

---

<b>Category</b>	<b>Title</b>
<b>General guidance</b>	Spatial mapping of emissions
<b>Version</b>	Guidebook 2023

---

**Lead authors**

Jeroen Kuenen

**Contributing authors (including to earlier versions of this chapter)**

John Van Aardenne, Justin Goodwin, Katarina Mareckova, Martin Adams, Paul Ruysenaars, Robert Wankmüller, Stephen Pye, Katie King, Nele Veldeman, Wim van der Maas, Susana Lopez-Aparicio, Marlene Schmidt Plejdrup, Ilaria d'Elia, Stefan Feigenspan, Marc Guevara Vilardell

# Contents

<b>1</b>	<b>Overview .....</b>	<b>4</b>
<b>2</b>	<b>Terminology .....</b>	<b>6</b>
2.1	General terms.....	6
2.2	Geographic features .....	6
<b>3</b>	<b>Methods for compiling a spatial inventory .....</b>	<b>9</b>
3.1	Compiling point source data .....	11
3.2	Quantifying diffuse emissions .....	14
3.3	Disaggregating diffuse emissions .....	15
3.4	Combining different spatial features.....	17
3.5	Estimating uncertainty in emission maps .....	19
3.6	General Tiered guidance for spatial disaggregation of emissions by sector .....	19
<b>4</b>	<b>Sourcing key spatial data sources .....</b>	<b>19</b>
4.1	General.....	20
4.2	National datasets .....	20
4.3	International datasets .....	21
4.4	Verification of emissions maps using satellite data.....	25
<b>5</b>	<b>Overview of available spatial emissions data (updated 2023).....</b>	<b>27</b>
<b>6</b>	<b>References .....</b>	<b>28</b>
<b>7</b>	<b>Point of enquiry.....</b>	<b>30</b>



# 1 Overview

The aim of this 'Spatial emission mapping' chapter is to provide guidance on how to spatially distribute national air 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 reduction Commitment Directive (NECD) <sup>(1)</sup>, including the link to point source emissions (e.g. from E-PRTR).

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 as well as under the EU NEC Directive.

This chapter provides guidance on compiling spatially explicit emission 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);

<sup>(1)</sup> 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.

- years for which reporting of gridded data is required (every 4 years from 2017 onwards).
- For official reporting, the EMEP grid is to be used at a resolution of  $0.1^{\circ} \times 0.1^{\circ}$ , however the guidance provided in this chapter also applies to other resolutions.

## 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  $0.1^\circ \times 0.1^\circ$  longitude-latitude in the WGS84 geographic coordinate system. The domain covers the geographic area between  $30^\circ\text{N}$ - $82^\circ\text{N}$  latitude and  $30^\circ\text{W}$ - $90^\circ\text{E}$  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.

**GNFR** - Gridded Nomenclature For Reporting

**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** - Nomenclature of Economic Activities in the European Union.

**NFR** - Nomenclature For Reporting

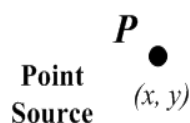
**NUTS** - Nomenclature of Units for Territorial Statistics, which is a hierarchical classification of administrative boundaries developed by Eurostat. The idea behind NUTS is to provide a common designation for different levels of administrative geographic boundaries across the EU regardless of local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

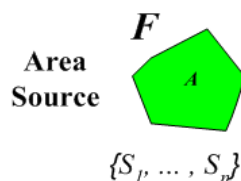


Emissions from point sources represent sectors of a national inventory either fully (e.g. often for power stations where the sector is made up of only large sites for which emissions reporting is mandatory) or in part (e.g. such as combustion in industry, for which only the large sites within the sector 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).



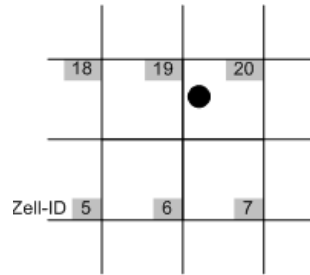
Residential fuel combustion is an example of a sector that can be represented in this way, using population census data mapped using the polygons defining the data collection boundaries.

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

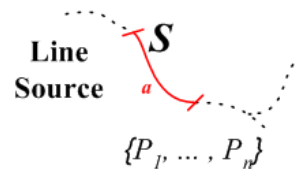
characterised by geographical coordinates for the centre or lower left corner of the grid and a definition of the size of each cell.



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.

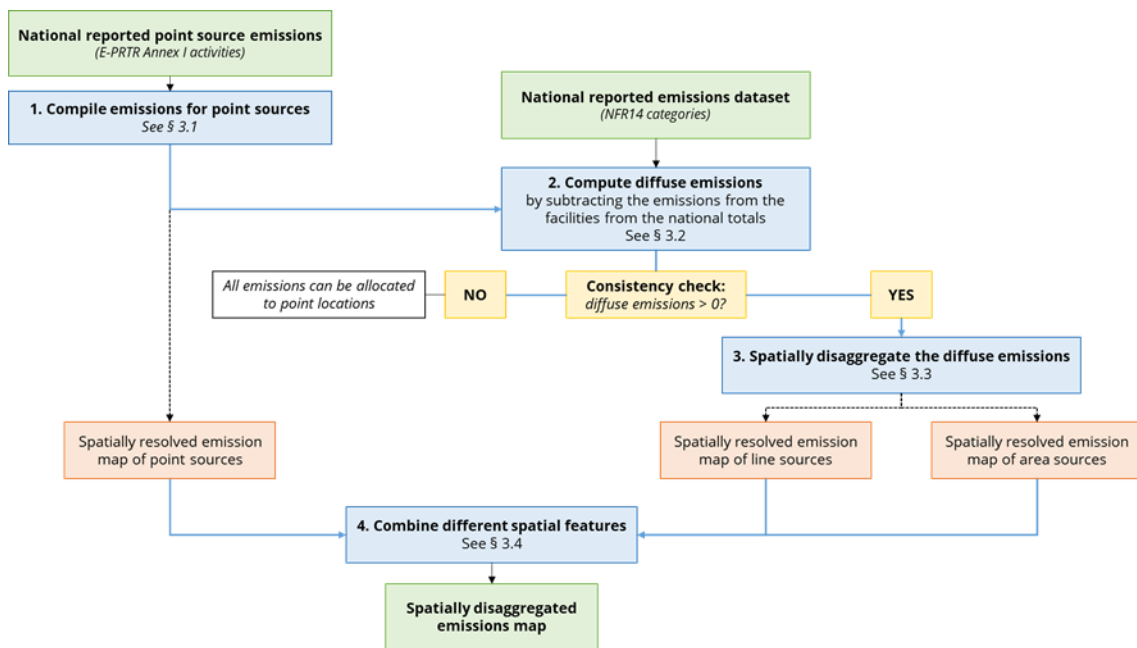
It is good practice to consider the elements below when defining an efficient spatial disaggregation project.

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. If limited resources are available, this key category analysis can also be conducted at the level of Gridded Nomenclature For Reporting (GNFR) categories instead of individual Nomenclature For Reporting (NFR) categories for the purpose of spatial emissions mapping. However, it is important to evaluate carefully in this case since some GNFR categories (e.g. GNFR Off-Road) consist of a wide range of activities which each have their specific spatial patterns, such as railways, mobile construction in industries/construction, in agriculture/forestry/fishing and recreational boats.
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 may be 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. The guidance in this chapter will provide a first starting point to define such proxies, but also documentation for spatial emissions mapping from other countries as well as other spatially explicit inventories may be used.
5. **Describe the proxy data and report on the methodologies used** to spatially disaggregate emissions in the IIR. With the information provided, the reader of the documentation should be able to understand the methodology in detail and even reproduce the gridded emissions. For the documentation, a specific chapter is dedicated to spatial disaggregation of emissions in the recommended structure of the IIR.
6. Choose proxy **spatial datasets that are complete** (cover the whole national area). If substantial gaps are identified these should be gap filled or another proxy should be selected.
7. If new data are not available each year, then **continue to use the previous years' spatial data** until a new dataset is available to ensure consistency in the spatially distributed emissions.
8. 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.
9. 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 (GNFR level and by grid cell) 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 where relevant.
10. 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.
  11. 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. For EU Member States, the best starting point is the dataset on Industrial Emissions Reporting under the Industrial Emissions Directive 2010/75/EU and the European Pollutant Release and Transfer Register Regulation 166/2006/EC. A combined dataset is available from the European Environment Agency (EEA) from the European Industrial Emissions Portal (<https://industry.eea.europa.eu/>), which contains the location and details for larger industrial facilities in Europe, as well as data on releases and transfers of regulated substances to different environmental compartments including air. However, it should be noted that the European dataset is constructed based on national reported data, so also internal national contact points will be able to provide these point source data. In non-EU Member States, 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 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, including sectoral guidance.

Finally, different spatial features need to be combined, 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. the new European Industrial Emission Portal);
2. Point sources that are regulated but for which there are no annual emission reporting requirements (e.g., European Industrial Emissions Portal 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 dataset from which the necessary reporting to the IED and E-PRTR is made, or an equivalent national database. It should be noted that this is only available from 2007 onwards, before there was reporting under EPER (European Pollutant Emission Register) but only in 2001 and 2004. For other years no data is reported, and it is recommended to develop a backcasting methodology to estimate point source emissions back to 1990 when developing spatially distributed emissions for the earlier years. 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 may not be included in the E-PRTR database. Furthermore, earlier studies using the E-PRTR (and Industrial Emissions Portal reported data) have shown that despite improvements over the years, the dataset still contains errors and inconsistencies, for instance regarding the location of the facility. In some cases the coordinates are slightly off, or representing the head office of the facility rather than the actual emission location. Therefore, it is recommended to review coordinates of point sources where possible to ensure they accurately represent the actual emission location.

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. On the other hand, if the contribution to total emissions for a not reported or non-regulated source is small, the effort to estimate point source emissions should be similar. Depending on the contribution of the source to the total emissions and the expected distribution, a case-by-case decision should be made if and how to inventory point source emissions for unregulated or unreported sources, to ensure an overall balance in the resulting gridded inventory.

**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<sub>10</sub> 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<sub>10</sub>/PM<sub>2.5</sub> ratios can be established to estimate emissions for PM<sub>2.5</sub> where it is not reported, but PM<sub>10</sub> emissions are available for similar processes. Where no other data is available, ratios with other pollutants, such as NO<sub>x</sub> and SO<sub>2</sub>, 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 and the Industrial Emission Directive, point source emissions must be reported in categories covering 65 economic activities within 9 different industrial sectors. 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 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<sup>2</sup>.

In addition, facilities report based on their main activity, which may also include emissions from other activities. For instance, a large industrial facility may also have some on-site electricity generation (GNFR: A\_PublicPower) or further processing of their produced commodities, (GNFR: B\_Industry), which is all reported under the sector representing their main activity.

Source characteristics such as stack height, source diameter, source heat capacity, stack exit velocity and gas temperature are important parameters to estimate the vertical allocation of emissions. Whilst these characteristics are not mandatory under most reporting obligations, it is highly

<sup>2</sup> <https://www.ceip.at/reporting-instructions>

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 which are not covered by the reporting to E-PRTR/IED 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 (incl. the use of main activities in facility level point source reporting);
- 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 considered. 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 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 considered in the national totals.

An important consideration for the reporting of gridded emissions is the consistency to the national inventory (NFR tables; Annex I). Therefore, if it is not possible to resolve the inconsistencies with the point source emissions, it is recommended to implement a solution that ensures consistency between national inventory by sector and the gridded national inventory. This consistency also implies that if the national inventory reporting is based purely on fuel sold, that also the gridded inventory is based on the same principle. However, an inventory based on fuel used may be more representative for the modellers as it is a more realistic description of the actual emissions taking place in the country. In any case, the approach used should be documented upon in the IIR (Informative Inventory Report).

Starting a gridded emission inventory from scratch may be complicated, especially if limited resources are available. Apart from the guidance in this document, the methodologies applied by countries with a more advanced gridding system maybe be used as a starting point. Each country is required to report the methodology in the IIR, which can be very helpful for others to develop their gridded emissions. The approach used by Germany is an example which may be used, which is fully documented online ([https://iir.umweltbundesamt.de/2022/general/gridded\\_data/start](https://iir.umweltbundesamt.de/2022/general/gridded_data/start)).

### 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. **Error! Reference source not found.** (see Section 3.6) 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:

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

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

Where:

- i** : is a specific geographic feature;
- emission<sub>ix</sub>** : 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<sub>t</sub>** : is the total national emission for a sector to be disaggregated across the national area using the (x) proxy spatial dataset;
- value<sub>ix - jx</sub>** : are the proxy data values of each of the specific geographical features within the spatial proxy dataset x.

The following steps should be followed:

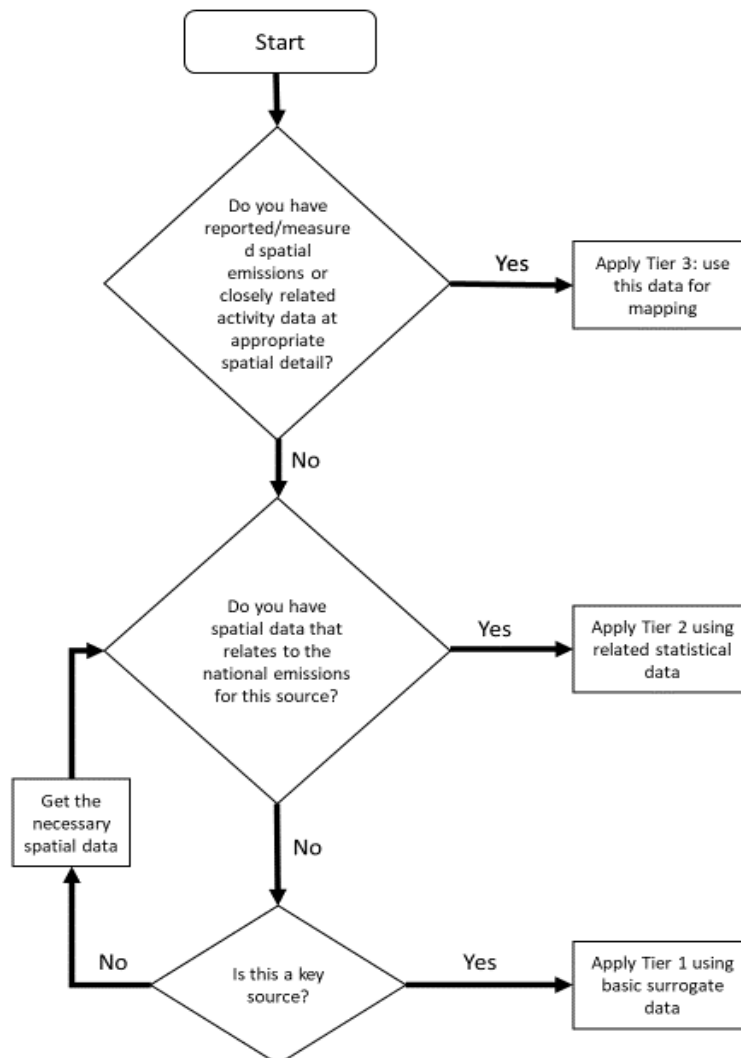
1. determine the emission to be disaggregated (emission<sub>t</sub>) (either national total for sector or where a sector is represented by some large point sources then it is the national total minus sum of point sources, as outlined in sections 3.1 and 3.2);
2. distribute that emission using the basic principles above using a suitable proxy statistic (according to the detailed guidance by sector given in **Error! Reference source not found.**);

- 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 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 links with information on traffic flows by vehicle type, spatial fuel consumption data by sector at sub-national level (e.g. NUTS 3).

**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 **Error! Reference source not found.** Of the Annex. The following box (Example 2) provides some general examples of disaggregating national emissions.

### EXAMPLE 2: DISTRIBUTION OF NATIONAL EMISSIONS

SO<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub> 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 per vehicle type, 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, the average speeds of traffic on these links, and the level of congestion, 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

**Error! Reference source not found.** gives general guidance for the tiered mapping of emissions for different sectors. The table also indicates which sectors are likely to include point sources, diffuse sources or a combination of the two. **Error! Reference source not found.** also contains a sector specific overview of different spatial mapping approaches ranging from Tier 3 to Tier 1. These are examples of spatial mapping approaches that may be used, other methodologies or proxy datasets that are believed to well represent the emissions distribution may also be used.

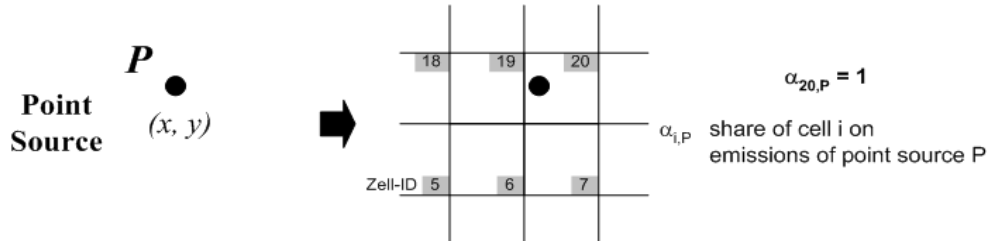
## 3.4 Combining different spatial features

Following the emission-disaggregation process, emissions at this stage are likely to be in several 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.

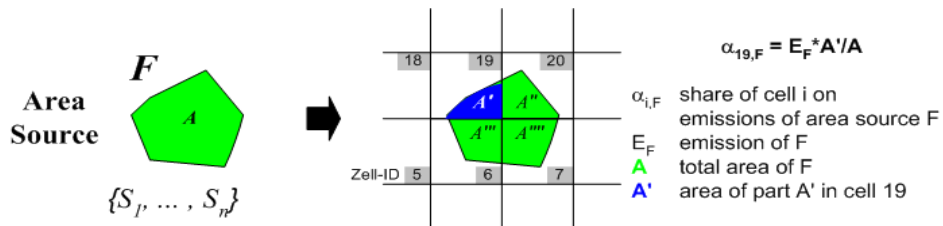
**3.4.1 Point sources to grids**

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](http://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 spatial allocation of emissions. For instance, sector GNFR I reports emissions from several off-road machinery categories that are associated to different locations including agricultural areas (i.e., agricultural machinery), industrial infrastructures (mobile sources in manufacturing industries) and lakes and coastal areas (i.e., recreational boats), among others.

### 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. For instance, emission maps for the UK have been assessed for uncertainty using a simple method, as explained in section 5.1 of the UK Emission Mapping report (Tsagatakis et al, 2017). Also in Denmark the gridding model takes into account uncertainty of the spatial distribution, considering both the quality of the spatial dataset itself and the applicability as spatial proxy (Plejdrup et al., 2021).

### 3.6 General Tiered guidance for spatial disaggregation of emissions by sector

The table in this section provides a starting point for spatial distribution of emissions by sector, by identifying possible Tier 1, 2 and 3 methodologies for spatially disaggregating emissions for each (G)NFR sector. Given the large size of the resulting table, it is available as a separate Annex to this chapter in Excel format.

---

**Table 3-1 General tiered guidance for the spatial disaggregation of emissions by sector**

---

Information available from separate Excel file as Annex to this chapter.

## 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 Other national datasets**

Besides the dataset mentioned above, many other datasets developed and published at national or regional level, may be useful to act as proxies. Examples include building or housing registers, cadastre maps, national land use maps (urban/rural, city centre, industrial areas, etc.). Also detailed spatialized information distinguishing areas with district heating and environmental zones with specific bans (heavy transport, solid fuel use) is useful when available.

In addition, chimney sweeper data might be mentioned as an example of input in a detailed gridding method for residential wood combustion, even though such data might only be available in few countries.

### **4.2.10 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 *CORINE 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 2018 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/clc2018>. 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 Climate Change Initiative (CCI) Land Cover project*

The ESA CCI land cover maps (ESA, 2017) consist of a 3-epoch series of global land cover maps at 300m spatial resolution, where each epoch covers a 5-year period (2008-2012, 2003-2007, 1998-2002). The maps were produced using the entire 2003-2012 MERIS Full and Reduced Resolution (FR and RR) archive.

The data are available here: (<https://www.esa-landcover-cci.org/?q=node/158>)

### **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>

The Global Human Settlement Layer (GHSL) project produces global spatial information about the human presence on the planet over time. The project, supported by the Joint Research Centre (JRC) and the DG for Regional and Urban Policy (DG REGIO) of the European Commission, together with the international partnership GEO Human Planet Initiative, includes an extensive collection of built-up maps, population density maps and settlement maps. Among the available datasets, GHSL includes spatial raster datasets representing the distribution of residential population for the years 1975 to 2020 in 5-year intervals and at spatial resolutions up to 100m (GHS-POP, Schiavina et al., 2022a) as well as settlement classification as a function of the degree of urbanisation (urban centre, dense urban cluster, semi-dense urban cluster, suburban, rural cluster, low density rural, very low density rural) for the same time period of time and resolution of 1kmx1km (GHS-SMOD, Schiavina et al., 2022b).

This data can be accessed from: <https://ghsl.jrc.ec.europa.eu/>

### **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 <https://www.copernicus.eu/en> for further details. A dedicated part of Copernicus focuses on Atmosphere Monitoring Service which may contain specific datasets relevant for spatial distribution of emissions, see <https://atmosphere.copernicus.eu/> for further information.

### **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. Data from Eurostat may be available at NUTS 1, 2 or 3 level in specific cases, allowing regionalisation of national emissions.

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 Map**

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>

### **4.3.1 Open Transport Map**

OpenTransportMap (OTM) is an open-source database that provides information on average daily traffic volumes at road link level for the whole EU. The underlying data (i.e., digitalised network) come from OSM and are accessible in a scheme compatible to INSPIRE Transport Network. As indicated by Degraeuwe et al., (2021), some gap filling of the original OTM data is required to match official annual kilometers travelled per country as, for instance, no traffic is allocated by OTM on OSM fourth class roads (small urban roads) or in some NUTS3 regions traffic is missing on other roads.

This data can be accessed from: <https://opentransportmap.info/>

### **4.3.2 Global Gas Infrastructure Tracker**

The Global Gas Infrastructure Tracker (GGIT) is an information resource compiled by the Global Energy Monitor (GEM) on natural gas transmission pipeline projects and liquefied natural gas import and export terminals.

This data can be accessed from: <https://globalenergymonitor.org/projects/global-gas-infrastructure-tracker/>

### **4.3.3 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.

### **4.3.4 Shipping: Lloyds Register and AIS**

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/>

Furthermore, in recent years AIS (Automatic Identification Signals) have become available which locate ship movements globally. However, fees apply to acquire these data and the data source may be very large. Processed data may be available e.g. from national maritime authorities.

### **4.3.1 EMSA traffic density maps**

The European Maritime Safety Agency (EMSA) has produced a collection of maritime traffic density maps at a spatial resolution of 1 x 1 km and per time periods (e.g., month, season, year) in the overall EU maritime area. The maps were computed for all vessels and individual categories (i.e., cargo, fishing, passenger, tanker and other vessels) for the years 2019 to 2022 using ship position data from several sources including Terrestrial and Satellite Automatic Identification System (AIS).

This data can be accessed from: <https://www.emsa.europa.eu/traffic-density-maps.html>

### **4.3.2 FAO**

The Food and Agricultural Organisation (FAO) of the United Nations develops and maintains the Gridded Livestock of the World (GLW) database, which provides free information on the global distribution and abundance of livestock species. The fourth version of the GLW has a reference year of 2015 and includes global distributions of cattle, buffaloes, sheep, goats, horses, pigs, chickens and ducks at a spatial resolution of 5 minutes of arc, approximately 10 km at the equator.

This data can be accessed from: <https://www.fao.org/livestock-systems/global-distributions/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<sub>x</sub>) 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.
- Most satellites currently in orbit have a fixed daily overpass time (e.g. 13.30 local time for Sentinel 5-P). Information on diurnal emission variation is needed to translate this one measurement into an emission representative for the whole day. Diurnal profiles for emissions, which are most typically used in this situation, come with their own uncertainties.

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<sub>2</sub> 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<sub>2</sub> concentrations compared to NO<sub>x</sub> 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. Since the data became available, many studies have been conducted and published with attempts to constrain anthropogenic emissions based on these data. Given that there is no sectoral information, a direct use for the inventory is difficult, but with increasing resolution these data become more and more useful for inventory compilers as verification, for instance in identifying point sources and look at trends in emissions.

Also, in the near future information from geostationary satellites (e.g. Sentinel 4) will be available, which will provide not daily but hourly data on key air quality parameters including NO<sub>2</sub>, SO<sub>2</sub>, HCHO and CHOCHO (glyoxal), and aerosols over Europe, and will allow improvements in the spatial and temporal resolution of satellite-derived emissions.

## 5 Overview of available spatial emissions data (updated 2023)

**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
<b>EDGAR v6.1</b>	2022	Every 2-5 yrs	IPCC sectors	- 0.1 x 0.1 ° - per country	Annual (& monthly)	Global	1970-2018	Calculation of emissions using a technology based emission factor approach	Crippa <i>et al.</i> (2018)	JRC	Publicly available <a href="#">Link to data download</a>
<b>CAMS-REG</b>	2022	Every 1-2 yrs	GNFR sectors	0.05° x 0.1°	Annual	Europe (EU+ non-EU)	2000-2020	Emissions reported by European Member States + gapfilling using IIASA and TNO data	Kuenen <i>et al.</i> (2022)	TNO	Publicly available <a href="https://eccad.iris-data.fr/">https://eccad.iris-data.fr/</a>

## 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 23 January 2023.

Crippa, M. et al., 2018 - Gridded emissions of air pollutants for the period 1970-2012 within EDGAR v4.3.2, Earth Syst. Sci. Data, 10, 1987-2013, [doi:10.5194/essd-10-1987-2018](https://doi.org/10.5194/essd-10-1987-2018), 2018.

Curier R.L. et al., 2014 – Synergistic use of OMI NO<sub>2</sub> tropospheric columns and LOTOS–EUROS to evaluate the NO<sub>x</sub> 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>.

Degraeuwe, B., Pisoni, E., Christidis, P., Christodoulou, A., & Thunis, P. (2021). SHERPA-city: A web application to assess the impact of traffic measures on NO<sub>2</sub> pollution in cities. Environmental Modelling & Software, 135, 104904.

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](http://www.eea.europa.eu/emep-eea-guidebook)), accessed 7 June 2019.

ESA. Land Cover CCI Product User Guide Version 2. Tech. Rep. (2017). Available at: [maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2\\_2.0.pdf](http://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf) See: [http://due.esrin.esa.int/page\\_globcover.php](http://due.esrin.esa.int/page_globcover.php)

Fioletov, V. E et al., 2016 – A global catalogue of large SO<sub>2</sub> sources 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.

Kuenen, J. et al - CAMS-REG-v4: a state-of-the-art high-resolution European emission inventory for air quality modelling, Earth Syst. Sci. Data, 14, 491–515, <https://doi.org/10.5194/essd-14-491-2022>, 2022.

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

Plejdstrup et al., 2021, Spatial high-resolution distribution of emissions to air – Spread 3.0. Technical report from DCE – Danish Centre for Environment and Energy, No. 2015.

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\\_12\\_Dec2017.pdf](https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1712140936_ED61406_NAEI_shipping_report_12_Dec2017.pdf)) accessed 7 June 2019.

Schiavina M., Freire S., MacManus K. (2022a): GHS-POP R2022A - GHS population grid multitemporal (1975-2030). European Commission, Joint Research Centre (JRC) PID: <http://data.europa.eu/89h/d6d86a90-4351-4508-99c1-cb074b022c4a>, doi:10.2905/D6D86A90-4351-4508-99C1-CB074B022C4A

Schiavina M., Melchiorri M., Pesaresi M. (2022b): GHS-SMOD R2022A - GHS settlement layers, application of the Degree of Urbanisation methodology (stage I) to GHS-POP R2022A and GHS-BUILT-S R2022A, multitemporal (1975-2030) European Commission, Joint Research Centre (JRC) PID: <http://data.europa.eu/89h/4606d58a-dc08-463c-86a9-d49ef461c47f>, doi:10.2905/4606D58A-DC08-463C-86A9-D49EF461C47F

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 al., 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](https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1710261436_Methodology_for_NAEI_2017.pdf)) accessed 14 March 2023.

## 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/](http://www.tfeip-secretariat.org/)) for the contact details of the current co-chairs.