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Contents

1 Overview

The aim of this 'Spatial emission mapping' chapter is to further elaborate on the gridding of emissions to:

- Support the link between emission data and air quality models that need emissions information at a proper spatial, temporal and sectoral resolution;
- Facilitate countries in (improving) the gridding of their emission inventories of air pollutants under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) and the EU National Emission Ceilings Directive (NECD) ([1]).

Sub-national spatial emissions are important because:

- reported spatial emissions data are an input for models used to assess atmospheric concentrations and deposition, as the spatial location of emissions determines to a great extent their atmospheric dispersion patterns and impact area. The results of model assessments inform national and international policies used to improve the environment and human health;
- regular reporting of spatial emissions is required under the Emission Reporting Guidelines for Parties to the LRTAP Convention.

This chapter provides guidance on compiling spatial emissions datasets. It focuses on methods suitable for generating and reporting spatial data required under the LRTAP Convention that are consistent with nationally-reported inventories.

This chapter starts with the definition of terms used when dealing with spatial datasets (Section 2). In Section 3 a generic set of methodologies for deriving spatial datasets from national emissions inventories is established. A sector-specific tiered approach for estimating spatial emissions is discussed and some sector-specific issues are dealt with. Furthermore, approaches to combining spatial datasets are presented to enable the inventory compiler to derive an aggregated spatial dataset combining sectoral emissions into a unified gridded dataset like that needed for European Monitoring and Evaluation Programme (EMEP) reporting. All methods rely on the identification and use of important spatial datasets. Therefore, generic data sources for this type of data are outlined in Section 4. In Section 5 an overview of available spatially disaggregated emission inventories is given, which could be used as a starting point for emission mapping.

When preparing spatial data for reporting under EMEP, this chapter should be used in conjunction with the EMEP Reporting Guidelines which are available on the CEIP website. These guidelines define the reporting requirements for spatially disaggregated data and templates are available for reporting: Annex VI for point sources emissions and Annex V for Gridded emissions (https://www.ceip.at).

The Reporting Guidelines give requirements concerning:

- the EMEP grid (0.1° x 0.1° longitude/latitude);
- the sectoral definitions for gridded and large point sources;
- additional large point source information requirements, e.g. height class;
- the required pollutants (main pollutants, PM, Pb, Cd, Hg, PAHs, HCB, dioxins/furans and PCBs);
- years for which reporting of gridded data is required.

([1]) The 2001 EU National Emissions Ceilings Directive has been superseded by the EU Directive on the Reduction of National Emissions of Certain Atmospheric Pollutants (Directive 2016/2284). For simplicity, this chapter retains the use of 'NECD' to refer to the new directive.

2 Terminology

2.1 General terms

CEIP - EMEP Centre on Emission Inventories and Projection (http://www.ceip.at).

Diffuse sources - Diffuse sources of a sector are defined as the national total of a sector minus the reported point sources. This definition is in agreement with the definition used in the E-PRTR (see below) and implies that diffuse sources may contain (non-reported) point sources, line sources, and area sources.

EMEP - the Cooperative Program for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe.

EMEP grid - the EMEP grid is the geographical extent covering the EMEP area at a resolution of 0.1° × 0.1° longitude-latitude in the WGS84 geographic coordinate system. The domain covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude.

E-PRTR - E-PRTR is the European Pollutant Release and Transfer Register, established under EU Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006, and is intended to fully implement the obligations of the UNECE PRTR Protocol.

GIS - Geographical Information Systems.

IED -Industrial Emissions Directive. This EU Directive (2010/75/EU) imposes a requirement for industrial and agricultural activities with a high pollution potential to have a permit which can only be issued if certain environmental conditions are met, so that the companies themselves bear responsibility for preventing and reducing any pollution they may cause. The IED replaced the IPPC Directive and a number of other sectoral directives as of 7 January 2014, with the exception of the Large Combustion Plant (LCP) Directive, which was replaced by the IED with effect from 1 January 2016.

NACE - Classification of Economic Activities in the European Union.

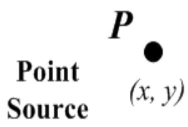
NUTS - Nomenclature of Units for Territorial Statistics, which is a hierarchical classification of administrative boundaries developed by Eurostat. The idea behind NUTS is to provide a common designation for different levels of administrative geographic boundaries across the EU regardless of local language and naming conventions.

Proxy spatial dataset - a geographically disaggregated dataset of statistics by grid, link, point or boundary such as land use coverage percentage by grid, vehicle flow by road link, employers number by industrial point, or population by administrative boundary. Applied as an alternative data source to spatially disaggregate emissions, when direct spatial information on the emission source is not available.

2.2 Geographic features

Geographical features will be used to represent emission sources. These features will define the geographical structure of the spatial dataset.

Point sources: A point source is an emission source at a known location, represented by x and y coordinates that indicate the main point of emission. Examples of point sources are industrial plants or power stations.

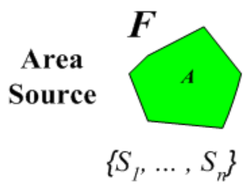


Emissions from point sources represent sectors of a national inventory either fully (e.g. often for power stations where the sector is made up of only large sites for which emissions reporting is mandatory) or in part (e.g. such as combustion in industry, for which only the large sites within the sector are typically required to report emissions). In the latter case, the remainder of the emissions for the sector are mapped as an area source.

Large point sources (LPS): LPS are defined in the EMEP reporting guidelines (see Section **Error! Reference source not found.**) as facilities whose combined emissions, within the limited identifiable area of the site premises, exceed certain pollutant emission thresholds. *Note: although stack height is an important parameter for modelling emissions, it is not a criterion used for defining LPS.*

Area sources: An area source is an emission source that exhibits diffuse characteristics. For example, sources that are too numerous or small to be individually identified as point sources or from which emissions arise over a large area. This could include forests, residential areas and administrative/commercial activities within urban areas.

Area sources as polygons: polygons are often used to represent data attributed to administrative or other types of boundaries (data collection boundaries, site boundaries and other non-linear or regular geographical features).

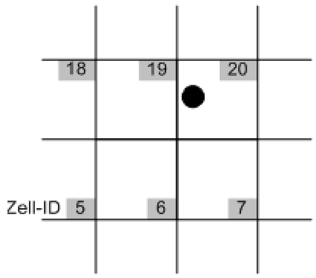


Residential fuel combustion is an example of a sector that can be represented in this way, using population census data mapped using the polygons defining the data collection boundaries.

Polygons are vector- (line-) based features and are characterised by multiple x, y coordinates for each line defining an area. Examples of areas defined by polygons are the regions as defined by the NUTS classification (Nomenclature of Units for Territorial Statistics). According to this classification, the economic territory of the EU is divided in several zones, presented by polygons:

- NUTS 1: major socio-economic regions
- NUTS 2: basic regions for the application of regional policies
- NUTS 3: small regions for specific diagnoses

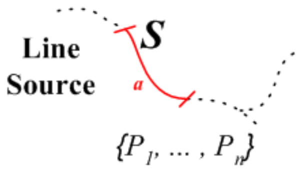
Area sources as grids: area sources can be represented in a regular grid of identically-sized cells (either as polygons or in a raster dataset). The spatial aspects of grids are usually characterised by geographical coordinates for the centre or corner of the grid and a definition of the size of each cell.



Agricultural and natural emissions sectors can be represented using land use data derived from satellite images in raster format.

Grids are often used to harmonise datasets: point, line and polygon features can be converted to grids and then several different layers of information (emission sources) can easily be aggregated together (see Section **Error! Reference source not found.**).

Line sources: A line source is an emission source that exhibits a line type of geography, e.g. a road, railway, pipeline or shipping lane. Line sources are represented by vectors with a starting node and an end node specifying an x, y location for each. Line source features can also contain vertices that define curves between the start and end reference points.



3 Methods for compiling a spatial inventory

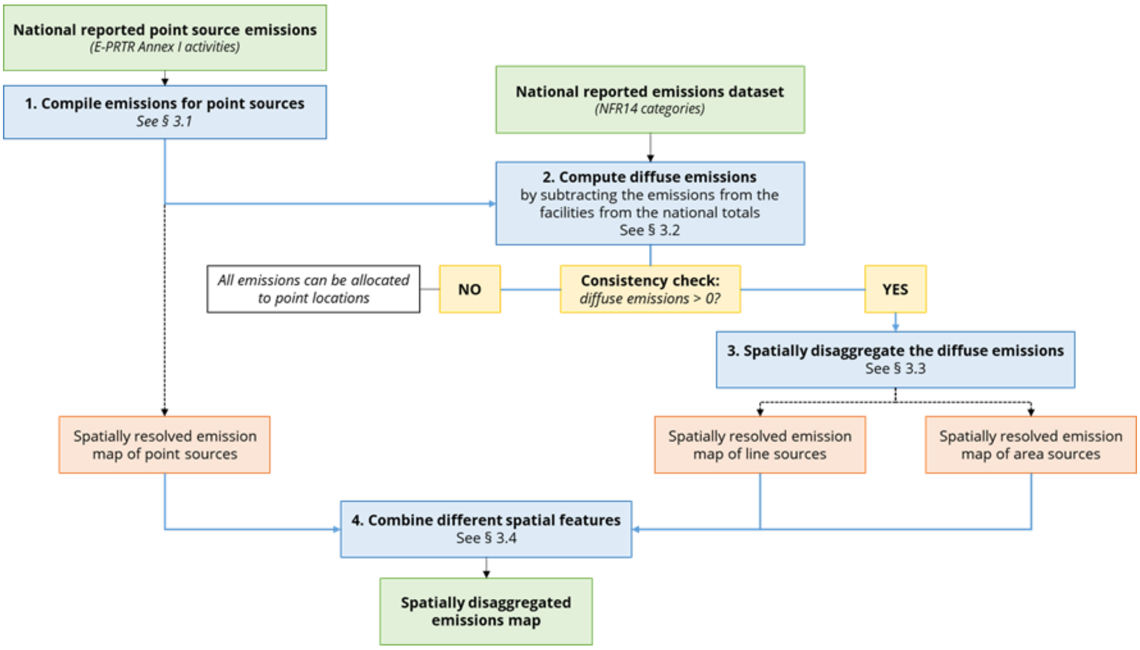
This section provides general guidance on the approaches to deriving spatially disaggregated (e.g. sub-national) datasets. First, an introduction on general good practice is given and a schematic overview of consecutive steps is provided (see Figure 3-1). The different steps as outlined in the scheme are then discussed in more detail in separate paragraphs.

It is good practice to consider the elements below when defining an efficient spatial disaggregation project.

1. Use **key category analysis** (see Chapter 2, Key category analysis and methodological choice) to identify the most important sources and give the most time to these.
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.
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.
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.
5. Proxy **spatial datasets that are complete** (cover the whole national area) should be preferred.
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.
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.
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.
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.
10. When the budget is very limited the **available international datasets** in section 5 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.

Different methods for compiling spatially disaggregated estimates can be used depending on the availability of data. However, the general approach always contains the same basic steps. Therefore, a general scheme can be followed which is presented in Figure 3-1.

Figure 3-1 General approach for compiling a spatial emission inventory



First, an emissions inventory for point sources should be compiled for which various different data sources are available. In general, for many European countries, the best starting point is the European Pollutant Release and Transfer Register (E-PRTR) database, which was established by Regulation 166/266/EC of 18 January 2006. It should be noted that E-PRTR is based on data officially submitted by national competent authorities, and so internal national contact points will be able to provide point source data. In other countries, many industrial point sources and their emission reports are similarly available through the relevant national or regional competent authorities, especially for those countries that are Parties to the UNECE Aarhus Convention PRTR protocol. In order to obtain a comprehensive point source emissions inventory, the E-PRTR or other point source emissions should however be combined with emissions stemming from point sources that are regulated but for which there are no annual emissions reporting requirements and from point sources for sites or pollutants not reported or regulated. In section 3.1 a specific method for compiling point source data is described.

In a second step, the shares of releases from diffuse sources should be determined. The point source emissions compiled in the first step should not exceed national total emissions reported under LRTAP Convention, which include all anthropogenic emissions occurring in the geographical area of the country (large point sources, linear and area sources). However, due to inconsistent reporting under different reporting obligations and due to different sector classification systems, point source emissions might exceed the national totals. Therefore, linking national point source data and national total emissions turns out to be a challenging task: computation of diffuse emissions is not as straightforward as a simple subtraction per sector. In section 3.2 some guidance to develop a subtraction methodology for diffuse emissions to air is outlined.

Once the national diffuse emission totals are determined per source category, a gridding methodology for each category should be developed. National emission estimates will need to be disaggregated across the national spatial area using a proxy spatial dataset, according to a common basic principle which can be presented in a straightforward formula that refers to the specific proxy spatial dataset. The methods used can range in quality from Tier 3 to Tier 1 depending on the appropriateness of the spatial activity data being used. An extensive description of the basic principle and the different methodologies is provided in section 3.3. Further sectoral guidance is given and some examples are listed.

Finally, different spatial features need to be combined, in order to obtain a spatially disaggregated emissions map. Information on how this could be done is provided in section **Error! Reference source not found.**.

3.1 Compiling point source data

Emissions from point sources can be compiled using a number of different data sources and techniques. For convenience, the point source data can be divided into three groups:

1. Regulated point sources such as those regulated under the Industrial Emissions Directive (IED) regulatory regime and/or where there is a requirement for centralised annual emissions reporting (e.g. for E-PRTR facilities or large combustion plant (LCP) under the IED);
2. Point sources that are regulated but for which there are no annual emissions reporting requirements (e.g. E-PRTR does not cover all point source emissions as it uses emission reporting thresholds, emissions below the specified threshold are not included);
3. Point sources for sites or pollutants not reported or regulated.

To obtain a detailed point source emission data set, point source emissions of all three groups should be combined.

First **the regulated point sources with requirement for reporting** should be considered. As outlined in the introduction, the best starting point is the E-PRTR or equivalent national database. Such data can be used directly: emission data are known at exact locations, represented by x and y coordinates indicating the main point of emission on the site. As such there is no need to further spatially disaggregate the data to obtain spatially resolved emission maps of point sources per specific sector.

The E-PRTR or equivalent national data represent the total annual emission releases during normal operations and accidents. For E-PRTR, releases and transfers must however be reported only if the emissions of a facility are above the activity and pollutant thresholds set out in the E-PRTR Regulation. Therefore, sources may not need to report emissions if these are below a specified reporting threshold or reporting is not required for the specific activity undertaken at a facility. Consequently point source emissions from smaller plants or from specific activities might not be included in the E-PRTR database.

Emissions from **regulated point sources without annual emissions reporting requirements** can however often be estimated based on centralised data on process type and/or registered capacities and initialisation reports associated with the original application for emission permits. Estimating point source emissions for non-E-PRTR sources and representing them with x and y coordinates according to their exact location, results in spatially resolved maps of the smaller point sources.

Finally, emissions from **not reported or non-regulated sources** can be modelled by disaggregating national emission estimates over the known sources on the basis of capacity, pollutant correlations with reported data or some other 'proxy' statistic, such as employment. The following box (Example 1) provides some examples of approaches used to derive emissions for point sources in the absence of reported data. With the possible exception of using plant capacity, many of the approaches listed will yield emission estimates that are subject to significant uncertainty. However, most of the emission estimates generated using these methods are, individually, relatively small and the generation of point source data by these means is judged better than mapping the emissions as area sources.

EXAMPLE 1: ESTIMATING POINT SOURCE EMISSIONS FOR SOURCES/POLLUTANTS THAT ARE NOT REPORTED

In some cases, datasets are not complete. Furthermore, some point sources are not regulated. In these cases, point source data is generated using national emission factors and some 'proxy' activity statistic. Examples of approaches used are given below:

- Estimates of plant capacity can be used to disaggregate the national emission estimate. This approach can be used, for example, for bread bakeries where estimates of the capacity of large mechanised bakeries can be made or gathered from national statistics or trade associations.
- Emission estimates for one (reported) pollutant can be used to provide a weighted estimate of the national emission estimate of another pollutant. For example, emissions of PM_{10} from certain coating processes can be estimated by allocating the national total to sites based on their share of the national VOC emission.
- Deriving point source estimates based on pollutant ratios can be used to fill gaps in reported emissions data. In some cases known $PM_{10}/PM_{2.5}$ ratios can be established to estimate emissions for $PM_{2.5}$ where it is not reported, but PM_{10} emissions are available for similar processes. Where no other data is available, ratios with other pollutants, such as NO_x and SO_2, can be used to distribute other pollutant emissions.
- Assuming that all plants in a given sector have equal emissions: in a few cases where there are relatively few plants in a sector but no activity data can be derived, emissions can be assumed to be equal at all of the sites.

Finally, the obtained point source inventories and maps of the three different groups should be combined. It is therefore recommended to compile the different data sets based on the same sector classification. In principle any classification can be chosen initially, however, it is advisable to consider the categories required under different reporting obligations when compiling the point source emission data such as Annex I of the E-PRTR Regulation. The derived point source datasets should be structured such that it is possible to differentiate point source emissions into the relevant reporting sectors and to identify the methods and/or sources used to compile the data.

According to the E-PRTR Regulation, point source emissions have to be reported in categories covering 65 economic activities within 9 different industrial sectors. In order to allow computation of diffuse emissions, the E-PRTR or equivalent national LPS emission data will however need to be reconciled with the national totals and sectoral definitions in the inventory as reported under CLRTAP. So the data will need to be classified into process or Nomenclature For Reporting (NFR) categories (see section 3.2). Therefore it might be advisable to model and/or estimate non-reported emissions (Group 2 and 3) using the E-PRTR and/or NFR categories as well. Also, it might be worth to consider any other national or international uses, before deciding on the sector classification. The CEIP website provides a spreadsheet of reporting formats which maps different classifications from the various reporting obligations:

For modelling purposes, source characteristics such as stack height, source diameter and source heat capacity are important parameters. Nevertheless, while these characteristics are not required under most reporting obligations, it is highly recommended to include them when compiling the national point source emission inventory for modelling purposes.

3.2 Quantifying diffuse emissions

Point source emissions, as compiled in the first step, can represent sectors of a national inventory either fully or partly. Where a sector includes no point sources the whole sector is represented by diffuse emissions only. Where points represent part of a sector the quantity of the remaining emissions needs to be calculated using the **subtraction methodology** and are to be considered as diffuse emissions.

Different methodologies to identify the diffuse shares of the national emissions (CLRTAP) which are not covered by the reporting to E-PRTR have been developed in the past. In all approaches, firstly the different categorisations (NFR for CLRTAP and Annex I of the E-PRTR Regulation) used for reporting requirements have been analysed. Based on this correlation of activities (link NFR – E-PRTR) several subtraction methodologies have been applied. An overview of different procedures can be found in Theloke *et al.*, 2009.

In some cases, a review of different datasets (e.g. E-PRTR inventory versus CLRTAP inventory) can reveal that the total or sector specific E-PRTR emissions of some countries exceed the emissions officially reported by the same countries to CLRTAP (e.g. CEIP, 2010). If this occurs, a straightforward subtraction cannot be used. Instead of developing potentially complicated procedures to overcome this problem, it is strongly advised to first try to solve the issue before moving further in the process of spatial disaggregation of emissions. As the problem might occur due to different reasons and as it is impossible to provide a check list covering all causes, only some general guidance can be given in this section.

In most cases, exceedances of national totals by point emissions are caused by:

- inconsistent reporting under different reporting obligations;
- different sector classification systems;
- missing data (e.g. not all point sources included in national total);
- inconsistent data updates.

It is therefore suggested to first compare the different reporting obligations, making sure the same activities are taken into account. Furthermore, it should be checked whether the sector classifications are applied in a consistent manner (e.g. quite often total E-PRTR emissions do not exceed the national total whereas sector specific totals do, and this can be a consequence of inconsistent sector conversions). , It is also advised to check whether the point source contribution in the national total equals the totals that are effectively reported to E-PRTR. It might be that the point source data were revised after reporting to E-PRTR, and that the update is only taken into account in the national totals.

3.3 Disaggregating diffuse emissions

There will be many cases where emissions cannot be directly mapped at a suitably small spatial scale or where estimates are inconsistent with national estimates and statistics. Hence, national emission estimates will need to be disaggregated across the national spatial area using a proxy spatial dataset. The methods used can range in quality from Tier 3 to Tier 1 depending on the appropriateness of the spatial activity data being used, the basic principle behind the different methods is however the same for all cases. In this section, both the basic principles and some derived methodologies are outlined. Table 3.1 at the end of Section 3 provides suggestions for approaches on a sector by sector basis.

3.3.1 Basic principles

The basic principle of disaggregating emissions is presented in the formula below using a proxy spatial dataset x. This approach effectively shares out the national emissions according to the intensity of a chosen or derived spatially resolved statistic:

$$emission_{ix} = emission_t \times \frac{value_{ix}}{\sum_{jx}^{ix} value}$$

Where:

i	:	is a specific geographic feature;
$emission_{ix}$	:	is the emissions attributed to a specific geographical feature (e.g. a grid, line, point or administrative boundary) within the spatial proxy dataset x;
$emission_t$	:	is the total national emission for a sector to be disaggregated across the national area using the (x) proxy spatial dataset;
$value_{ix-jx}$	:	are the proxy data values of each of the specific geographical features within the spatial proxy dataset x.

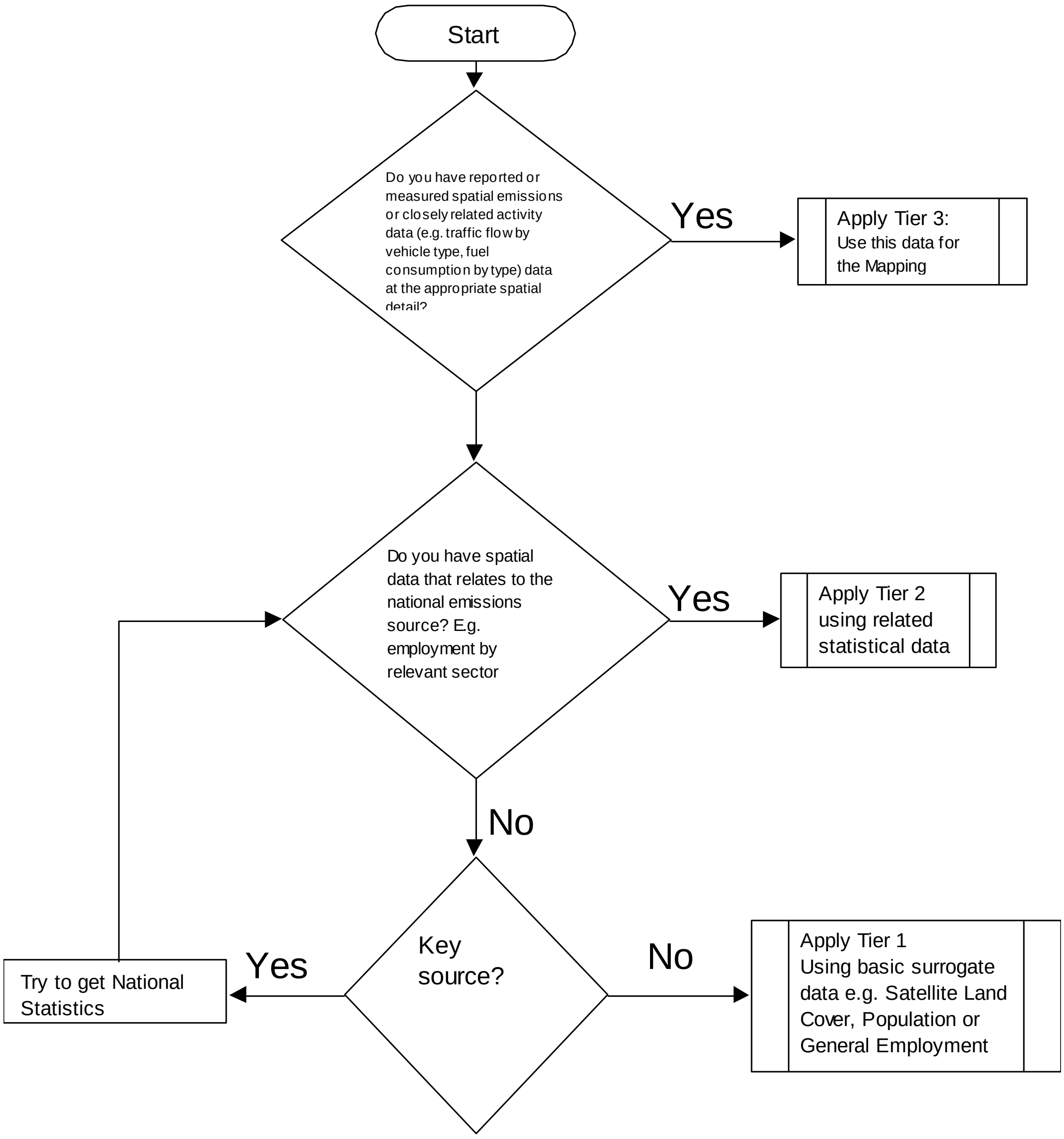
The following steps should be followed:

1. determine the emission to be disaggregated ($emission_t$) (either national total for sector or where a sector is represented by some large point sources then it is the national total minus sum of point sources, as outlined in sections 3.1 and 3.2);
2. distribute that emission using the basic principles above using a suitable proxy statistic (according to the detailed guidance by sector given in Table 3.1 below).
3. Keep the proxy spatial data in its original shape as long as possible in the calculation. This makes it easy to correct for mistakes or add new information without a big effort later on.

3.3.2 Decision tree

Different tiered methods for compiling spatially disaggregated estimates can be used depending on the data available. A general decision tree for prioritising approaches for each sector is presented below in Figure 3-2.

Figure 3-2 General decision tree for diffuse emissions mapping



Tier 3 methods will include estimates that are based on closely related spatial activity statistics, e.g. road traffic flows by vehicle type, spatial fuel consumption data by sector (e.g. sub-national energy data).

Tier 2 methods will be based on the use of proxy statistics. However, for Tier 2, these statistics need to relate to the sector and could include detailed sector specific employment, population or household size and number (for domestic emissions).

Tier 1 methods will include the use of loosely related proxy statistics such as urban rural land cover data, population (for non-domestic sources).

These principles apply to the general methods for estimating spatial emissions. Detailed methods are provided for each sector in Table 3-1. The following box (Example 2) provides some general examples of disaggregating national emissions.

EXAMPLE 2: DISTRIBUTION OF NATIONAL EMISSIONS

SO_x emissions from residential combustion may be disaggregated based on a gridded or administrative boundary (e.g. NUTS) spatial dataset of population density. However, emissions of SO_2 may not correlate very well to population density in countries where a variety of different fuels are burned (e.g. city centres may burn predominantly gas and therefore produce very low SO_x emissions per head of population). Additional survey information and or energy supply data (e.g. metered gas supply) could be used to enhance the population-based proxy for residential emissions and achieve a better spatial correlation to 'real' emissions.

National transport emissions may be disaggregated to road links (road line maps) based on measured or modelled traffic flow, road type or road width information for each of the road links. Again, the closer the distribution attributes for each road link correlate to the actual emissions, the better. For example, road width and road type only loosely relate to traffic emissions and provide a poor disaggregation method. Being able to distinguish between the numbers of heavy goods vehicles and cars using different road links each year, and the average speeds of traffic on these links, will improve the compiler's ability to accurately disaggregate emissions.

In many cases the combination of more than one spatial dataset will provide the best results for disaggregating emissions. For example, where traffic count/density information is not available, basic road link information can be combined with population data to derive appropriate emission distribution datasets to provide a Tier 1 methodology.

3.3.3 Sectoral guidance

Table 3.1 at the end of section 3 gives general guidance for the tiered mapping of emissions for different sectors. The table indicates which sectors are likely to include point sources, diffuse sources or a combination of the two. Table 3.1 also contains a sector specific overview of different spatial mapping approaches ranging from Tier 3 to Tier 1.

3.3.4 *Example 3: Gridding methodology of the emissions from road transport (NFR sector 1.A.3.b)*

Several European countries (e.g. BE, NL or UK) apply country specific methods to grid emissions from road transport. In this section, the methodology developed by Theloke *et al.* (2009) is described, as it is general and widely applicable over the whole of Europe. However, note that some information sources quoted in this section are only available commercially.

Sector description

The emissions from road transport arise from the combustion of fuels such as gasoline, diesel, liquefied petroleum gas (LPG), and natural gas in internal combustion engines (EMEP/EEA, 2013). The sector road transport considers road transportation of passengers and goods by vehicle classes and split by fuel type. This sector is considered as diffuse (see Table 3.1, NFR sector 1.A.3.b), therefore, according to the scheme presented in Figure 3-1. Compilation of point source emissions is not relevant and consequently the complete national reported emissions can be considered as diffuse emissions.

Exhaust emissions from road transport are reported according to the following NFR sector codes:

- 1.A.3.b.i Road Transport: Passenger cars;
- 1.A.3.b.ii Road Transport: Light duty vehicles;
- 1.A.3.b.iii Road Transport: Heavy duty vehicles;
- 1.A.3.b.iv Road Transport: Mopeds & Motorcycles.

The allocation of emissions distinguishes on-road activities on the following street types:

- highways;
- rural roads;
- urban roads.

Furthermore, the vehicle types are distinguished by fuel type for each relevant NFR code:

- passengers cars (LPG, diesel and gasoline)
- light duty vehicles (diesel and gasoline)
- heavy duty vehicles (diesel)
- motor cycles (two and four-strokes, gasoline)

Non-exhaust emissions are not considered in the worked example that follows. However, $PM_{2.5}$ emissions from brake and tyre wear and road abrasion can be disaggregated across the road transport network according to vehicle kilometres driven on different road links. NMVOC emissions from evaporative losses can similarly be mapped according to the disaggregation of activity across the road network, but if running and standing losses (and cold start) emissions are estimated as individual components, then standing losses are better assigned to spatial disaggregation that represents start and finish locations of journeys – such as a population disaggregation.

Emission input data

Emission data used for the gridding procedure are reported sectoral totals from the CLRTAP NFR sectors 1.A.3.b.i, Passenger cars; 1.A.3.b.ii, Light duty vehicles; 1.A.3.b.iii, Heavy duty vehicles; and 1.A.3.b.iv, Mopeds & Motorcycles.

Additional preparation of the emission data sets is necessary to distinguish between different road and vehicle types. The first intermediate calculation is the allocation of the emissions reported to CLRTAP into different road classes (highway, rural and urban) based on the TREMOVE model (TREMOVE, 2010). The results are road and vehicle class specific shares for each pollutant and country.

The next step is to harmonize the road and vehicle classes with the road network from the TRANSTOOLS model (TRANSTOOLS, 2010). The road classes (highway, rural and urban) are allocated to both roads which are covered and those that are not covered by TRANSTOOLS. As TRANSTOOLS covers only highways and major rural roads the emissions from rural roads based on TREMOVE calculation therefore have to be partly allocated to the roads covered by TRANSTOOLS. The assumption is that 50 % of the rural roads are allocated to the TRANSTOOLS roads and the remaining 50 % are categorised as rural road emissions.

The second intermediate calculation is for the distinction of the rural and urban road traffic into line and area sources. The assumption for the rural roads not covered by TRANSTOOLS is that 70 % of the emissions are categorised as line sources and the remaining 30 % of the rural roads not covered by TRANSTOOLS are categorised as area sources. The urban roads are categorised 50 % as line and 50 % as area sources. This strategy is clarified in the upper part of the scheme presented in **Error! Reference source not found.**. The assumptions used above for percentage splits may need to be varied for different countries depending on the level of urbanisation etc.

Applied methodology

The spatial disaggregation of emission data into target grid cells is carried out using the approach and formula outlined in section 3.3.1.
In this case, the specific geographic feature for which emissions are estimated is the line (road segment) at grid level. The proxy spatial dataset consists of the fraction of traffic volume for each individual road segment within each target grid cell of the sum of the overall traffic volume within the country.
The use of proxy data allows determining the share of annual emissions which are attributed to each grid cell. The proxy data are correlated with the emission source sectors and defined by means of:

- geographical resolved statistical information or
- land cover/land use data

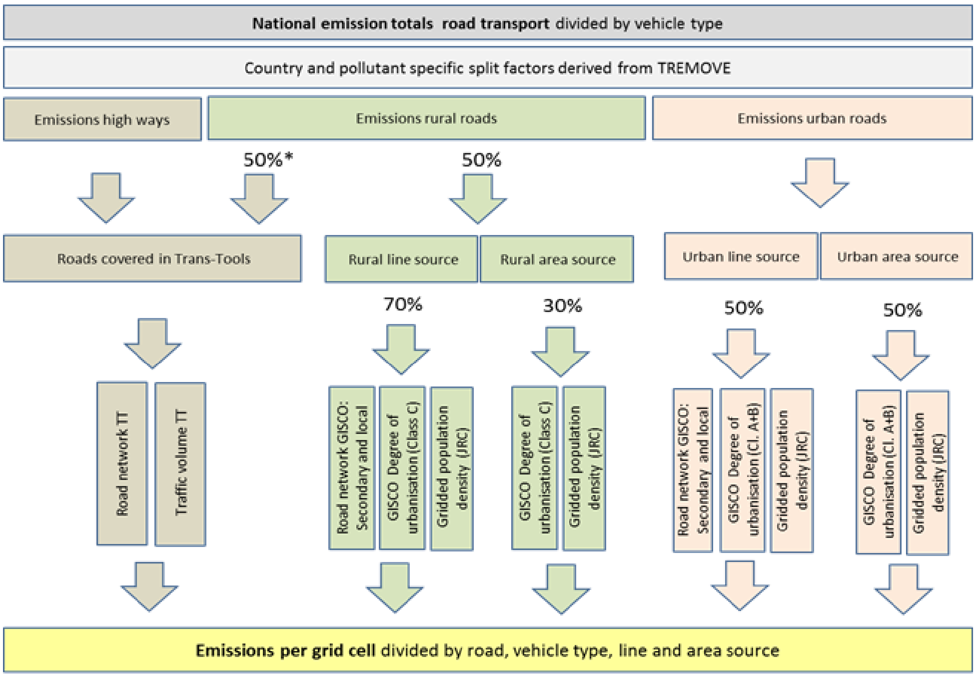
Spatial disaggregation and gridding

The methodology of the spatial disaggregation of the road transport can be summarised into the following main steps:

1. **Regionalisation of national emission releases**: allocation of the emission values based on traffic volume data for each road segment and also population density related to roads not covered by TRANSTOOLS. This disaggregates the share of the national totals of each specific pollutant to each road segment in the TRANSTOOLS model and to NUTS level 3 regions for the urban and rural traffic not covered by TRANSTOOLS.
2. **Gridding**: spatial disaggregation of the regionalised emission values on grid cell level is based on TRANSTOOLS, GISCO (ROAD) road network (GISCO, 2010) and gridded population density from JRC (Gallego, 2010). The results are gridded emissions for each road segment and regional unit to each grid cell, using the following underlying parameters:
    - Traffic volume and road network from TRANSTOOLS for highways and partly for rural roads;
    - Road network divided by road type from GISCO (ROAD) for the roads not covered in TRANSTOOLS (secondary and local roads);
    - Gridded population density as weighting factor for line sources in relation to rural and urban roads not covered by TRANSTOOLS. Additionally as disaggregation parameter for rural and urban area sources.
    - Degree of urbanisation (GISCO, 2010) for the categorization of the roads from GISCO and the gridded population from JRC (Gallego, 2010) into urban and rural.

The methodology for the spatial disaggregation of national total emissions from road transport activities to a grid for each vehicle and road type is shown in **Error! Reference source not found.**.

Figure 3-3 Overview of the applied methodology for the spatial disaggregation of the road transport, Theloke *et al.* (2009).



* *Trans-Tools covers major rural roads*

3.3.5 *Example 4: Gridding methodology for the diffuse emissions from Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel (NFR sector 1.A.2.a)*

Several European countries (e.g. BE, NL and UK) apply country specific methods to grid diffuse emissions from industrial releases. In this section, a general methodology based on employment data is described. NFR sector 1.A.2.a is chosen as an example, but the methodology can be applied for several sectors (see Table 3.1) and moreover is widely applicable over the whole of Europe.

Sector description

The NFR sector 1.A.2.a, Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel, is dominated by E-PRTR related point sources, but is also containing diffuse emissions (see Table 3.1). This comprises industrial releases from industrial facilities not covered by the E-PRTR Regulation and its Annexes.

In this section a methodology to spatially disaggregate the diffuse emissions from stationary combustion in iron and steel industry is described.

Emission input data

As input emission data for the spatial disaggregation of diffuse industrial releases, national data reported to the LRTAP Convention can be taken. To obtain the diffuse part of the country specific emissions, not covered by the E-PRTR regulation, a subtraction methodology, as described in Section 3.2, first needs to be applied. It is important to check that the sector representations are the same in the point source dataset and the national emissions data, to ensure compatibility for the subtraction methodology.

Applied methodology

Diffuse industrial releases can be spatially disaggregated according to different proxy data using the approach described in section 3.3.1: In this case, the specific geographic feature for which emissions are estimated is the 1 x 1 km grid cell. The proxy spatial dataset is based on a combination of land use and employment statistics: the share of employees in each 'Industrial or Commercial' CORINE land cover unit, related to the national total of the employees.

The use of proxy data allows calculation of the share of annual emissions that have to be attributed to each cell. The crucial part in the methodology described above, is the construction of the spatial proxy. It basically consists of the following steps:

- Select the appropriate land cover types in the CORINE land cover map. In this example using "Industrial or commercial units" (CLC 2012, 2016);
- Calculate the share of employees in each polygon of the selected units; (e.g. EUROSTAT Employment statistics - Manufacture of basic iron and steel and of ferroalloys)
- Use the employee weighted industrial zones as spatial proxy in the above formula.

It is also important to consider if double counting of emissions may occur at point source locations when using the above methodology. Removal of this double counting would then be necessary.

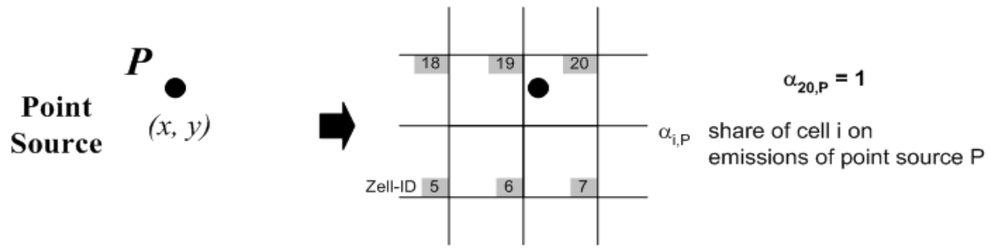
3.4 Combining different spatial features

Following the emission-disaggregation process, emissions at this stage are likely to be in a number of different spatial forms including different sizes of grids, polygons, lines and even point sources (where emissions are derived by allocating national estimates according to published capacity or employment information), each determined by the spatial characteristics of the source data. There is then a need to combine these together into a unifying format. This is usually a regular grid at a resolution appropriate to the spatial accuracy of the data inputs.

Spatial emission data will need to be combined to form emission maps. This is generally done by resolving the different spatial forms to a common grid so that different sectors/sources can be aggregated. The common grid can either be the EMEP 0.1 x 0.1 degree grid or another grid based on national coordinates and/or smaller cell sizes. The methodologies for converting the different forms to a common grid are outlined below. For line and area conversion to grids an intersect operation is needed. This intersects the boundaries of the polygon or the length of the line with the boundaries of the grid and creates a new set of features cut to the extent of each grid cell.

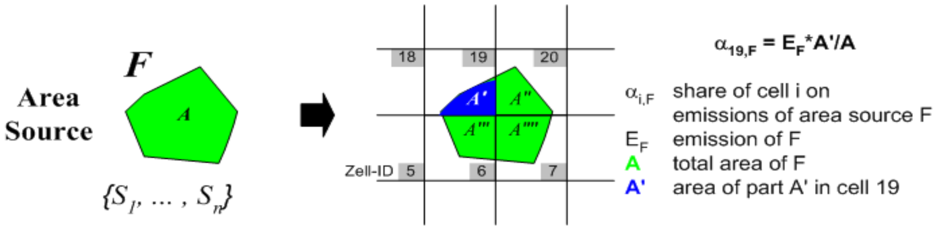
3.4.1 Point sources to grids

Point sources can be allocated directly to the grid within which they are contained by converting the x,y values to that of the coordinates used to geo-reference the grid or by intersecting the point with the grid.



3.4.2 Area source (polygons) to grids

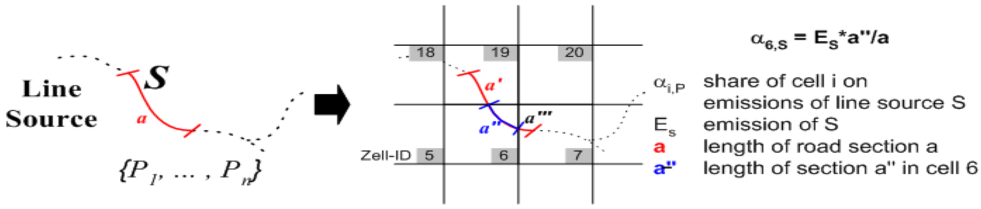
Intersecting the polygon with the grid will produce a dataset of polygons contained within each grid.



The fraction of the area of the new polygons can be used to distribute the emissions/proxy statistics from the original polygon to the grid cells. Alternatively, an emission rate/area can be applied to the new polygon area and that emission/proxy statistic assigned to the grid cell.

3.4.3 Line sources to grids

Intersecting the line features with the grid will produce a dataset of shorter line lengths contained within each grid.



The fraction of the original line length of the new line can be used to distribute the emissions/proxy statistics from the original line to the grid cells. Alternatively, an emission rate/unit of length can be applied to the new line length and that emission/proxy statistic assigned to the grid cell.

3.4.4 Converting between different spatial projections (e.g. WGS84 to ETRS89)

In a number of cases, an inventory compiler may need to combine data from different spatial datasets and extents to eventually derive the 0.1 x 0.1 degree EMEP grid.

The Open Geospatial Consortium Inc. provides guidance and standards for coordinate transformation (see www.opengeospatial.org/standards/ct).

3.4.5 Aggregating to the UNECE GNFR

The aggregated sectors 'gridded NFR' (GNFR) for reporting are defined in Annex I to the Guidelines for reporting emission data under the Convention on Long-range Transboundary Air Pollution (see section 1). These aggregations can be achieved through the aggregation of the spatially resolved (mapped) detailed NFR sectors (or sector groups). Aggregation of NFR to GNFR prior to mapping is not recommended as it may result in reduced accuracy in the placement of emissions.

3.5 Estimating uncertainty in emission maps

Where the location of emissions is estimated using proxy statistics, this will introduce significant uncertainty into the resulting emission maps. It can be useful to make an overall assessment of uncertainty for different sectors and different overall emission maps by pollutant in order that the data users can use the data in ways that best reflect the level of uncertainty.

Emission maps for the UK have been assessed for uncertainty using a simple method. This is explained in section 5.1 of the UK Emission Mapping report (Tsagatakis et al, 2017).

Table 3.1: General tiered guidance for the spatial disaggregation of emissions by sector

Notes on columns:

NFR sector and **NFR sector name** describe the NFR sector codes used in national inventory report

GNFR sector is required for gridded emissions reporting – see mapping table at http://www.ceip.at/fileadmin/inhalte/emep/xls/ConversionTableReportingCodes_October2015.xlsx

Cat. gives an indication on whether the sector is fully, partly, or not covered by E-PRTR point sources using the following categories:

- A – E-PRTR point source relevant: covered by E-PRTR sources
- B – E-PRTR point source relevant: covered by E-PRTR sources but also including diffuse sources (below E-PRTR reporting threshold)
- C – E-PRTR relevant like industrial facilities (B), but only agricultural installations
- D – Diffuse sources, which are not covered by E-PRTR

Tier 3, Tier 2, Tier 1 describes examples of methods that can be used for the best quality output (Tier 3, to a simple approximation of the emissions disaggregation (Tier 1)

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
1.A.1 Energy industries	1.A.1.a Public Electricity and Heat Production	A_PublicPower	A	Reported point source data or national totals disaggregated using plant-specific capacity or other activity statistics	Employment data e.g. for 1.A.1.c: number of employees by economic activities (EUROSTAT Employment statistics - Manufacture of coke oven products) See also section 3.3.5 for an example	Industrial Land cover	A combination of tiered approaches might be needed depending on the availability of a complete dataset of point sources. Where only partial datasets are available for point sources use proxy data most relevant to sub-sectors to map diffuse remainder.
	1.A.1.b Petroleum Refining	B_Industry	A				
	1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	B_Industry	B				
	1.A.2.a Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel	B_Industry	B		Employment data		A combination of tiered approaches might be needed depending on the

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	NFR sector name	GNFR sector	Cat.	Tier 3	Tier 2	Tier 1	Notes
1.A.2 Manufacturing industries and construction	1.A.2.b Stationary Combustion in Manufacturing Industries and Construction: Non-ferrous Metals	B_Industry	B	Reported point source data or national totals disaggregated using plant-specific capacity or other activity statistics	e.g. for 1.A.2.a: number of employees by economic activities (EUROSTAT Employment statistics - Manufacture of basic iron and steel and of ferroalloys)	Population or Land cover	availability of a complete dataset of point sources. Where only partial datasets are available for point sources use proxy data most relevant to sub-sectors to map diffuse remainder.
	1.A.2.c Stationary Combustion in Manufacturing Industries and Construction: Chemicals	B_Industry	B				
	1.A.2.d Stationary Combustion in Manufacturing Industries and Construction: Pulp, Paper and Print	B_Industry	B				
1.A.2 Manufacturing industries and construction	1.A.2.e Stationary Combustion in Manufacturing Industry and Construction: Food Processing, Beverages and Tobacco	B_Industry	B	Reported point source data or national totals disaggregated using plant-specific capacity or other activity statistics	e.g. for 1.A.2.f: number of employees by economic activities (EUROSTAT Employment statistics - Manufacture of other non-metallic mineral products; of glass & glass products; of other porcelain & ceramic products; of cement, lime & plaster; of central heating radiators and	Population or Industrial Land cover	A combination of tiered approaches might be needed depending on the availability of a complete dataset of point sources. Where only partial datasets are available for point sources use proxy data most relevant to sub-sectors to map diffuse remainder.
	1.A.2.f.i Stationary Combustion in Manufacturing Industries and Construction: Other	B_Industry	B				
	1.A.2.f.ii Mobile Combustion in Manufacturing Industries and Construction	I_OffRoad	D				

				Best quality---------→--------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
					boilers; of industrial ashes)		
1.A.3 Transport	1.A.3.a.i (i) International Aviation (LTO) 1.A.3.a.ii (i) Civil Aviation (Domestic, LTO)	H_Aviation H_Aviation	D D	Estimated detailed emissions by airport for Landing and Take-Off by type of aircraft	Disaggregate national emissions estimates to each airport based on Take-Off and Landing statistics	Airports Land cover	Emissions from domestic cruise and from international aircraft flights should be excluded from the mapping as these are estimated centrally by EMEP. Where possible, additional weightings to take account of the average size of aircraft at each airport should be used (e.g. emission factor to aircraft size ratios).

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
1.A.3 Transport	1.A.3.b.i Road Transport: Passenger cars 1.A.3.b.ii Road Transport: Light duty vehicles 1.A.3.b.iii Road Transport: Heavy duty vehicles 1.A.3.b.iv Road Transport: Mopeds & Motorcycles 1.A.3.b.v Road Transport: Gasoline evaporation 1.A.3.b.vi Road Transport: Automobile tyre and brake wear 1.A.3.b.vii Road Transport: Automobile road abrasion	F_RoadTransport F_RoadTransport F_RoadTransport F_RoadTransport F_RoadTransport F_RoadTransport F_RoadTransport l	D D D D D D D	Traffic flows and types of vehicles (2)	Using road network information and population-based traffic intensity	Population and Land cover	Different tiered approaches will usually be needed for different road types. Major roads will often have traffic counts or modelled flows, while minor roads will not. Countries that have traffic count/flow information will usually need to apply a Tier 2 method for minor roads. See section 3.3.4.
	1.A.3.c Railways	I_Offroad	D	Diesel rail traffic on the rail network reconciled with	Rail network and population-based traffic weightings	Population-weighted disaggregation of	Rail networks that have been electrified should be excluded from the

(2) Spatial traffic flow statistics that have a basic vehicle type split should be used in order to enable appropriate emissions allocation for the key NFR reporting categories. Where traffic composition data (flows by vehicle type) are unavailable, averaged composition % can be applied to total flow by road type based on national survey data or on data available on the COPERT4/FLEETS webpages Gkatzoflias *et al.* (2007), or from the European MEET (Methodologies to Estimate Emissions from Transport), a European Commission (DG VII) sponsored project in the framework of the 4th Framework Programme in the area of Transport project.

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
1.A.3 Transport				national mobile locomotive consumption data		land cover class for rail	disaggregation where possible. This may only be important if large areas are all electrified (e.g. cities).
	1.A.3.d.i (i) International maritime Navigation 1.A.3.d.i (ii) International inland waterways 1.A.3.d.ii National Navigation (Shipping)	z_Memo G_Shipping G_Shipping	D D D	Route-specific ship movement data and details of fuel quality by region, consumption and emission factors by type of ship & fuel	Port arrival & destination statistics used to weight port and coastal shipping areas	Assign national emissions to Land cover classes for ports and coastal shipping areas	Tier 1 & 2 methods will need to make assumptions about the weighting of in-port vs. in-transit emissions. Tier 3 methods will need to use ship movement data from centralised databases and account for in-port emissions from loading and unloading of ships. Harbourmaster or coast guard data can sometimes provide details of ship time in ports and operations. Emissions will need to be broken down into national and international data. Useful information for the mapping of shipping data can be obtained from Ricardo Energy & Environment (2017).
	1.A.3.e Pipeline compressors	B_Industry	D	Reported/collected data	Land cover	Land cover	
1.A.4 Other sectors	1.A.4.a.i Commercial / Institutional: Stationary 1.A.4.a.ii Commercial / Institutional: Mobile	C_OtherStationary Comb I_OffRoad	B D	Reported/collected point source data, boiler census or surveys	Employment for public and commercial services	Land cover	Large point source data is likely to be minimal unless there are large district heating or commercial/institutional heating plant included in the

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
							national inventory under sector 1A4a.
	1.A.4.b.i Residential: Stationary plants 1.A.4.b.ii Residential: Household and gardening (mobile)	C_OtherStationary Comb I_OffRoad	D D	Detailed fuel deliveries for key fuels (e.g.gas) and modelled estimates for other fuels using data on population density and/or household numbers and types.	Population or household density combined with land cover data if smoke control areas exist in cities.	Land cover	Tier 1 & 2 methods assume that a linear relationship between emissions and population density or land cover exists. This assumption will be most realistic if a country has a uniform distribution of fuel use by type. Where there is a broad variation of fuel type use in different areas, the accuracy of the simple method will be much lower. An example Tier 3 method is described in the UK Inventory mapping method report https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1710261436_Methodology_for_NAEI_2017.pdf.
	1.A.4.c.i Agriculture/Forestry/Fishing: Stationary 1.A.4.c.ii Agriculture/Forestry/Fishing: Off-road Vehicles & Other Machinery	C_OtherStationary Comb I_OffRoad	D D	For 1.A.4.c.i and 1.A.4.c.ii: Detailed fuel deliveries for key fuels (e.g. gas) and modelled estimates for other fuels using employment data	For 1.A.4.c.i and 1.A.4.c.ii: Employment data for the agricultural and forestry sectors	Land cover	Where land cover is used, emissions for agriculture and forestry should be split and disaggregated according to the relevant classes. Where this is not possible, emissions should be disaggregated according to a combined land cover class for agriculture and forests or allocated to the dominant class e.g. 'arable land' for

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
	1.A.4.c.iii Agriculture/Forestry/Fishing: National Fishing	G_Shipping	D	For 1.A.4.c.iii: Allocation of emissions to ports on fish landings and to geographic areas of fishing grounds	For 1.A.4.c.iii: Allocation of emissions to ports on fish landings	For 1.A.4.c.iii: Assign national emissions to Land cover classes for ports	countries where emissions from agricultural combustion dominate. Where employment data is used, care should be taken to ensure that the employment classes are representative of the national sector for Agriculture and Forestry. Employment statistics will often include the financial and administrative head offices (often located in cities) while energy statistics based national emissions from these 'head offices' may be included under 1.A.4.a.i Commercial / Institutional: Stationary. Care should be taken to ensure that the emissions are located where they occur. The use of employment data will locate emissions at registered places or regions of work and may tend to focus emissions inappropriately to urbanised areas. Emissions from fishing are likely to be associated with fishing grounds rather than port activities. Tier 3

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
							methods will need to disaggregate emissions to ports and fishing grounds.
1.A.5 Other	1.A.5.a Other, Stationary (including Military)	C_OtherStationary Comb	D	Population and Land cover	Population and Land cover	Population and Land cover	
	1.A.5.b Other mobile (Incl. military, land based & recreational boats).	I_OffRoad	D				
1.B.1 Fugitive emissions from solid fuels	1.B.1.a Fugitive emission from Solid Fuels: Coal Mining and Handling 1.B.1.b Fugitive emission from Solid Fuels: Solid Fuel Transformation 1.B.1.c Other fugitive emissions from solid fuels	D_Fugitive D_Fugitive D_Fugitive	B B B	Reported point source data or using plant-specific capacity or other activity statistics	Locate point sources and use employment data for specific sectors to disaggregate emissions e.g. for 1.B.1.b: number of employees by economic activities (EUROSTAT Employment statistics - Electric power generation, transmis-sion and distribution; Manufacture of coke oven products)	Total employment for the mining and transformation industry as a whole	Mines, fuel transformation plant, depots and distribution centres are likely to be regulated and significant national industrial sites. In these cases site-specific information can be collected and used to distribute national emission estimates over a number of point sources or grids.
1.B.2	1.B.2.a.i Exploration Production, Transport	D_Fugitive		Exploration and production distribution centres	Location of off shore extraction installations and	Identification of large point sources and	Many of the exploration, refining and storage facilities will be regulated and data

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
Fugitive emissions oil and natural gas 1.B.3 Other fugitive emissions	1.B.2.a.ii Refining / Storage 1.B.2.a.iii Distribution of oil products 1.B.2.b Natural gas 1.B.2.c Venting and flaring	D_Fugitive D_Fugitive D_Fugitive D_Fugitive	B B D B B	should be identified and emissions estimated allocated to the point locations using production activity data. Distribution emissions should be mapped using details of distribution network and leakage rates or losses along the systems.	allocation of emissions using proxies such as employment or capacity. Distribution to be allocated evenly over the distribution network e.g. for 1.B.2.a.i: number of employees by economic activities (EUROSTAT Employment statistics - Manufacture of gas; distribution of gaseous fuels through mains; Manufacture of refined petroleum products)	disaggregated evenly over locations. Use population or employment data for distribution	available from energy ministries or regulators. Operators or regulators for distribution of fuels will often be able to provide network maps.

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
2.A Mineral Products	2.A.1 Cement production	B_Industry	B	Integrate reported point source data or derive emissions using plant specific, activity, throughput, production, capacity or other activity statistics	Employment data e.g. for 2.A.1 and 2.A.2: number of employees by economic activities (EUROSTAT Employment statistics - Manufacture of paper and paper products; Manufacture of cement, lime and plaster; Manufacture of abrasive products and non-metallic mineral products; Manu-facture of basic iron and steel and of ferro-alloys)	Population or Land cover	Where possible, try to use point source data as the basis for estimating process emissions. The methodology for Tier 2 relies heavily on detailed sectoral employment data for proxy spatial disaggregation. However, in many cases these are not specific to the processes producing emissions, as emissions are likely to be highly specific to particular plants and processes. Employment data will also distribute emissions to locations that may have administrative or head office activities only where process emissions do not occur.
	2.A.2 Lime production	B_Industry	B				
	2.A.3 Glass production	B_Industry	B				
	2.A.4.a Quarrying and mining of minerals other than coal	B_Industry	B				
	2.A.4.b Construction and demolition	B_Industry	D				
	2.A.4.c Storage, handling and transport of mineral products	B_Industry	D				
	2.A.4.d Other mineral products	B_Industry	B				

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
2.B Chemical Industry	2.B.1 Ammonia production	B_Industry	B	Integrate reported point source data or derive emissions using plant specific, activity, throughput, production, capacity	Employment data e.g. for 2.B.1, 2.B.2, 2.B.3 and 2.B.4: number of employees by economic activities (EUROSTAT Employment statistics - Manufacture of other inorganic basic chemicals) e.g. for 2.C.1 and 2.C.2: number of	Population or Land cover	
	2.B.2 Nitric acid production	B_Industry	B				
	2.B.3 Adipic acid production	B_Industry	B				
	2.B.5 Carbide production	B_Industry	B				
	2.B.6 Titanium dioxide production	B_Industry	B				
	2.B.7 Soda ash production	B_Industry	B				
	2.B.10.a Other chemical industry	B_Industry	B				
	2.B.10.b Storage, handling and transport of chemical products	B_Industry	B				
2.C Metal Production	2.C.1 Iron and steel production	B_Industry	B				
	2.C.2 Ferroalloys production	B_Industry	B				

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
	2.C.3 Aluminium production	B_Industry	B	or other activity statistics	employees by economic activities (EUROSTAT Employment statistics - Manufacture of basic iron and steel and of ferro-alloys)		
	2.C.4 Magnesium production	B_Industry	B				
	2.C.5 Lead production	B_Industry	B				
	2.C.6 Zinc production	B_Industry	B				
	2.C.7.a Copper production	B_Industry	B				
	2.C.7.b Nickel production	B_Industry	B	Integrate reported point source data or derive emissions using plant specific, activity, throughput, production, capacity or other activity statistics		Population or Land cover	
	2.C.7.c Other metal production	B_Industry	B		Employment data e.g.: number of employees by economic activities (EUROSTAT		
	2.C.7.d Storage, handling and transport of metal products	B_Industry	B				

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
2.D – 2.L Solvent use and Other production	2D3a Decorative coating application	E_Solvents	D	Integrate reported point source data or derive emissions using plant-specific, activity, throughput, production, capacity or other activity statistics	Employment or appropriate population data e.g. for number of employees by economic activities (Employment for coating industries including metal packaging, vehicle refinishing, rolling mills, vehicle repair, wood coating, ...)	Population or Land cover	For Tier 2 where processes are industrial and there is a good employment dataset, use this. For emissions that result from consumption of products in the home, use population.
	2D3b Industrial coating application	E_Solvents	B				
	2D3c Other coating application	E_Solvents	B				
	2D3d Asphalt roofing	B_Industry	D				
	2D3e Road paving with asphalt	B_Industry	D				
2.D – 2.L Solvent use and Other industrial production	2D3f Degreasing	E_Solvents	B				
	2D3g Dry cleaning	E_Solvents	D				
	2D3h Domestic solvent use including fungicides	E_Solvents	D				
	2D3i Chemical products	E_Solvents	B				
	2D3j Printing	E_Solvents	B		Employment or appropriate population data		
	2D3k Other solvent use	E_Solvents	D				For Tier 2 where processes are industrial and there is a
	2G Other product use	E_Solvents	B	Integrate reported point source data or	e.g. for number of employees by		

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
	2H1 Pulp and paper industry 2H2 Food and beverages industry 2H3 Other industrial processes 2I Wood processing 2J Production of POPs 2K Consumption of POPs and heavy metals (e.g. electrical and scientific equipment) 2L Other production, consumption, storage, transportation or handling of bulk products	B_Industry B_Industry B_Industry B_Industry B_Industry B_Industry B_Industry	B B B B B D D	derive emissions using plant-specific, activity, throughput, production, capacity or other activity statistics	economic activities (Employment in newspaper and magazine industry) e.g. for 3.D.2 and 3.D.3: population density	Population or Land cover	good employment dataset, use this. For emissions that result from consumption of products in the home, use population.
	3.B.1.a Manure management - Dairy cattle 3.B.1.b Manure management - Non-dairy cattle 3.B.2 Manure management – Sheep 3.B.3 Manure management - Swine	K_AgriLivestock K_AgriLivestock K_AgriLivestock K_AgriLivestock	D D D C	Reported emissions from regulated farms or detailed spatial farm livestock survey statistics	Employment statistics or land cover and agricultural production statistics	Land cover for arable land or improved	When using these statistics care should be taken to account for possible over allocations to head/offices or market employment in urban areas that will distort

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	NFR sector name	GNFR sector	Cat.	Tier 3	Tier 2	Tier 1	Notes
	3.B.4.a Manure management – Buffalo 3.B.4.f Manure management – Goats 3.B.4.g Manure management – Horses 3.B.4.i Manure management - Mules and asses 3.B.4.j Manure management – Poultry 3.B.4.n Manure management - Other animals	K_AgriLivestock K_AgriLivestock K_AgriLivestock K_AgriLivestock K_AgriLivestock K_AgriLivestock	D D D D C D	Reported emissions from regulated farms or detailed spatial farm livestock survey statistics	or land cover and livestock statistics Employment statistics or land cover and agricultural production statistics or land cover and livestock statistics	grassland as appropriate Land cover for arable land	the pattern of emissions and allocate too many emissions to urban areas When using these statistics care should be taken to account for possible over allocations to head/offices or market employment in urban areas that will distort the pattern of emissions and allocate too many emissions to urban areas
3.D – 3.I Other agriculture	3.D.a.1 Inorganic N-fertilizers (includes also urea application) 3.D.a.2.a Animal manure applied to soils 3.D.a.2.b Sewage sludge applied to soils 3.D.a.2.c Other organic fertilisers applied to soils (including compost) 3.D.a.3	L_AgriOther L_AgriOther L_AgriOther L_AgriOther L_AgriOther	D D D D D	Reported emissions from regulated farms or detailed spatial farm crop/fertilizer use survey statistics	Employment statistics or land cover and agricultural production statistics or land cover and livestock statistics	Land cover for arable land	For Tier 3 survey statistics for crop production can be combined with fertilizer use/stubble burning rates to estimate weightings by crop type. Farm level data is often commercially sensitive and may need to be aggregated

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
	Urine and dung deposited by grazing animals 3.D.a.4 Crop residues applied to soils 3.D.b Indirect emissions from managed soils 3.D.c Farm-level agricultural operations including storage, handling and transport of agricultural products 3.D.d Off-farm storage, handling and transport of bulk agricultural products 3.D.e Cultivated crops 3.D.f Use of pesticides 3.F Field burning of agricultural residues 3.I Agriculture other	L_AgriOther L_AgriOther L_AgriOther L_AgriOther L_AgriOther L_AgriOther L_AgriOther L_AgriOther	D D D D D D D D	Reported emissions from regulated farms or detailed spatial farm crop/fertilizer use survey statistics	Employment statistics or land cover and agricultural production statistics or land cover and livestock statistics	Land cover for arable land	For Tier 3 survey statistics for crop production can be combined with fertilizer use/stubble burning rates to estimate weightings by crop type. Farm level data is often commercially sensitive and may need to be aggregated
5.A – 5B Biological treatment of waste	5.A Biological treatment of waste - Solid waste disposal on land 5.B.1	J_Waste J_Waste	D D	Waste disposal to land statistics and landfill disposal records by site Composting records	Evenly disaggregated emissions over landfill site locations	Population statistics weighted with discontinuous urban fabric land cover	Most countries with regulated land disposal will have records of landfill sites in use. It may be more difficult to identify disused

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
	Biological treatment of waste – Composting 5.B.2 Biological treatment of waste - Anaerobic digestion at biogas facilities	J_Waste	D				sites or sites that are not regulated
5.C Waste incineration	5.C.1.a Municipal waste incineration 5.C.1.b Industrial waste incineration 5.C.1.c Clinical waste incineration 5.C.1.d Sewage sludge incineration 5.C.1.e Cremation 5.C.1.f Other waste incineration 5.C.2 Open burning of waste	J_Waste J_Waste J_Waste J_Waste J_Waste J_Waste J_Waste	A A B B B B B	Regulated process emissions by site	Emissions disaggregated over known sites based on capacity or population	Employment data for the specific industry or population/ farm statistics for small scale burning	Incineration 5C1a–d is generally regulated or controlled. Regulators or trade associations will hold site location details and often records of activity. Small scale waste burning (5C2) should be disaggregated using population or farm statistics depending on the dominant small scale burning sector.
5.D Waste-water handling	5.D.1 Domestic wastewater handling 5.D.2 Industrial wastewater handling 5.D.3 Other wastewater handling	J_Waste J_Waste J_Waste	B B B	Regulated process information and data on wastewater treatment plant	Employment statistics for wastewater treatment location of plant and capacity or some proxy of capacity-based on population density	Population statistics	Many countries now regulate wastewater treatment plant. Locations should be well known and activity data/emissions available by site.

				Best quality---------→-------------→----------Approximate estimate			
NFR sector	**NFR sector name**	**GNFR sector**	**Cat.**	**Tier 3**	**Tier 2**	**Tier 1**	**Notes**
6 Other	6.A Other (included in National Total for Entire Territory)	R_Other	D				
11 Biogenic emissions and forest fires				Detailed surveys of land use types and burned area combined with (Ing, 2007) factors for emissions	National emissions disaggregated using land cover data and any available data on burned areas	Basic land cover data	

4 Sourcing key spatial data sources

There are a variety of different sources of spatial data. The first place to look should be national statistical centres such as demographic, economic, transport, regulatory, energy, or regulating bodies and trade associations, as these data are likely to be most up-to-date.

4.1 General

4.1.1 Administrative boundaries

Statistics may be collected and stored with reference to regional or local government names while the information that defines the spatial boundaries of these areas (geographies) could be maintained in separate mapping datasets. Often a national mapping body is responsible for the boundary datasets while specific statistics attributable to these boundaries can be available from elsewhere. In these cases the statistics will need to be joined to the boundary dataset using lookups between the statistical dataset and the spatial structure dataset (e.g. area IDs or names). A number of common national datasets are listed below and give a starting point for data collection activities.

4.1.2 Geo-referenced data

Some data will be available with grid reference attributes, whereas other data may have postal address details. A grid reference lookup will be required to place the latter on a map.

Where national data are unavailable or too time consuming to collect, a number of international datasets can be used (see section 4.3 of the present chapter).

4.2 National datasets

4.2.1 Population and employment

Most countries will have spatial population and employment datasets based on administrative boundaries that can be used/combined to derive specific distributions or used as general default distributions where other methods are not feasible. These are good basic datasets that can be used in many ways for disaggregating emissions from different sources.

4.2.2 Gas distribution networks

Information on gas supply by region or on a GIS basis is often available from energy departments, from gas suppliers or from national statistical centres. National information on the number of households with/without gas supply can be useful when combined with population to estimate a distribution network.

4.2.3 Agricultural data

Most countries have agricultural census or survey data collected (e.g. livestock numbers, crop production, fertilizer use) at a detailed spatial scale at the administrative boundary level.

4.2.4 Road network information

It is likely that many countries will hold national or commercial road network datasets that includes the road geography. These can be used to distribute road traffic emissions in combination with traffic intensity statistics for administrative boundaries or specific count points.

4.2.5 Rail

Rail networks can be relatively easy to identify and datasets of the network are usually held by national mapping departments or organisations. Rail activity data is more difficult to obtain but can be part of national statistics or generated from detailed timetable information.

4.2.6 Aviation and airport activity data

Many countries have detailed aircraft movement datasets as part of their national statistics, detailing aircraft movements, the aircraft type, origin and destination by airport. These can be used to distribute emissions from Landing and Take-Off (LTO) and from airside support vehicles to airport areas and allocate these emissions to the appropriate grid square.

4.2.7 National shipping

National shipping data are usually in the form of port arrival and departure statistics and available from the national statistical authority. These will need to separate national and international shipping but can be used to provide an indication of port activity for attributing national emissions.

4.2.8 Point source information

Regulation of large point sources is common in most countries and public reporting of regulated emissions occurs under the requirements of the Aarhus Convention PRTR Protocol, E-PRTR Regulation and IED, all of which have established requirements for regular point source emissions reporting. Regulators within countries that are subject to these protocols and legal instruments will have publicly available records of reported emissions data. Alternative large point source information sources can include:

- trade associations
- operators
- statistical energy and productivity publications (capacity).

4.2.9 Local inventory data

In some cases local inventory data can be used to improve the spatial distribution of emissions for transport and stationary sources by providing smaller process emissions by point source and traffic information. However, integration of this data with the nationally reported data and resolving emissions allocated to other areas can be time consuming and difficult to document.

4.3 International datasets

There are also some international datasets that can be used to help derive the spatial emissions of a country. In this section both publicly and commercially available spatial data sets are listed. It is mentioned if a data access fee is required.

Note that existing spatial emission inventories at international or European level can be used as proxy data to derive spatial emissions of a country. Existing spatial inventories are however not listed here; an overview of spatial inventories is provided in section 5.

4.3.1 INSPIRE

The EU provides access to spatial datasets through the INSPIRE programme http://inspire.jrc.ec.europa.eu/. A number of different geographical datasets are available under this European initiative.

4.3.2 Land cover, population density and settlement data

If relevant national spatial statistics are not available then a simpler and less accurate method using land cover data can be used to derive emissions.

The CORINE 2012 dataset provides processed satellite images showing different land cover classes. This data can be accessed from: https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012 . Among the 44 different land covers provided, CORINE provides the following datasets of relevance to emissions mapping:

- continuous urban fabric
- discontinuous urban fabric
- industrial or commercial units
- road and rail networks and associated land
- port areas
- airports
- mineral extraction sites
- dump sites
- construction sites
- green urban areas
- arable land
- sport and leisure facilities.

A number of these CORINE datasets can be used individually or in combination to generate spatial distributions for sectoral emissions. Where CORINE or similar data are not available, satellite-based land cover data can often be derived from raw images using the CORINE methodology.

The CORINE population density dataset provides population density derived from the CORINE 2000 land cover data set. If relevant national spatial statistics are not available then for some sectors (see Table 3.1) a simpler and less accurate method using population density data can be used to derive emissions. This data can be accessed from: http://www.eea.europa.eu/data-and-maps/data/population-density-disaggregated-with-corine-land-cover-2000-2.

The European Settlement Map released was in 2017 and provides a high resolution spatial raster dataset of human settlements in Europe based on SPOT5 and SPOT6 satellite imagery. The dataset represents the percentage of built-up area coverage per spatial unit. More information is available at https://land.copernicus.eu/pan-european/GHSL/european-settlement-map.

4.3.3 ESA GlobCover

GlobCover is a European Space Agency initiative which began in 2005 in partnership with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. The aim of the project was to develop a service capable of delivering global composites and land cover maps using as input observations from the 300 m MERIS sensor on board the ENVISAT satellite mission.

ESA makes available the land cover maps, which cover 2 periods: December 2004 - June 2006 and January - December 2009.

See: http://due.esrin.esa.int/page_globcover.php

4.3.4 Alternative population density datasets

Where CORINE or similar data are not available, global population density data can be used.

The Socioeconomic Data and Applications Center (SEDAC) of NASA provides Gridded Population of the World (GPW). GPWv4 depicts the distribution of human population across the globe. GPWv4 provides globally consistent and spatially explicit human population information and data for use in research, policy making, and communications.

For GPWv4, population input data were collected at the most detailed spatial resolution available from the results of the 2010 round of Population and Housing Censuses, which occurred between 2005 and 2014. The input data were extrapolated to produce population estimates for the years 2000, 2005, 2010, 2015, and 2020. A set of estimates adjusted to national level, historic and future, population predictions from the United Nation's World Population Prospects report were also produced for the same set of years. The raster data sets are constructed from national or subnational input administrative units to which the estimates have been matched. GPWv4 is gridded with an output resolution of 30 arc-seconds (approximately 1 km at the equator).

This data can be accessed from: http://sedac.ciesin.columbia.edu/data/collection/gpw-v4

4.3.5 COPERNICUS

COPERNICUS, the European Earth Observation programme, (previously called GMES) provides accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

See http://copernicus.eu/

4.3.6 Eurostat

Eurostat is a Directorate-General of the European Commission located in Luxembourg. Its main responsibilities are to provide statistical information to the institutions of the European Union (EU) and to promote the harmonisation of statistical methods across its member states and candidates for accession as well as EFTA countries.

Employment data are available from Eurostat at NUTS 3 level, split into three categories: services, industry and agriculture. Employment statistics are reported using the NACE classification system.

Eurostat also has several useful datasets on 'Industry, trade and services', 'Agriculture and Fisheries', and 'Transport'.

This data can be accessed from: https://ec.europa.eu/eurostat

4.3.7 ESRI data

ESRI provides a full spectrum of ready-to-use, high-quality geospatial data for your GIS visualization and analysis projects. Some data sets are publicly available and can be used for spatial distribution of emissions. Interesting examples are locations of airports at global scale (World Airports), World Roads, World Railroads, World Urban Areas, Europe Population Density and so on. Data can be accessed from:

http://www.arcgis.com/home/group.html?owner=esri&title=ESRI%20Data%20%26%20Maps&content=all

Some data sets are only commercially available, e.g. through ArcGIS licenses.

4.3.8 Open Street Maps

OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. Rather than the map itself, the data generated by the OpenStreetMap project are considered its primary output. Examples of data made available through OSM are locations of airports, road network, railroad network and so on.

Geofabrik is a consulting and software development firm based in Karlsruhe, Germany specialising in OSM services. The OSM data can easily be accessed through the Geofabrik website: http://download.geofabrik.de/osm/europe/

MapCruzin also provides extracts of the OpenStreetMap dataset such as locations of airports, road network, railroad network, waterways. This data can be accessed from: http://www.mapcruzin.com/free-europe-arcgis-maps-shapefiles.htm

4.3.9 ICAO and EUROCONTROL

Airport statistics for major airports can be obtained from the International Civil Aviation Organisation (ICAO) website if country-specific data are not available. Fees apply.

Another interesting point of contact with respect to airport statistics is EUROCONTROL (https://www.eurocontrol.int/).

Airport statistics can be used to distribute nationally calculated emissions to different airports to estimate LTO emissions for each.

4.3.10 Shipping: Lloyds Register

The Lloyds Register contains detailed ship movements data that can be used to distribute emissions from shipping. A fee is required to access the data.

See: https://www.lr.org/en/

4.4 Verification of emissions maps using satellite data

In recent years, several satellite instruments for observing the Earth's atmosphere have been launched into space. These satellites now provide a wealth of environmentally relevant information, amongst others about air pollutant concentrations in the atmosphere. The main advantage of the satellite is that it produces a consistent series of measurements for many years, often with global coverage, and it implicitly includes the spatial (and part of the temporal) variability of the pollutant concentrations. The satellite provides a completely independent picture of the pollutant concentrations in the Earth's atmosphere, which can be used to compare the results of air quality modelling and measurements against.

Several attempts have been made to derive emission estimates including their spatial variability based on the satellite observations (Streets et al., 2013). However, when doing this, there are several important issues to be taken into consideration when comparing the satellite measurements with data from emission inventories:

- The satellite sensors used for air pollutant concentration measurements generally only measure when there are no clouds obstructing the view, therefore a significant portion of the measurements cannot be used. However, since satellites typically have an overpass at each location once every few days, this problem can be overcome by using a longer time series of data from the satellite.
- The satellite measures concentrations rather than emissions. This makes it necessary to use inverse modelling techniques to derive emissions based on the concentration measurements from the satellite instrument.

- Satellites measure from space downward to the Earth's surface, resulting in a vertical column density for a specific pollutant (e.g. NO_x) from the Earth's surface to the top of the atmosphere, instead of a concentration at a certain height. Vertical profiles of pollutant concentrations are often used to introduce the height distribution of air pollutant concentrations measured by the satellite.
- When the above issues have been overcome and an emission estimate has been made based on the satellite measurement, it is not possible to attribute this to a specific source directly. The satellite only measures the pollutant concentration and does not provide any information about the source that it originates from. This is one of the main obstacles for using satellite-based data in estimation and mapping of emissions.

Thus, satellite-based information cannot feed directly into an emission inventory. However, these data are useful for verification of (spatial variability of) emissions. For instance, large point sources can be distinguished from space (e.g. Fioletov et al., 2016 for SO_2 from large power plants in South Eastern Europe), and compared against what is being reported. This approach can only be used if the point source strength is sufficiently large, and there are not too many other sources for that pollutant in the area. Also, trends in atmospheric concentrations over a certain area can be assessed from the space-based data, and compared against reported trends in emission inventories (e.g. Curier et al., 2014 for NO_2 concentrations compared to NO_x emissions). In those cases where larger differences are found, this could be a trigger to investigate emissions for that specific pollutant in the emission inventory in more detail.

Spatial and temporal resolution of the satellites are rapidly improving. With the latest available satellite (TROPOMI aboard the Sentinel-5p, launched in October 2017) a spatial resolution of 7x7km can be achieved globally, with a single measurement every day. This is a significant improvement compared to pre-existing satellites and will introduce new opportunities for verification of emission inventories with space-based data.

5 Overview of available spatial emissions data (updated 2018)

Table 5.1: Overview of available spatial emissions data. For each data set the following information is provided: (i) Last and foreseen update, (ii) Sectoral, spatial, and temporal resolution, (iii) Spatial and temporal coverage, (iv) Underlying emission and proxy data, (v) Developer.

Inventory	Last update	Foreseen update	Sectoral resolution	Spatial resolution	Temporal resolution	Spatial coverage	Temporal coverage	Underlying emission data	Reference	Developer	Data access
EDGAR 4.3.2	2018	Every 5 yrs	IPCC sectors	- 0.1 x 0.1 ° - per country	Annual (& monthly)	Global	1970-2012	Calculation of emissions using a technology based emission factor approach	http://edgar.jrc.ec.europa.eu/index.php	JRC	Publicly available Link to data download
TNO-MACC III	2013	2018	SNAP01 sectors	0.125° x 0.0625°	Annual	Europe (EU+ non-EU)	2000-2011	Emissions reported by European Member States + gapfilling using IIASA and TNO data	Kuenen *et al.* (2014)	TNO	Available on request – (free)
E-PRTR diffuse emissions	2011	Not known yet	NFR_09 and CRF sector	5 x 5 km^2 1 x 1 km^2 on request (EEA)	Annual	Europe (EU27 and EFTA countries)	2008	Emissions reported by European Member States	Theloke *et al.* (2009)	University of Stuttgart	Publicly available Link to data download
E-MAP	2012	Both spatial distribution and national totals: yearly	SNAP sectors	1 x 1 km^2 Belgium; 5 x 5 km^2 Central Europe; 60 x 60 km^2 Europe	Annual	Europe	1990-2009	Emissions reported by European Member States	Maes *et al.* (2004)		Available on request – fee may be required

6 References

CEIP, 2010 – Technical Report CEIP 1/2010, Inventory Review 2010, Review of emission data reported under the LRTAP Convention and NEC Directive, Stage 1 and 2 review - Status of gridded data and LPS data.

CLC2012, 2016 – CORINE Land Cover (https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012), accessed 7 June 2019.

Curier R.L. et al., 2014 – Synergistic use of OMI NO2 tropospheric columns and LOTOS–EUROS to evaluate the NOx emission trends across Europe, Remote Sensing of Environment, Vol. 149, pp 58-69, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2014.03.032.

Dore et al., 2004 – APMOSPHERE, Air Pollution Modelling for Support to Policy on Health and Environmental Risk in Europe (EVK2-2002-00577)). Emission Mapping Methodology Progress Report (January 2004). AEA Technology, Netcen, UK

EMEP/EEA 2013, '1.A.3.b Exhaust emissions from road transport' in 'EMEP/EEA Air Pollutant Emission Inventory Guidebook, 2013', European Environment Agency, (www.eea.europa.eu/emep-eea-guidebook), accessed 7 June 2019.

Fioletov, V. E et al., 2016 – A global catalogue of large SO2sources and emissions derived from the Ozone Monitoring Instrument, Atmos. Chem. Phys., 16, 11497-11519, https://doi.org/10.5194/acp-16-11497-2016.

Gallego et al., 2010 – A population density grid of the European Union, Population and Environment (2010), 31: 460-473.

GISCO, 2010 – Geographic Information System of the European Commission (EUROSTAT), (https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Geographical_information_system_of_the_Commission_%28GISCO%29) accessed 7 June 2019.

Gkatzoflias et al., 2007 – COPERT 4 model. European Topic Centre on Air and Climate Change (ETC-ACC). (http://www.eea.europa.eu/publications/copert-4-2014-estimating-emissions), accessed 7 June 2019.

Kuenen et al., 2014 – TNO-MACC_II emission inventory; a multi-year (2003–2009) consistent high-resolution European emission inventory for air quality modelling, Atmos. Chem. Phys., 14, 10963-10976, https://doi.org/10.5194/acp-14-10963-2014, 2014.

Maes et al., 2009 – Atmospheric Environment 43 (2009) 1246-1254, Spatial surrogates for the disaggregation of CORINAIR emission inventories.

Ricardo Energy & Environment (2017) A review of the NAEI shipping emissions methodology. Final report. Report for the Department for Business, Energy & Industrial Strategy. Ricardo Energy & Environment Ref: ED61406 Issue Number 5 (https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1712140936_ED61406_NAEI_shipping_report_12Dec2017.pdf) accessed 7 June 2019.

Streets D.G. et al., 2013 – Emissions estimation from satellite retrievals: a review of current capability. Atmospheric Environment, Vol. 77, pp 1011-1042, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2013.05.051.

Theloke et al., 2009 – Final Report Diffuse Air Emissions in E-PRTR, Methodology development for the spatial distribution of the diffuse emissions in Europe.

Tsagatakis et all 2017 - UK Emission Mapping Methodology: A report of the National Atmospheric Emission Inventory 2015, Prepared by Ricardo Energy & Environment for Department for Business, Energy and Industrial Strategy; Department for Environment, Food and Rural Affairs; The Scottish Government; Welsh Government; Department of Agriculture, Environment and Rural Affairs for Northern Ireland (https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1710261436_Methodology_for_NAEI_2017.pdf) accessed 7 June 2019.

TRANSTOOLS, 2010 – URL: (http://energy.jrc.ec.europa.eu/transtools/index.html), accessed 7 June 2019.

TREMOVE, 2010 – URL: (https://www.tmleuven.be/en/navigation/TREMOVE), accessed 7 June 2019.

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the co-chairs of the Task Force on Emission Inventories and Projections (TFEIP). Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current co-chairs.