalIndustry

Emissions from chemical industry are distributed using the GeoKey for chemical industry based on employment statistics. The GeoKey is described in Chapter 5.2.8.

5.5.3 Metal industry

As mentioned previously, there was an electro steelwork operating in Denmark, but this closed permanently in 2005. This is included in the inventory as an LPS. Other sources of emissions from metal production not covered by LPS are shown in Table 5.102 together with the corresponding GeoKey.

Table 5.102 Activities within metal industries and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Cast iron production	030303	_Industry
Secondary lead production	030307	_Industry
Secondary aluminium production	030310	_Industry
Iron and steel	0304	_Key_Metal
Allied metal manufacturing	040306	_Key_Metal

Emissions from metal industry are distributed using the GeoKey for metal industry based on employment statistics. The GeoKey is described in Chapter 5.2.8.

5.5.4 Non-energy products from fuels and product use

This sector covers some specific product uses related to the non-energy use of fuels. The different activities covered by this sector and the corresponding GeoKey are shown in Table 5.103.

Table 5.103 Activities related to product use from non-energy use of fuels and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Paint application	0601	_Key_Population
Dry cleaning	060202	_Key_Building
Chemical products	0603	_Key_ChemicalIndustry
Domestic solvent use	0604	_Key_Population
Paraffin wax use (candles)	060606	_Key_Population
Asphalt roofing	040610	_Key_Building
Road paving with asphalt	040611	_Key_RoadNetwork

The use of population density as a spatial proxy is often not very accurate. However, in the cases of some product uses, e.g. candles, it is probably the most reliable spatial proxy. The population GeoKey is described in Chapter 5.1.1.

For use of solvents in chemical products and asphalt roofing, the default GeoKey for industry is used. This general GeoKey is described in Chapter 5.1.2 and is therefore not repeated here. The GeoKey for buildings are used for emissions from dry cleaning, this GeoKey is described in Chapter 5.1.3. The GeoKey for use of solvents in road paving with asphalt is based on the road network.

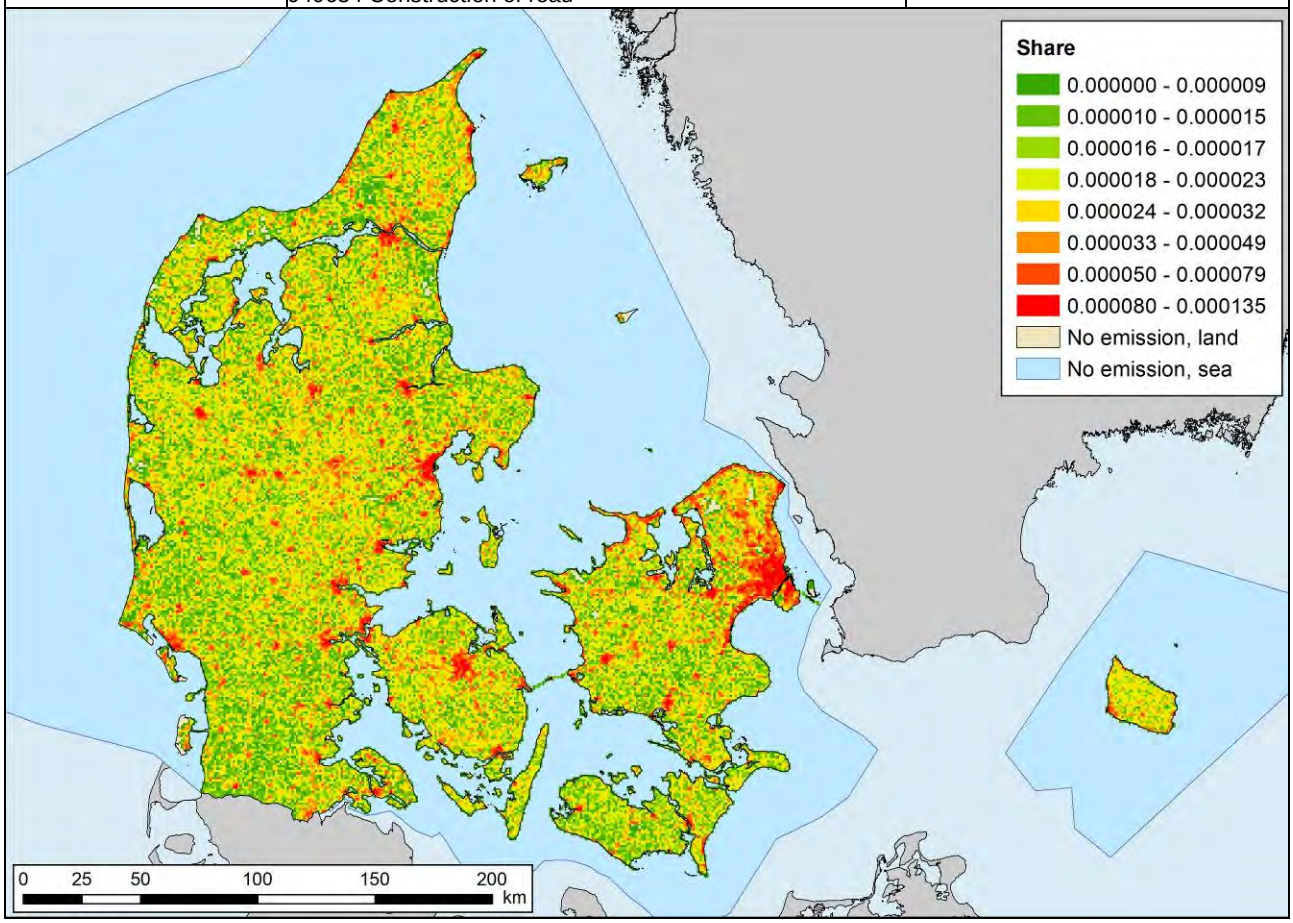
The GeoKey for the road network is based on the GIS based National Road and Traffic Database 1960-2020. Mileage data are available for every fifth year

and only roads with mileage data are included in the GeoKey for the respective year. The GeoKey is applied for the remaining years included in SPREAD using the same approach as for road transport (Table 5.56).

The spatial dataset used for the GeoKey is considered to have low uncertainty as the road and traffic database is based on a large number of traffic data collected from various sources. The highway network has been updated in 2019 (Jensen et al., 2019). The GeoKey is based road lengt for road segments with traffic (mileage larger than zero), and data for the closest year is applied for years in between. The spatial applicability is considered poor as road paving occur only on parts of the road network and outside the present roads for construction of new roads. Further, no activity data or time variations are included in the GeoKey.

Table 5.104 GeoKey for road paving with asphalt.

Source data	The GeoKey is based on mileage data the GIS based National Road and Traffic Database 1960-2020			
Data provider	Aarhus University			
Projection	ETRF 1989 UTM Zone 32N			
Data description	The database includes annual averge daily traffic (AADT) according to the Danish national GIS based road network and traffic database for 1960-2020. AADT is based on statistics from the Danish Road Directorate for national mileage for Danish vehicles.			
Workflow	The GeoKey is calculated as the share of the total road length with mileage data (AADT>0) for the individual years by the 1 km x 1 km grid cell. Data are available for every fifth year.			
GeoKey name	_Key_RoadNetwork			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	TSP, PM_{10}	TSP, PM_{10}	TSP, PM_{10}
	< 1 %	NMVOC, CO, $PM_{2.5}$, BC	NMVOC, CO, $PM_{2.5}$, BC	NMVOC, CO, $PM_{2.5}$, BC
Quality of spatial dataset	B			
Applicability as spatial proxy	040611 Road paving with asphalt			4
	040634 Construction of road			4



5.5.5 Other product manufacture and use

In the Danish inventory, this category covers a number of product uses, such as use of fireworks and tobacco. The different activities covered by this sector nd the corresponding GeoKey are shown in Table 5.105.

Table 5.105 Activities related to product use and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Use of fireworks	060601	_Key_Population
Use of tobacco (smoking)	060602	_Key_Population
Use of shoes	060603	_Key_Population
Use of charcoal (barbequing)	060605	_Key_Building_OneStorey

The population GeoKey is described in Chapter 5.1.1 and the GeoKey for one-storey settlement in Chapter 5.1.4.

5.5.6 Other industrial processes

This category mainly consists of activities within the food and drinks industry and the emissions are mainly related to NMVOC. The different activities covered by this sector and the corresponding GeoKey are shown in Table 5.106.

Table 5.106 Activities related to other industrial processes and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Bread production	040605	_Key_Food_Drinks_Tobacco
Wine production	040606	_Key_Wine
Beer production	040607	_Key_Food_Drinks_Tobacco
Spirits production	040608	_Key_Food_Drinks_Tobacco
Quarrying and mining of minerals other than coal	040616	_Key_Quarrying
Treatment of slaughterhouse waste	040617	_Key_040617_SlaughterhouseWaste
Wood manufacturing	040620	_Key_Wood_Paper_Print
Flour production	040626	_Key_Food_Drinks_Tobacco
Meat curing	040627	_Key_Food_Drinks_Tobacco
Margarine and solid cooking fat production	040698	_Key_Food_Drinks_Tobacco
Coffee roasting	040699	_Key_Food_Drinks_Tobacco

Sugar production occurs at very few facilities and these are handled as LPS in SPREAD. The remaining activities covered by this sector are distributed using the GeoKeys _Key_Food_Drinks_Tobacco, _Key_Quarrying, _Key_Wine, _Key_040617_SlaughterhouseWaste. The first two are described in Chapter 5.2.8 and the reaining two are described separately in the following.

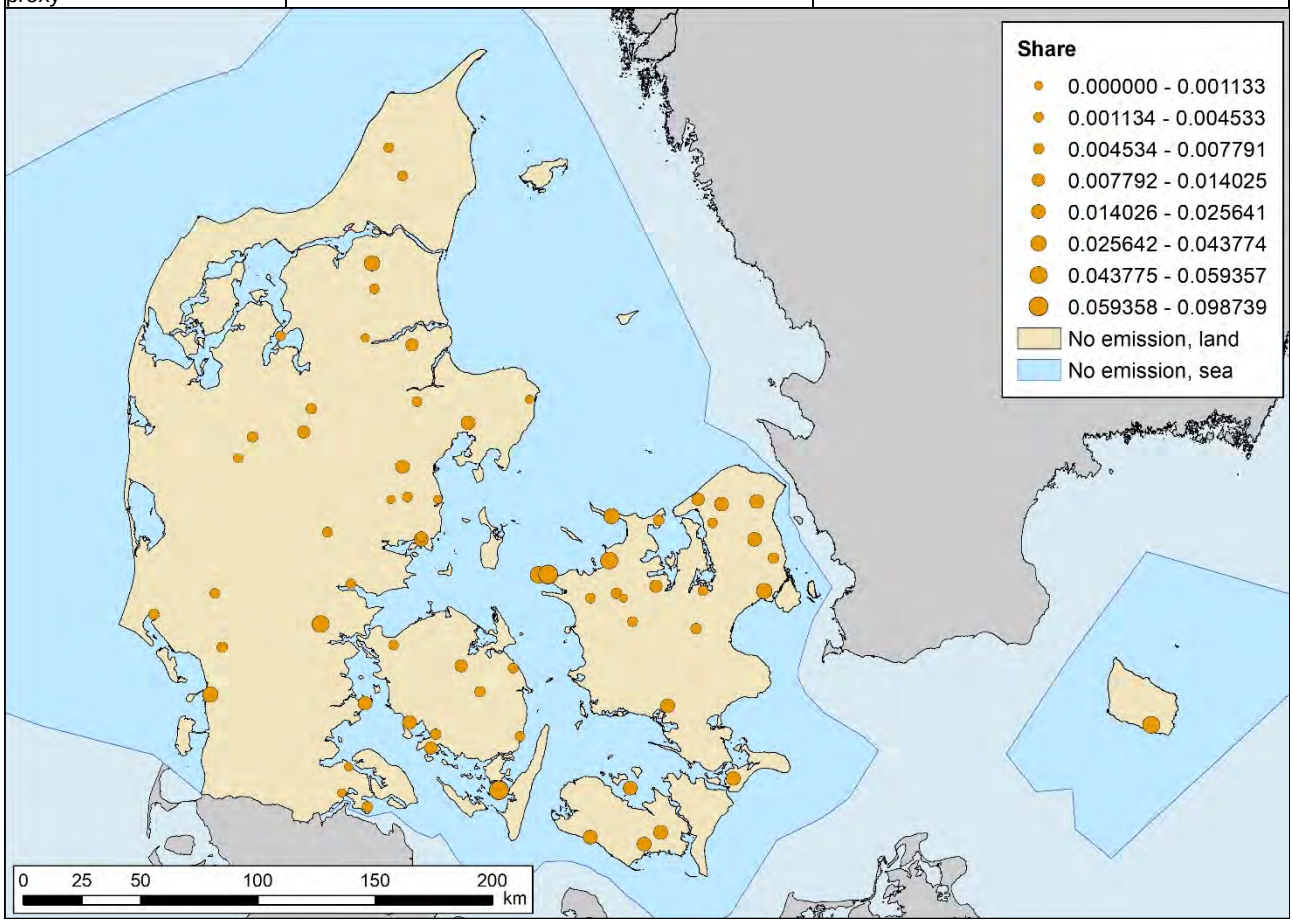
Wine industry

The distribution of emissions from wine industry is based on data on wine fields from the field parcel maps and the General Agricultural Register (GLR). The field parcel map include agricultural fields as polygons and the GLR holds information on crop types for the fields.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on field level data. The spatial applicability is considered poor as the wine production is assumed mainly to take place in the proximity of the wine fields and emissions are assumed to some degree proportional with the field area.

Table 5.107 GeoKey for wine industry.

Source data	Ministry of Environment and Food			
Data provider	ETRS89 UTM zone 32N			
Projection	See Chapter 5.6.2			
Data description	See Chapter 5.6.2			
Workflow	The wine field area is intersected with the 1 km x 1 km Danish grid net and the share of the total wine field area is calculated by grid cell.			
GeoKey name	_Key_Wine			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	040606 Wine production		4	



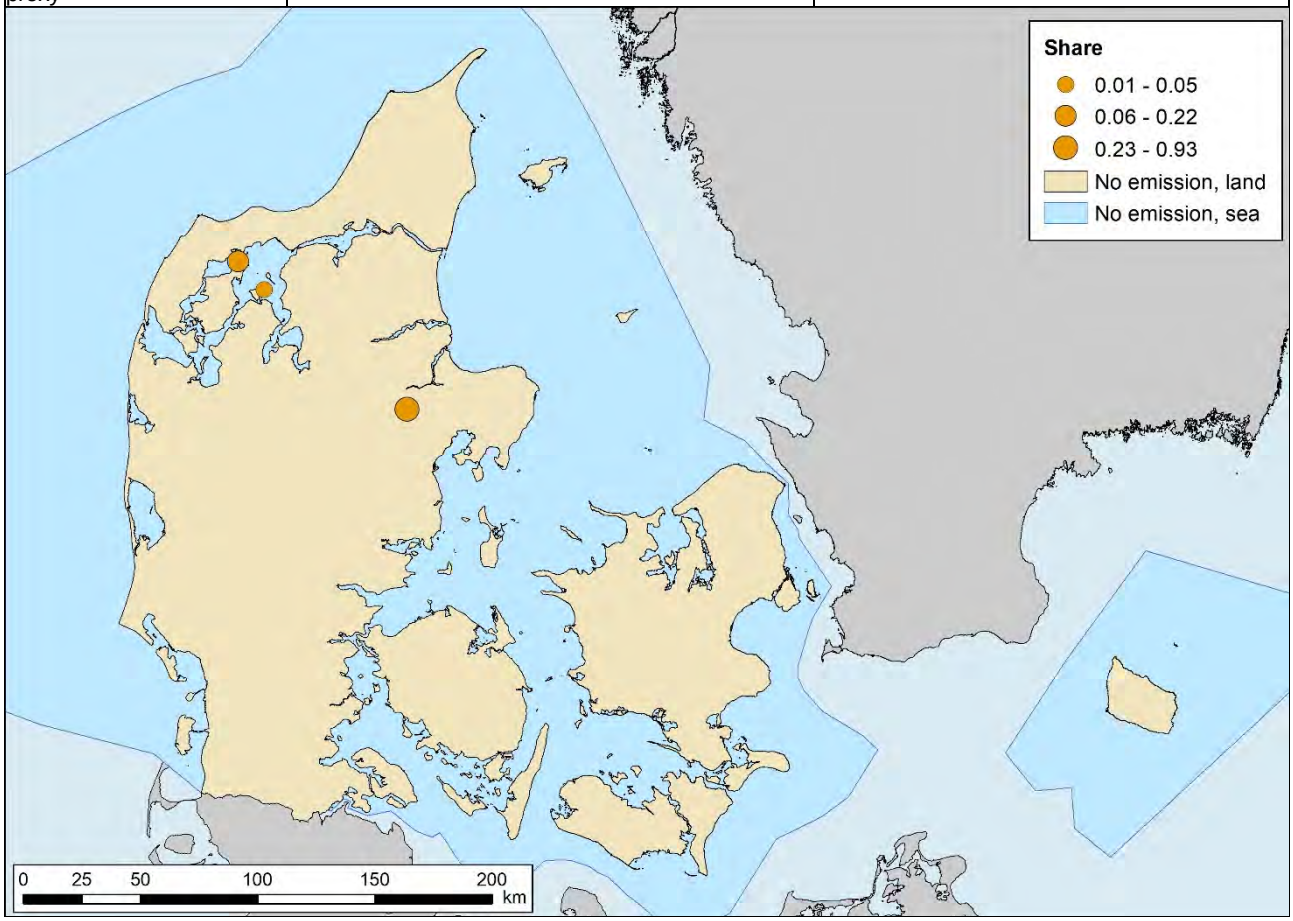
Treatment of slaughterhouse waste

The distribution of emissions from treatment of slaughterhouse waste is based on activity data for the plants to the extent that the data are available both regarding coverage of plants and years. Data are mainly available for the later part of the time series.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it is based on plant specific data. The spatial applicability is considered good, as the data set does not have detailed plant-specific data for all years in the SPREAD model.

Table 5.108 GeoKey for treatment of slaughterhouse waste.

Source data	Plant specific activity data			
Data provider	Individual plants			
Projection				
Data description	Activity data for the largest slaughterhouse waste treatment plants			
Workflow	The annual activity data is intersected with the 1 km x 1 km Danish grid net and the share of the total annual activity data is calculated by grid cell			
GeoKey name	_Key_040617_SlaughterhouseWaste			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	040617 Treatment of slaughterhouse waste		2	



5.6 Agriculture

Agriculture covers emissions from animal husbandry and manure management as well as emissions from agricultural soils, e.g. emissions from fertiliser applied to soils, growing crops, and emissions from agricultural field operations. Agriculture is the dominant source of NH_3 emissions and contribute significantly to the emissions of NMVOC, NO_x and PM.

Table 5.109 shows the share of emissions from agriculture of the national total emissions for the pollutants covered by the SPREAD model. It can be seen that the share for most pollutants have remained below 1 % of the national total throughout the time series. Many of these pollutants are only associated with field burning of agricultural residues and have minor contributions to the national total.

Emissions of NO_x, NMVOC, NH_3, PM and HCB are contributing most to the national total. For NH_3, the main sources are manure management and application as well as field application of other fertiliser and emissions from growing crops. NO_x emissions are mainly associated with application of manure and mineral fertiliser. NMVOC emissions stem mainly from animal husbandry and manure management. Most of the PM emissions originate from the farm level field operations, e.g. from ploughing and harvesting. HCB emissions are associated with the use of pesticides, of which some contains impurities of HCB.

Combustion related emissions from tractors, harvesters and other agricultural machinery are included under mobile combustion (Chapter 5.3.8).

Table 5.109 Share of emissions from agriculture of the national total.

Share	1990	2005	2019
> 10 %	NMVOC, NH_3, TSP, PM_{10}, HCB	NMVOC, NH_3, TSP, PM_{10},	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP, HCB
5-10 %	NO_x, $PM_{2.5}$	NO_x, $PM_{2.5}$, Cd	Cd
1-5 %	Cd, BbF	Hg, BbF, BkF, IcdP, HCB	BC, CO, Hg, BaP, BbF, BkF, IcdP
< 1 %	SO_2, BC, CO, Pb, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, BaP, BkF, IcdP, PCBs	SO_2, BC, CO, Pb, As, Cr, Cu, Ni, Se, Zn, PCDD/F, BaP, PCBs	SO_2, Pb, As, Cr, Cu, Ni, Se, Zn, PCDD/F, PCBs

An overview of the different activities within agriculture is provided together with the GeoKey for the individual activities in Table 5.110.

Table 5.110 Activities within agriculture and corresponding GeoKeys.

Activity	NFR category	GeoKey
Dairy cattle	3B1a	_Key_3B1a_DairyCattle
Non-dairy cattle	3B1b	_Key_3B1b_NonDairyCattle
Sheep	3B2	_Key_3B2_Sheep
Swine	3B3	_Key_3B3_Swine
Goats	3B4d	_Key_3B4d_Goats
Horses	3B4e	_Key_3B4e_Horses
Laying hens	3B4gi	_Key_3B4gi_LayingHens
Broilers	3B4gii	_Key_3B4gii_Broilers
Turkeys	3B4giii	_Key_3B4giii_Turkeys
Other poultry	3B4giv	_Key_3B4giv_OtherPoultry
Other animals	3B4h	_Key_3B4h_OtherAnimals
Inorganic fertiliser	3Da1	_Key_3Da1_MineralFertiliser
Animal manure applied to soils	3Da2a	_Key_3Da2a_ManureSoils
Sewage sludge applied to soils	3Da2b	_Key_3Da2b_SludgeSoils
Other organic fertilisers applied to soils	3Da2c	_Key_3Da2c_OtherFertiliserSoils
Grazing animals	3Da3	_Key_3Da3_Grazing
Farm-level agricultural operations	3Dc	_Key_AgriculturalArea
Crops	3De	_Key_AgriculturalArea
Use of pesticides	3Df	_Key_AgriculturalArea
Field burning of agricultural residues	3F	_Key_AgriculturalArea
NH_3 treated straw	3I	_Key_3B1a_DairyCattle

The subsectors within agriculture are described in more detail in the following chapters.

5.6.1 Animal husbandry and manure management

The workflow for data processing is the same for all animals, except horses, and are therefore described here rather than for each animal type. For a description of the data processing for creating the GeoKey for horses, see Table 5.116.

The distribution of emissions from animal husbandry and manure management is based on data from the General Agricultural Register (GLR), the Central Husbandry Register (CHR) and the Fertilizer and livestock reporting (GHI), see Chapter 4.5. The CHR is a central register of animals managed by the Ministry of Environment, including all animals regardless of farm size except for horses. The GeoKey for horses is based on the GHI, which only include farms that report to fertilizer accounts. No national register includes all horses, as horses are not included in the CHR register. The GHI does not support a time series for the GeoKey for horses, and following the same distribution is used for all years in the SPREAD model.

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. The correction for grazing is also used to develop the GeoKey for the category 'Urine and dung deposited by grazing animals'. This is done by using information on the number of days per year when the different animal types are grazing. The nitrogen excreted for these days of the year is allocated to pastures around the farm, and this is allocated to the 1 km x 1 km grid and normalised.

The calculated NH_3 emissions from animal husbandry and manure management on farm level for the individual animal types are imported to GIS and aggregated to the 1 km x 1 km grid using the geographical coordinates for the farms included in the CHR. The GeoKeys are calculated as the share of the total NH_3 emission for a given source. The GeoKeys based on NH_3 emissions are used for NO_x, NMVOC and PM emissions as well.

The spatial data underpinning the GeoKeys for animals except horses are considered to have a very low uncertainty. As a spatial proxy, the developed GeoKeys are considered to have a good correlation.

Dairy cattle

Dairy cattle is an important emission source for NH_3 and NMVOC while also contributing to the PM emission and to a very small extent to the NO_x emission.

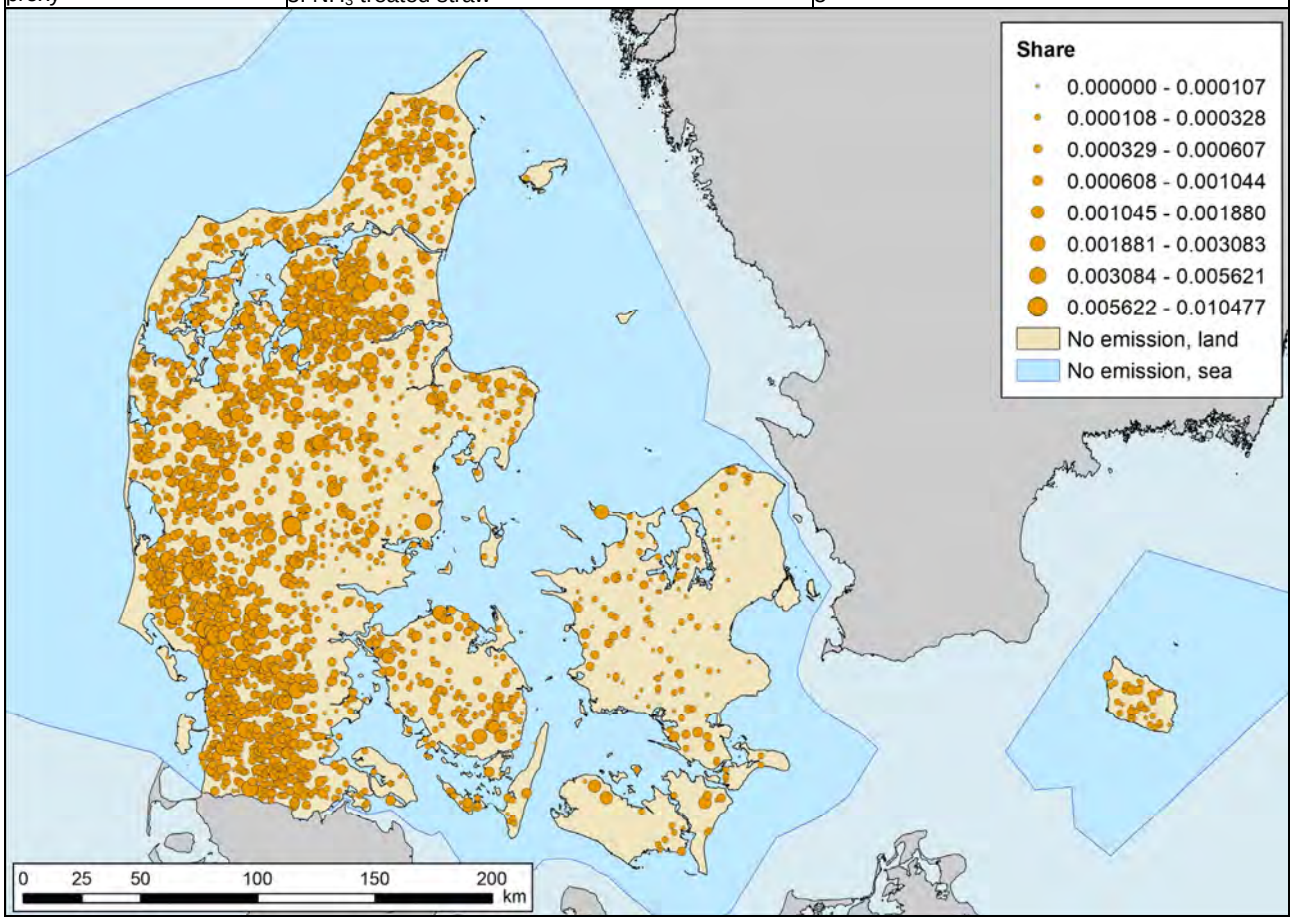
The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Use of NH_3 for straw conservation is normally forbidden in Denmark, but in case of heavy rainfall during harvest, this ban can be lifted. Emissions from NH_3 treated straw take place in connection with dairy cattle farming. While the activity does not occur on all dairy cattle farms, there is no specific information available that allows for a further disaggregation. The uncertainty of the spatial data is very low, but the applicability as spatial proxy is very poor

(Applicability rating 5), as the use of NH_3 treated straw only occurs on a limited number of farms, but the emission is distributed on all farms.

Table 5.111 GeoKey for dairy cattle.

Source data	CHR			
Data provider	Ministry of Environment			
Projection	ETRS89 UTM zone 32N			
Data description	Information on number of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B1a_DairyCattle			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	NH_3		NH_3
	5-10 %		NH_3	NMVOC
	1-5 %	NMVOC, PM_{10}, PM10	NMVOC, PM_{10}, $PM_{2.5}$	TSP, PM_{10}, $PM_{2.5}$
	< 1 %	NO_x, TSP	NO_x, TSP	NO_x
Quality of spatial dataset	A			
Applicability as spatial proxy	3B1a Manure management – Dairy cattle		2	
	3I NH_3 treated straw		5	



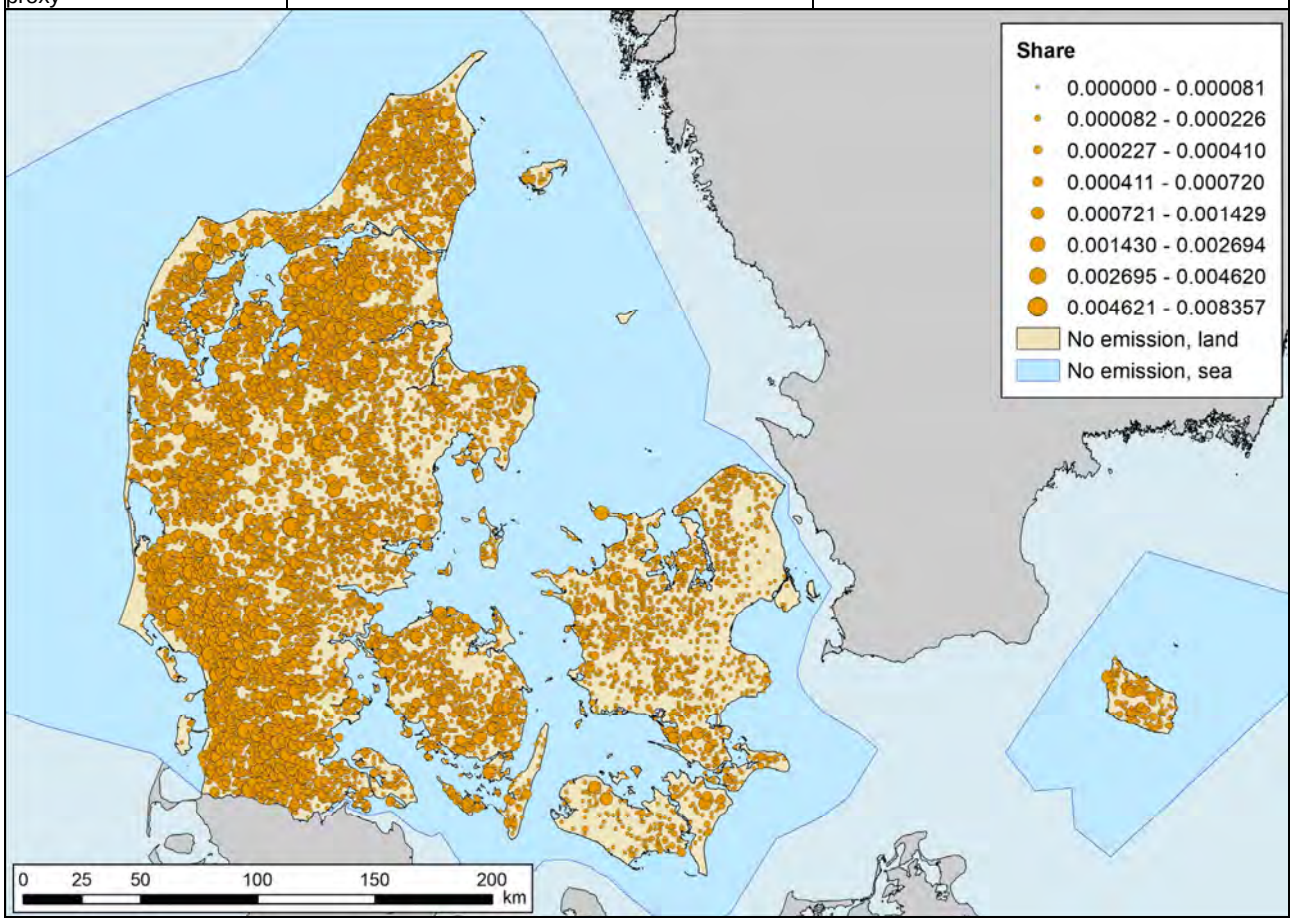
Non-dairy cattle

Non-dairy cattle is an important emission source of NMVOC emissions while also contributing to the NH_3 emission. The emissions of PM and NO_x especially in the later years contribute very little to the national total.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.112 GeoKey for non-dairy cattle.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on number of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B1b_NonDairyCattle			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NMVOC, NH_3, PM_{10}, $PM_{2.5}$	NMVOC, NH_3	NMVOC, NH_3
	< 1 %	NO_x, TSP	NO_x, TSP, PM_{10}, $PM_{2.5}$	NO_x, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B1b Manure management – Non-dairy cattle		2	



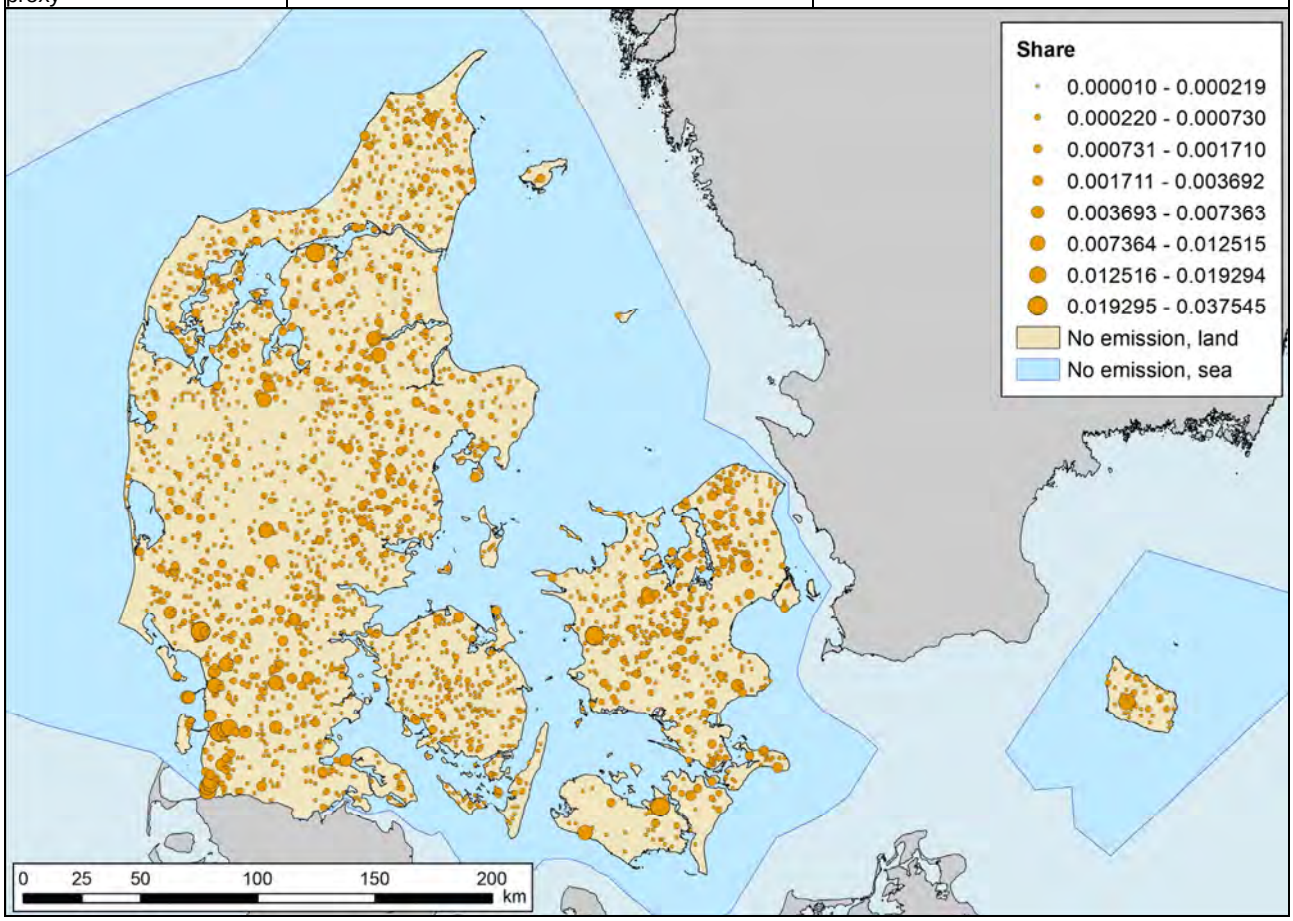
Sheep

The number of sheep in Denmark is quite low and therefore, the emissions associated with sheep farming is contributing little to the national emissions. For all years, the contribution to the national total is below 1 %.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.113 GeoKey for sheep.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B2_Sheep			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B2 Manure management – Sheep		2	



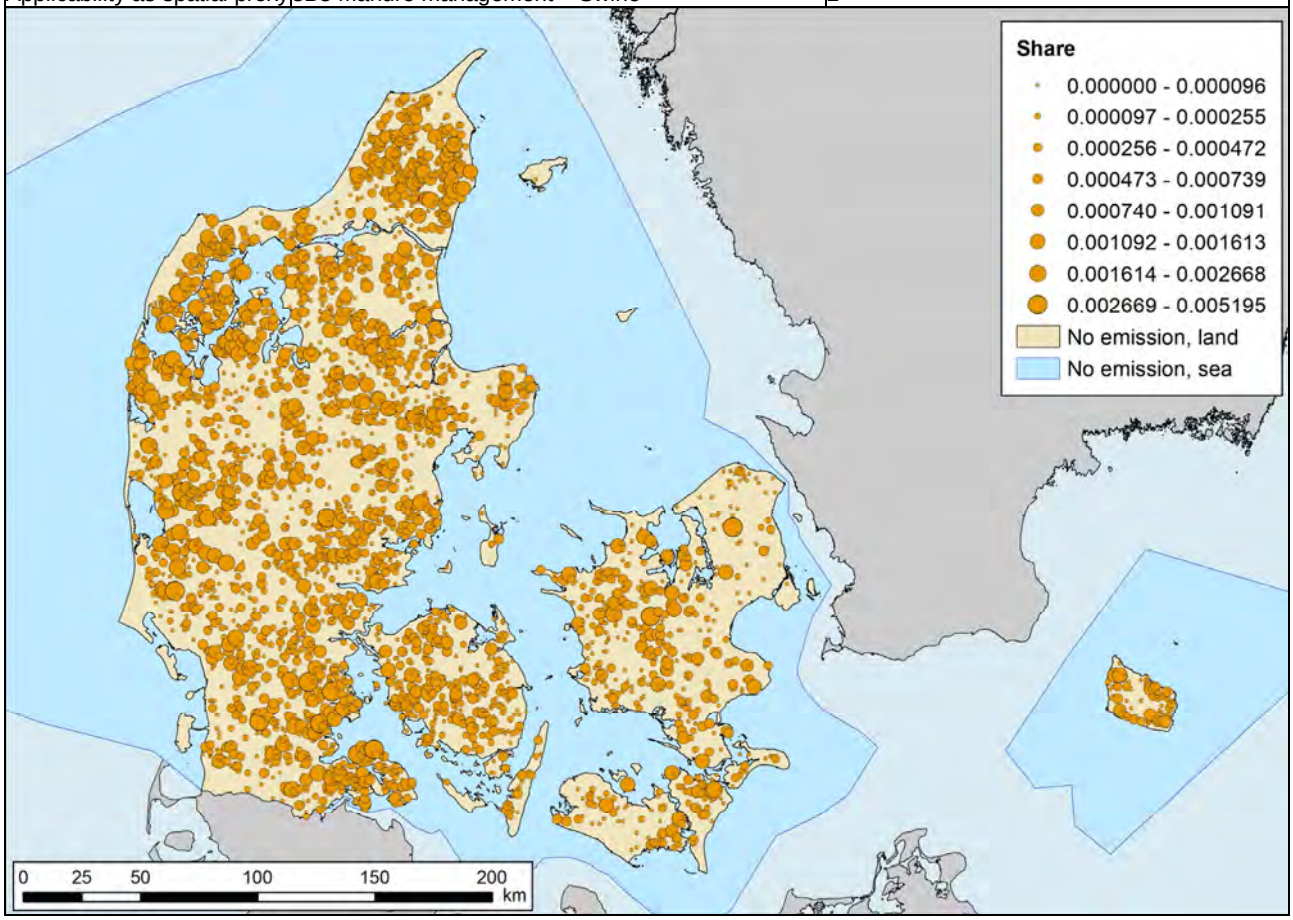
Swine

Swine is an important emission source for NH_3 and NMVOC while also contributing to the PM emission and to a very small extent to the NO_x emission.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.114 GeoKey for swine.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B3_Swine			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %	NH_3	NH_3	NH_3
	1-5 %	TSP, PM_{10}	NMVOC, TSP, PM_{10}	TSP, PM_{10}
	< 1 %	NO_x, NMVOC, $PM_{2.5}$	NO_x, $PM_{2.5}$	NO_x, NMVOC, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B3 Manure management – Swine		2	



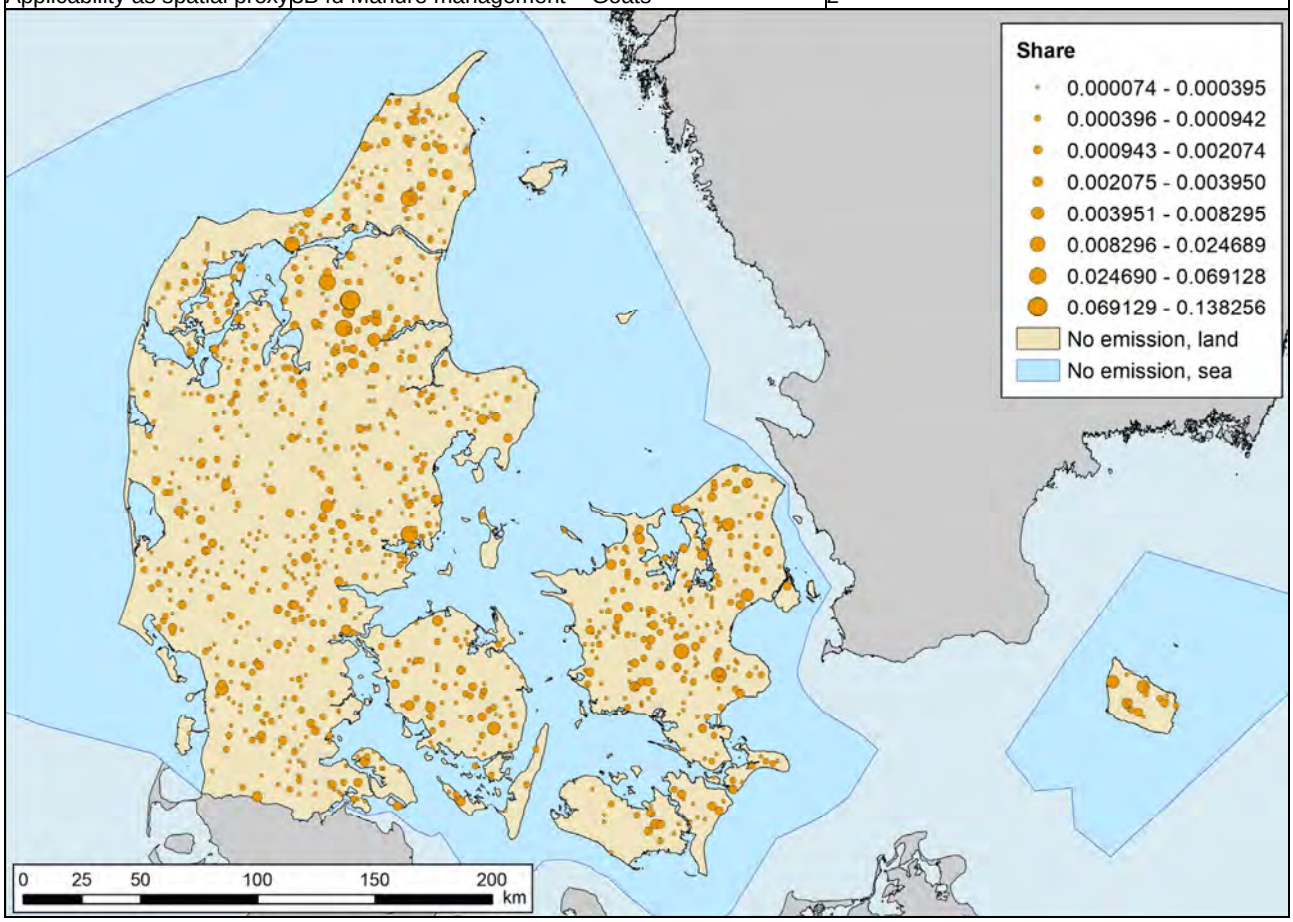
Goats

The number of goats in Denmark is very low and therefore, the emissions associated with goat farming is contributing very little to the national emissions. For all years, the contribution to the national total is below 1 %.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.115 GeoKey for goats.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B4d_Goats			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B4d Manure management – Goats		2	



Horses

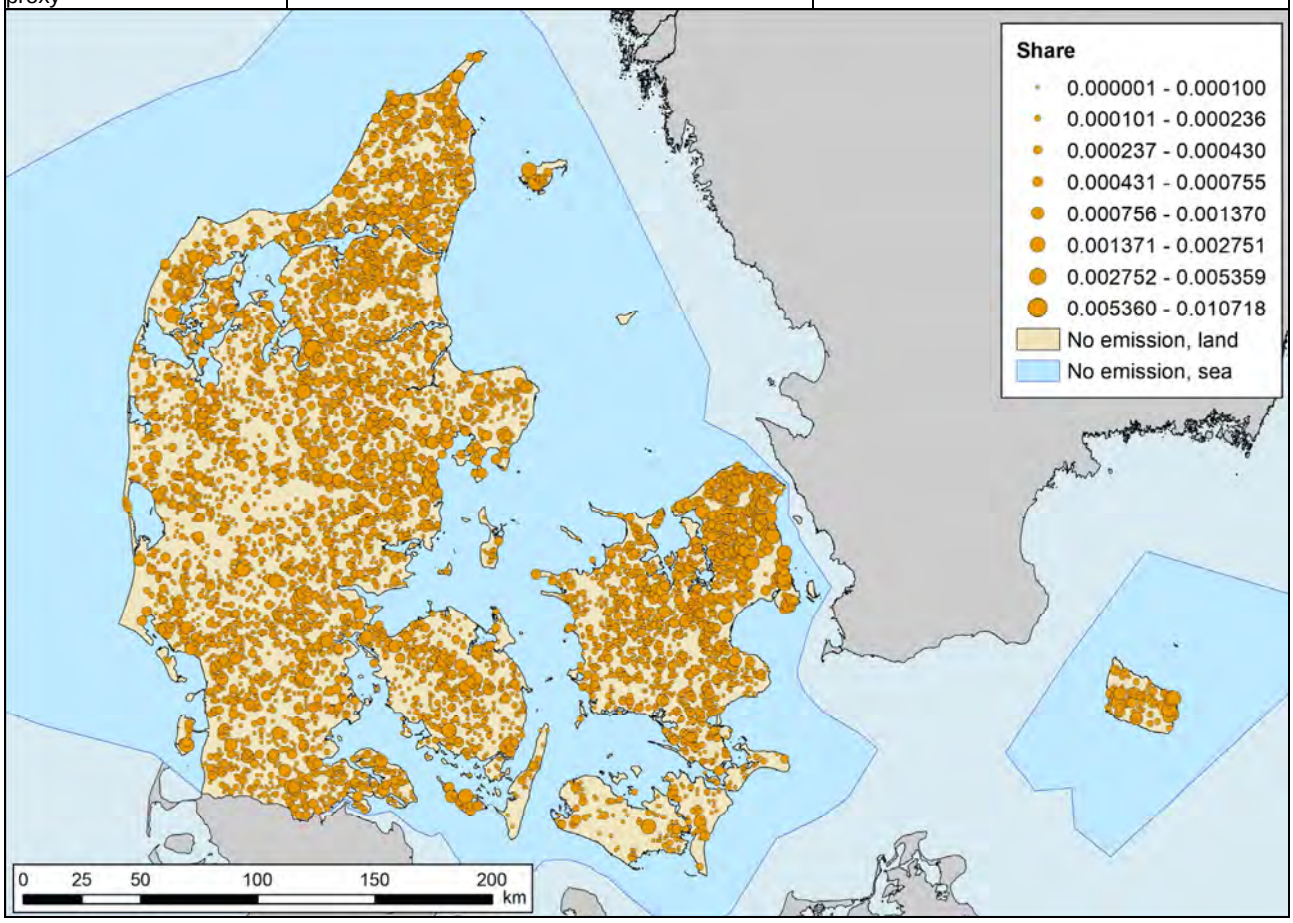
As mentioned in Chapter 5.6.1, the methodology for horses is different from the other animal types. As the available spatial dataset does not contain all horses there is some uncertainty regarding the spatial distribution. However, as the majority of the horses, i.e. all larger herds, are included, it is considered that the uncertainty of the spatial dataset is low and that it is a fair correlated proxy.

The number of horses in Denmark is quite low and therefore, the emissions associated with horses is contributing very little to the national emissions. For all years, the contribution to the national total is below 1 %.

Most horses are used in riding schools or for recreational purposes and not in agriculture. Therefore, the information on their exact location is more uncertain than for the agricultural production animals. However, the data quality is still considered to have low uncertainty and the applicability as spatial proxy is considered fair.

Table 5.116 GeoKey for horses.

Source data	Fertilizer and livestock reporting (GHI)			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on N-excretion from horses at farm level. The GeoKey is based on data from 2013.			
Workflow	The N-excretion for each farm is allocated to the 1 km x 1 km grid and the GeoKey is normalised by dividing each cell value with the total N-excretion from horses. GHI only contains information on about 60 000 horses, which is used as a proxy for the remaining number of horses.			
GeoKey name	_Key_3B4e_Horses			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			NH3
	< 1 %	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	B			
Applicability as spatial proxy	3B4e Manure management – Horses		3	



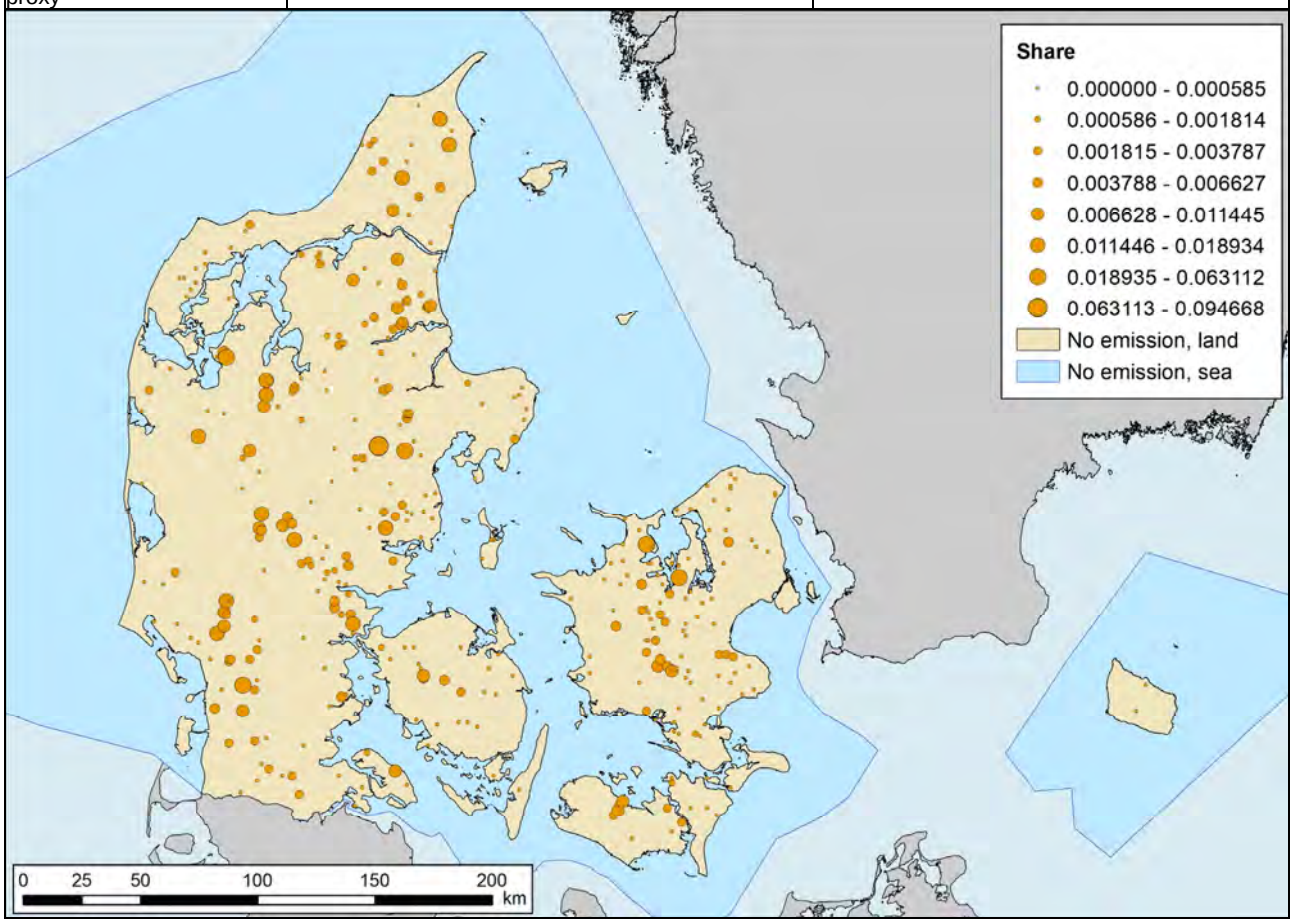
Laying hens

Poultry production is significant in Denmark. For laying hens, the contribution to the national emission of NH_3, NMVOC and TSP is significant in the later years of the time series.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.117 GeoKey for laying hens.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B4gi_LayingHens			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %		NH_3	NH_3, TSP, PM_{10}
	< 1 %	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B4gi Manure management – Laying hens		2	



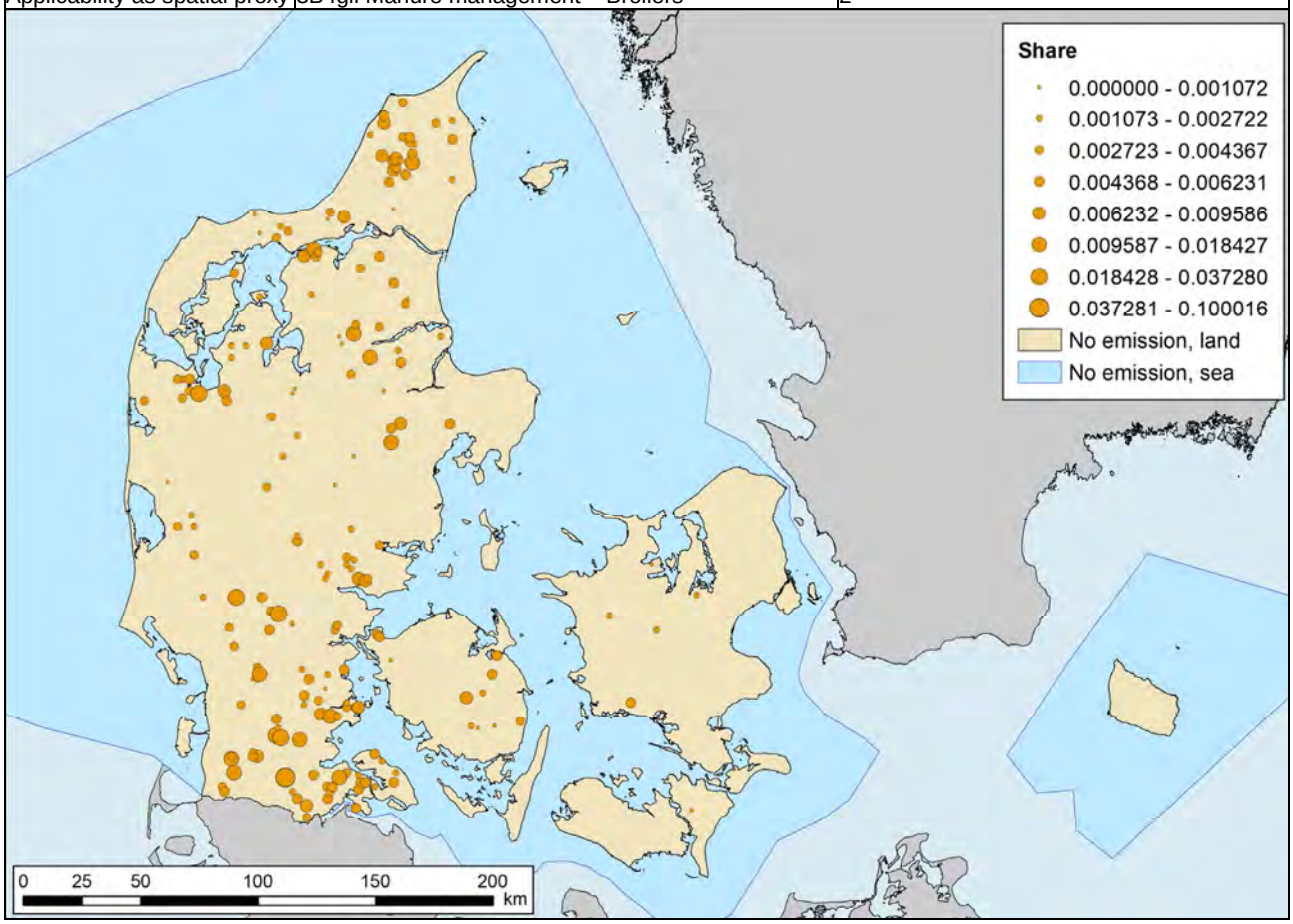
Broilers

The production of broilers contributes significantly to the national total emission of NH_3 and NMVOC.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.118 GeoKey for broilers.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B4gii_broilers			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NH_3	NH_3	PM_{10}
	< 1 %	NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B4gii Manure management – Broilers		2	



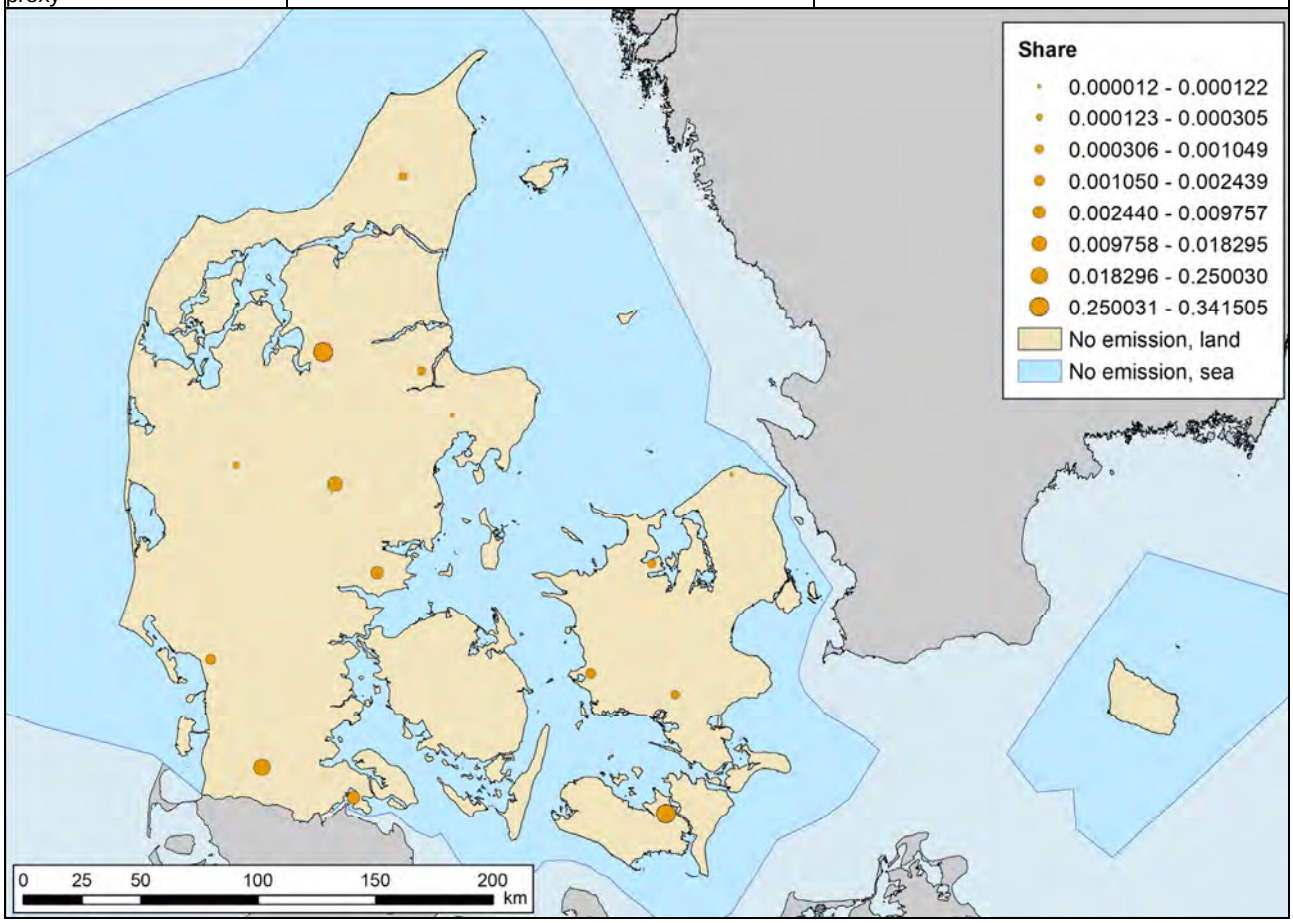
Turkeys

The number of turkeys in Denmark is very low and therefore, the emissions associated with turkey farming is contributing very little to the national emissions. For all years, the contribution to the national total is below 1 %.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.119 GeoKey for turkeys.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B4giii_Turkeys			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B4giii Manure management – Turkeys		2	



Other poultry

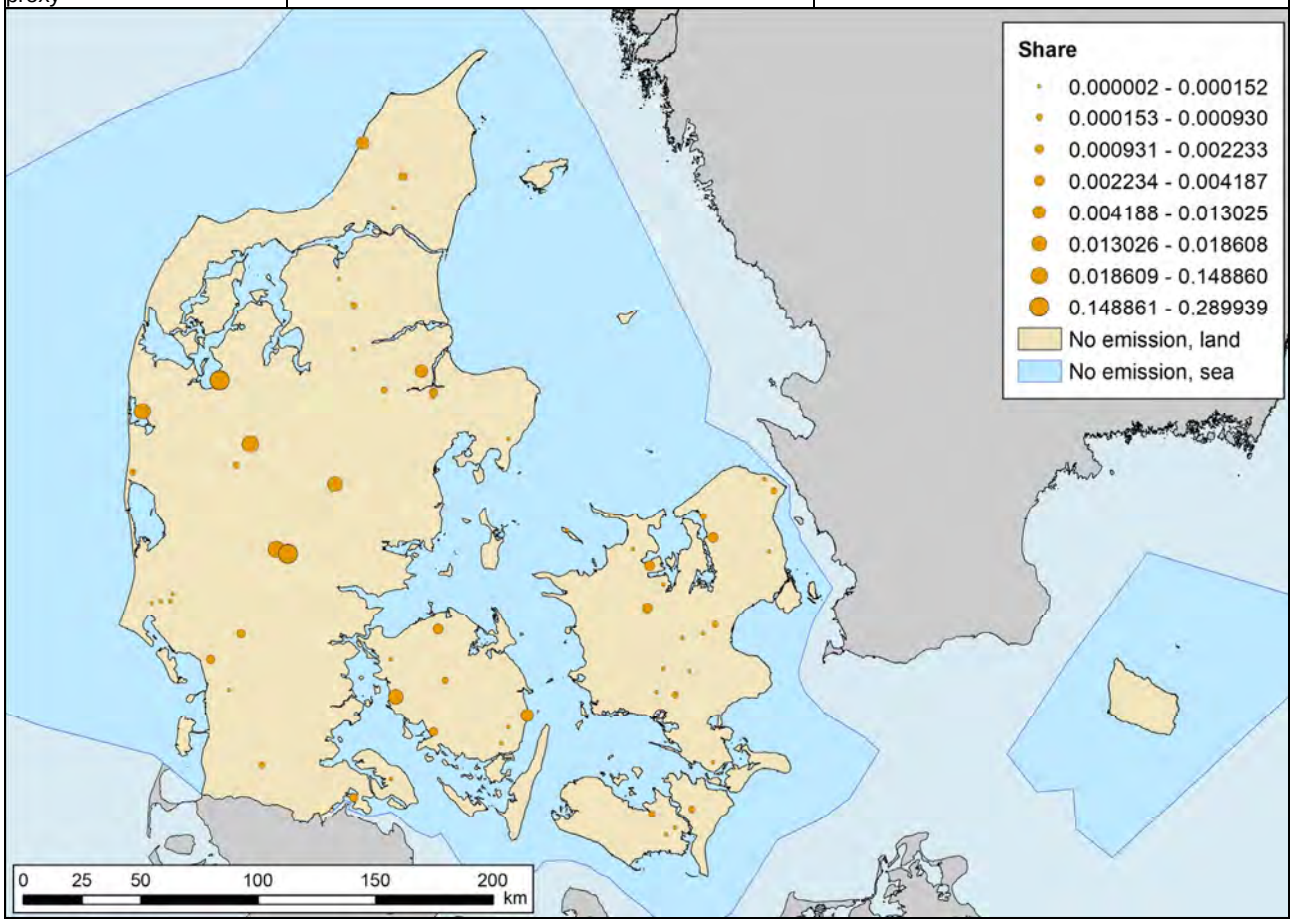
The category 'Other poultry' covers ducks, geese, pheasants and ostriches.

The farming of these animals in Denmark is limited and therefore their contribution to the national total emission is limited. For all years, the combined contribution of these animals is less than 1 % of the national total.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.120 GeoKey for other poultry.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B4giv_OtherPoultry			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B4giv Manure management – Other poultry		2	



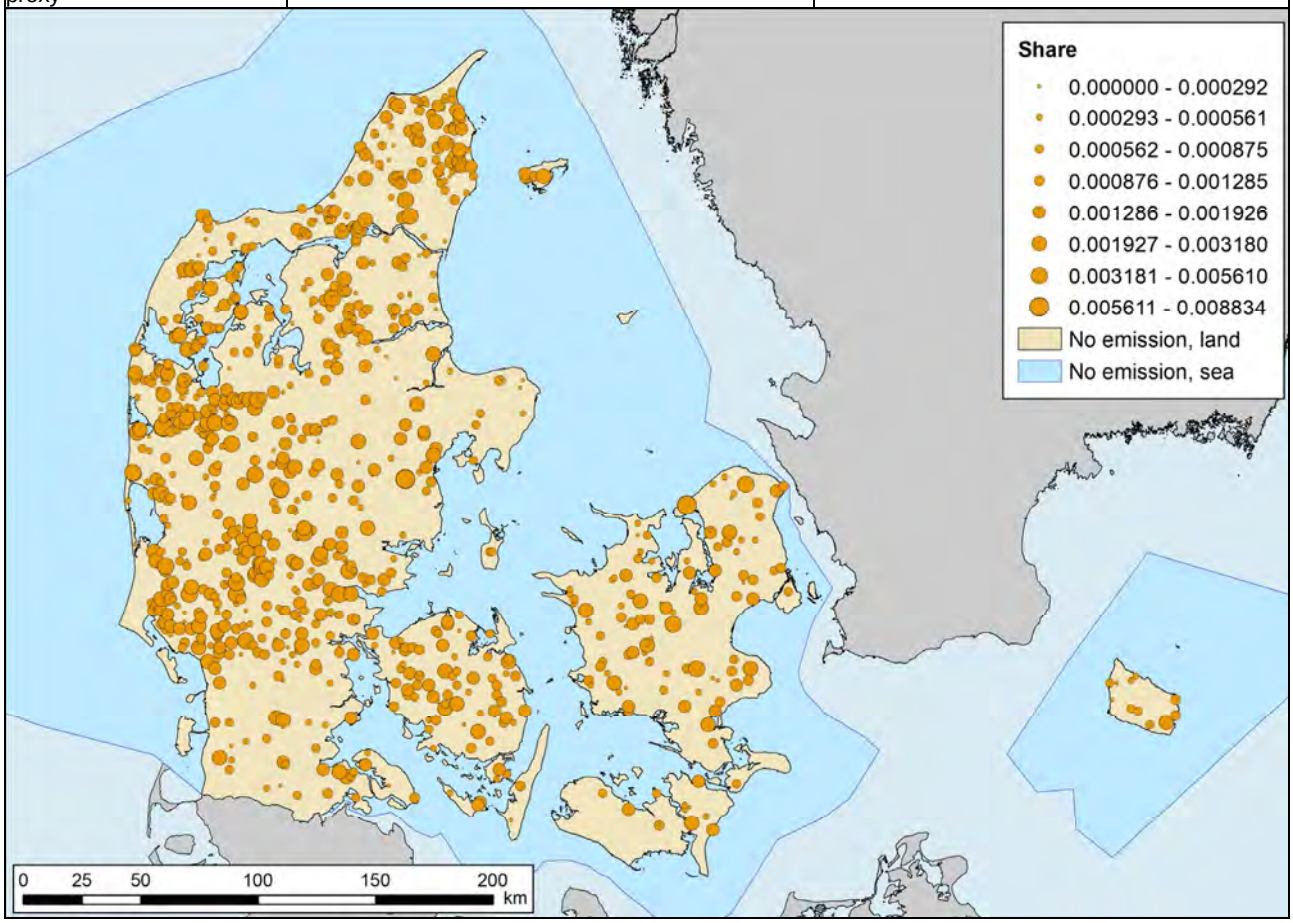
Other animals

The category 'Other animals' refers to mink, deer and foxes. Mink is the only animal type that contributes significantly to the national total. In later years, the contribution to especially the NH_3 emission, but also to the NMVOC emission is significant.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as the register includes all animals and the spatial applicability is considered good as the emissions are calculated on a highly disaggregated level.

Table 5.121 GeoKey for other animals.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	Information on stock of livestock at farm level			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3B4h_OtherAnimals			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %		NH_3	NH_3
	1-5 %	NH_3		
	< 1 %	NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$	NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	3B4h Manure management – Other animals		2	



5.6.2 Agricultural soils

The distribution of emissions from nitrogen application to agricultural soils is based on data from the field parcel maps, the GLR and the fertilizer accounts. The field parcel map include agricultural fields as polygons, the GLR holds information on crop types for the fields, and the fertilizer accounts are the farmers reporting of animal manure, inorganic fertilisers and other organic fertilisers.

The workflow is the same for all nitrogen inputs to soils, and it is only described here. The Danish agricultural fields are firstly geocoded. To keep the work manageable, the centerpoint of the field has been used to allocate emissions to a specific grid cell.

The nitrogen quotas for each field is known and from the GHI, the total application of nitrogen can be assessed. This is done for four different categories of nitrogen, i.e. inorganic fertiliser, animal manure, sewage sludge and other nitrogen components. For each farm (based on CVR number), the total nitrogen quota is calculated. Correction factors are calculated based on the total nitrogen quota and the use of the different types of nitrogen. The latter also has the effect that organic farmers, who are not using inorganic mineral fertilisers, are included in the spatial allocation. These correction factors are then used to correct the nitrogen quota. The nitrogen input per field is then calculated divided into the four different types. Finally, these values are aggregated to the 1 km x 1 km grid and normalised.

Inorganic fertilisers applied to soils

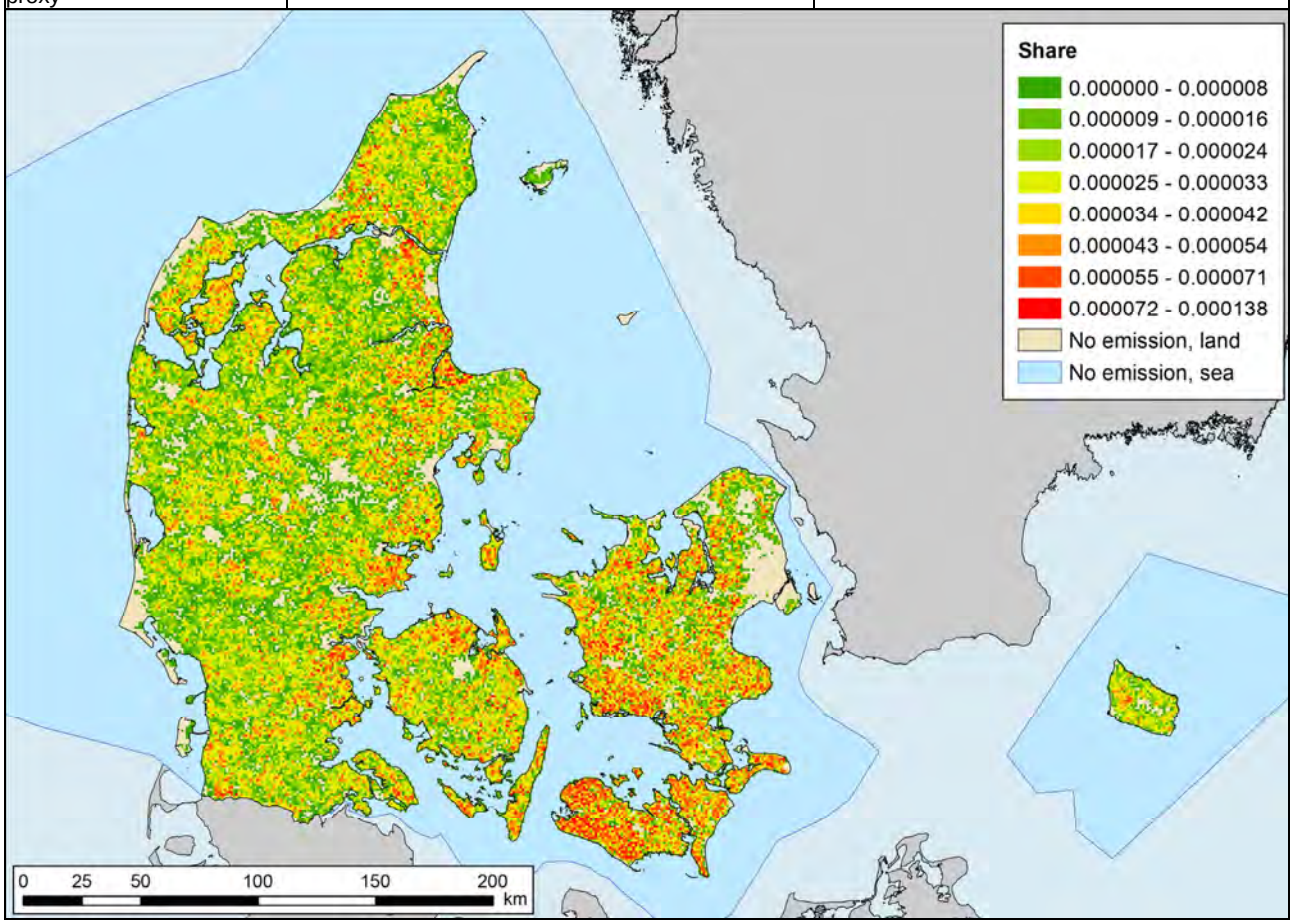
The application of inorganic fertilisers on soils is a major source of NH_3 and NO_x emissions.

As shown in Chapter 5.6.1, the majority of the agricultural animal production takes place in the western part of Denmark. In eastern Denmark, there is fewer animals but a large crop production. This causes the use of inorganic fertiliser to be more prevalent in the eastern part of Denmark compared to the western part.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on field level data. The spatial applicability is considered good as the emissions are calculated on a highly disaggregated level and as the register data is updated annually.

Table 5.122 GeoKey for inorganic fertilisers applied to soils.

Source data	GLR, GHI			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 5.6.2			
Workflow	See Chapter 5.6.2			
GeoKey name	_Key_3Da1_MineralFertiliser			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	NH_3	NH_3	NH_3
	5-10 %	NO_x		NO_x
	1-5 %		NO_x	
	< 1 %			
Quality of spatial dataset	A			
Applicability as spatial proxy	3Da1 Inorganic fertilisers		2	



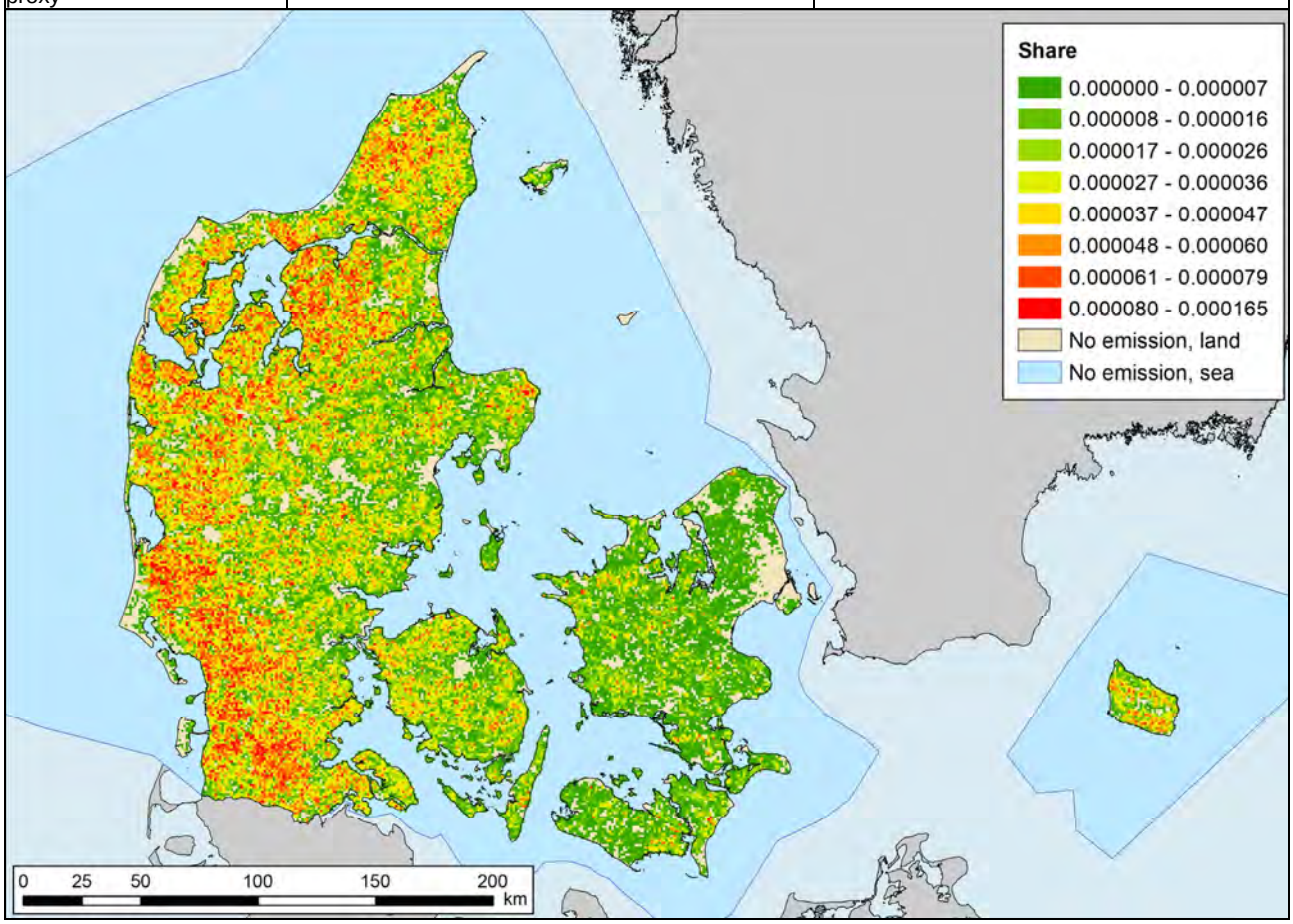
Animal manure applied to soils

The application of animal manure on soils is the single most important source of NH_3 emissions and it is a very significant source to NO_x emissions.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on field level data. The spatial applicability is considered good as the emissions are calculated on a highly disaggregated level and as the register data is updated annually.

Table 5.123 GeoKey for animal manure applied to soils.

Source data	GLR, GHI			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 5.6.2			
Workflow	See Chapter 5.6.2			
GeoKey name	_Key_3Da2a_ManureSoils			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %	NH_3	NH_3	NH_3
	5-10 %			NO_x
	1-5 %	NO_x, NMVOC	NO_x, NMVOC	NMVOC
	< 1 %			
Quality of spatial dataset	A			
Applicability as spatial proxy	3Da2a Animal manure		2	



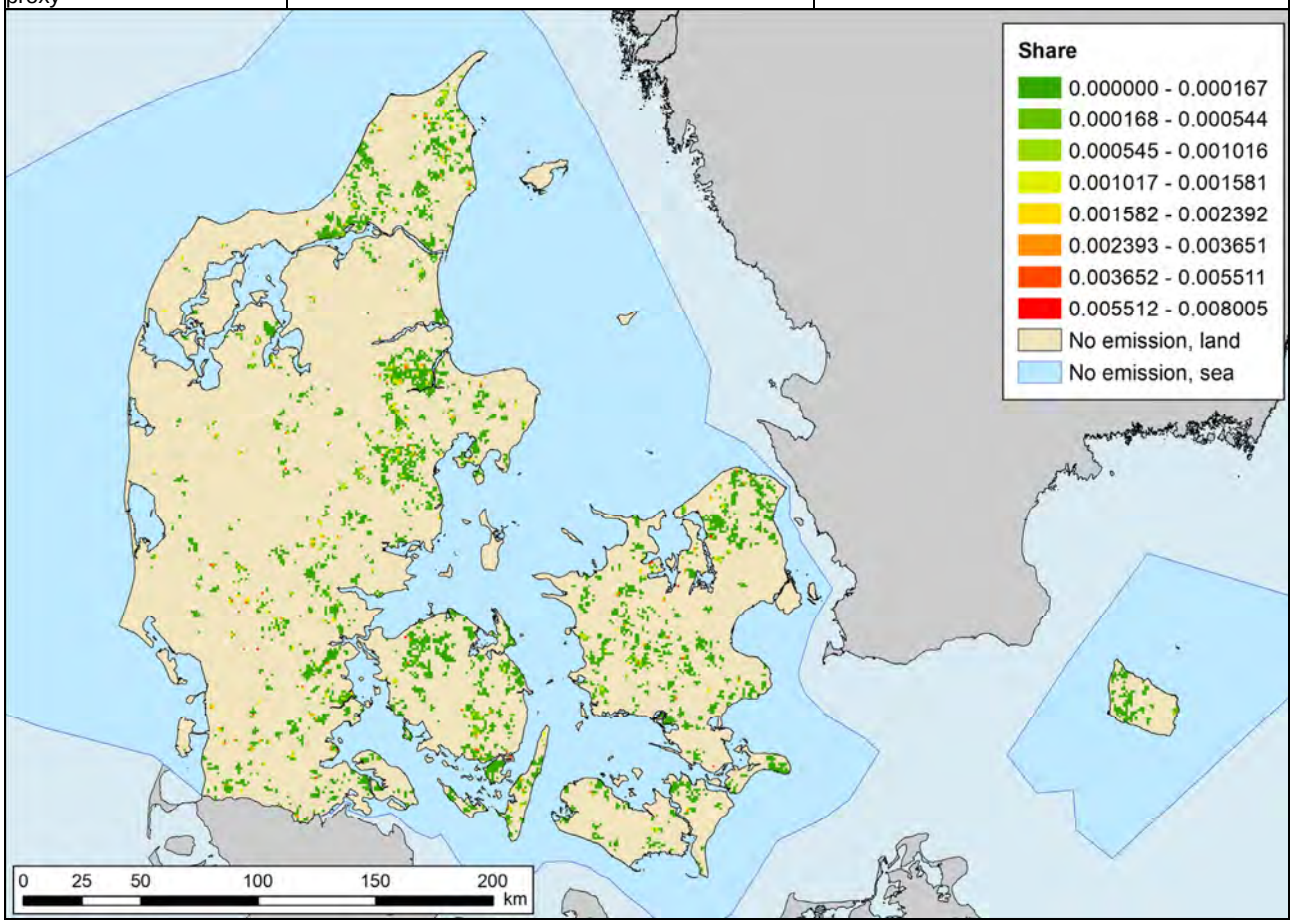
Sewage sludge applied to soils

The nitrogen applied to agricultural soils in the form of sewage sludge is very limited compared to the amounts in inorganic fertiliser and animal manure. As a result, the emission from sewage sludge applied to agricultural soils is negligible and for all years, the NH_3 emission from sewage sludge is far below 1 % of the national total.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on field level data. The spatial applicability is considered good as the emissions are calculated on a highly disaggregated level and as the register data is updated annually.

Table 5.124 GeoKey for sewage sludge applied to soils.

Source data	GLR, GHI			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 5.6.2			
Workflow	See Chapter 5.6.2			
GeoKey name	_Key_3Da2b_SludgeSoils			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NO_x, NH_3	NO_x, NH_3	NO_x, NH_3
Quality of spatial dataset	A			
Applicability as spatial proxy	3Da2b Sewage sludge		2	



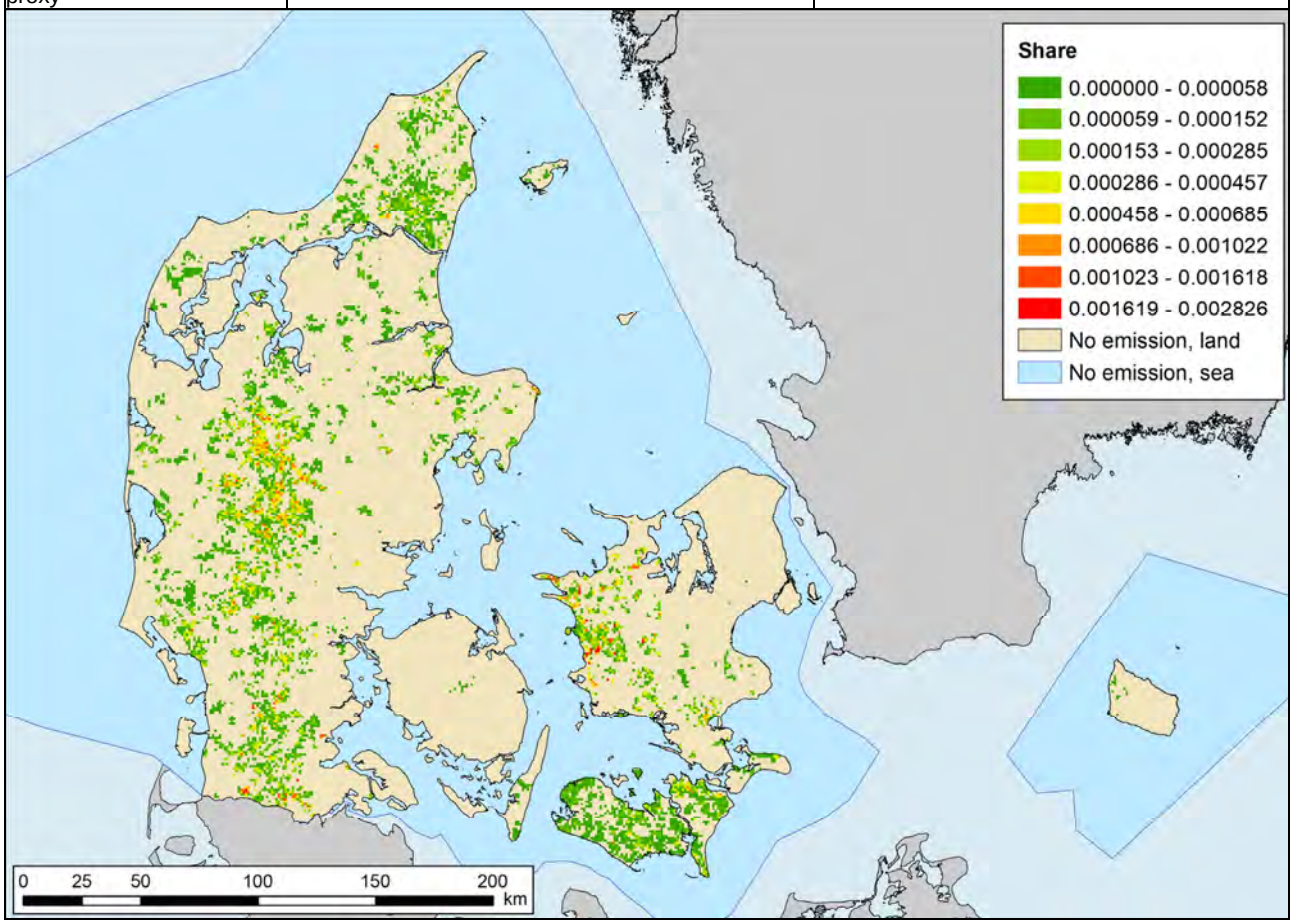
Other organic fertiliser applied to soils

Other types of organic fertiliser such as sludge from industrial productions are applied to soils and leads to emissions of NH_3 and NO_x. The major sources are nitrogen containing sewage water from potato flour processing and sugar production factories. However, as the amounts are very small, the emissions are insignificant compared to the national total emissions.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on field level data. The spatial applicability is considered good as the emissions are calculated on a highly disaggregated level and as the register data is updated annually.

Table 5.125 GeoKey for other organic fertiliser applied to soils.

Source data	GLR, GHI			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 5.6.2			
Workflow	See Chapter 5.6.2			
GeoKey name	_Key_3Da2c_OtherFertiliserSoils			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NO_x, NH_3	NO_x, NH_3	NO_x, NH_3
Quality of spatial dataset	A			
Applicability as spatial proxy	3Da2c Other organic fertiliser		2	



Urine and dung deposited by grazing animals

Nitrogen deposited by grazing animals leads to emissions of NH_3. The majority of Danish livestock spends little time grazing, and hence the emission is limited. However, the contribution to the NH_3 emission is significant, accounting for between 2 and 2.5 % of the national total emission.

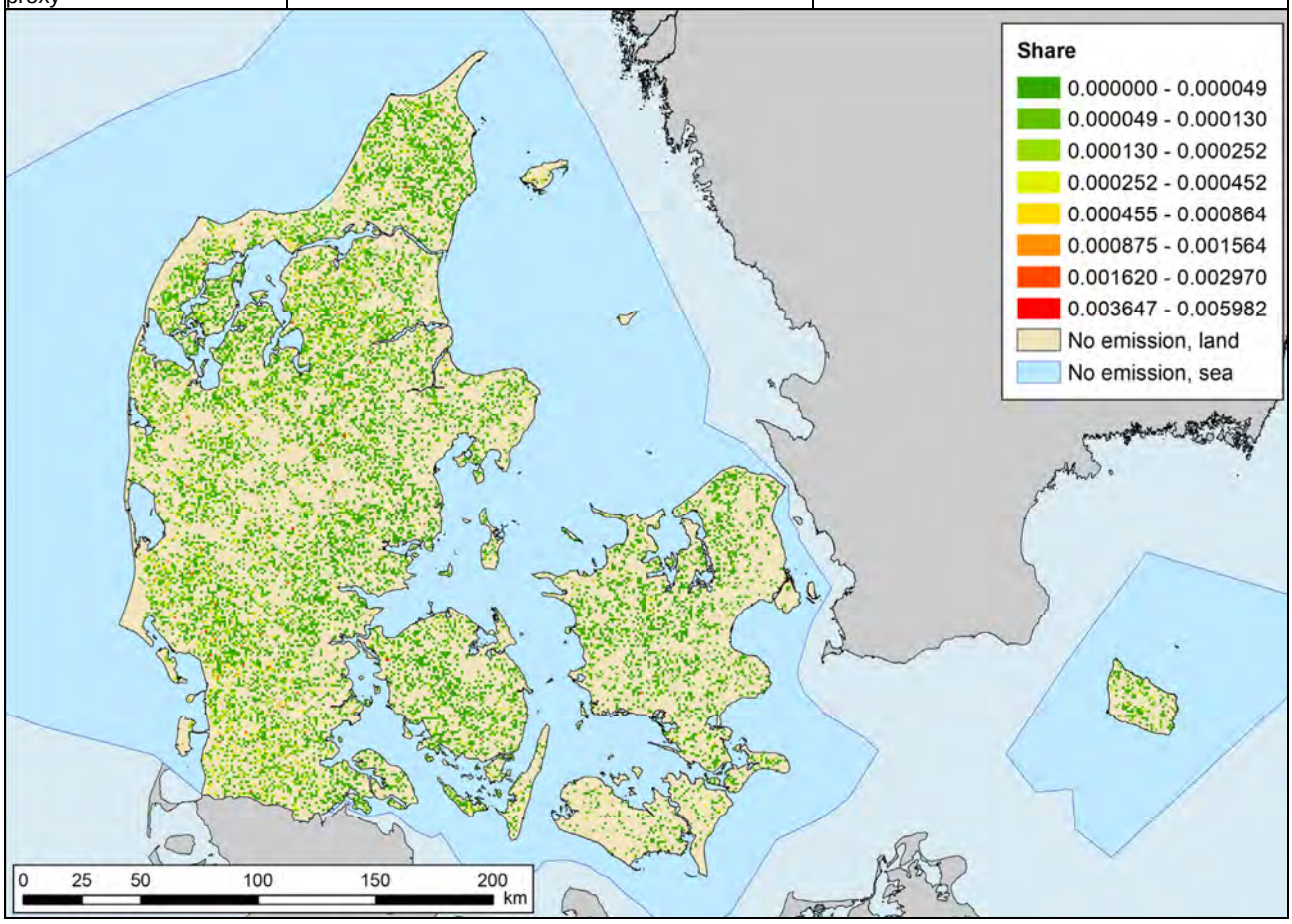
Emission calculations are based on information on the number of days per year when the different animal types are grazing. The nitrogen excreted for these days of the year is allocated to pastures around the farm, and this is allocated to the 1 km x 1 km grid and normalised.

The spatial dataset used for the GeoKey is considered to have very low uncertainty as it is based on field level data. The spatial applicability is considered good as the data include information on the number of animals at farm level

combined with knowledge of the average numbers of days on grass for the different animal types.

Table 5.126 GeoKey for urine and dung deposited by grazing animals.

Source data	CHR			
Data provider	Ministry of Environment and Food			
Projection	ETRS89 UTM zone 32N			
Data description	See Chapter 5.6.1			
Workflow	See Chapter 5.6.1			
GeoKey name	_Key_3Da3_Grazing			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %	NH_3	NH_3	NH_3
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	3Da3 Grazing animals		2	



Other soil emissions

This category covers particle emissions from farm level field operations, emissions from growing crops (NMVOC and NH_3) and emissions from the use of pesticides (HCB).

These activities all use the same GeoKey for the agricultural area. This GeoKey is described in Chapter 5.1.6.

5.6.3 Other agricultural emissions

Other agricultural emissions come from agricultural field burning and NH_3 treated straw.

As no information is available on the exact location of the agricultural field burning, the emissions are distributed using the GeoKey for the agricultural area described in Chapter 5.1.6.

Emissions from NH_3 treated straw take place in connection with dairy cattle farming. While the activity does not occur on all dairy cattle farms, there is no specific information available that allows for a further disaggregation; see Chapter 5.6.1. Emissions from NH_3 treated straw are distributed using the GeoKey for Dairy cattle; see Table 5.111.

5.7 Waste

The waste sector covers a number of different sources, some of which are occurring at a limited number of facilities, e.g. crematoria, and other sources, where the emission pattern is more diffuse, e.g. accidental fires.

Table 5.127 shows the share of emissions from waste of the national total emissions for the pollutants covered by the SPREAD model. It can be seen that the share for most pollutants have been stable during the years. The main source of emissions for most pollutants is accidental fires and this source has been relatively stable during the years. Changes in the level of specific pollutants are therefore mainly related to emission changes in other sectors, e.g. the increasing share of the Pb emission is mainly due to the significant decrease in emission from road transport in the early 1990s.

In 2019, the waste sector accounts for more than 10 % of the national emissions for Pb, Zn and PCDD/F. For these pollutants, accidental fires causes the vast majority of emissions, with only minor contributions coming from cremations.

The decrease in the share of Hg since 2005 is due to the implementation of flue gas abatement at Danish crematoria. The increase in the share of SO_2 is caused by the decrease in emissions from other sectors (primarily combustion), and the increase in NH_3 in the later years is due to the increased popularity of composting as a waste management system.

Table 5.127 Share of emissions from waste of the national total.

Share	1990	2005	2019
> 10 %	Zn, PCDD/F	Pb, Zn, PCDD/F	Pb, Zn, PCDD/F
5-10 %		Hg	SO_2, BkF, IcdP, PCBs
1-5 %	$PM_{2.5}$, Pb, Hg, BaP, BbF, BkF, IcdP	SO_2, $PM_{2.5}$, PM_{10}, BaP, BbF, BkF, IcdP, PCBs	$PM_{2.5}$, PM_{10}, As, BaP, BbF
< 1 %	NO_x, NMVOC, SO_2, NH_3, TSP, PM10, BC, CO, Cd, As, Cr, Cu, Ni, Se, HCB, PCBs	NO_x, NMVOC, NH_3, TSP, BC, CO, Cd, As, Cr, Cu, Ni, Se, HCB	NO_x, NMVOC, TSP, NH_3, BC, CO, Cd, Hg, Cr, Cu, Ni, Se, HCB

An overview of the different activities within the waste sector is provided together with the GeoKey for the individual activities in Table 5.128.

Table 5.128 Activities within the waste sector and corresponding GeoKeys.

Activity	SNAP category	GeoKey
Managed waste disposal on land	090401	_Key_SolidWasteDisposal
Composting of garden and park waste	091101	_Key_SolidWasteDisposal
Composting of organic waste	091102	_Key_SolidWasteDisposal
Composting of sludge	091103	_Key_SolidWasteDisposal
Home composting of garden and organic food waste	091104	_Key_Building_OneStorey
Anaerobic digestion at biogas facilities	091006	_Key_Biogas
Human cremation	090901	_Key_090901_Cremation
Animal cremation	090902	_Key_090902_AnimalCremation
Industrial wastewater handling	091001	_Key_WasteWater
Domestic wastewater handling	091002	_Key_WasteWater
Accidental fires – Vehicles	091201	_Key_Population
Accidental fires – Containers	091202	_Key_Population
Accidental fires – Detached houses	091203	_Key_Population
Accidental fires – Undetached houses	091204	_Key_Population
Accidental fires – Apartment buildings	091205	_Key_Population
Accidental fires – Industrial buildings	091206	_Key_Industry
Accidental fires – Other buildings	091207	_Key_Population

The subsectors within waste are described in more detail in the following chapters.

5.7.1 Solid waste disposal on land

Solid waste disposal on land covers emissions from managed waste disposal on land (landfills). The GeoKey has been prepared as it is used for some parts of composting. See Chapter 5.7.2 and Table 5.129 for more information.

5.7.2 Biological treatment of waste

Biological treatment of waste covers two different activities namely composting and anaerobic digestion at biogas facilities. Composting occurs both on the industrial scale and at the residential scale, while biogas plants with anaerobic digestion occurs on known locations. The separate activities are described in the following.

Composting

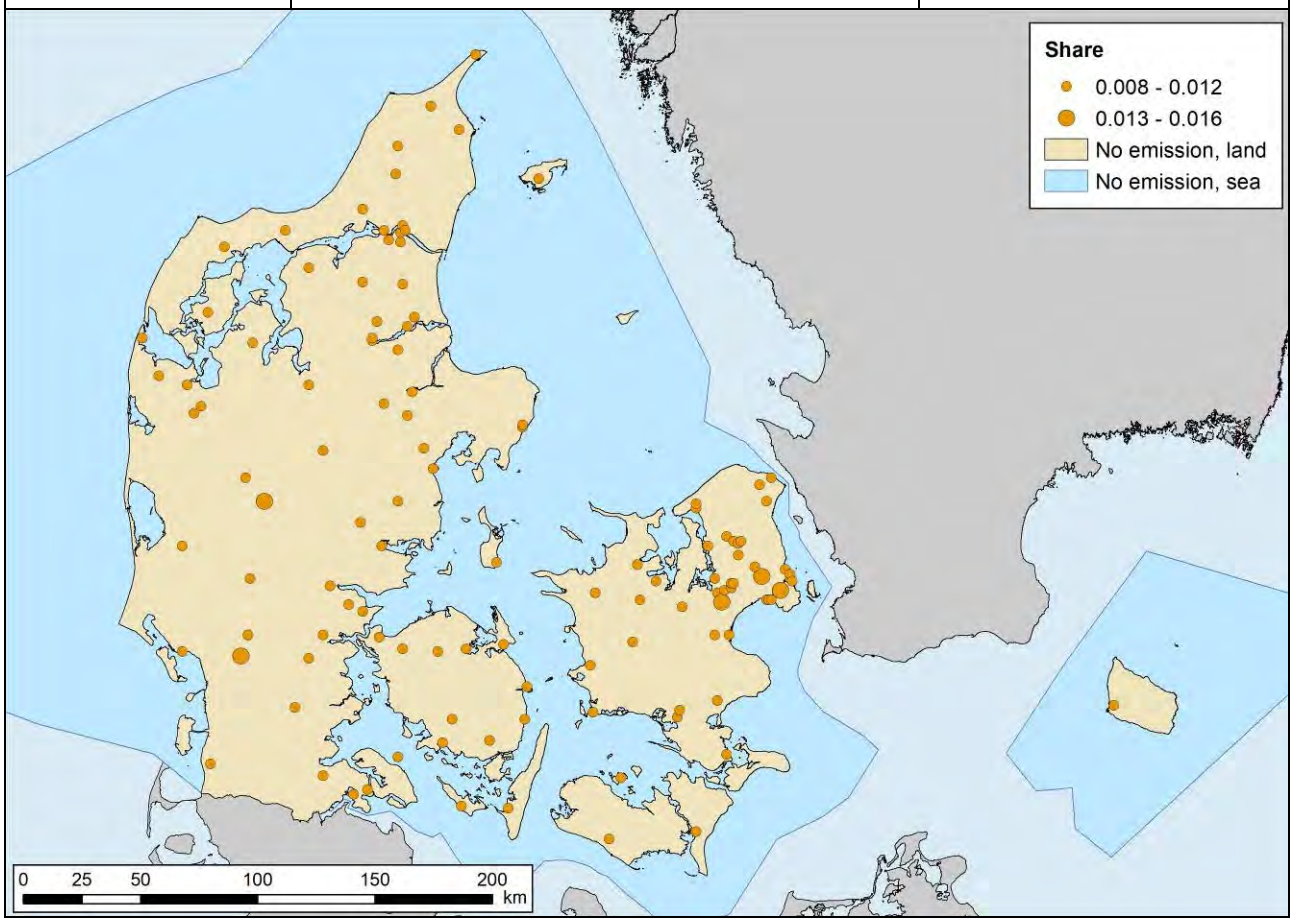
There are two separate activities covered by the composting category, one is the industrial scale composting, which is usually located in connection with existing landfills. The other is home composting, which usually occurs in gardening, mainly in connection with one-storey settlement. Of the pollutants currently covered by SPREAD, only NH_3 and CO are emitted from composting.

The GeoKey for one-storey settlement is described in Chapter 5.1.4. The GeoKey used for the industrial composting facilities is described in Table 5.129.

The spatial dataset used for the GeoKey for industrial composting is considered to have very low uncertainty as the database include all waste treatment facilities with composting. The spatial applicability is considered poor as neither activity data nor time variations are included.

Table 5.129 GeoKey for industrial composting.

Source data	ISAG database (Information System for Waste and recycling), version 2008			
Data provider	The Danish EPA			
Projection	ETRS89 UTM zone 32N			
Data description	The ISAG database holds addresses for waste treatment companies with processing, incineration, deposition, special treatment and/or temporary storage. Waste amounts in the different categories are included by company. Data for 2008 is used.			
Workflow	Companies with processing of waste category “branches, leafs, grass, etc.” is selected in the ISAG database and geocoded from the address information. Emissions are distributed evenly between the companies, and the GeoKey is calculated as the share of the total number of companies by 1 km x 1 km grid cell.			
GeoKey name	_Key_SolidWasteDisposal			
Year dependent	No			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$	NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$	NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$
Quality of spatial dataset	A			
Applicability as spatial proxy	090401 Managed waste disposal on land			4
	091101 Composting of garden and park waste			4
	091102 Composting of organic waste			4
	091103 Composting of sludge			4



Anaerobic digestion at biogas facilities

Of the pollutants currently covered by SPREAD, only NH_3 is emitted from anaerobic digestion at biogas facilities. The emissions are very low and the contribution to the national total is far below 1 % for all years.

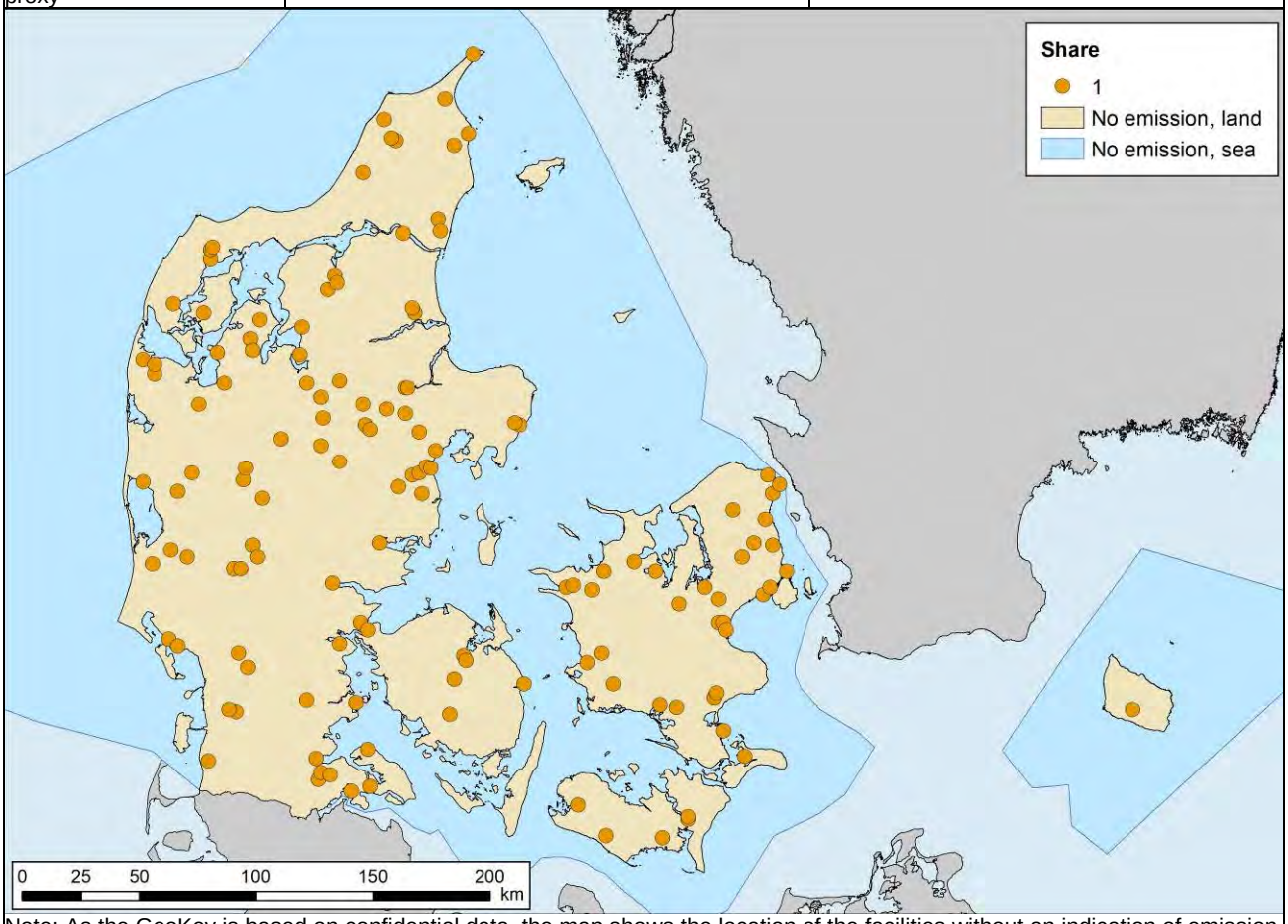
The spatial dataset used for the GeoKey is considered to have a very low uncertainty, since the exact location of the biogas plants is known and the dataset

is complete. The spatial applicability is considered good, since the GeoKey takes into account the biogas production at the different plants.

As the data on the annual activity level have been received on the condition of confidentiality, the map below simply identifies the location of the facilities without an indication of the distribution in activity data between the three sites.

Table 5.130 GeoKey for biogas plants.

Source data	EPT (Chapter 5.2.2)			
Data provider	Danish Energy Agency (DEA)			
Projection	ETRS89 UTM zone 32N			
Data description	(Chapter 5.2.2)			
Workflow	The EPT data include some LPS, which are all identified and excluded from the data processing to avoid double counting. Further, PS without any biogas fuel consumption are excluded from the data processing. The GeoKey for biogas is calculated as the share of the total biogas consumption by plant and summarised by 1 km x 1 km grid cell.			
GeoKey name	_Key_Biogas			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NH_3	NH_3	NH_3
Quality of spatial dataset	A			
Applicability as spatial proxy	091006 Anaerobic digestion at biogas facilities	2		



Note: As the GeoKey is based on confidential data, the map shows the location of the facilities without an indication of emission shares.

5.7.3 Waste incineration

In Denmark, all traditional waste incineration, i.e. municipal, industrial, chemical and hazardous waste incineration is carried out with energy recovery and all facilities are included as LPS (Chapter 5.2.1). The activities covered within this sector are therefore limited to human and animal cremations.

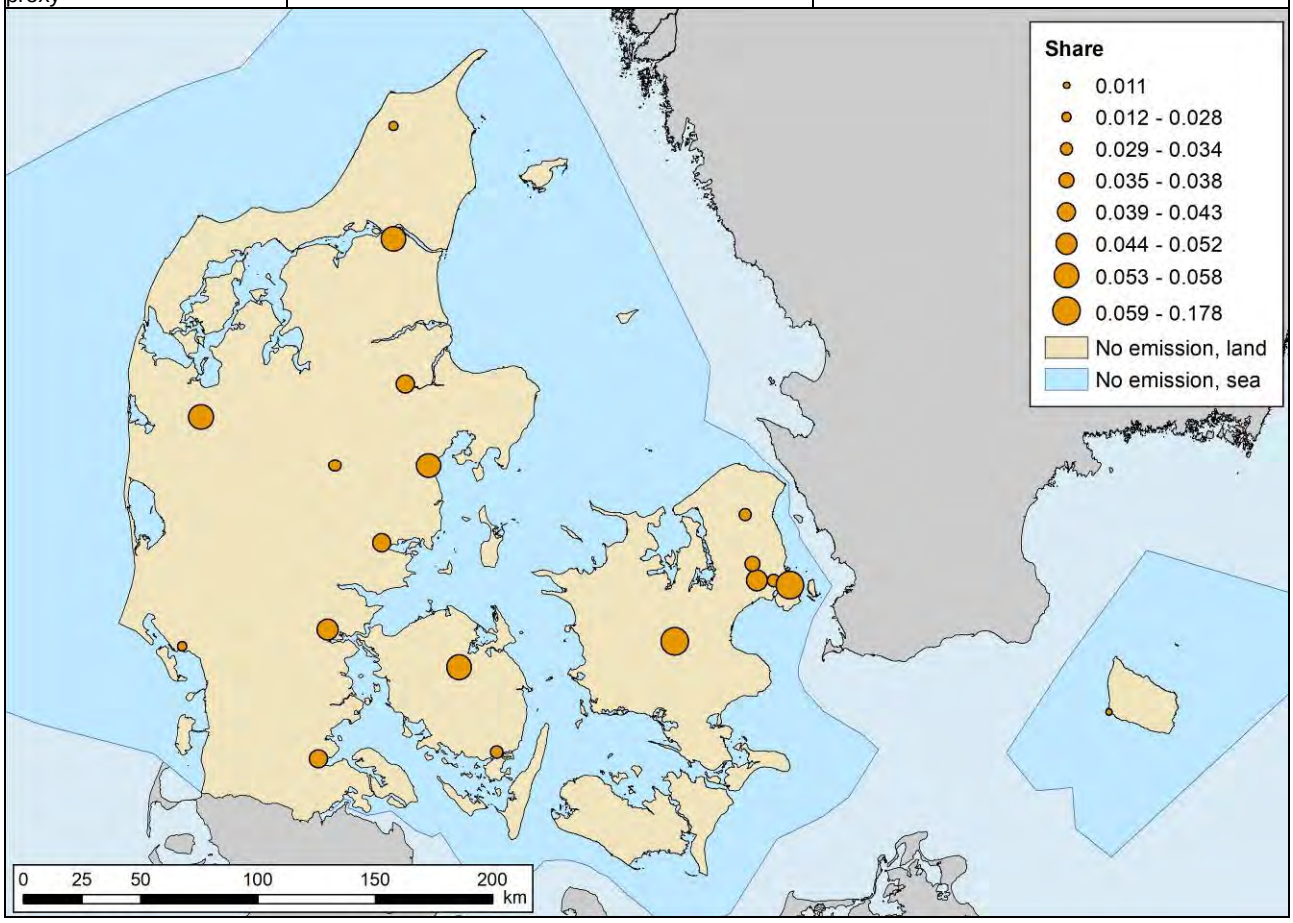
Human cremations

The emissions from human cremations are for the majority of pollutants negligible. An exception is mercury, where the share of national total emissions are significant in the early years of the time series. In later years, the share has decreased due to legislation requiring the installation of abatement equipment at the crematoria. Further, emissions of PCBs are considerable.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty since the exact location and the number of cremated bodies are known. The spatial applicability is considered good since the coverage is complete.

Table 5.131 GeoKey for human cremations.

Source data	Address and activity data for crematoria			
Data provider	Danish crematoria National Association			
Projection	ETRS89 UTM zone 32N			
Data description	Address and annual activity data for human crematoria			
Workflow	The GeoKey is calculated as share of total activity by crematorium and summarised by 1 km x 1 km grid cell.			
GeoKey name	_Key_090901_Cremation			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %		Hg	
	1-5 %	Hg	PCBs	PCBs
	< 1 %	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP	SO_2, NO_x, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	090901 Incineration of corpses		2	



Animal cremations

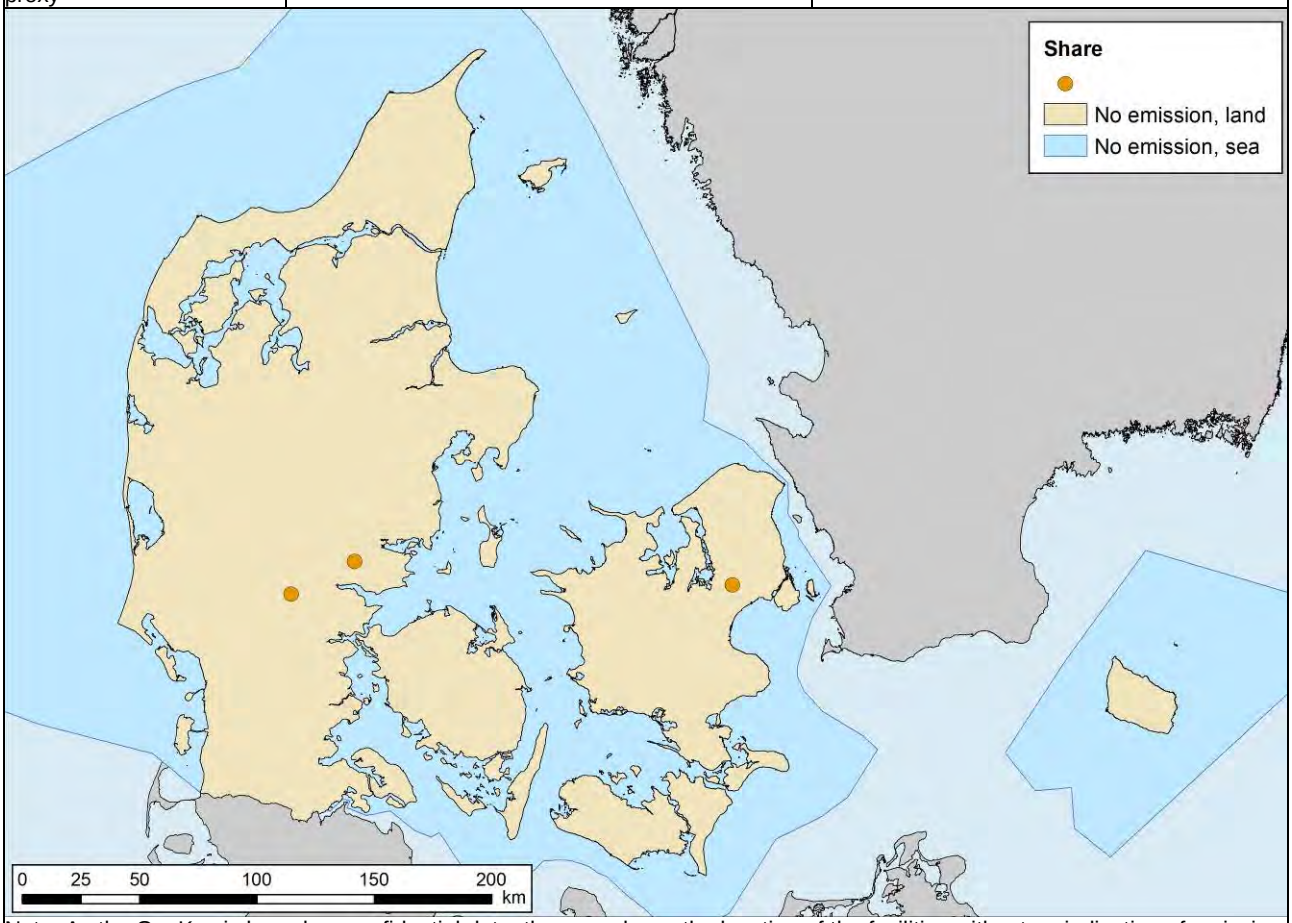
Animal cremations only occur at very few facilities. As the data on the annual activity level have been received on the condition of confidentiality, the map below simply identifies the location of the facilities without an indication of the distribution in activity data between the three sites. Emissions from animal cremations have a negligible impact on the national total emissions.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty since the exact location and the amount of cremated animals are

known. The spatial applicability is considered good since the coverage is complete.

Table 5.132 GeoKey for animal cremations.

Source data	Address and activity data for animal crematoria			
Data provider	The Danish pet crematoria			
Projection	ETRS89 UTM zone 32N			
Data description	Address and annual activity data for animal cremation			
Workflow	The GeoKey is calculated as share of total activity by animal crematorium			
GeoKey name	_Key_090902_AnimalCremation			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			PCBs
	< 1 %	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP, PCBs	SO_2, NO_x, NMVOC, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$, As, Cd, Cr, Cu, Ni, Pb, Se, Zn, HCB, PCDD/F, BbF, BkF, BaP, IcdP
Quality of spatial dataset	A			
Applicability as spatial proxy	090902 Incineration of carcasses		2	



Note: As the GeoKey is based on confidential data, the map shows the location of the facilities without an indication of emission shares.

5.7.4 Wastewater handling

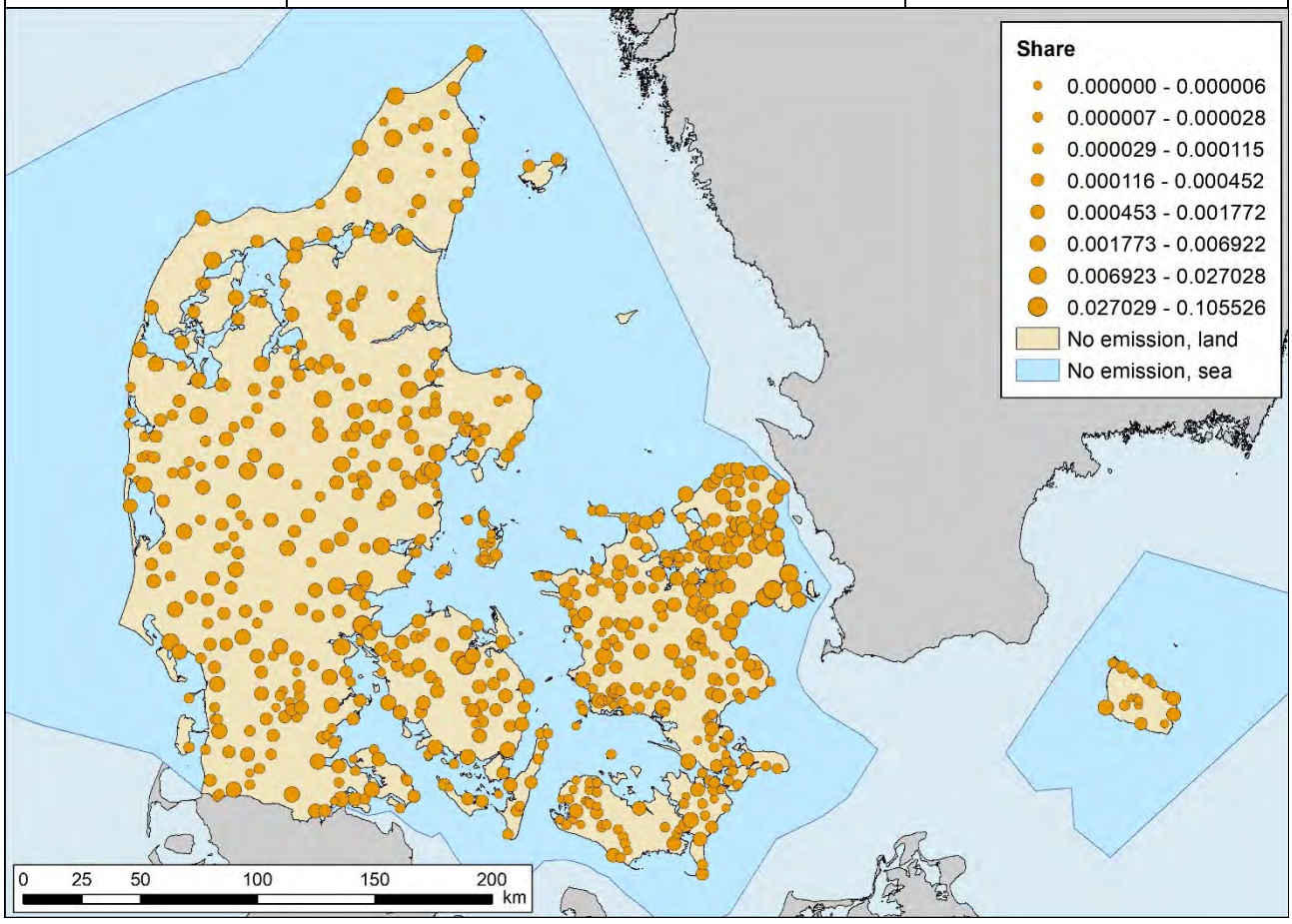
Monitoring data on the influent and effluent, e.g. BI5 (five days oxygen consumption) for the wastewater are available for all waste water treatment plants (WWTPs) in Denmark reported by the Danish Nature Agency, the National Focal Point for point sources. The GeoKey is based on annual BI5 data for the wastewater treatment plants. BI5 is an expression of the amount of

biologically easily degradable organic matter, which enters with the inlet wastewater and is treated at the individual plant.

The spatial dataset used for the GeoKey is considered to have a very low uncertainty as it represents plant specific measurements data. The spatial applicability is considered fair.

Table 5.133 GeoKey for wastewater handling.

Source data	Plant specific BI5 data			
Data provider	The Danish Nature Agency			
Projection	ETRS89 UTM zone 32N			
Data description	Annual BI5 data per waste water treatment plant			
Workflow	The GeoKey is calculated as share of total BI5 for each wastewater treatment plant, and aggregated to the 1 km x 1 km Danish grid net			
GeoKey name	_Key_WasteWater			
Year dependent	Yes			
Pollutant dependent	No			
Share of national emission		1990	2005	2019
	> 10 %			
	5-10 %			
	1-5 %			
	< 1 %	NMVOC	NMVOC	NMVOC
Quality of spatial dataset	A			
Applicability as spatial proxy	091001 Industrial wastewater handling			3
	091002 Domestic wastewater handling			3



5.7.5 Other waste

Emissions from other waste handling include emissions from accidental fires. The emissions from fires in the Danish inventory are based on different building types, and vehicles are considered as a separate category.

Currently, emissions from fires in industrial buildings are distributed evenly on the industrial areas; see Chapter 5.1.2. The emissions from all other types of fires listed in Table 5.128, are distributed using the GeoKey for population; see Chapter 5.1.1.

6 Spatial distribution of national emissions

Based on the GeoKeys documented in Chapter 5 and the national emission inventory, the gridded emissions are calculated and outputs are generated from the model. These outputs are imported to ArcGIS to create emission maps. The outputs are created for several different purposes, e.g. for reporting to the UNECE and the European Commission (0.1 degree x 0.1 degree and Gridding Nomenclature for Reporting - GNFR) and for the national modelling of air pollution (1 km x 1 km and at a more detailed level than the GNFR).

Some examples of the resulting emission maps are included below for some of the most important pollutants together with comments and an explanation of the spatial patterns.

6.1 Nitrogen oxides – NO_x

Figure 6.1 shows the NO_x emission in 2019 distributed on 1 km x 1 km. Clearly visible are the major road network in Denmark, the large metropolitan areas especially around Copenhagen, Aarhus, Aalborg and Odense and ferry / airline routes. The major sources of NO_x emissions are distributed using GeoKeys with very low or low uncertainty and with very good or good applicability. However, there are still room for improvement for certain categories, see Chapter 9.1.

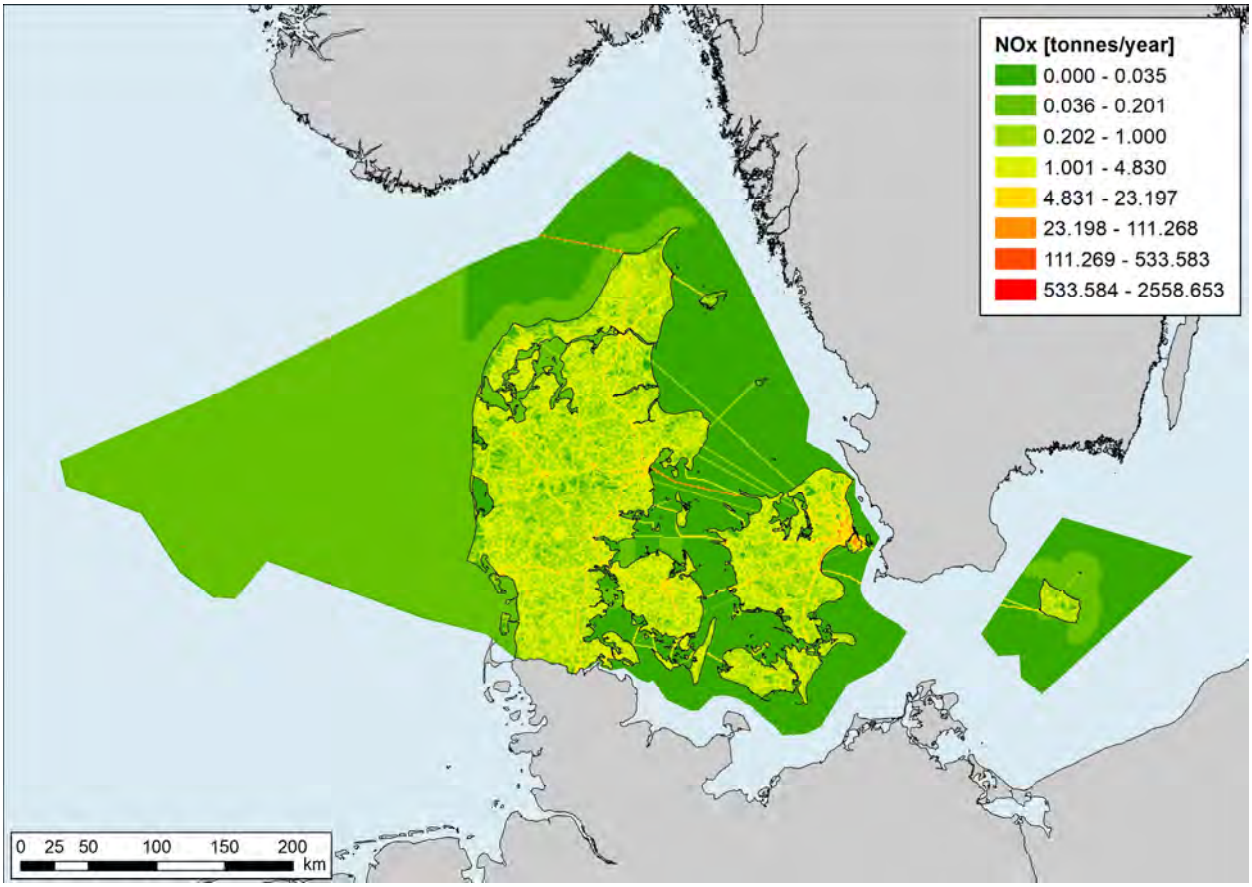


Figure 6.1 Gridded emissions of NO_x for 2019.

6.2 Sulphur dioxide – SO_2

Figure 6.2 shows the SO_2 emission in 2019 distributed on 1 km x 1 km. Major urban areas are visible as well as ferry / airline routes. However, a large part of the SO_2 emission stems from various industries, either as process emissions (such as production of bricks and tiles) or as combustion emissions from plants using coal or fuel oil. The major part of the emissions in 2019 are distributed with GeoKeys with very low uncertainty and very good applicability, mainly LPS. Many of these emissions are currently distributed using GeoKeys with limited applicability, see Chapter 5.1.2. Planned improvements that would improve the distribution of SO_2 emissions are listed in Chapter 9.1.

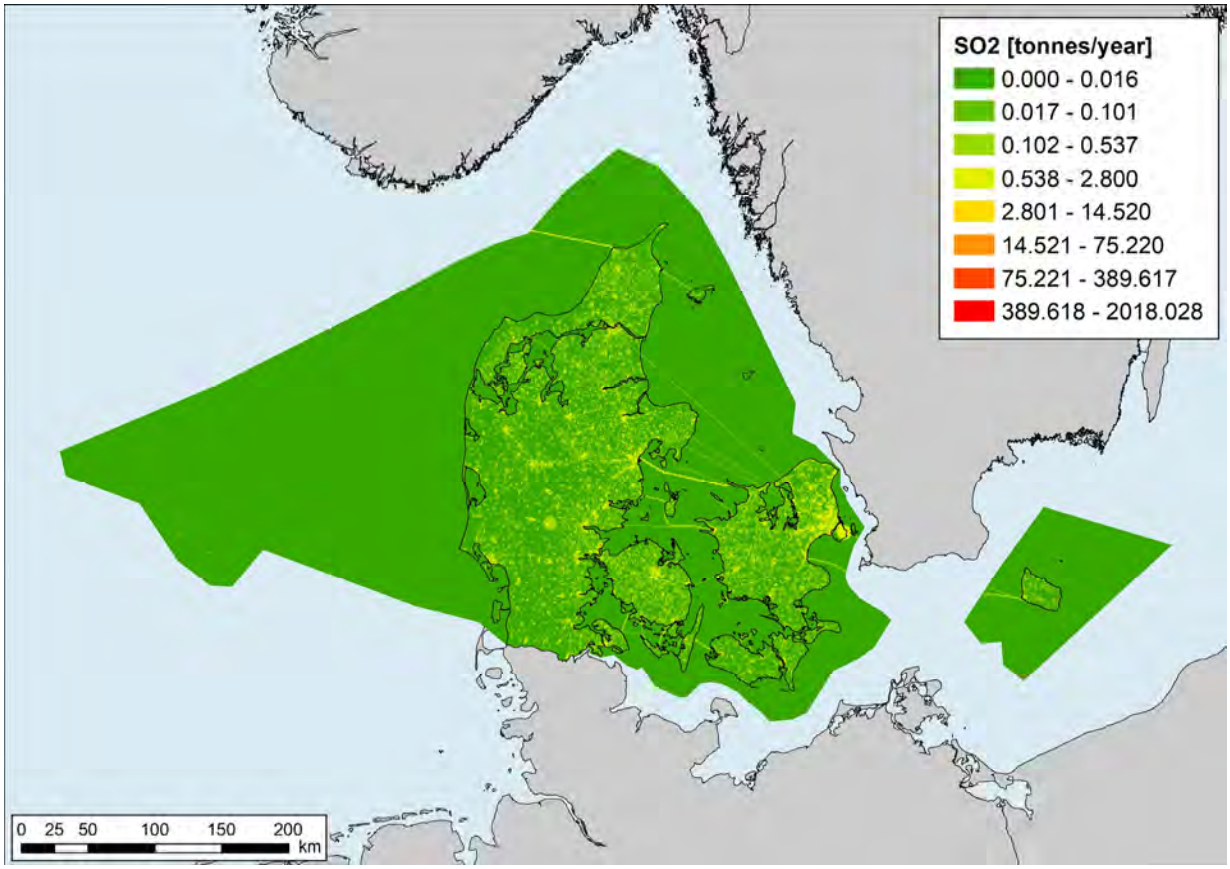


Figure 6.2 Gridded emissions of SO_2 for 2019.

6.3 Non-Methane Volatile Organic Compounds – NMVOC

Figure 6.3 shows the NMVOC emission in 2019 distributed on 1 km x 1 km. There are many significant sources of NMVOC emissions, e.g. agriculture, use of solvents, residential combustion, oil / gas industry and gasoline fuelled machinery. The major part of the emissions in 2019 are distributed with GeoKeys with very low uncertainty. For most of these emissions, the GeoKeys have good or fair applicability, while GeoKeys with poor applicability are used for a significant part of these emissions. There are planned improvements addressing a number of sources, see Chapter 9.1.

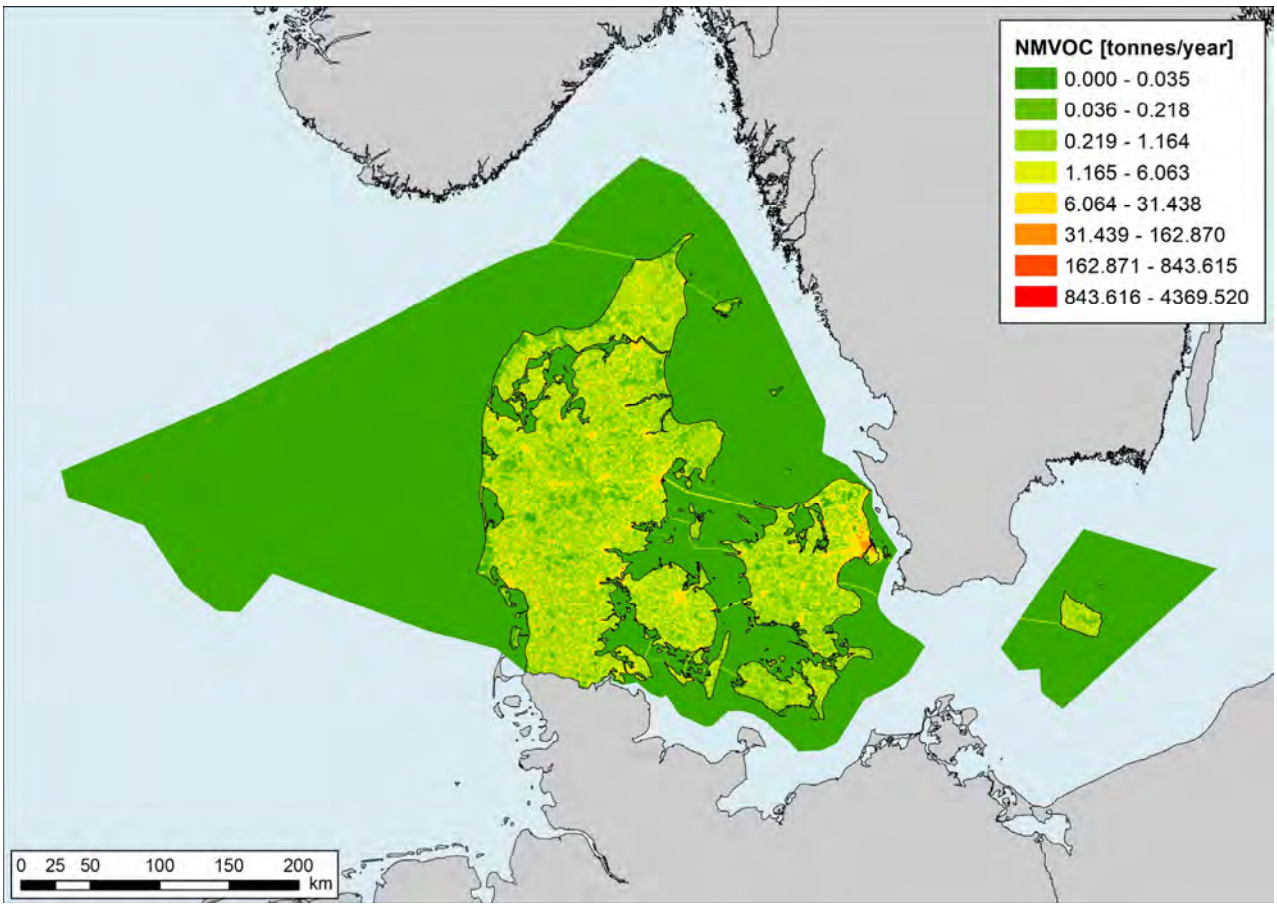


Figure 6.3 Gridded emissions of NMVOC for 2019.

6.4 Ammonia – NH_3

Figure 6.4 shows the NH_3 emission in 2019 distributed on 1 km x 1 km. Emissions of NH_3 is dominated by the agricultural sector with small contributions from small scale combustion and waste treatment. As such, the distribution of NH_3 emissions closely follows the density of livestock production. The agricultural emissions are distributed using the excellent register data available for the Danish agriculture and the distribution is therefore considered very accurate. Therefore, there are no planned improvements that would significantly change the distribution of NH_3 emissions.

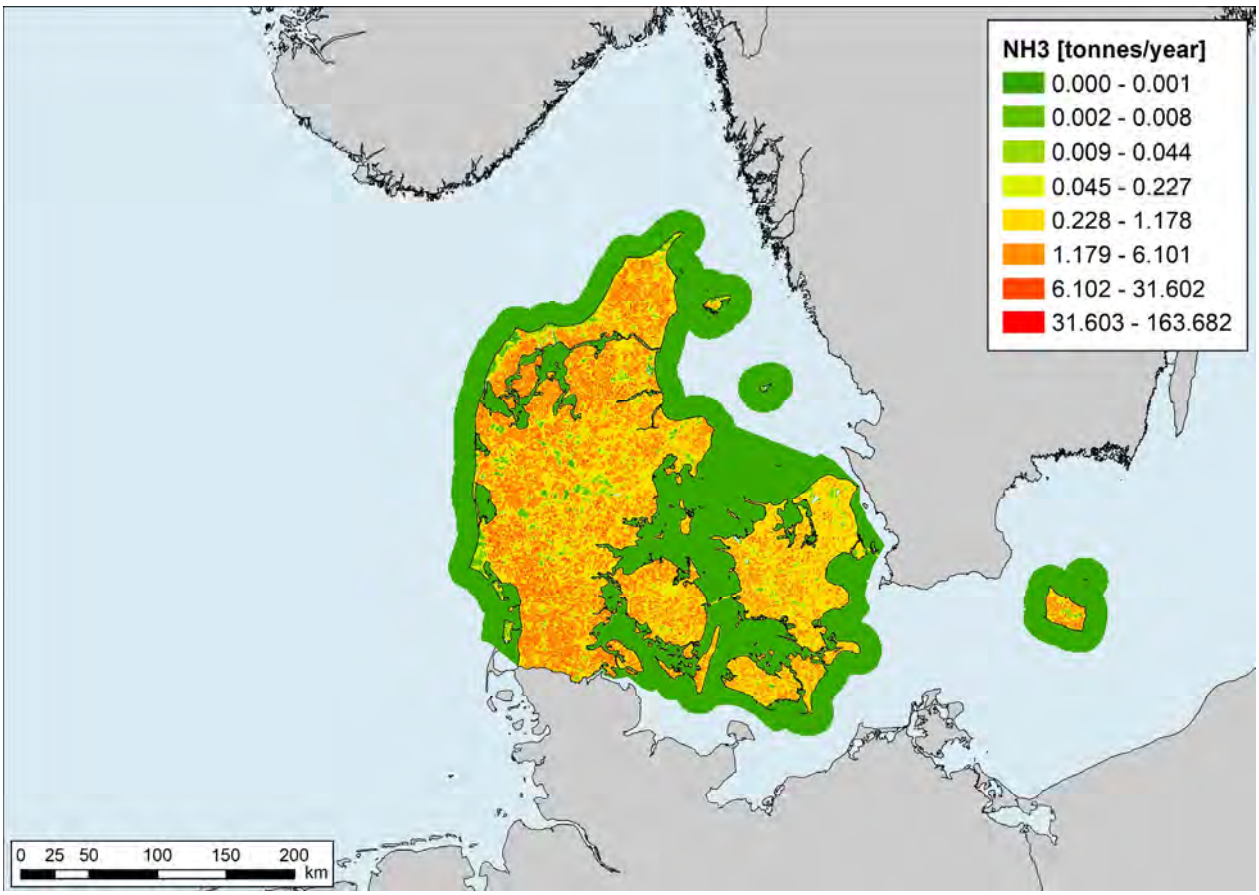


Figure 6.4 Gridded emissions of NH_3 for 2019.

6.5 Fine particulate matter – $PM_{2.5}$

Figure 6.5 shows the $PM_{2.5}$ emission in 2019 distributed on 1 km x 1 km. The $PM_{2.5}$ emissions are dominated by small-scale combustion, especially wood and straw, but there is also significant contributions from road transport, industrial machinery and agriculture. The largest sources are distributed using GeoKeys with low uncertainties and good or fair applicability. See Chapter 9.1 for a description of the planned improvements.

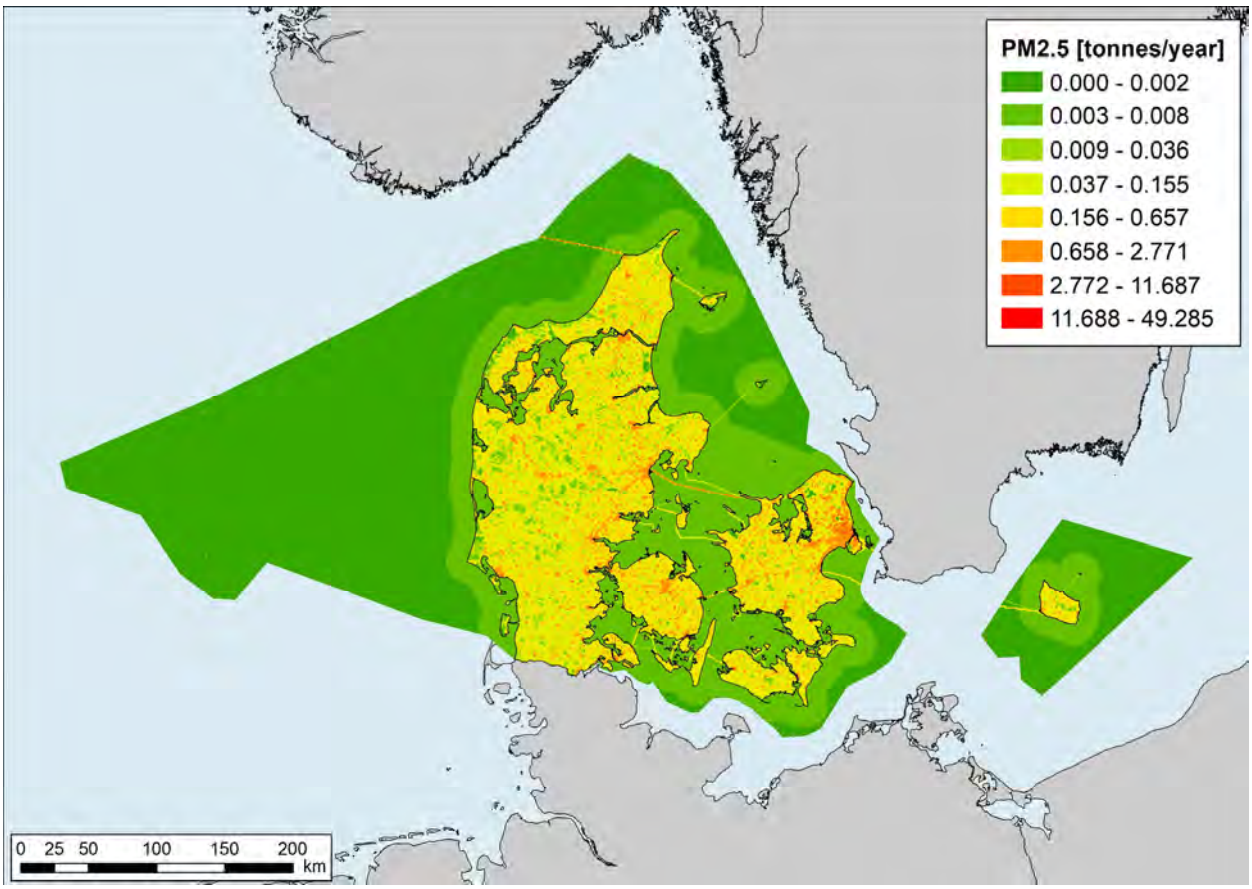


Figure 6.5 Gridded emissions of $PM_{2.5}$ for 2019.

7 Adherence to international requirements

7.1 Reporting obligations

Under both the CLRTAP (UNECE, 2015) and the NECD (EU, 2016), there is an obligation to report gridded emissions. The requirements are identical and therefore described together in this report.

The obligation is to report gridded emissions every four years by 1 May on the EMEP grid according to GNFR sectors (Gridding Nomenclature for Reporting). The EMEP grid refers to a 0.1°×0.1° latitude-longitude projection in the geographic coordinate World Geodetic System (WGS) latest revision, WGS 84. The EMEP domain covers the geographic domain between 30°N–82°N latitude and 30°W–90°E longitude. The first reporting was due in 2017, this report refers to the reporting in 2021, and the next reporting is due by 1 May 2025.

The spatial distribution of emissions should be carried out in accordance with the guidance provided by the EMEP / EEA Guidebook (EEA, 2019), see Chapter 7.2 for more details.

As mentioned, Parties / Member States (MS) are obligated to report every four years from 2017 onward. Parties / MS shall report for the year x-2 updated aggregated sectoral (GNFR) gridded emissions. The submission shall include the following pollutants: SO_2, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, Cd, Pb, Hg, PAHs, PCDD / F, PCBs and HCB. The NECD further requires reporting of BC, if available.

While the reporting under the UNECE and the NECD are identical, it is technically reported twice. The latest reporting of gridded emissions can be found at the Eionet (European Environment Information and Observation Network) Central Data Repository:

- UNECE: http://cdr.eionet.europa.eu/dk/un/clrtap/gridded/
- NECD: http://cdr.eionet.europa.eu/dk/eu/nec_revised/gridded/

7.2 Technical guidance

The EMEP / EEA Guidebook (EEA, 2019) provides guidance on spatial distribution of emissions. The Guidebook lists a number of elements as 'good practice'. These are shown in Table 7.1 together with an assessment of how the element is incorporated in SPREAD.

Table 7.1 Good practice elements from the EMEP/EEA Guidebook.

	Good practice element	SPREAD adherence
1	Use key category analysis (KCA) to identify the most important sources and give the most time to these.	At present, a KCA is not carried out for the Danish gridded inventory. However, efforts are prioritised for sources with large contributions to total emissions. In Chapter 5, it has for each GeoKey been listed the share of the national total emission that is distributed using the particular GeoKey.
2	Make use of GIS tools and skills to improve the usefulness of available data. This will mean understanding the general types of spatial features and possibly bringing in skills from outside the existing inventory team for the production/manipulation of spatial datasets.	This is documented in Chapter 3, 4 and 5.
3	Make use of existing spatial datasets and carefully consider the merits versus costs of extensive new surveying or data processing to derive new spatial datasets. It is often more important to generate a timely dataset based on less accurate data than a perfect dataset that means reporting deadlines are missed or all resources are consumed.	The rating system used for both the accuracy and applicability of the spatial proxy as well as contribution to emissions, enables the judgement on where to prioritise resources.
4	Select the proxy data that is judged to most closely represent the spatial emissions patterns and intensity, e.g. for combustion sources, proxy spatial datasets that most closely match the spatial patterns of fuel consumed by type should be chosen.	For each GeoKey, the applicability is assessed and scored.
5	Proxy spatial datasets that are complete (cover the whole national area) should be preferred.	This is documented in Chapter 5.
6	If new data are not available each year, then continue to use the previous years' spatial data until a new dataset is available. This is to guarantee consistency.	The GeoKeys in SPREAD are either used for the entire time series, or they are based on detailed annual data allowing for a GeoKey time series.
7	When updating a spatial inventory it is often not possible to update all the spatial datasets every year (for economic reasons). A data acquisition plan (DAP) can describe which proxy data is updated with which frequency, depending on its importance, costs and variation in time.	The SPREAD model uses annual GeoKeys to the extent possible. As part of the planned improvements, it is considered whether it is feasible to move to annual GeoKeys, see Chapter 9.1.
8	Issues relating to non-disclosure may be encountered (at a sectoral or spatial level) that may impose barriers to acquiring data (e.g. population, agriculture, employment data). As only highly aggregated output data is needed for reporting, signing of non-disclosure or confidentiality agreements or asking the data supplier to derive aggregated datasets may improve the accessibility of this data. It is important that issues relating to this are identified and dealt with in consultation with the national statistical authority.	As mentioned, SPREAD runs at a resolution of 1 km x 1 km, and at that resolution, we have not had any issues with confidentiality. We have received confidential datasets, but these are aggregated with other data to protect the data confidentiality.
9	It is advisable to consider the resolution (spatial detail) required in order to meet any wider national or international uses. Aggregation to the present EMEP 0.1 x 0.1 degree longitude/latitude grid could be done, for example, from more detailed spatial resolutions that might be more useful in a national context. Most nationally reported emissions datasets are based on national statistics and are not resolved spatially in a manner that could be readily disaggregated to the required 0.1 x 0.1 degree EMEP grid. Possible exceptions in some countries are detailed road transport networks and reported point source emissions data.	SPREAD runs at a resolution of 1 km x 1 km and this is judged as sufficient for the main use, which is to form the basis of air quality modelling and subsequent evaluations of human exposure.
10	When the budget is very limited, available international datasets can act as a starting point when they are used as proxy data for the spatial allocation of the national total for some sectors. The limited resources can then be used for the most relevant sectors.	Not relevant.

The general approach, as outlined in the Guidebook, is first to separate between point sources (PS) and diffuse emission (or area sources, AS) (Figure 7.1). Generally, SPREAD follows this principle. However, as outlined in Chapter 5, there are several distinct types of PS. Some are used with emission information, e.g. LPS, while other point source data are used for developing the GeoKey.

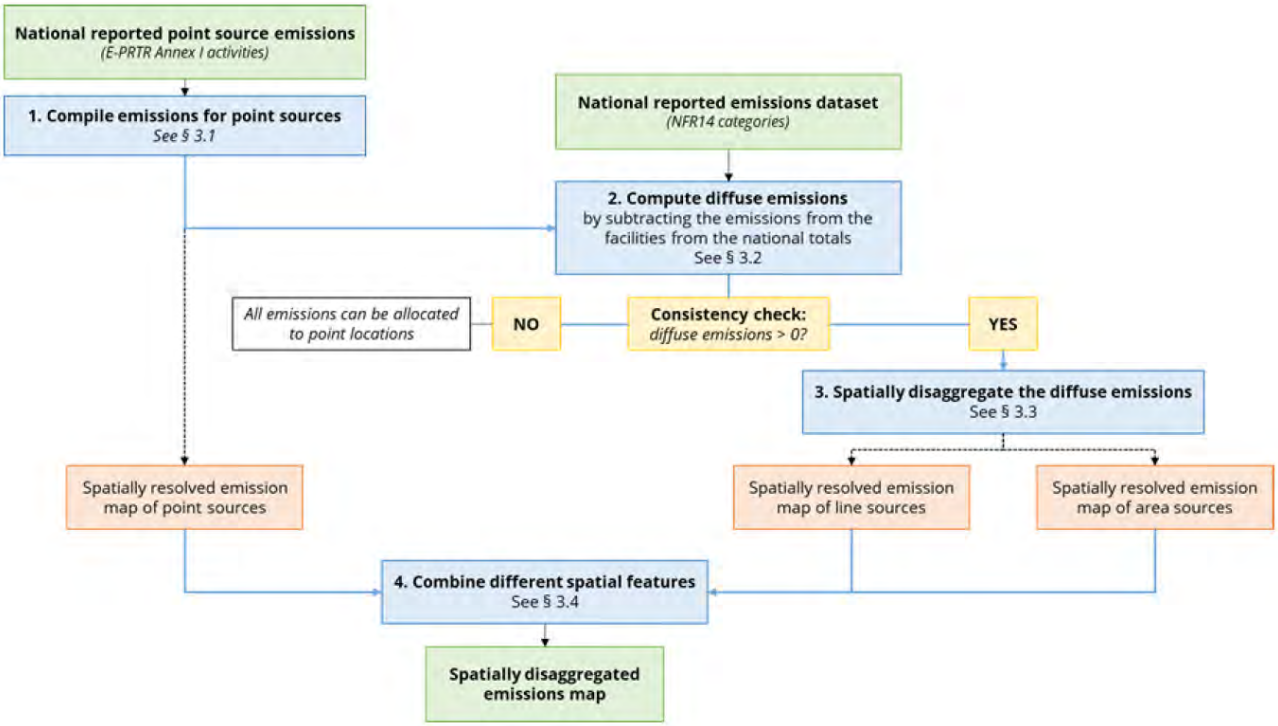


Figure 7.1 General approach for compiling a spatial emission inventory (EEA, 2019).

The Guidebook presents a decision tree for emissions mapping (Figure 7.2). In general, the SPREAD model uses methods that are mostly considered as tier 3 or tier 2 methodologies. In some cases, the authors of this report disagrees with the tier levels indicated in the Guidebook. For example, in many instances, the tier 2 methodology is listed as employment statistics. The employment in certain branches of industry says very little on the emission intensity, in some cases employment will be registered at a main office, which in many cases can be located elsewhere than the production site. Population is listed as tier 1 in the decision tree (Figure 7.2). This might be true in many cases, but exceptions are e.g. use of candles, where population is found an appropriate proxy.

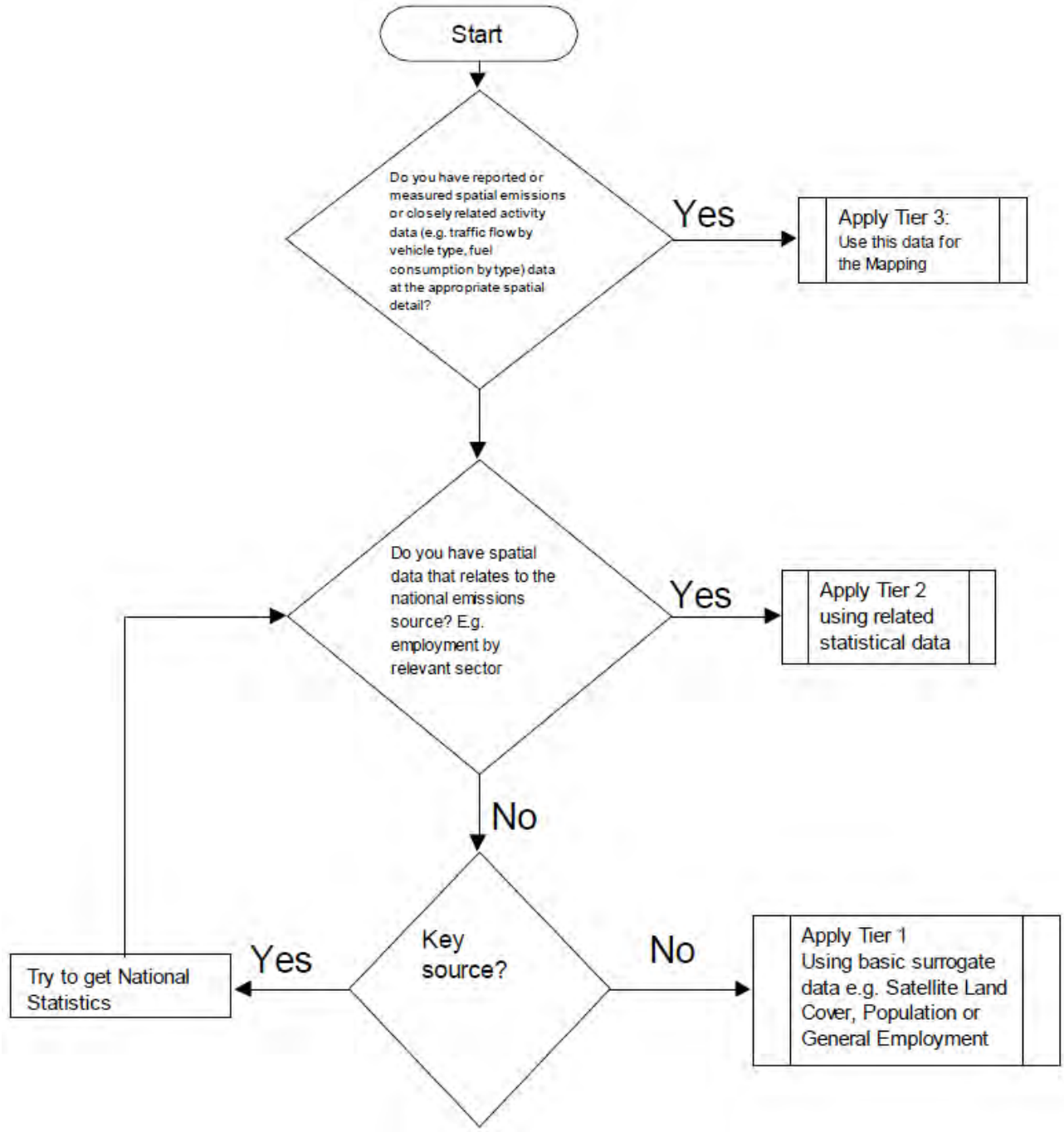


Figure 7.2 General decision tree for diffuse emissions mapping (EEA, 2019).

Due to the disagreement in defining the tier levels, the tiers have not been included in the description of the GeoKeys in Chapter 5. Instead, the quality of the spatial data as well as the applicability of the spatial data as spatial proxy have been assessed for each GeoKey. The system for ranking the quality and applicability is explained in Chapter 5 (Table 5.1 and Table 5.2).

8 Discussion

Since the development of SPREAD in 2010, a number of improvements have been carried out. The improvements have been made possible through various advisory and research projects, where the aim of the projects has been to improve certain aspects of SPREAD. These improvements have mainly focussed on small combustion, industrial processes and non-road mobile sources as well as making design changes to the model to ensure, that it can perform better and deliver the requested outputs.

However, as highlighted in Chapter 9, there is still plenty of opportunities for further improvement of the model. When considering possible improvements, focus should be given to several aspects, i.e. the uncertainty of the spatial proxy, the applicability of the spatial proxy to a given emission source and the emission impact of a given source.

In Chapter 5, when describing the GeoKeys, an assessment has been made of the uncertainty of the GeoKey as well as an assessment of the applicability of the spatial proxy to the emission source. Finally, the share of the Danish emissions that have been spatially distributed using each GeoKey has been presented. The combination of the uncertainty, spatial applicability and share of emissions distributed will be used in prioritising the planned improvements described in Chapter 9.1.

At the moment, there is no plans to increase the spatial resolution as 1 km x 1 km is deemed sufficient. Firstly, the resolution is sufficient to meet the reporting requirement under international obligations (Chapter 7.1), and secondly the resolution is considered high enough to be used in air quality modelling and human exposure studies.

It could be considered to introduce a temporal component to the SPREAD model as this is often sought after by modellers. However, at the present time resources have not been available to develop temporal profiles for Denmark.

For a complex model system such as SPREAD, it is important to make verification of the output. Verification can focus on the overall results or on parts of the model system, e.g. a sector, a case area or a pollutant. Comparison of modelled air quality, based on the spatial emissions, and air quality measurements is often the best way to verify the spatial emissions. Due to the limited number of measurement sites, it is only possible to verify the model for relatively few locations. Comparison of modelled and measured air quality can provide valuable information that can be used to improve the spatial distribution of emissions, e.g. by identifying emission sources that are over- or underestimated on a given location. Depending on the source characteristics, the spatial distribution can be changed to reflect local conditions better.

When the first version of the SPREAD model was finalised, the urban level air quality modelling improved significantly compared with measurements. Before, gridding of Danish emissions was prepared on 17 km x 17 km resolution for national air quality modelling. The high resolution applied in SPREAD contributed to improve the national air quality modelling. Gridded emissions from SPREAD were applied in two Danish air quality models, the Danish Eulerian Hemispheric Model, DEHM (Christensen, 1997; Brandt et al., 2012) and

the Urban Background Model, UBM (Brandt et al., 2001; Brandt et al., 2003). The performance of the latter did significantly improve, leading to less deviation between modelled and measured concentrations in selected urban areas. Before the SPREAD model was developed, the UBM model was run using only traffic emissions. This was a problem especially for the city of Aalborg, where the traffic emissions only constituted approximately 18 % of the total emissions. Spatial emissions data for other sectors were not available. Furthermore, the old traffic emissions, which were based on rough assumptions, were approximately 25 % lower than the new traffic emissions for the SPREAD model. In general, the model was underestimating the measured values using the old emissions based on traffic, since the old traffic emissions were underestimated and the other sectors were missing. With the new emissions from SPREAD, the UBM model performance improved significantly, so that the modelled annual mean values of NO_x and NO_2 were within +/- 20% of the mesurements for the four cities modelled.

Some emission sources have a varying and upredictable pattern regarding amounts and spatial location, which is not possible to reflect in the model. An example is building and construction machinery where the activity depends on where construction and maintenance work take place. In a project funded by the Danish Environmental Protection Agency ('Luftforurening fra mobile ikke-vejgående maskiner i byområder' – 'Air pollution from non-road machinery in urban areas'), it was identified that especially two large building projects were not reflected in the spatial emissions. When focusing on a case area it can be possible and important to include such emission sources, while they cannot be incorporated on national level, as the nessecary data are not available.

In another project funded by the Danish Environmental Protection Agency ('Luftforurening fra togdrift i byområder' – 'Air pollution from railways in urban areas'), it was found that the measured air pollution concentrtions were higher than the estimated concentrations for a specific site. In this case, the measurement station is located near a larger shunting area, which was not included in the spatial distribution for railways. The finding lead to an improvement of the railway GeoKey to include all tracks, and not only main tracks as was the case for the old GeoKey. This change improved the correspondence between modelled and measured emissions for the current location.

In a project funded by the Municipality of Copenhagen ('Brændeovnes bidrag til luftforurening i København' – 'Wood stoves contribution to air pollution in Copenhagen), a study was made for residential wood combustion in Copenhagen, e.g. comparing data from different data sources. In the national emission inventory it was assumed that there were 750 000 woodstoves in Denmark. Detailed data from the Danish chimney sweepers in Copenhagen show that the total number of woodstoves in Copenhagen is 16 349, which corresponds to 2.18 % of the woodstoves in Denmark. In the BBR register only 12 068 woodstoves is identified in Copenhagen, indicating and underestimation of approximately 25 % compared to the number from the chimney sweepers. Following, the chimney sweeper data have been included to improve the national emission inventoryin and the spatial distribution for small combustion.

Results from a survey focusing on residential wood consumption in Copenhagen was published in 2015 (Andersen, 2015). This indicated that the residential wood consumption in Copenhagen comprised 0.72 % of the national residential wood consumption, and that the unit consumption in Copenhagen is lower than the national average unit consumption. This seems reasonable, as there is almost complete coverage of district heating and more difficult access to store fuel wood in apartment buildings. This has been implemented in the emission inventory through weighting factors.

Generally, a higher spatial resolution allow for more detailed and accurate spatial emissions. In the 2014 guidelines for reporting under the LRTAP convention, the requirement for reporting of gridded emissions were changed, and from 2017 onwards, gridded emissions shall be reported on a spatial resolution of 0.1 degree x 0.1 degree (~10 km x 6 km for Denmark) instead of previous resolution of 50 km x 50 km.

In 2018, the Meteorological Synthesizing Centre - West (MSC-W) made a comparison of the correlation between modelled and measured concentrations for Parties to the LRTAP Convention. For most Parties the shift to the higher resolution spatial emissions improved the correlation for PM_{10} (Figure 8.1), among which is Denmark.

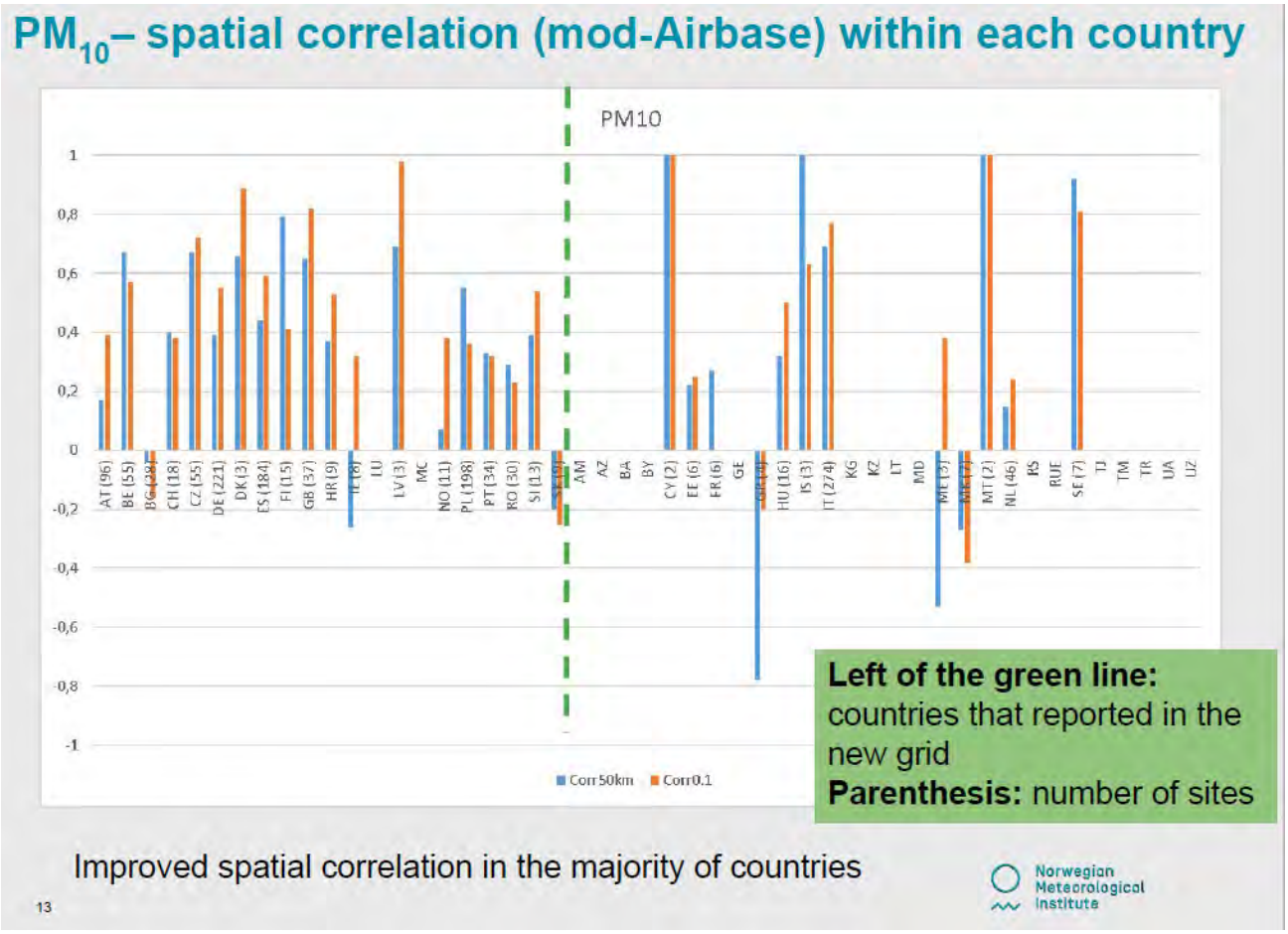


Figure 8.1 Correlation of measured and modelled PM_{10} concentrations (MSC-W, 2018). Blue lines refer to the 50 km x 50 km grid and red lines refer to the 0.1° x 0.1°.

A separate comparison for Denmark showed that the correlation between modelled and measured NO_2 concentrations significantly improved with the new higher resolution spatial emissions (Figure 8.2).

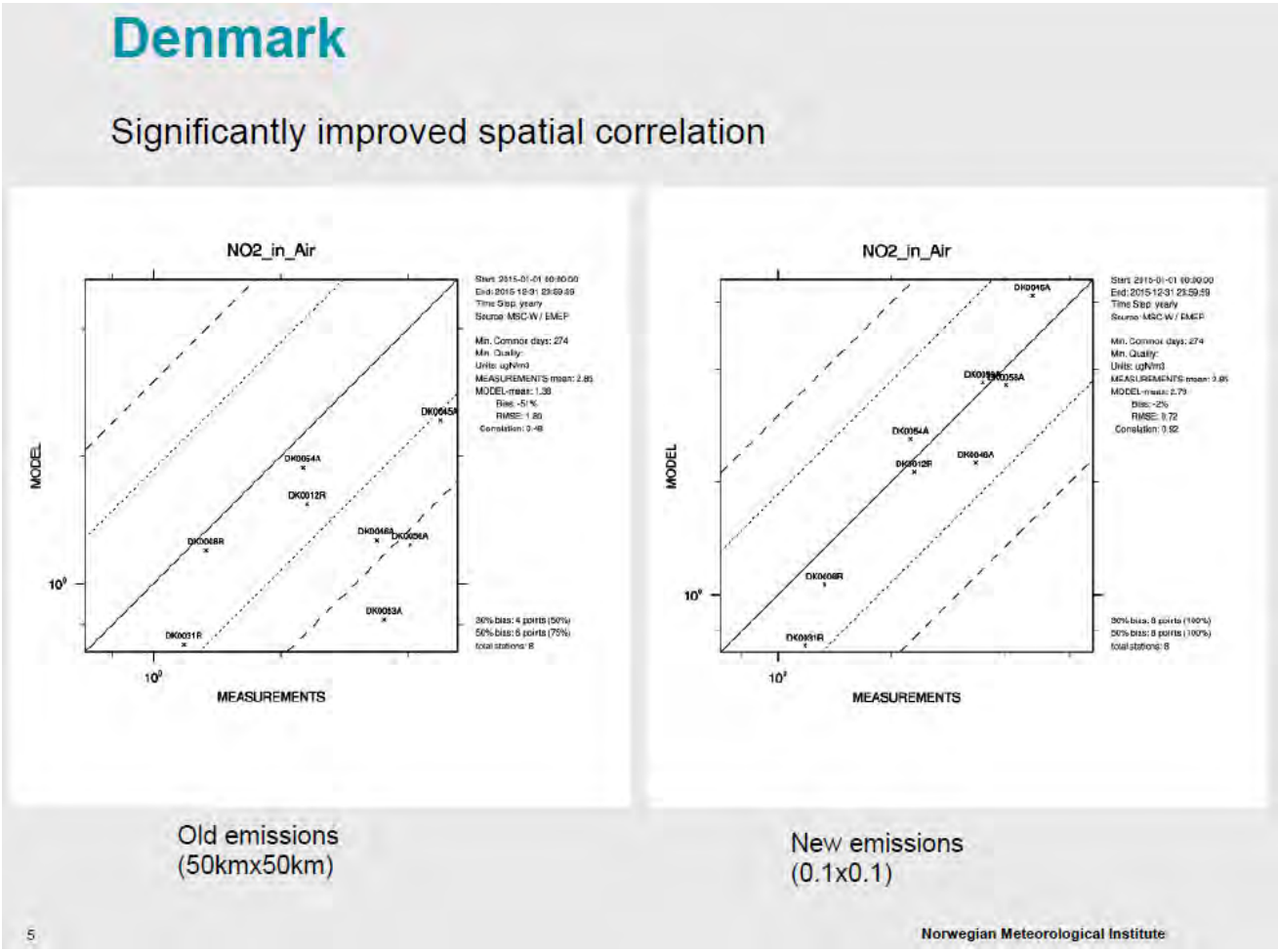


Figure 8.2 Correlation of measured and modelled NO_2 concentrations (MSC-W, 2018). Old emissions: measurements mean = 2.85, Model mean = 1.39, correlation = 0.48. New emissions: measurements mean = 2.85, Model mean = 2.79, correlation = 0.92.

9 Planned improvements

The work on improving the SPREAD model is continuous. However, significant improvements relies on resources from projects and hence it is not possible to have a specific timeline for the implementation of the identified improvements.

In Chapter 9.1, a number of potential improvements has been identified. In some cases, the necessary data are available but is not yet implemented 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 SPREAD.

Furthermore, the SPREAD model only covers the air pollutants and not greenhouse gases. Consequently, sources that only emit greenhouse gases are not included in SPREAD.

An improvement plan is made for SPREAD, including issues revealed when updating and running the model. The issues for improvement are prioritised according to importance and the ease of implementation, i.e. the size of the emissions source (share of national total), the quality and applicability of the present GeoKey compared to the improved GeoKey, and the easiness of making the improvement. This means that an improvement for a GeoKey used for only minor emission sources can be of high priority if the update is relatively easy to make. Other high priority improvements necessitate considerable workload to identify, select and analyse spatial data sets and to build and incorporate new GeoKeys in the SPREAD model system.

Most improvements relate to a single source or sector, while other refer to the model system. Improvements to the model system are made to improve calculation speed and minimise the risk for user-introduced errors.

Another issue related to model improvements is the framework. Due to the reporting requirements for gridded emissions to the CLRTAP convention, the area is limited to the EEZ. As mentioned earlier, this require that emissions from navigation and aviation, which occur outside the EEZ, needs to be allocated to areas inside the EEZ. For modelling purpose, it is relevant to build an alternative SPREAD model, which are not limited to the Danish EEZ area, but where emissions from e.g. ferries between Denmark and Greenland are allocated to the entire route and not only the part of the route that falls within the Danish EEZ.

The quality of the spatial data set is crucial when generating a GeoKey. The quality of spatial data depend on how well the spatial pattern reflect real life. If shapes are generalised they may not reflect the pattern correct, which can be the case for e.g. land-use maps and infrastructure networks. Another parameter is the update frequency and / or the latest update of the data. This is most important for parameters with large variations over time, e.g. heating type or land use, while it is less important for parameters with minor and / or slow changes over time, e.g. the gas transmission network or military training areas. Few spatial datasets like coastline and the EEZ does not under normal conditions change over time.

The planned improvements of the GeoKeys are described by sector in the following chapters.

9.1 Refinement of GeoKeys

There is potential for further refinement and improvement of many of the GeoKeys currently used. For each main sector, the GeoKeys used have been assessed below regarding their uncertainty, applicability and contribution to the national total emissions. Planned improvements are assigned a priority based on a combination on the elements mentioned above as well as whether data to improve the GeoKey is known to be readily available.

9.1.1 Stationary combustion

The GeoKeys used for stationary combustin are listed in Table 9.1. Most of the GeoKeys are based on spatial data of medium quality or better. The spatial data for manufacturing plants and for commercial and institutional plants using liquid and solid fuels have high uncertainty.

Table 9.1 Quality of spatial dataset by GeoKey for stationary combustion (excl. LPS).

GeoKey	Quality of spatial dataset	Applicability of GeoKey	Highest contribution to national emission in 2019
_Key_010306_AS	A	2 (3)	
_Key_010504_OffshoreGasturbines	A	1	1-5 % (NO_x)
_Key_EPT	A	1	>10 % (SO2, PCBs)
_Key_0202_Solid	B	2	5-10 % (TSP, Hg, Pb, HCB)
_Key_0203_Solid	B	2	5-10 % (IcdP)
_Key_02_Straw	B	3	>10 % (PM2.5, BC)
_Key_0201_Gas	C	3	<1 % (all pollutants)
_Key_0202_Gas	C	3	1-5 % (As, Hg)
_Key_0202_Liquid	C	3	<1 % (all pollutants)
_Key_0203_Gas	C	3	<1 % (all pollutants)
_Key_0203_Liquid	C	3	<1 % (all pollutants)
_Key_0201_Liquid	D	3	<1 % (all pollutants)
_Key_0201_Solid	D	3	1-5 % (PCDD/F, PAH)
_Key_Industry	D	4	<1 % (all pollutants)

Emissions from LPSs are based on plant specific data with very low uncertainty and very good applicability. Still distribution of LPS emissions could be improved for 1990, as only few plants are treated as LPS before 1994. This causes emissions from LPSs, which is a rather large source, to be distributed using the EPT GeoKey for 1995 as a proxy. This can be improved by extending the time series for LPSs back to 1990 to the extent possible based on the availability of data and other information.

The GeoKeys for commercial and institutional plants are based on the BBR, which have large uncertainties regarding heating installations, especially for liquid and solid fuels.

The number of liquid fired plants are generally overestimated in the BBR. The total number of liquid fired plants was estimated to 100 000 by Danish Fuels Industry Association (Drivkraft Danmark, previously Energi og Olieforum (EOF)) in 2015, while the total number based on SFL and BBR data is around

200 000 in 2017. The SFL data include liquid fueled plants that are taken out of use, but still exists on the address, due to the obligation for chimney sweep. The BBR register is only updated if either the property owner report changes, or if the municipality change the heating data e.g. in connection with approval of building projects. Separate data for the commercial and institutional sector are not available, but the tendency is assumed to be similar even if it might be less pronounced compared to the residential sector.

Solid fueld plants are generally underestimated in the BBR, which include around 425 000 woodstoves / fireplaces, compared to the 635 000 woodstoves / fireplaces included in the SFL data. Most woodstoves / fireplaces in the BBR are supplementary heating installations, and both installation and dismantling have to be reported to the register by the property owners, which is often neglected. Therefore, the BBR both includes appliances on addresses where they do not occur and miss appliances on addresses where they do occur. Separate data for the commercial and institutional sector are not available, but the tendency is assumed to be similar even if it might be less pronounced compared to the residential sector.

Despite the uncertainties of the BBR data, this is assumed the best available dataset to use for preparing GeoKeys. Comparisons with other datasets can contribute to qualification of the uncertainty level of the BBR data. However, the GeoKeys can be improved by including newer BBR data and by adding a time series based on BBR data for different years.

Since 2011, energy consumption, data have been included in the BBR based on reportings from the energy utility companies regarding electricity, district heating, natural gas, town gas and fuel oil. Data are not collected for the remaining energy sources (LPG, wood, wood pellets and straw). Depending on the format and completeness of the energy consumption data, it could be used to improve the GeoKeys based on BBR heating information. Fuel consumptions can be used as activity data, which will be an improvement compared to the even distribution on buildings, which is used in the present GeoKeys. For the fuel without fuel consumption data in BBR, heat demand modelling could be used to estimate consumption levels, for use as activity data. Preparing the energy data in the BBR for use in SPREAD is expected to demand a large workload, as energy data are not reported by calender year and following needs to be scaled according to time and e.g. heating degree days. Due to the expected workload, this improvement has low priority.

The GeoKey used for manufacturing plants (_Key_Industry) is based on KORT10 with a very high uncertainty, as areas with industry are often a mix of different landuse (residential, commercial / institutional, agricultural and industrial). Further, it is a landuse class that changes over time, which is not reflected in the GeoKey. It can be evaluated if e.g. production or employment statistics can be used to generate a new GeoKey with a better applicability.

Table 9.2 Planned improvements for stationary combustion.

Improvement priority	Sector	Current GeoKey	Planned improvement
Medium	Agricultural plants	_Key_0203_Gas	Verification of uncertainties of the BBR data. Update with new BBR data. Preparing time series if uncertainties do not exeed the time variations. Assess if energy data in the BBR can be used to improve the GeoKeys.
Medium	Agricultural plants	_Key_0203_Liquid	Verification of uncertainties of the SFL and the BBR data. Update with new BBR data. Preparing time series if SFL data become available for more years. Assess if energy data in the BBR can be used to improve the GeoKeys.
Medium	Commercial and institutional plants	_Key_0201_Gas, _Key_0201_Liquid	Verification of uncertainties of the BBR data. Update with new BBR data. Preparing time series if uncertainties do not exeed the time variations. Assess if energy data in the BBR can be used to improve the GeoKeys.
Medium	LPS	No GeoKey. Based on inventory data	Create LPS distribution for 1990 to replace the present use of the EPT GeoKey for 1995.
Medium	Residential plants	_Key_0202_Gas	Verification of uncertainties of the BBR data. Update with new BBR data. Preparing time series if uncertainties do not exeed the time variations. Assess if energy data in the BBR can be used to improve the GeoKeys.
Medium	Residential plants	_Key_0202_Liquid	Verification of uncertainties of the SFL and the BBR data. Update with new BBR data. Preparing time series if SFL data become available for more years. Assess if energy data in the BBR can be used to improve the GeoKeys.
Low	Agricultural plants	_Key_0203_Solid, _Key_02_Straw	Verification of uncertainties of the SFL and the BBR data. Update with new BBR data. Preparing time series if SFL data become available for more years. Assess if energy data in the BBR can be used to improve the GeoKeys.
Low	Commercial and institutional plants	_Key_0201_Solid	Verification of uncertainties of the BBR data. Update with new BBR data. Preparing time series if uncertainties do not exeed the time variations. Assess if energy data in the BBR can be used to improve the GeoKeys.
Low	Residential plants	_Key_02_Straw	Verification of uncertainties of the SFL and the BBR data. Update with new BBR data. Preparing time series if SFL data become available for more years. Assess if energy data in the BBR can be used to improve the GeoKeys.
Low	Residential plants	_Key_0202_Solid	Verification of uncertainties of the SFL and the BBR data. Update with new BBR data. Preparing time series if SFL data become available for more years. Assess if energy data in the BBR can be used to improve the GeoKeys and/or weighting factors.

9.1.2 Mobile combustion

The GeoKeys used for mobile combustion are listed in Table 9.3. Most of the GeoKeys are based on spatial data with low or very low uncertainty.

Table 9.3 Quality of spatial dataset by GeoKey for mobile combustion.

GeoKey	Quality of spatial dataset	Applicability of GeoKey	Highest contribution to national emission in 2019
_Key_080501_DomLTO	A	2	5-10 % (Pb)
_Key_080502_IntLTO	A	2	1-5 % (SO_2, NO_x)
_Key_0801_Military	A	3	<1 % (all pollutants)
_Key_AgriculturalArea	A	3	5-10 % (BC)
_Key_Buffer_15km	A	3	1-5 % (BC)
_Key_070101_Road_PC_Highway	B	2	1-5 % (NO_x, CO, BC, Cd, Hg, Zn, HCB, PAH)
_Key_070102_Road_PC_Rural	B	2	5-10 % (NO_x, HCB)
_Key_070103_Road_PC_Urban	B	2	>10 % (CO)
_Key_070201_Road_LD_Highway	B	2	1-5 % (NO_x, BC, HCB)
_Key_070202_Road_LD_Rural	B	2	1-5 % (NO_x, BC, HCB)
_Key_070203_Road_LD_Urban	B	2	1-5 % (NO_x, BC, HCB)
_Key_070301_Road_HD_Highway	B	2	5-10 % (HCB)
_Key_070302_Road_HD_Rural	B	2	5-10 % (HCB)
_Key_070303_Road_HD_Urban	B	2	1-5 % (HCB)
_Key_070501_Road_PC_Highway	B	2	<1 % (all pollutants)
_Key_070502_Road_PC_Rural	B	2	1-5 % (CO)
_Key_070503_Road_PC_Urban	B	2	1-5 % (CO)
_Key_0706_0707_0708_NonExhaust	B	2	>10% (Cu, Pb, Zn)
_Key_080402_Ferry	B	3	>10 % (As, Ni, Se)
_Key_080503_DomCruise	B	3	<1 % (all pollutants)
_Key_0808_IndustrialMachinery	B	3	5-10 % (BC)
_Key_0704_Mopeds	B	4	<1 % (all pollutants)
_Key_0802_Railways	B	4	1-5 % (NO_x, PCBs)
_Key_080403_Fishing	B	5	1-5 % (SO2,NOx, As, Hg, Se)
_Key_Area_EEZ	B	5	<1 % (all pollutants)
_Key_Building_OneStorey	C	3	1-5 % (CO)
_Key_Forest	C	3	<1 % (all pollutants)
_Key_0811_CommInstMachinery	C	4	>10 % (CO)

Due to reporting requirements, emissions can only be allocated inside the Danish EEZ area, which leads to accumulation of emissions to a small part of the total flight routes. Still this will serve as an improvement, as it reflect the flight route pattern. When spatial emissions are used for air quality modelling, this accumulation of emissions needs to be kept in mind, as it will lead to overestimation of air pollution concentrations. An extension of the SPREAD model with a module allowing emissions to be allocated outside the Danish EEZ will improve the applicability of spatial emissions for air quality modelling.

The GeoKeys for road transport are based on older data, both regarding the road network and mileage data. Road network and mileage data for highways was updated in 2019. The road transport GeoKeys can be significantly improved by including new mileage data preferably corresponding the vehicle categories in the national emission inventory.

The railway GeoKey is based on a rather simple railway network map. A dataset including mileage data are not identified, but for part of the railway network, a dataset is available including network classes, e.g. main track and siding. This can be used to make assumptions of activity levels. Further, the GeoKey can be improved by including information about electrification. This require data about share of electrification of the railway mileage per route segment.

The weighting factors used to prepare the GeoKey for fishing is based on expert judgement and should be adjusted if further information of the split between emissions from fishing of fish and shellfish is found. An alternative approach is to assess if automatic identification system (AIS) data for Danish fishing vessels in Danish sea territory can be used to prepare the GeoKey.

Table 9.4 Planned improvements for mobile combustion.

Improvement priority	Sector	Current GeoKey	Planned improvement
High	Railways	_Key_0802_Railways	Update the GeoKey by including more detailed data for the railway network, e.g. from GeoDanmark. If available, mileage data or train passages can be used to further improve the GeoKey. Further, include information about the share of electrification by route.
Medium	Fishing	_Key_080403_Fishing	Evaluate the weighting factors used for fish and shellfish. Alternatively, evaluate the possibility to use AIS data.

9.1.3 Fugitive emissions from fuels

The GeoKeys used for fugitive emissions from fuels are listed in Table 9.5. Most of the GeoKeys are based on spatial data with very low uncertainty, but in more cases, the applicability is poor.

Table 9.5 Quality of spatial dataset by GeoKey for fugitive emissions from fuels.

GeoKey	Quality of spatial dataset	Applicability of GeoKey	Highest contribution to national emission in 2019
_Key_050208_OilTerminal	A	1	<1 % (all pollutants)
_Key_090298_Flaring_GasStorage	A	1	
_Key_050103_CoalStorage	A	2	1-5 % (BC)
_Key_050205_OilProduction	A	2	<1 % (all pollutants)
_Key_050305_GasProduction	A	2	<1 % (all pollutants)
_Key_090206_FlaringOffshore	A	2	<1 % (all pollutants)
_Key_090206_FlaringOffshore	A	2	
_Key_050206_LoadingOffshore	A	3	<1 % (all pollutants)
_Key_050699_Venting	A	3	
_Key_050204_050304_Exploration	A	4	<1 % (all pollutants)
_Key_050601_GasTransmission	A	5	<1 % (all pollutants)
_Key_050503_ServiceStations	B	4	<1 % (all pollutants)
_Key_050604_TownGas	B	4	<1 % (all pollutants)
_Key_0202_Gas	C	4	<1 % (all pollutants)

Emissions from service stations are distributed evenly between the service stations included in the list provided by the Danish Petroleum Association. The GeoKey can be improved by using an updated list of service stations and further improved if activity data become available by service station or e.g. by municipality or region.

Town gas network maps are available for the three areas where distribution occur in the later years. It is not expected that data exist for the companies shut down years ago. The GeoKey can be improved by the use of the available spatial data. Rough assumptions must be made for areas supplied by the closed down companies to generate time series.

The spatial distribution for gastransmission can be improved by changing the spatial dataset from the M/R stations to the gas transmission network. Further, it can be assessed if more detailed information about maintenance locations are available.

Table 9.6 Planned improvements for fugitive emissions from fuels.

Improvement priority	Sector	Current GeoKey	Planned improvement
High	Service stations	_Key_050503_ServiceStations	Update with new data.
Medium	Natural gas transmission	_Key_050601_GasTransmission	New GeoKey based on transmission network or information regarding gas loss from the transmission network.
Medium	Town gas distribution	_Key_050604_TownGas	Update with town gas pipeline data. Development of time series require assumptions for areas around closed down distribution companies.

9.1.4 Industrial processes and product use

The GeoKeys used for industrial processes and product use are listed in Table 9.7.

Table 9.7 Quality of spatial dataset by GeoKey for industrial processes and product use.

GeoKey	Quality of spatial dataset	Applicability of GeoKey	Highest contribution to national emission in 2019
_Key_Population	A	2-4	>10 % (NMVOC, PM_{10}, $PM_{2.5}$, As, Cr, Cu, Ni, Zn)
_Key_040617_SlaughterhouseWaste	A	3	<1 % (all pollutants)
_Key_040691_Brickworks	A	3	1-5 % (SO_2)
_Key_040692_ExpandedClayProducts	A	3	<1 % (all pollutants)
_Key_ChemicalIndustry	A	4	1-5 % (NMVOC, Se)
_Key_Food_Drinks_Tobacco	A	4	1-5 % (Hg, Se)
_Key_Metal	A	4	<1 % (all pollutants)
_Key_Wine	A	4	<1 % (all pollutants)
_Key_Building	B	3-4	<1 % (all pollutants)
_Key_RoadNetwork	B	4	1-5 % (TSP, PM_{10})
_Key_Quarrying	B/D	3/5	1-5 % (TSP, PM_{10})
_Key_Building_OneStorey	C	3-4	1-5 % (Se, PAH)
_Key_Industry	D	3-5	>10 % (As, Pb, PCBs)

The uncertainty of the GeoKey based on industrial area is high (Chapter 9.1.1), and the applicability is fair to very poor. For many sources, the major part of the emissions come from relatively few plants, and the distribution can be improved by using the location of the major plants combined with activity data when available. In addition, it can be evaluated if the same approach can be used to improve the spatial distribution for 'Storage, handling and transport of mineral products'.

The quarrying data are relatively old and can be improved by adding new data and creating a time series.

Population has in many cases a fair or poor applicability, but is still considered the best available proxy. This is the case for e.g. use of fireworks and tobacco, which is expected to show reasonable correlation with the population density, eventhough regional and local differences occur. Another issue is, that population density describe where people live while the activities might be better correlated to the places where people spend their time, e.g. on workplaces. Improvements would require alternative activity data, which does not exist or are not available.

Spatial distribution of emissions from asphalt roofing buildings. A GeoKey could be prepared from BBR data, if the information on roofing material is useful.

The GeoKeys for road network and the one-storey buildings should be updated with new data.

Table 9.8 Planned improvements for industrial processes and product use.

Improvement priority	Sector	Current GeoKey	Planned improvement
High	Construction and demolition Dry cleaning	_Key_Building	Update with new data or other data source if available.
Medium	Lime production Storage, handling and transport of mineral products	_Key_Industry	Update with new data or other data source if available.
Low	Quarrying and mining of minerals other than coal	_Key_Quarrying	Update wit new data and development of time series.
Low	Use of charcoal (barbequing)	_Key_Building_OneStorey	Update with new data.
Low	Road paving with asphalt	_Key_RoadNetwork	Update with new road network data.

9.1.5 Agriculture

The GeoKeys used for agriculture are listed in Table 9.9. Most of the GeoKeys are based on spatial data with very low uncertainty.

Table 9.9 Quality of spatial dataset by GeoKey for agriculture.

GeoKey	Quality of spatial dataset	Applicability of GeoKey	Highest contribution to national emission in 2019
_Key_3B1a_DairyCattle	A	2, 5*	>10 % (NH_3)
_Key_AgriculturalArea	A	3-5	>10 % (TSP, PM_{10})
_Key_3B1b_NonDairyCattle	A	2	1-5 % (NMVOC, NH_3)
_Key_3B2_Sheep	A	2	<1 % (all pollutants)
_Key_3B3_Swine	A	2	>10 % (NH_3)
_Key_3B4d_Goats	A	2	<1 % (all pollutants)
_Key_3B4gi_LayingHens	A	2	1-5 % (NH_3, TSP, PM_{10})
_Key_3B4gii_Broilers	A	2	1-5 % (PM_{10})
_Key_3B4giii_Turkeys	A	2	<1 % (all pollutants)
_Key_3B4giv_OtherPoultry	A	2	<1 % (all pollutants)
_Key_3B4h_OtherAnimals	A	2	5-10 % (NH_3)
_Key_3Da1_MineralFertiliser	A	2	>10 % (NH_3)
_Key_3Da2a_ManureSoils	A	2	>10 % (NH_3)
_Key_3Da2b_SludgeSoils	A	2	<1 % (all pollutants)
_Key_3Da2c_OtherFertiliserSoils	A	2	<1 % (all pollutants)
_Key_3Da3_Grazing	A	2	1-5 % (NH_3)
_Key_3B4e_Horses	B	3	1-5 % (NH_3)

** 5 for indirect emissions from managed soils*

Table 9.10 Planned improvements for agriculture.

Improvement priority	Sector	Current GeoKey	Planned improvement
			At the moment no GeoKeys used for agriculture is considered for improvement

9.1.6 Waste

The GeoKeys used for waste are listed in Table 9.11. Most of the GeoKeys are based on spatial data with very low uncertainty.

Table 9.11 Quality of spatial dataset by GeoKey for waste.

GeoKey	Quality of spatial dataset	Applicability of GeoKey	Highest contribution to national emission in 2019
_Key_090901_Cremation	A	2	1-5 % (PCBs)
_Key_090902_AnimalCremation	A	2	1-5 % (PCBs)
_Key_Biogas	A	2	<1 % (all pollutants)
_Key_WasteWater	A	3	<1 % (all pollutants)
_Key_Population	A	4	5-10 % (IcdP)
_Key_SolidWasteDisposal	A	4	<1 % (all pollutants)
_Key_Building_OneStorey	C	3	>10 % (PCDD/F)
_Key_Industry	D	3	5-10 % (SO_2, PCDD/F)

The GeoKey for composting is based on data from 2008 and can be improved by applying updated data and a time series if sufficient data is available.

Table 9.12 Planned improvements for waste.

Improvement priority	Sector	Current GeoKey	Planned improvement
Medium	Industrial composting	_Key_SolidWasteDisposal	Update with new data.

9.2 Verification

In accordance with the planned improvements of the GeoKeys, it is relevant to make verification of the SPREAD model, both regarding input data and resulting spatial emissions.

Verification of the spatial emission can be made by comparison with measurements, but it is also relevant to make comparison of spatial emissions data prepared with different models. SPREAD is the only national model, but if a local model is developed, it will be relevant to make comparisons. Often a local model make use of more detailed data and thereby is able to reflect real life better, but these detailed data are often of local extent and cannot be included in a national model like SPREAD, as data with full coverage is prioritised. Still, it should be evaluated if a number of local datasets can be used in combination with a more general national dataset.

Comparison with other spatial emission inventories can contribute knowledge about methodological differences. In the FAIRMODE project, the Delta benchmarking tool has been prepared to enable comparison of bottom-up and top-down emission estimates at regional and local scale. It include four different comparison methods; 1) pollutant emission comparisons across sectors, 2) evaluation of the differences between inventories allocated in terms of activity data and emission factors, 3) emission per capita comparisons, and 4) comparison of pollutant ratios (Guevara et al., 2017).

The Delta tool analyse discrepancies between the total emissions reported by macro-sector and pollutant, contribution of each macro-sector to the total emissions, and the identification and quantification of the different factors causing the discrepancies between total emissions (Thunis et al., 2016).

Verification of input data can contribute to quantify uncertainties, and to make comparison of different input datasets and support the decision of which data to use in the model.

Combustion in residential plants is an important emission source with large contribution to the national total emission for a number of pollutants. The GeoKeys for residential plants are based on SFL data and BBR data. It is planned to make comparisons of SFL and BBR. The SFL data includes all registered wood stoves on address level, and is assumed to have low uncertainty. On the contrary, the BBR is known to have large uncertainties regarding heating information, e.g. the number of residential wood stoves is largely underestimated. It is planned to analyse the differences between the SFL and the BBR. It will be assessed how many woodstoves in the SFL that can be found in the BBR. In addition, it will be assessed how many addresses that have registered woodstoves in the BBR but not in the SFL and opposite, and it will be evaluated if any regional patterns occur for the BBR errors. The number of liquid-fired appliances are overestimated in both the BBR and the SFL, due to errors in the BBR registrations and occurrence of appliances in the SFL database that is no longer in use. It is planned to use the energy data in the BBR register to identify liquid fired appliances not in use, as no or very little fuel

consumption indicate that another heating installation is used instead. The same approach can be made for gas fired appliances, eventhough the uncertainty is expected to be far lower for gas fired that for liquid fired appliances.

The SFL database does not include building use information, which has to be added from the BBR. The coupling of these two datasets is associated with uncertainty as the SFL data is on address level, while the BBR data is on building level and one address can have more buildings with different building use. Further, the addresses in the SFL database have been geocoded based on the public information server (Den Offentlige Informationsserver, OIS), which to some degree deviate from the address coordinated in the BBR. Therefore building use from the nearest BBR point is added to each of the SFL points. A further evaluation of this workflow could determine the number of addresses without a direct coubling between the BBR and the SFL, and if there is a pattern that indicate areas that need a more thorough methodology. For addresses with more buildings having different building use, it can be evaluated if the present methodology needs improvement, e.g. prioritising one building use class for another for a specific type of appliance. In the present methodology, agricultural building use is prioritised for straw fired appliances, while residential building use is prioritised for other appliances.

9.3 Model setup and documentation

Currently, the results from the SPREAD model is only presented in reports (e.g. Nielsen et al., 2018a). It is planned that a webpage will be created for the SPREAD model providing results and documentation.

Currently, there is no standard outputs created for data visualisation. It is planned that the future version of SPREAD will include predefined outputs for easy visualisation in ArcGIS to be included in reports, presentations and on the webpage.

10 References

Andersen, J.S., 2015: Undersøgelse om brug af brændeovne i Københavns Kommune. Teknologisk Institut, 2015.

Brandt, J., Silver, J.D., Frohn, L.M., Geels, C., Gross, A., Hansen, A.B., Hansen, K.M., Hedegaard, G.B., Skjøth, C.A., Villadsen, H., Zare, A. & Christensen, J.H., 2012: An integrated model study for Europe and North America using the Danish Eulerian Hemispheric Model with focus on intercontinental transport, Atmospheric Environment, Volume 53, June 2012, pp. 156-176, doi:10.1016/j.atmosenv.2012.01.011.

Brandt, J., Christensen, J.H. Frohn, L.M. Palmgren, F. Berkowicz R. & Zlatev, Z., 2001: Operational air pollution forecasts from European to local scale. Atmospheric Environment, Vol. 35, Sup. No. 1, pp. S91-S98.

Brandt, J., Christensen, J.H., Frohn, L.M. & Berkowicz, R., 2003: Air pollution forecasting from regional to urban street scale – implementation and validation for two cities in Denmark. Physics and Chemistry of the Earth, Vol. 28, pp. 335-344.

Christensen, J.H., 1997: The Danish Eulerian Hemispheric Model – a three-dimensional air pollution model used for the Arctic, Atm. Env., 31, 4169–4191.

EEA, 2016: EMEP/EEA air pollutant emission inventory guidebook 2019. Technical guidance to prepare national emission inventories. EEA Report 13/2019. Available at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019 (18-01-2021).

Ellermann, T., Nygaard, J., Nøjgaard, J.K., Nordstrøm, C., Brandt, J., Christensen, J., Ketzel, M., Massling, A., Bossi, R., Frohn, L.M., Geels, C. & Jensen, S.S. 2020. The Danish Air Quality Monitoring Programme. Annual Summary for 2018. Aarhus University, DCE – Danish Centre for Environment and Energy, 83 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 218. http://dce2.au.dk/pub/SR360.pdf.

EU, 2013: Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0525&from=EN (07-01-2021).

EU, 2016: Directive 2016/2284/EU on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Di rective 2001/81/EC. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016L2284&from=EN (07-01-2021).

Gyldenkærne, S. & Frederiksen, P., 2015: The Danish SINKs project. Final report on the Danish monitoring project for Land Use, Land Use Change and Forestry under the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 111 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 155. Available at: http://dce2.au.dk/pub/SR155.pdf (07-01-2021).

Guevara, M., Lopez-Aparicio, S., Cuvelier, C., Tarrason, L., Clappier, A., & Thunis, P. 2017: A benchmarking tool to screen and compare bottom-up and top-down atmospheric emission inventories. Air Qual Atmos Health (2017) 10: 627. Available at: https://doi.org/10.1007/s11869-016-0456-6 (07-01-2021).

IPCC 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/ (07-01-2021).

Jensen, M. T., Nielsen, O-K., Mikkelsen, M. H., Winther, M., Gyldenkærne, S., Viuf, P. Ø. & Illerup J. B., 2008: Rapportering af Luftemissioner på Grid – Metoder og Principper. Danmarks Miljøundersøgelser, Århus Universitet. 58 s. – Faglig rapport fra DMU nr. 654. Available at: http://www.dmu.dk/Pub/FR654.pdf (in Danish with summary in English). (07-01-2021).

Jensen, S.S., Plejdrup, M.S., Hillig, K. (2019): GIS-based National Road and Traffic Database 1960-2020. Aarhus University, DCE – Danish Centre for Environment and Energy, 25 pp - Technical Report No. 151. Available at: http://dce2.au.dk/pub/TR151.pdf (07-01-2021).

MSC-W, 2018: Emissions for CLRTAP modelling - experience and feedback. Presentation at the 19th Joint EIONET & UNECE Task Force on Emission Inventories & Projections Meeting, Sofia, Bulgaria. Available at: https://b0fec36b-4a3f-4c69-9b2f-36ce96956516.filesusr.com/ugd/e5a9c7_efeb38c45c604c2ca061cc9b72226139.pdf (07-01-2021).

Nielsen, O.-K. & Plejdrup, M.S. 2018: Antal og placering af små fyringsanlæg i Danmark. Research note from DCE. Available at: http://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2018/Antal_og_placering_af_smaa_fyringsanlaeg_i_Danmark.pdf (In Danish). (07-01-2021).

Nielsen, O-K., Plejdrup, M.S., Winther, M., Mikkelsen, M.H., Nielsen, M., Gyldenkærne, S., Fauser, P., Albrektsen, R., Hjelgaard, K.H., Bruun, H.G. & Thomsen, M. 2021. Annual Danish Informative Inventory Report to UNECE. Emission inventories from the base year of the protocols to year 2019. Aarhus University, DCE – Danish Centre for Environment and Energy, 580 pp. Scientific Report No. 435. Available at: http://dce2.au.dk/pub/SR435.pdf

Nielsen, O.-K., Plejdrup, M.S., Winther, M., Nielsen, M., Gyldenkærne, S., Mikkelsen, M.H., Albrektsen, R., Thomsen, M., Hjelgaard, K., Fauser, P., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Vesterdal, L., Stupak, I., Scott-Bentsen, N., Rasmussen, E., Petersen, S.B., Olsen, T. M. & Hansen, M.G. 2021. Denmark's National Inventory Report 2021. Emission Inventories 1990-2019 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 944 pp. Scientific Report No. 437. Available at: http://dce2.au.dk/pub/SR437.pdf

Plejdrup, M.S. & Gyldenkærne, S. 2011: Spatial distribution of emissions to air – the SPREAD model. National Environmental Research Institute, Aarhus University, Denmark. 72 pp. – NERI Technical Report no. FR823. Available at: http://www.dmu.dk/Pub/FR823.pdf (07-01-2021).

Plejdrup, M.S., Nielsen, O-K. & Brandt, J., 2016: Spatial emission modelling for residential wood combustion in Denmark. Atmospheric Environment. 144, pp. 389-396. Available at: https://doi.org/10.1016/j.atmosenv.2016.09.013 (07-01-2021).

Plejdrup, M.S., Nielsen, O.-K., Gyldenkærne, S. & Bruun, H.G. 2018. Spatial highresolution distribution of emissions to air – SPREAD 2.0. Aarhus University, DCE – Danish Centre for Environment and Energy, 186 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 131 http://dce2.au.dk/pub/TR131.pdf

Thunis, P., Degraeuwe, B., Cuvelier, K., Guevara, M., Tarrason, L. & Clappier, A., 2016: A novel approach to screen and compare emission inventories Air Qual Atmos Health (2016) 9: 325. Available at: https://doi.org/10.1007/s11869-016-0402-7 (07-01-2021).

UN. 1982: Available at: http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (07-01-2021).

UNECE, 2015: Guidelines for reporting emissions and projections data under the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/128). Available at: https://unece.org/fileadmin/DAM/env/documents/2015/AIR/EB/English.pdf (07-01-2021).

Annex 1 List of SNAP codes and corresponding NFR and GNFR categories

As mentioned, the agriculture sector in the Danish emission inventories is not using the SNAP nomenclature, but rather the NFR nomenclature. Therefore, the agricultural sources are not included in this Annex but can be seen in Annex 2. SNAP cateogies that are not occurring in Denmark have not been included.

SNAP code	SNAP name	NFR	GNFR
010100	**Public power**	**1A1a**	**A_PublicPower**
010101	Combustion plants >= 300 MW (boilers)	1A1a	A_PublicPower
010102	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	A_PublicPower
010103	Combustion plants < 50 MW (boilers)	1A1a	A_PublicPower
010104	Gas turbines	1A1a	A_PublicPower
010105	Stationary engines	1A1a	A_PublicPower
010200	**District heating plants**	**1A1a**	**A_PublicPower**
010202	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	A_PublicPower
010203	Combustion plants < 50 MW (boilers)	1A1a	A_PublicPower
010300	**Petroleum refining plants**	**1A1b**	**B_Industry**
010304	Gas turbines	1A1b	B_Industry
010306	Process furnaces	1A1b	B_Industry
010500	**Coal mining, oil / gas extraction, pipeline compressors**	**1A1c**	**B_Industry**
010503	Combustion plants < 50 MW (boilers)	1A1c	B_Industry
010504	Gas turbines	1A1c	B_Industry
020100	**Commercial and institutional plants**	**1A4ai**	**C_OtherStationaryComb**
020103	Combustion plants < 50 MW (boilers)	1A4ai	C_OtherStationaryComb
020104	Stationary gas turbines	1A4ai	C_OtherStationaryComb
020105	Stationary engines	1A4ai	C_OtherStationaryComb
020200	**Residential plants**	**1A4bi**	**C_OtherStationaryComb**
020202	Combustion plants < 50 MW (boilers)	1A4bi	C_OtherStationaryComb
020204	Stationary engines	1A4bi	C_OtherStationaryComb
020300	**Plants in agriculture, forestry and aquaculture**	**1A4ci**	**C_OtherStationaryComb**
020302	Combustion plants < 50 MW (boilers)	1A4ci	C_OtherStationaryComb
020303	Stationary gas turbines	1A4ci	C_OtherStationaryComb
020304	Stationary engines	1A4ci	C_OtherStationaryComb
030100	**Comb. in boilers, gas turbines and stationary**	**1A2gviii**	**B_Industry**
030106	Other stationary equipments	1A2gviii	B_Industry
030303	Gray iron foundries	2C1	B_Industry
030307	Secondary lead production	2C5	B_Industry
030310	Secondary aluminium production	2C3	B_Industry
030312	Lime (includ. iron and steel and paper pulp industry)	2A2	B_Industry
030315	Container glass	2A3	B_Industry
030316	Glass wool (except binding)	2A3	B_Industry
030318	Mineral wool (except binding)	2A6	B_Industry
030400	**Iron and steel**	**1A2a**	**B_Industry**
030402	Combustion plants >= 50 and < 300 MW (boilers)	1A2a	B_Industry
030403	Combustion plants < 50 MW (boilers)	1A2a	B_Industry
030600	**Chemical and petrochemical**	**1A2c**	**B_Industry**
030602	Combustion plants >= 50 and < 300 MW (boilers)	1A2c	B_Industry
030603	Combustion plants < 50 MW (boilers)	1A2c	B_Industry
030604	Gas turbines	1A2c	B_Industry
030605	Stationary engines	1A2c	B_Industry
030700	**Non-metallic minerals**	**1A2f**	**B_Industry**
030701	Mineral wool	1A2f	B_Industry
030702	Glass	1A2f	B_Industry

SNAP code	SNAP name	NFR	GNFR
030703	Tile	1A2f	B_Industry
030705	Stationary engines	1A2f	B_Industry
030706	Other non-metallic minerals	1A2f	B_Industry
030800	**Mining and quarrying**	**1A2gviii**	**B_Industry**
030900	**Food and tobacco**	**1A2e**	**B_Industry**
030902	Combustion plants >= 50 and < 300 MW (boilers)	1A2e	B_Industry
030903	Combustion plants < 50 MW (boilers)	1A2e	B_Industry
030904	Gas turbines	1A2e	B_Industry
030905	Stationary engines	1A2e	B_Industry
031000	**Textile and leather**	**1A2gviii**	**B_Industry**
031005	Stationary engines	1A2gviii	B_Industry
031100	**Paper, pulp and print**	**1A2d**	**B_Industry**
031102	Combustion plants >= 50 and < 300 MW (boilers)	1A2d	B_Industry
031103	Combustion plants < 50 MW (boilers)	1A2d	B_Industry
031104	Gas turbines	1A2d	B_Industry
031200	**Transport equipment**	**1A2gviii**	**B_Industry**
031205	Stationary engines	1A2gviii	B_Industry
031300	**Machinery**	**1A2gviii**	**B_Industry**
031305	Stationary engines	1A2gviii	B_Industry
031400	**Wood and wood products**	**1A2gviii**	**B_Industry**
031403	Combustion plants < 50 MW (boilers)	1A2gviii	B_Industry
031405	Stationary engines	1A2gviii	B_Industry
031500	**Construction**	**1A2gviii**	**B_Industry**
031505	Stationary engines	1A2gviii	B_Industry
031600	**Cement production**	**1A2f**	**B_Industry**
032000	**Non-specified (Industry)**	**1A2gviii**	**B_Industry**
032003	Combustion plants < 50 MW (boilers)	1A2gviii	B_Industry
032004	Gas turbines	1A2gviii	B_Industry
032005	Stationary engines	1A2gviii	B_Industry
040100	**Processes in petroleum industries**	**1B2aiv**	**D_Fugitive**
040101	Petroleum products processing	1B2aiv	D_Fugitive
040103	Sulphur recovery plants	1B2aiv	D_Fugitive
040104	Storage and handling of petroleum produc. in refinery	1B2aiv	D_Fugitive
040200	**Processes in iron and steel industries and collieries**	**2C1**	**B_Industry**
040207	Electric furnace steel plant	2C1	B_Industry
040208	Rolling mills	2C1	B_Industry
040304	Magnesium production (except 03.03.23)	2C4	B_Industry
040306	Allied metal manufacturing	2C7c	B_Industry
040401	Sulfuric acid	2B10a	B_Industry
040402	Nitric acid	2B2	B_Industry
040416	Other	2B10a	B_Industry
040500	**Processes in organic chemical industry (bulk production)**	**2B10a**	**B_Industry**
040525	Pesticide production	2B10a	B_Industry
040527	Other (phytosanitary)	2B10a	B_Industry
040605	Bread	2H2	B_Industry
040606	Wine	2H2	B_Industry
040607	Beer	2H2	B_Industry
040608	Spirits	2H2	B_Industry
040610	Roof covering with asphalt materials	2D3c	B_Industry
040611	Road paving with asphalt	2D3b	B_Industry
040612	Cement (decarbonizing)	2A1	B_Industry
040613	Glass (decarbonizing)	2A3	B_Industry
040614	Lime (decarbonizing)	2A2	B_Industry
040616	Extraction of mineral ores	2A5a	B_Industry
040617	Other (including asbestos products manufacturing)	2L	B_Industry
040618	Limestone and dolomite use	2A6	B_Industry
040619	Soda ash production and use	2B7	B_Industry
040620	Wood manufacturing	2I	B_Industry
040625	Sugar production	2H2	B_Industry

SNAP code	SNAP name	NFR	GNFR
040626	Flour production	2H2	B_Industry
040627	Meat curing	2H2	B_Industry
040631	Construction of Houses	2A5b	B_Industry
040632	Construction of apartment buildings	2A5b	B_Industry
040633	Construction of non-residential buildings	2A5b	B_Industry
040634	Construction of road	2A5b	B_Industry
040690	Storage, handling and transport of mineral products	2A5c	B_Industry
040691	Production of yellow bricks	2A6	B_Industry
040692	Expanded clay products	2A6	B_Industry
040698	Margarine and solid cooking fats	2H2	B_Industry
040699	Coffee roasting	2H2	B_Industry
050103	Storage of solid fuel	1B1a	D_Fugitive
050200	**Extraction, 1st treatment and loading of liquid fossil fuels**	**1B2ai**	**D_Fugitive**
050204	Exploration of oil	1B2ai	D_Fugitive
050205	Production of oil	1B2ai	D_Fugitive
050206	Offshore loading of oil	1B2ai	D_Fugitive
050207	Onshore loading of oil	1B2ai	D_Fugitive
050208	Storage of crude oil	1B2ai	D_Fugitive
050304	Exploration of gas	1B2b	D_Fugitive
050305	Production of gas	1B2b	D_Fugitive
050500	**Gasoline distribution**	**1B2ai**	**D_Fugitive**
050503	Service stations (including refuelling of cars)	1B2av	D_Fugitive
050600	**Gas distribution networks**	**1B2ai**	**D_Fugitive**
050601	Natural gas transmission	1B2b	D_Fugitive
050603	Natural gas distribution	1B2b	D_Fugitive
050604	Town gas distribution	1B2b	D_Fugitive
050699	Venting in gas storage	1B2c	D_Fugitive
060100	**Paint application**	**2D3d**	**E_Solvents**
060200	**Degreasing, dry cleaning and electronics**	2D3f	E_Solvents
060202	Dry cleaning	2D3f	E_Solvents
060300	**Chemical products manufacturing or processing**	**2D3g**	**E_Solvents**
060400	Other use of solvents and related activities	2D3i	E_Solvents
060403	**Printing industry**	**2D3h**	**E_Solvents**
060408	Domestic solvent use (other than paint application)	2D3a	E_Solvents
060501	Anaesthesia	2G	E_Solvents
060506	Aerosol cans	2G	E_Solvents
060508	Other	2G	E_Solvents
060601	Use of fireworks	2G	E_Solvents
060602	Use of tobacco	2G	E_Solvents
060603	Use of shoes	2G	E_Solvents
060604	Lubricants	2D	E_Solvents
060605	BBQ	2G	E_Solvents
060606	Use of candles	2G	E_Solvents
070100	**Passenger cars**	**1A3bi**	**F_RoadTransport**
070101	Highway driving	1A3bi	F_RoadTransport
070102	Rural driving	1A3bi	F_RoadTransport
070103	Urban driving	1A3bi	F_RoadTransport
070200	**Light duty vehicles < 3.5 t**	**1A3bi**	**F_RoadTransport**
070201	Highway driving	1A3bii	F_RoadTransport
070202	Rural driving	1A3bii	F_RoadTransport
070203	Urban driving	1A3bii	F_RoadTransport
070300	**Heavy duty vehicles > 3.5 t and buses**	**1A3bi**	**F_RoadTransport**
070301	Highway driving	1A3biii	F_RoadTransport
070302	Rural driving	1A3biii	F_RoadTransport
070303	Urban driving	1A3biii	F_RoadTransport
070400	**Mopeds and motorcycles < 50 cm3**	**1A3biv**	**F_RoadTransport**
070500	**Motorcycles > 50 cm3**	**1A3bi**	**F_RoadTransport**
070501	Highway driving	1A3biv	F_RoadTransport
070502	Rural driving	1A3biv	F_RoadTransport

SNAP code	SNAP name	NFR	GNFR
070503	Urban driving	1A3biv	F_RoadTransport
070600	**Gasoline evaporation from vehicles**	**1A3bv**	**F_RoadTransport**
070700	**Automobile tyre and brake wear**	**1A3bvi**	**F_RoadTransport**
070800	**Automobile road abrasion**	**1A3bvii**	**F_RoadTransport**
080100	**Military**	**1A5b**	**I_Offroad**
080200	**Railways**	**1A3c**	**I_Offroad**
080300	**Inland waterways**	**1A5b**	**I_Offroad**
080402	National sea traffic within EMEP area	1A3dii	G_Shipping
080403	National fishing	1A4ciii	I_Offroad
080404	International sea traffic (international bunkers)	1A3di(i)	P_IntShipping
080501	Domestic airport traffic (LTO cycles - <1000 m)	1A3aii(i)	H_Aviation
080502	International airport traffic (LTO cycles - <1000 m)	1A3ai(i)	H_Aviation
080503	Domestic cruise traffic (>1000 m)	1A3aii(ii)	O_AviCruise
080504	International cruise traffic (>1000 m)(i)	1A3ai(ii)	O_AviCruise
080600	**Agriculture**	**1A4cii**	**I_Offroad**
080700	**Forestry**	**1A4cii**	**I_Offroad**
080800	**Industry**	**1A2gvii**	**I_Offroad**
080900	**Household and gardening**	**1A4bii**	**I_Offroad**
081100	**Off-road - Commercial and institutional**	**1A4aii**	**I_Offroad**
090203	Flaring in oil refinery	1B2c	D_Fugitive
090206	Flaring in gas and oil extraction	1B2c	D_Fugitive
090298	Flaring in gas storage	1B2c	D_Fugitive
090299	Flaring in gas transmission and distribution	1B2c	D_Fugitive
090401	Managed waste disposal on land	5A	J_Waste
090901	Incineration of corpses	5C1bv	J_Waste
090902	Incineration of carcasses	5C1bv	J_Waste
091001	Waste water treatment in industry	5D2	J_Waste
091002	Waste water treatment in residential/commercial sector	5D1	J_Waste
091006	Biogas production	5B2	J_Waste
091099	N_2O from human sewage	5D	J_Waste
091101	Composting of garden and park waste	5B1	J_Waste
091102	Composting of organic waste	5B1	J_Waste
091103	Composting of sludge	5B1	J_Waste
091104	Home composting	5B1	J_Waste
091200	**Accidental fires**	**5E**	**J_Waste**
091201	Vehicle fires	5E	J_Waste
091202	Container fires	5E	J_Waste
091203	Detached house fires	5E	J_Waste
091204	Undetached house fires	5E	J_Waste
091205	Apartment building fires	5E	J_Waste
091206	Industrial building fires	5E	J_Waste
091207	Other building fires	5E	J_Waste

Annex 2 List of GNFR codes and corresponding NFR codes

The categories shaded grey are not occurring, included under another category or not estimated in the Danish emission inventory.

GNFR	NFR	NFR name
A_PublicPower	1A1a	Public electricity and heat production
B_Industry	1A1b	Petroleum refining
B_Industry	1A1c	Manufacture of solid fuels and other energy industries
B_Industry	1A2a	Stationary combustion in manufacturing industries: Iron and steel
B_Industry	1A2b	Stationary combustion in manufacturing industries: Non-ferrous metals
B_Industry	1A2c	Stationary combustion in manufacturing industries: Chemicals
B_Industry	1A2d	Stationary combustion in manufacturing industries: Pulp, paper and print
B_Industry	1A2e	Stationary combustion in manufacturing industries: Food processing, beverages and tobacco
B_Industry	1A2f	Stationary combustion in manufacturing industries: Non-metallic minerals
I_Offroad	1A2gvii	Mobile Combustion in manufacturing industries and construction
B_Industry	1A2gviii	Stationary combustion in manufacturing industries and construction: Other
H_Aviation	1A3ai(i)	International aviation LTO (civil)
H_Aviation	1A3aii(i)	Domestic aviation LTO (civil)
F_RoadTransport	1A3b	Road transport
F_RoadTransport	1A3bi	Road transport: Passenger cars
F_RoadTransport	1A3bii	Road transport: Light-duty vehicles
F_RoadTransport	1A3biii	Road transport: Heavy-duty vehicles and buses
F_RoadTransport	1A3biv	Road transport: Mopeds & motorcycles
F_RoadTransport	1A3bv	Road transport: Gasoline evaporation
F_RoadTransport	1A3bvi	Road transport: Automobile tyre and brake wear
F_RoadTransport	1A3bvii	Road transport: Automobile road abrasion
I_Offroad	1A3c	Railways
G_Shipping	1A3di(ii)	International inland waterways
G_Shipping	1A3dii	National navigation (shipping)
I_Offroad	1A3ei	Pipeline transport
I_Offroad	1A3eii	Other
C_OtherStationaryComb	1A4ai	Commercial/institutional: Stationary
I_Offroad	1A4aii	Commercial/institutional: Mobile
C_OtherStationaryComb	1A4bi	Residential: Stationary
I_Offroad	1A4bii	Residential: Household and gardening (mobile)
C_OtherStationaryComb	1A4ci	Agriculture/Forestry/Fishing: Stationary
I_Offroad	1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
I_Offroad	1A4ciii	Agriculture/Forestry/Fishing: National fishing
C_OtherStationaryComb	1A5a	Other stationary (including military)
I_Offroad	1A5b	Other, Mobile (including military, land based and recreational boats)
D_Fugitive	1B1a	Fugitive emission from solid fuels: Coal mining and handling
D_Fugitive	1B1b	Fugitive emission from solid fuels: Solid fuel transformation
D_Fugitive	1B1c	Other fugitive emissions from solid fuels
D_Fugitive	1B2ai	Fugitive emissions oil: Exploration, production, transport
D_Fugitive	1B2aiv	Fugitive emissions oil: Refining / storage
D_Fugitive	1B2av	Distribution of oil products
D_Fugitive	1B2b	Fugitive emissions from natural gas
D_Fugitive	1B2c	Venting and flaring (oil, gas, combined oil and gas)
D_Fugitive	1B2d	Other fugitive emissions from energy production
B_Industry	2A1	Cement production
B_Industry	2A2	Lime production
B_Industry	2A3	Glass production
B_Industry	2A5a	Quarrying and mining of minerals other than coal
B_Industry	2A5b	Construction and demolition
B_Industry	2A5c	Storage, handling and transport of mineral products
B_Industry	2A6	Other mineral products
B_Industry	2B1	Ammonia production
B_Industry	2B2	Nitric acid production
B_Industry	2B3	Adipic acid production
B_Industry	2B5	Carbide production
B_Industry	2B6	Titanium dioxide production
B_Industry	2B7	Soda ash production

GNFR	NFR	NFR name
B_Industry	2B8f	Carbon black production
B_Industry	2B10a	Chemical industry: Other
B_Industry	2B10b	Storage, handling and transport of chemical products
B_Industry	2C1	Iron and steel production
B_Industry	2C2	Ferroalloys production
B_Industry	2C3	Aluminium production
B_Industry	2C4	Magnesium production
B_Industry	2C5	Lead production
B_Industry	2C6	Zinc production
B_Industry	2C7a	Copper production
B_Industry	2C7b	Nickel production
B_Industry	2C7c	Other metal production
B_Industry	2C7d	Storage, handling and transport of metal products
E_Solvents	2D	Other product use
E_Solvents	2D3a	Domestic solvent use including fungicides
E_Solvents	2D3b	Road paving with asphalt
B_Industry	2D3c	Asphalt roofing
B_Industry	2D3d	Coating applications
E_Solvents	2D3e	Degreasing
E_Solvents	2D3f	Dry cleaning
E_Solvents	2D3g	Chemical products
E_Solvents	2D3h	Printing
E_Solvents	2D3i	Other solvent use
E_Solvents	2G	Other product use
B_Industry	2H1	Pulp and paper industry
B_Industry	2H2	Food and beverages industry
B_Industry	2H3	Other industrial processes
B_Industry	2I	Wood processing
B_Industry	2J	Production of POPs
B_Industry	2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)
B_Industry	2L	Other production, consumption, storage, transportation or handling of bulk products
K_AgriLivestock	3B1a	Manure management - Dairy cattle
K_AgriLivestock	3B1b	Manure management - Non-dairy cattle
K_AgriLivestock	3B2	Manure management - Sheep
K_AgriLivestock	3B3	Manure management - Swine
K_AgriLivestock	3B4a	Manure management - Buffalo
K_AgriLivestock	3B4d	Manure management - Goats
K_AgriLivestock	3B4e	Manure management - Horses
K_AgriLivestock	3B4f	Manure management - Mules and asses
K_AgriLivestock	3B4gi	Manure management - Laying hens
K_AgriLivestock	3B4gii	Manure management - Broilers
K_AgriLivestock	3B4giii	Manure management - Turkeys
K_AgriLivestock	3B4giv	Manure management - Other poultry
K_AgriLivestock	3B4h	Manure management - Other animals
L_AgriOther	3Da1	Inorganic N-fertilizers (includes also urea application)
L_AgriOther	3Da2a	Animal manure applied to soils
L_AgriOther	3Da2b	Sewage sludge applied to soils
L_AgriOther	3Da2c	Other organic fertilisers applied to soils (including compost)
L_AgriOther	3Da3	Urine and dung deposited by grazing animals
L_AgriOther	3Da4	Crop residues applied to soils
L_AgriOther	3Db	Indirect emissions from managed soils
L_AgriOther	3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products
L_AgriOther	3Dd	Off-farm storage, handling and transport of bulk agricultural products
L_AgriOther	3De	Cultivated crops
L_AgriOther	3Df	Use of pesticides
L_AgriOther	3F	Field burning of agricultural residues
L_AgriOther	3I	Agriculture other
J_Waste	5A	Biological treatment of waste - Solid waste disposal on land
J_Waste	5B1	Biological treatment of waste - Composting
J_Waste	5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities
J_Waste	5C1a	Municipal waste incineration
J_Waste	5C1bi	Industrial waste incineration
J_Waste	5C1bii	Hazardous waste incineration
J_Waste	5C1biii	Clinical waste incineration
J_Waste	5C1biv	Sewage sludge incineration
J_Waste	5C1bv	Cremation
J_Waste	5C1bvi	Other waste incineration
J_Waste	5C2	Open burning of waste
J_Waste	5D	Domestic wastewater handling
J_Waste	5D1	Domestic wastewater handling
J_Waste	5D2	Industrial wastewater handling

GNFR	NFR	NFR name
J_Waste	5D3	Other wastewater handling
J_Waste	5E	Other waste
M_Other	6A	Other (included in national total for entire territory)
O_AviCruise	1A3ai(ii)	International aviation cruise (civil)
O_AviCruise	1A3aii(ii)	Domestic aviation cruise (civil)
P_IntShipping	1A3di(i)	International maritime navigation
z_Memo	1A5c	Multilateral operations
z_Memo	1A3	Transport (fuel used)
z_Memo	6B	Other not included in national total of the entire territory
N_Natural	11A	Volcanoes
N_Natural	11B	Forest fires
N_Natural	11C	Other natural emissions

Annex 3 List of SPREAD categories and corresponding GeoKeys

GeoKey	SPREAD snap	SPREAD category	Quality of spatial dataset	Applicability as spatial proxy	Annual update
_Key_010306_AS	010300	Refineries - process furnaces (not covered by LPS)	A	2 (3 for 1990)	Yes
_Key_010306_AS	010304	Refineries - process furnaces (not covered by LPS)	A	2 (3 for 1990)	Yes
_Key_010306_AS	010306	Refineries - process furnaces (not covered by LPS)	A	2 (3 for 1990)	Yes
_Key_010306_AS	090203	Refineries - process furnaces (not covered by LPS)	A	2 (3 for 1990)	Yes
_Key_010504_OffshoreGasturbines	010504	Gasturbines - offshore	A	1	Yes
_Key_02_Straw	0202	Residential plants - straw	B	3	No
_Key_02_Straw	0203	Agricultural plants - straw	B	3	No
_Key_0201_Gas	0201	Commercial and institutional plants - gaseous fuels	C	3	No
_Key_0201_Liquid	0201	Commercial and institutional plants - liquid fuels	D	3	No
_Key_0201_Solid	0201	Commercial and institutional plants - solid fuels	D	3	No
_Key_0202_Gas	0202	Residential plants - gaseous fuels	C	3	No
_Key_0202_Gas	050603	Natural gas distribution	C	4	No
_Key_0202_Liquid	0202	Residential plants - liquid fuels	C	3	No
_Key_0202_Solid	0202	Residential plants - solid fuels	B	2	No
_Key_0203_Gas	0203	Agricultural plants - gaseous fuels	C	3	No
_Key_0203_Liquid	0203	Agricultural plants - liquid fuels	C	3	No
_Key_0203_Solid	0203	Agricultural plants - solid fuels	B	2	No
_Key_0401_Refineries_AS	0401	Processes in petroleum industries (not covered by LPS)	A	3	Yes
_Key_040617_Slaughterhouse-Waste	040617	Treatment of slaughterhouse waste	A	2	Yes
_Key_040691_Brickworks	040691	Production of yellow bricks	A	3	Yes
_Key_040692_ExpandedClayProd-ucts	040692	Expanded clay products	A	3	Yes
_Key_050103_CoalStorage	050103	Coal handling and storage	A	2	Yes
_Key_050204_050304_Exploration	050204	Oil exploration	A	4	No
_Key_050204_050304_Exploration	050304	Gas exploration	A	4	No
_Key_050205_OilProduction	050205	Oil production	A	2	Yes
_Key_050206_LoadingOffshore	050206	Offshore loading of crude oil	A	3	Yes
_Key_050208_OilTerminal	050207	Onshore loading of crude oil	A	1	No
_Key_050208_OilTerminal	050208	Storage of crude oil	A	1	No
_Key_050305_GasProduction	050305	Natural gas production	A	2	Yes
_Key_050503_ServiceStations	050503	Service stations (including refuelling of cars)	B	4	No
_Key_050601_GasTransmission	050601	Natural gas transmission	A	5	No
_Key_050601_GasTransmission	090299	Flaring in gas transmission and distribution	A	5	No
_Key_050604_TownGas	050604	Town gas distribution	B	4	Yes
_Key_050699_Venting	050699	Venting	A	3	Yes
_Key_070101_Road_PC_Highway	070101	Road transport - passenger cars, highway driving	B	2	Yes
_Key_070102_Road_PC_Rural	070102	Road transport - passenger cars, rural driving	B	2	Yes
_Key_070103_Road_PC_Urban	070103	Road transport - passenger cars, urban driving	B	2	Yes
_Key_070201_Road_LD_Highway	070201	Road transport - light-duty vehicles, highway driving	B	2	Yes
_Key_070202_Road_LD_Rural	070202	Road transport - light-duty vehicles, rural driving	B	2	Yes

GeoKey	SPREAD snap	SPREAD category	Quality of spatial dataset	Applicability as spatial proxy	Annual update
_Key_070203_Road_LD_Urban	070203	Road transport - light-duty vehicles, urban driving	B	2	Yes
_Key_070301_Road_HD_Highway	070301	Road transport - heavy-duty vehicles, highway driving	B	2	Yes
_Key_070302_Road_HD_Rural	070302	Road transport - heavy-duty vehicles, rural driving	B	2	Yes
_Key_070303_Road_HD_Urban	070303	Road transport - heavy-duty vehicles, urban driving	B	2	Yes
_Key_0704_Mopeds	0704	Road transport - mopeds	B	4	Yes
_Key_070501_Road_PC_Highway	070501	Road transport - motor cycles, highway driving	B	2	Yes
_Key_070502_Road_PC_Rural	070502	Road transport - motor cycles, rural driving	B	2	Yes
_Key_070503_Road_PC_Urban	070503	Road transport - motor cycles, urban driving	B	2	Yes
_Key_0706_0707_0708_NonExhaust	0706	Gasoline evaporation from vehicles	B	2	Yes
_Key_0706_0707_0708_NonExhaust	0707	Automobile tyre and brake wear	B	2	Yes
_Key_0706_0707_0708_NonExhaust	0708	Automobile road abrasion	B	2	Yes
_Key_0801_Military	0801	Military - land based	A	3	No
_Key_0802_Railways	0802	Railways	B	4	No
_Key_080402_Ferry	080402	National navigation	B	3	Yes
_Key_080403_Fishing	080403	Fishing	B	5	Yes
_Key_080501_DomLTO	080501	Aviation - landing and take-off, national	A	2	Yes
_Key_080502_IntLTO	080502	Aviation - landing and take-off, international	A	2	Yes
_Key_080503_DomCruise	080503	Aviation - cruise, national	B	3	Yes
_Key_0808_IndustrialMachinery	0808	Mobile sources and machinery - Industry	B	3	Yes
_Key_0811_CommInstMachinery	0811	Mobile sources and machinery - Commercial and institutional	C	4	No
_Key_090206_FlaringOffshore	090206	Flaring in gas and oil extraction (offshore)	A	2	Yes
_Key_090298_Flaring_GasStorage	090298	Flaring in gas treatment and storage	A	1	Yes
_Key_090901_Cremation	090901	Human cremation	A	2	Yes
_Key_090902_AnimalCremation	090902	Animal cremation	A	2	Yes
_Key_3B1a_DairyCattle	3B1a	Dairy cattle	A	2	Yes
_Key_3B1a_DairyCattle	3Ia	NH_3 treated straw	A	5	Yes
_Key_3B1b_NonDairyCattle	3B1b	Non dairy cattle	A	2	Yes
_Key_3B2_Sheep	3B2	Sheep	A	2	Yes
_Key_3B3_Swine	3B3	Swine	A	2	Yes
_Key_3B4d_Goats	3B4d	Goats	A	2	Yes
_Key_3B4e_Horses	3B4e	Horses	B	3	Yes
_Key_3B4gi_LayingHens	3B4gi	Laying hens	A	2	Yes
_Key_3B4gii_Broilers	3B4gii	Broilers	A	2	Yes
_Key_3B4giii_Turkeys	3B4giii	Turkeys	A	2	Yes
_Key_3B4giv_OtherPoultry	3B4giv	OtherPoultry	A	2	Yes
_Key_3B4h_OtherAnimals	3B4h	OtherAnimals	A	2	Yes
_Key_3Da1_MineralFertiliser	3Da1	Inorganic fertilisers applied to soils	A	2	Yes
_Key_3Da2a_ManureSoils	3Da2a	Animal manure applied to soils	A	2	Yes
_Key_3Da2b_SludgeSoils	3Da2b	sewage sludge applied to soils	A	2	Yes
_Key_3Da2c_OtherFertiliserSoils	3Da2c	Other organic fertiliser applied to soils	A	2	Yes
_Key_3Da3_Grazing	3Da3	Urine and dung deposited by grazing animals	A	2	Yes
_Key_AgriculturalArea	0806	Non-road machinery - agriculture	A	3	Yes
_Key_AgriculturalArea	3Dc	Farm-level agricultural operations	A	3	Yes
_Key_AgriculturalArea	3De	Cultivated crops	A	3	Yes

GeoKey	SPREAD snap	SPREAD category	Quality of spatial dataset	Applicability as spatial proxy	Annual update
_Key_AgriculturalArea	3Df	Use of pesticides	A	4	Yes
_Key_AgriculturalArea	3F	Field burning of agricultural residues	A	5	Yes
_Key_Area_EEZ	0801	Military - aviation	A	5	No
_Key_Biogas	091006	Anaerobic digestion at biogas facilities	A	2	Yes
_Key_Buffer_15km	0803	Inland waterways - recreational crafts	A	3	No
_Key_Building	040610	Asphalt roofing	B	3	No
_Key_Building	060202	Dry cleaning	B	4	No
_Key_Building	091202	Container fires	B	4	No
_Key_Building	091207	Other building fires	B	3	No
_Key_Building_Appartment	040632	Construction of apartment buildings	C	3	No
_Key_Building_Appartment	091205	Apartment building fires	C	3	No
_Key_Building_OneStorey	040631	Construction of houses	C	4	No
_Key_Building_OneStorey	060605	Use of charcoal (barbequing)	C	3	No
_Key_Building_OneStorey	0809	Non-road machinery - residential (household and gardening)	C	3	No
_Key_Building_OneStorey	091104	Home composting	C	3	No
_Key_Building_OneStorey	091203	Detached house fires	C	3	No
_Key_Building_OneStorey	091204	Undetached house fires	C	3	No
_Key_ChemicalIndustry	0306	Manufacturing plants - Chemical and Petrochemical	A	4	Yes
_Key_ChemicalIndustry	0603	Chemical products manufacturing or processing	A	4	Yes
_Key_EPT	0101	Public power (not covered by LPS)	A	1	Yes
_Key_EPT	0102	District heating plants (not covered by LPS)	A	1	Yes
_Key_EPT	0201	Commercial and institutional plants (not covered by LPS)	A	1	Yes
_Key_EPT	0203	Plants in agriculture, forestry and aquaculture (not covered by LPS)	A	1	Yes
_Key_EPT	0301	Combustion in manufacturing industry (not covered by LPS)	A	1	Yes
_Key_Food_Drinks_Tobacco	0309	Manufacturing plants - Food and tobacco	A	4	Yes
_Key_Food_Drinks_Tobacco	040605	Bread	A	4	Yes
_Key_Food_Drinks_Tobacco	040607	Beer	A	4	Yes
_Key_Food_Drinks_Tobacco	040608	Spirits	A	4	Yes
_Key_Food_Drinks_Tobacco	040626	Flour production	A	4	Yes
_Key_Food_Drinks_Tobacco	040627	Meat curing	A	4	Yes
_Key_Food_Drinks_Tobacco	040698	Margarine and solid cooking fats	A	4	Yes
_Key_Food_Drinks_Tobacco	040699	Coffee roasting	A	4	Yes
_Key_Forest	0807	Mobile sources and machinery - Forestry	C	3	Yes
_Key_Industry	0301	Combustion in manufacturing industry (not covered by LPS or EPT)	D	4	No
_Key_Industry	0303	Manufacturing plants - Processes with contact	D	4	No
_Key_Industry	0307	Manufacturing plants - Non-Metallic Minerals	D	4	No
_Key_Industry	0315	Manufacturing plants - Construction	D	4	No
_Key_Industry	0316	Manufacturing plants - Cement production (not covered by LPS)	D	4	No
_Key_Industry	0320	Manufacturing plants - Non-specified (Industry)	D	4	No
_Key_Industry	040633	Construction of non-residential buildings	D	5	No
_Key_Industry	040690	Storage, handling and transport of mineral products	D	4	No
_Key_Industry	091206	Industrial building fires	D	3	No
_Key_Industry	030303	Manufacturing plants - Cast iron production	D	4	No
_Key_Industry	030307	Manufacturing plants - Secondary lead production	D	4	No

GeoKey	SPREAD snap	SPREAD category	Quality of spatial dataset	Applicability as spatial proxy	Annual update
_Key_Industry	030310	Manufacturing plants - Secondary aluminium production	D	4	Yes
_Key_Industry	030312	Lime (includ. iron and steel and paper pulp industry)	D	4	Yes
_Key_MachineryIndustry	0313	Manufacturing industry - Machinery	A	4	Yes
_Key_MeansOfTransportIndustry	0312	Manufacturing industry -Transport equipment	A	4	Yes
_Key_Metal	0304	Manufacturing plants - Iron and steel	A	4	Yes
_Key_Metal	040306	Allied metal manufacturing	A	4	Yes
_Key_Population	0601	Paint application	A	4	Yes
_Key_Population	0604	Other use of solvents and related activities	A	3	Yes
_Key_Population	060408	Domestic solvent use	A	3	Yes
_Key_Population	060502	Refrigeration and air conditioning equipment using halocarbons	A	4	Yes
_Key_Population	060506	Aerosol cans	A	3	Yes
_Key_Population	060507	Electrical equipment	A	3	Yes
_Key_Population	060508	Other use of HFC, N_2O, NH_3, PFC and SF_6	A	4	Yes
_Key_Population	060601	Use of fireworks	A	4	Yes
_Key_Population	060602	Use of tobacco (smoking)	A	3	Yes
_Key_Population	060603	Use of shoes	A	3	Yes
_Key_Population	060606	Use of candles	A	2	Yes
_Key_Population	091201	Accidental fires - Vehicles	A	4	Yes
_Key_Quarrying	0308	Manufacturing plants - Mining and Quarrying	D	5	No
_Key_Quarrying	040616	Quarrying and mining of minerals other than coal	B	3	No
_Key_RoadNetwork	040611	Road paving with asphalt	B	4	No
_Key_RoadNetwork	040634	Construction of road	B	4	No
_Key_SolidWasteDisposal	090401	Managed Waste Disposal on Land	A	4	No
_Key_SolidWasteDisposal	091101	Composting of garden and park waste	A	4	No
_Key_SolidWasteDisposal	091102	Composting of organic waste	A	4	No
_Key_SolidWasteDisposal	091103	Composting of sludge	A	4	No
_Key_Textile_Leather	0310	Manufacturing industry - Textile and leather	A	4	Yes
_Key_WasteWater	091001	Industrial wastewater handling	A	3	Yes
_Key_WasteWater	091002	Domestic wastewater handling	A	3	Yes
_Key_Wine	040606	Wine production	A	4	No
_Key_Wood_Paper_Print	0311	Manufacturing plants - Paper, pulp and print	A	4	Yes
_Key_Wood_Paper_Print	0314	Manufacturing plants - Wood and wood products	A	4	Yes
_Key_Wood_Paper_Print	040620	Wood manufacturing	A	4	Yes
_Key_Wood_Paper_Print	060403	Other use of solvents and related activities - printing industry	A	4	Yes

Annex 4 List of the plants included as LPS in the Danish inventory and their coordinates

LPS plant name	Longitude, ETRS89 UTM zone 32N	Latitude, ETRS89 UTM zone 32N
AffaldPlus+, Naestved Forbraendingsanlaeg	673566	6121470
AffaldPlus+, Naestved Kraftvarmevaerk	673702	6121332
Affaldplus+, Slagelse Forbr. and DONG Slagelse KVV	648352	6143575
Affaldscenter aarhus - Forbraendsanlaegget	571785	6232085
Affaldsforbraendingsanlaeg I/S REFA	685470	6074097
AffaldVarme Aarhus, Biomasse	571785	6232085
Amagerforbraending	727665	6176819
Amagervaerket	728025	6177190
Ardagh Glass Holmegaard A/S	678982	6130322
Asnaesvaerket	631021	6170419
Avedoerevaerket	719115	6167294
AVV Forbraendingsanlaeg	561865	6368221
Bofa I/S	865405	6122924
Centralkommunernes Transmissionsselskab F_berg	721357	6176474
Cheminova	451369	6279469
Dalum Varmecentral, Fjernvarme Fyn	587465	6136044
Danisco Grindsted	495571	6179998
Danisco Sugar Assens	556732	6124757
Danisco Sugar Nakskov	637993	6078044
Danisco Sugar Nykoebing	684916	6072034
DanSteel	687796	6205745
DTU	720902	6187727
Duferco Danish Steel	688216	6205699
Energi Randers Produktion	564537	6257613
Enstedvaerket	528264	6097186
Esbjergvaerket	465552	6145510
Faxe Kalk	699272	6126497
Fjernvarme Fyn, Centrum Varmecentral	588262	6140309
Frederiksberg Varmevaerk	721357	6176474
Frederikshavn Affaldskraftvarmevaerk	588994	6369339
Frederikshavn Kraftvarmevaerk	591233	6369335
Fynsvaerket	589288	6143526
Goerlev Sukkerfabrik	640877	6156808
Grenaa Forbraending	617572	6254827
Grenaa Kraftvarmevaerk	617466	6254807
H.C.Oerstedsvaerket	723735	6173536
Haderslev Kraftvarmevaerk	529071	6117196
Hadsund Bys Fjernvarmevaerk	567840	6287875
Hals Metal	579840	6318443
Hammel Fjernvarmeselskab	553305	6232984
Helsingoer Kraftvarmevaerk	721701	6214047
Herningvaerket	500452	6219521
Hilleroed Kraftvarmevaerk	706981	6200721
Hjoerring Varmeforsyning	559490	6368558
Holmegaard A/S	678982	6130322
Horsens Kraftvarmevaerk	553712	6189957
I/S Faelles Forbraending	549365	6279146
I/S Kara Affaldsforbraendingsanlaeg	696336	6170478
I/S Kraftvarmevaerk Thisted	482464	6313563
I/S Nordforbraending	718278	6200503
I/S Reno Nord	561678	6320478
I/S Reno Syd	558772	6212178
I/S Vestforbraending	714904	6178706
Kastrup Lufthavn	730277	6169690
Kemira Danmark	547885	6157475
Knudmosevaerket	500231	6219502
Koege Kraftvarmevaerk	701702	6150643
Kolding Forbraendingsanlaeg TAS	528256	6151811
Kommunekemi	615239	6129954
Koppers	613595	6129819
Kyndbyvaerket	680370	6189066
L90 Affaldsforbraending	468965	6146340
LECA Danmark	564275	6248349

LPS plant name	Longitude, ETRS89 UTM zone 32N	Latitude, ETRS89 UTM zone 32N
Lille Torup Naturgaslager	525431	6277446
Maricogen	563746	6282294
Masnedoevaerket	684402	6098108
Midtkraft	574938	6223326
Maabjergvaerket	476455	6250060
Nordic Sugar Nykoebing	684916	6072034
Nordjyllandsvaerket	563014	6326209
Nybro Gasbehandlingsanlaeg	460422	6169662
Odense Kraftvarmevaerk	588917	6143377
Oestkraft	863289	6120018
Q8 Raffinaderi	644099	6120078
Rensningsanlaegget Lynetten	727110	6178181
Rockwool A/S Doense	551501	6286157
Rockwool A/S Hedehusene	699792	6171210
Rockwool A/S Vamdrup	518427	6142686
Saint-Gobain Isover A/S	519006	6142478
Shell Raffinaderi	547182	6160917
Silkeborg Kraftvarmevaerk	534712	6228558
Skaerbaekvaerket	538847	6151868
Skagen Forbraending	593440	6400564
Skive Fjernvarmeanlaeg	501923	6268599
Soenderborg Kraftvarmevaerk	550238	6087216
Special Waste System	685220	6087473
Statoil Raffinaderi	631973	6169627
Stenlille Naturgaslager	665499	6158912
Stigsnaesvaerket	643307	6120217
Studstrupvaerket	583332	6234738
Svanemoellevaerket	725398	6180014
Svendborg Kraftvarmevaerk	600737	6104909
VEGA (Vestforbraending Taastrup)	704769	6173082
Vejen Kraftvarmevaerk	510915	6146923
Vestfyns Forbraendingsanlaeg	548308	6150698
Viborg Kraftvarme	524394	6257654
Vordingborg Kraftvarme	684402	6098108
Aalborg Portland	559134	6324607
Aalborgvaerket	556681	6323180
AarhusKarlshamn Denmark A/S	575355	6222981
Aars Fjernvarmeforsyning	533059	6295988

Note: The names in the table do not necessarily reflect the latest company names, but the name with which they are listed in the national emission database.

[Blank page]

SPATIAL HIGH-RESOLUTION DISTRIBUTION OF EMISSIONS TO AIR – SPREAD 3.0

The report documents the model for spatially distributing emissions. The model has undergone significant improvements since the last published version in 2018. The model covers all emissions of air pollutants included in the Danish reporting under the Convention on Long-Range Transboundary Air Pollution and the National Emission Ceilings Directive. The model distributes emissions on a 1 km × 1 km grid and the outputs are used for reporting under international agreements as well as for air quality modelling.

ISBN: 978-87-7156-618-5
ISSN: 2244-999X