Milestone M13 (M3.2) First emission inventory

RI-URBANS

Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (GA n. 101036245)

By

TNO

16th September 2022

RI-URBANS (www.RIURBANS.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-GD-2020, Grant Agreement number: 101036245

Milestone M13 (M3.2): Dataset on PM ultrafine and non-exhaust sectoral emission distribution over Europe and pilot cities

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Work package (WP)	WP3 Improving modelling and emission inventories for policy assessment using advanced observation-based methodologies
Milestone	M13 (M3.2)
Lead beneficiary	TNO
Means of verification	First dataset available for consortium use
Estimated delivery deadline	M12 (30/09/2022)
Actual delivery deadline	16/09/2022
Version	Final
Reviewed by	WP3 leaders
Accepted by	RI-URBANS Project Coordination Team
Comments	This document provides a short description of the first dataset of anthropogenic emissions which has been made available to the users within the RI-URBANS project, and also provides showcases on selected illustrative results. The emission inventory includes both the main air pollutants included in CAMS-REG (CH_4, CO, NH_3, NMVOC, NO_X, SO_2, PM_{10} and $PM_{2.5}$) as well as ultrafine particles, expressed as particle number emissions. Furthermore, PM emissions from road traffic include those from non-exhaust vehicle emissions. The datasets provide emissions at spatial resolution of 6x6km^2 over the European domain, including the pilot cities.

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1. About this document

This document provides a short description of the first dataset of anthropogenic emissions which has been made available to the users within the RI-URBANS project, and also provides showcases on selected illustrative results. While the official title of the deliverable is "**Dataset on PM ultrafine and non-exhaust sectoral emission distribution over Europe and pilot cities**", it is not limited to ultrafines and non-exhaust but rather provides a complete emission dataset for all relevant species, because this is what is needed to feed the modelling activities in RI-URBANS. Both the main air pollutants which are also included in CAMS-REG (CH_4, CO, NH_3, NMVOC, NO_X, SO_2, PM_{10} and $PM_{2.5}$) as well as ultrafine particles (UFP), expressed as particle number emissions, are included in this dataset. In terms of sectors, road transport exhaust and non-exhaust emissions are covered, but also other relevant sectors for air pollutant emissions. The emissions provided in this dataset have a spatial resolution of 6x6km^2 over the European domain, including the pilot cities. High resolution 1x1km^2 emission inventories will be derived for the pilot cities based on this dataset using the downscaling methodology tool developed by NOA and described in D3.2. The downscaled 1x1km resolution Emissions Will also be made available to the RI-URBANS community and used as input to the intercomparison exercise between local and downscaled emission inventories for urban areas as part of Task 3.2.

This milestone M13 (M3.2) addresses T3.3 on enhancing quality and completeness of emissions inventories for specific sectors of interest identified in WPs 1-2 (e.g., road transport non-exhaust particles). It has been constructed with a consistent methodology, which will be used for systematic evaluation of emission inventories (WP4). This document describes the first version of the emission inventory, which is meant to support users in the project so that they have a dataset to start working with and test the models and tools. Later in the project (in M28) a final emission inventory will be delivered (D18, D3.3).

This is a public document, available in the RI-URBANS website (https://riurbans.eu/work-package-3/#milestones-wp3). The document will be distributed to all RI-URBANS partners for their use and submitted to European Commission as an RI-URBANS milestone M13 (M3.2).

2. Description of the emission inventory

At European scale, the CAMS-REG emission inventory (Kuenen et al., 2022) is a widely used dataset for modelling of air pollutant concentrations and deposition in chemistry transport models at European scale. However, as this inventory is largely based on the official reported emission data from each European country, there are some shortcomings with regard to consistency of the emission data across the European domain, and the availability of specific pollutants of interest.

In RI-URBANS, we therefore work on an improved emission inventory, specifically addressing two aspects:

- Provide a complete emission inventory for primary UFP, expressed as total particle number (PN) emissions including aerosol size distributions.
- Improve the consistency of road transport (non-)exhaust emissions by estimating these emissions in a bottom-up manner using vehicle statistics, mileages and state-of-the-art emission factors and emission estimation methodologies.

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This means that the resulting emission inventory includes both the main air pollutants also included in CAMS-REG (CH_4, CO, NH_3, NMVOC, NO_X, SO_2, PM_{10} and $PM_{2.5}$) as well as UFP, expressed as PN emissions (including parameterised size distributions, currently using the 15 different size bins according to the CAMx CTM).

Given the availability of data, the current emission inventory has a single year (2018) as the base year. The remainder of this section describes the elements of the inventory in more detail.

2.1 Main air pollutants

For the main air pollutants (CH4, CO, NH3, NMVOC, NOX, SO2, PM10 and PM2.5), the CAMS-REG emission inventory version 5.1 is used as the basis. The inventory has a resolution of 0.1°x0.05° (lat-lon) which is equivalent to roughly 6x6km2 over central Europe. Version 5.1 is a further development of the CAMS-REG-v4.2 emission inventory which is described in detail in Kuenen et al. (2022). The most important change in v5.1 is that it is based on the reported data for the years 2000-2018 as reported by each European country in 2020. A couple of specific modifications of the CAMS-REG-v5.1 emission inventory have been made for RI-URBANS:

- Road transport emissions from CAMS-REG are excluded and replaced with a consistent bottom-up inventory (described in Section 2.3).
- Also, the inventory takes into account the Ref2 inventory for small combustion PM emissions, which implies that PM2.5 and PM10 emissions from small combustion appliances are replaced with a bottom-up “science-based” estimate which takes into account the condensable component of PM in a consistent and complete manner. This replacement of reported data is necessary since country reporting of PM emissions in this source category comprises a mix of emissions including and excluding the condensable component, which has a large impact on the emissions. Earlier studies e.g. in the framework of CAMS have shown that inclusion of the Ref2 inventory leads to improved modelling results (i.e. a better agreement with the measurements) (see e.g. Denier van der Gon et al. (2015) and EMEP (2020)).

2.2 Ultrafine particles

For UFP, a dedicated PN emission inventory for all known major sources of primary PNs has been developed. This is in part based on an earlier methodology that was applied for earlier PN emission inventories developed in the EU EUCAARI and TRANSPHORM projects, but takes into account new information from the literature, for transport activities and various industrial sources. Emissions are calculated at the highest level of sector detail which is also the basis for the CAMS-REG inventory (see Kuenen et al., 2022) which comprises around 250 different sector-fuel combinations.

Where the necessary information was available, direct emission factors are used which provide the PN released per unit of activity (energy consumption in the case of combustion activities).

In other cases, especially those in which flue gas after treatment with emission control technologies determine PN emissions, PN are derived from PM2.5 mass emissions (from the CAMS-REG dataset, see Section 2.1) in different steps: first mass PM1 is estimated as part of PM2.5, then mass PM0.3 is estimated as part of PM1, and finally the number of particles below 300 nm (aerodynamic) is estimated based on representative PN size distributions found in the literature. Mobility particle diameters are converted to equivalent aerodynamic diameters in order to make literature size distributions compatible with CTMs that use aerodynamic diameters. Sector- and technology-specific PM1 and PM0.3 mass fractions have been taken from mass size distribution data available from various existing PM inventories and literature.

The current PN inventory covers the size range from 10 to 325 nm (in electrical equivalent mobility) and includes total particles (sum of solid and volatile). Particle numbers as well as size distributions are not conservative and this usually complicates the development of PN emission inventories. The data are intended to represent a snapshot of

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a meta-stable situation shortly after emission. However, PN and size distributions continue to evolve as particle growth and coagulation, and also evaporation progresses after this stage.

2.3 Road transport emission model

Road transportation is a specific source that we have given additional attention, because of the importance of both exhaust and non-exhaust emissions in urban areas, because of the rapid changes in the fleet over time which influence emissions. A bottom-up methodology was developed for Europe to ensure consistency in the way the emissions are calculated.

The methodology starts from the total number of vehicles registered and the annual mileages of each of them. For each vehicle type, fuel type, engine capacity and technology (Euro class) has been obtained from EMISIA for the years 2000-2019 (EMISIA, 2020), for 33 countries in Europe (EU27 + United Kingdom, Turkey, Switzerland, Norway, Iceland and Northern Macedonia). These data have been processed which results in the annual vehicle kilometers at the same level of detail. Additionally, also average speed information and the distribution of vehicle kilometers over different road types (urban, rural, highway) have been obtained from the same dataset.

As a next step, emission factors have been selected for each of the categories, which are largely based on two data sources: 1) the EMEP/EEA Guidebook 2019 version (EEA, 2019), which provides the emission factors as used in the COPERT model, and 2) emission factors measured and established by TNO and applied in the Dutch emission inventory. For non-exhaust, emissions are calculated using a Tier 2/Tier 3 methodology, taking into account weight of heavy duty trucks and the dependency of speed for brake wear. For particle numbers, emission factors are primarily based total PN emission factors provided in Vouitsis et al. (2017). In the selection of emission factors specific attention has been given to the completeness of the dataset, i.e. in assigning an emission factor to each specific vehicle. This means that assumptions have been made for vehicles for which no direct emission factors were available (i.e. use a similar vehicle type).

3. Preliminary results

This section shows some preliminary results for the data, focusing on road transport emissions and PN emissions in particular, since these are the “new features” in the dataset. For more results for the main pollutants the reader is referred to Kuenen et al. (2022).

3.1 Ultrafine particles

Figure 1 shows PM2.5 emissions and PN emission totals for the year 2018 by GNFR sector. While for PM2.5 the largest contributing sources are small combustion (C) and industry (B), for ultrafine particles the transport sectors (F: Road Transport, G: Shipping, H: Aviation, I: Off-road vehicles and machinery) are the key contributors, with also a significant contribution from industry (B) is found for PN.

Figure 2 shows only the PN emissions, but now size distributed in the 15 different CAMx size bins. For each size bin, also the contribution of different GNFR sectors to the total PN emission is shown. It shows that different sources have a different size profile with different particle modes (or bi-modal, e.g. road transport).

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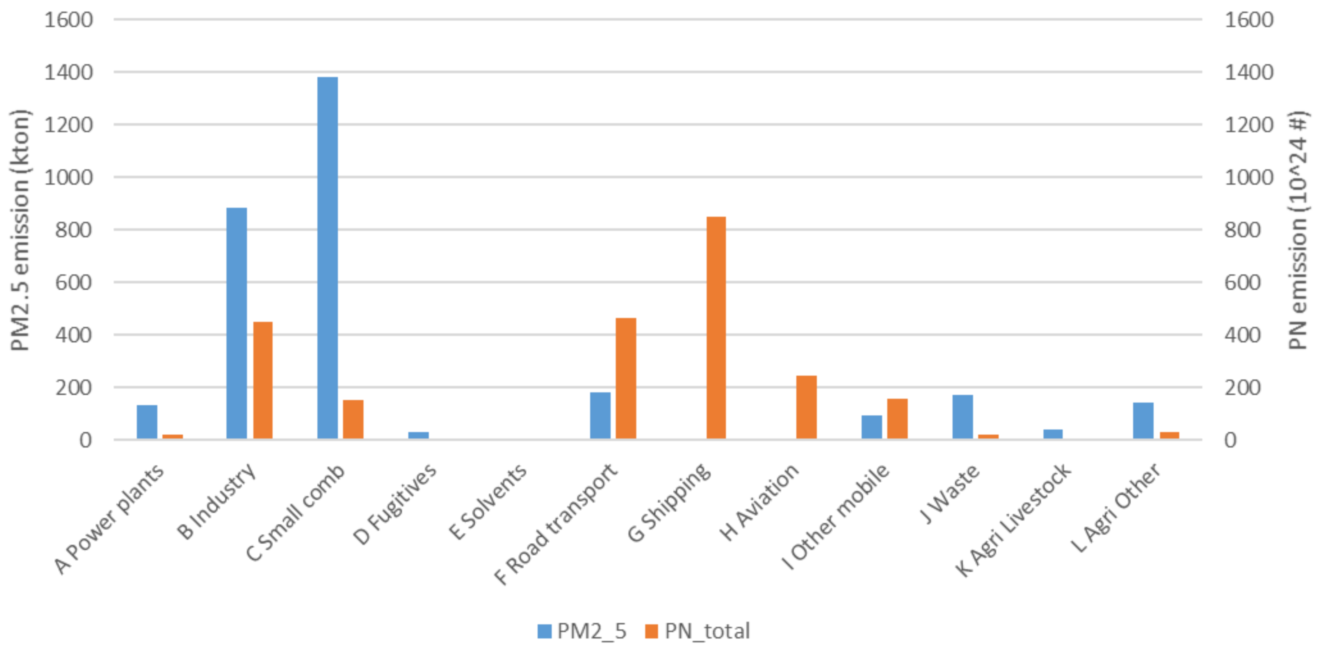

Figure 1. *PM2.5 and PN emissions by GNFR sector for 2018.*

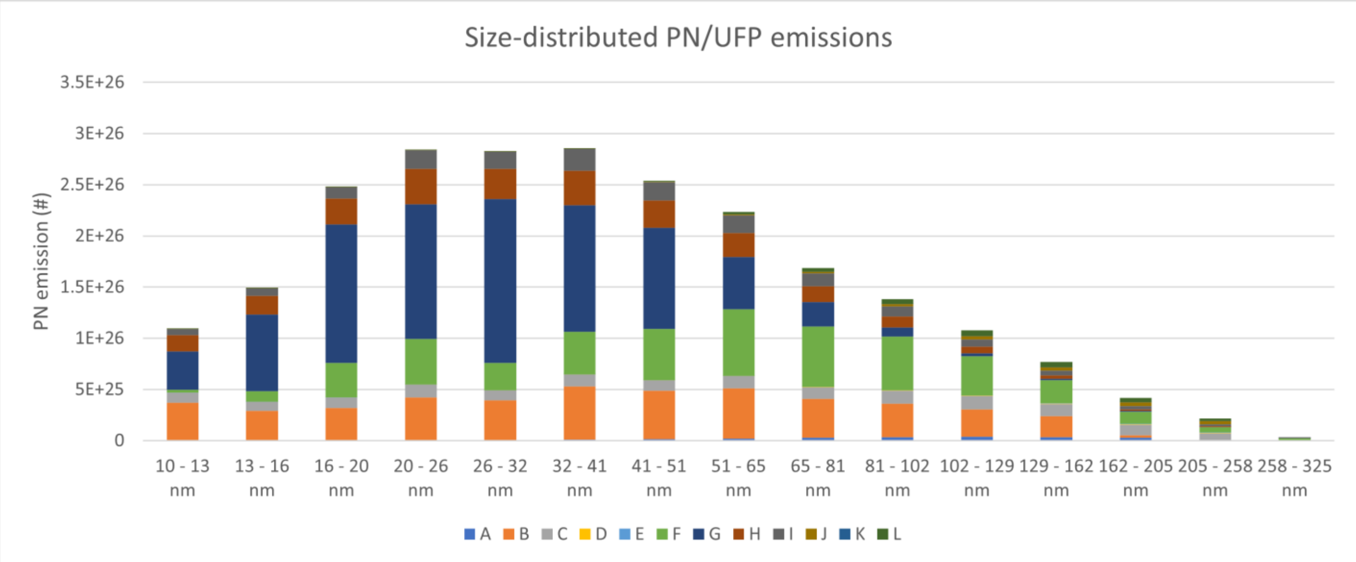

Figure 2. *Size distributed PN emissions and the contribution from different GNFR sectors in each of them: Power generation (A), industry (B), small combustion (C), fugitives (D), solvents (E), road transport (F), shipping (G), aviation (H), off-road vehicles and machinery (I), waste (J), agricultural livestock (K), and other agriculture (L).*

3.2 Road transport emissions

Road transport emissions have been estimated for both exhaust and non-exhaust, for the main air pollutants and also for total PN emissions. Figure 3 shows an illustrative result distinguishing emissions of NOx, PM2.5 and PN by fuel type and vehicle type, highlighting that for all 3 pollutants the majority of emissions comes from diesel combustion. Wear emissions are only relevant for PM (not for UFP), typical particles generated here are above the UFP range and far less in PN. When zooming in more, it can be seen the vast majority of both PM2.5 and PN

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emissions originates from vehicles without a diesel particulate filter (DPF). It is therefore expected that these emissions will decrease in the coming years as these older diesel vehicles will be replaced with particulate filter-equipped new vehicles. While small compared to diesel fuelled vehicles, it should be highlighted that petrol vehicles are also a source of UFP, especially the two-wheelers and older gasoline-fuelled direct injection (GDI) passenger cars. While also newer vehicles such as CNG-fuelled urban buses may be relatively high UFP emitters, they don't show up here because their relatively low number.

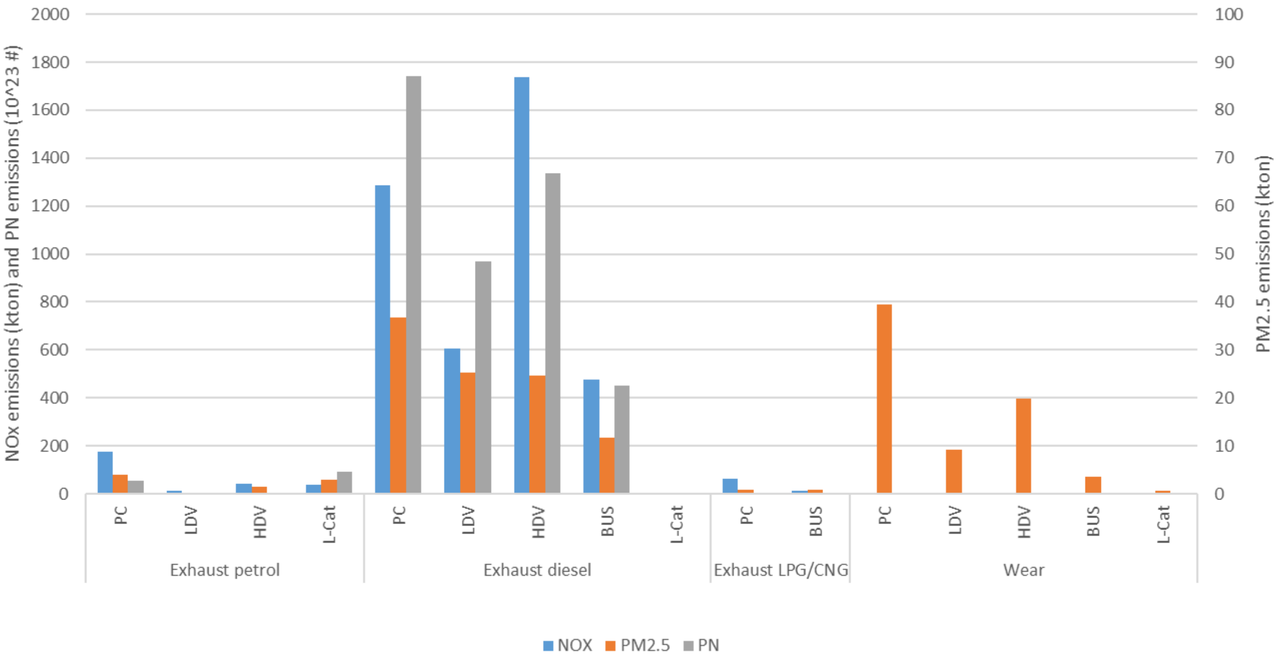

Figure 3. *Emissions of NOx, PM2.5 and particle number (PN) from road transport and the sub-sources therein for the year 2018. PC, passenger cars; LDV, light duty vehicles; HDV, heavy duty trucks; BUS, bus; L-Cat, mopeds and motorcycles. CNG, compressed natural gas; LPG, liquefied petroleum gas.*

3.3 Resulting emission maps

Figure 4 and Figure 5 show spatially distributed emissions of PM2.5 and PN, respectively. For PM2.5, the main emission sources are small combustion (mainly residential heating), transport and industrial sources (see also Figure 1). For UFP, shipping is an important source as is clearly illustrated by the MAP, and also other transport lines (main roads) are visible in the maps next to the urban centres.

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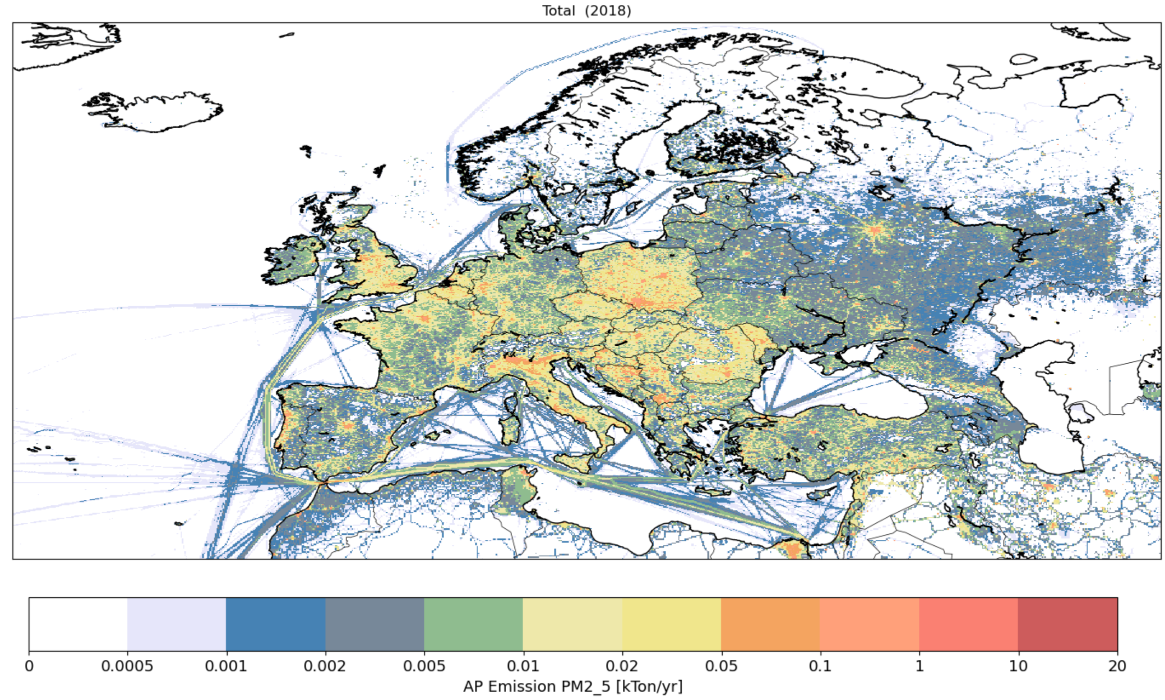

Figure 4. *Emissions of PM2.5 distributed in space at 6x6 km2 resolution.*

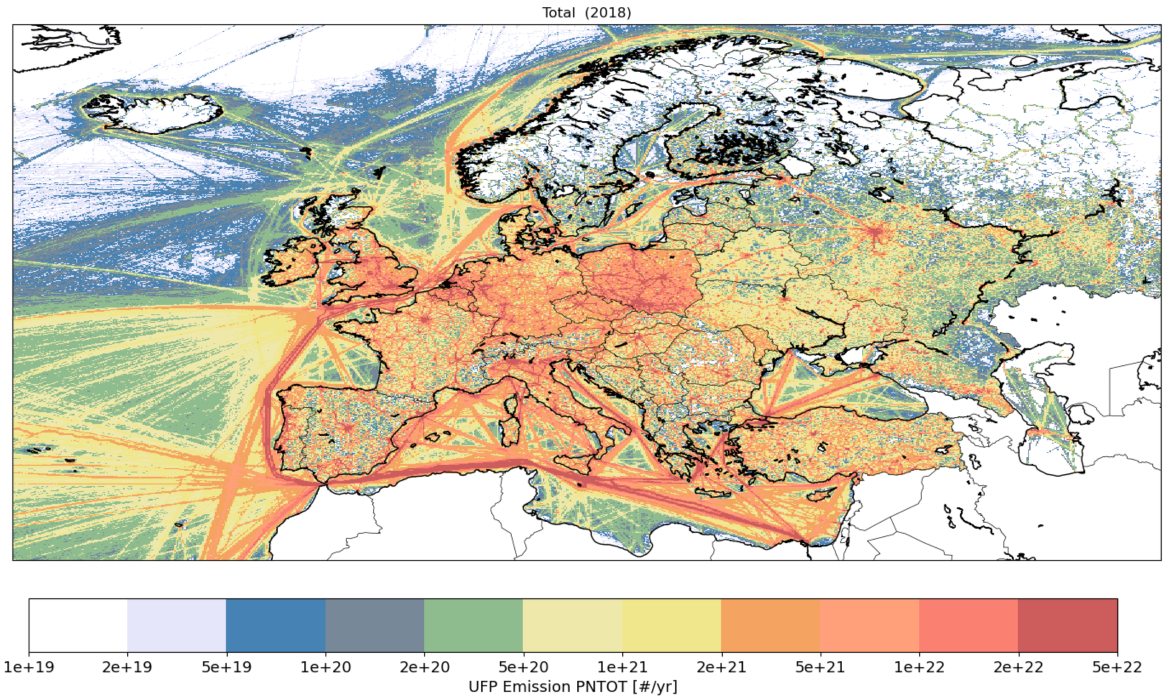

Figure 5. *Emissions of total PN for 2018 distributed in space at 6x6 km2 resolution.*

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4. Data availability

The gridded emission data are available through TNO's FTP site, details have been or will be shared with the relevant partners involved and can also be made available on request. The sectors distinguished in the gridded files are the GNFR (aggregated NFR) classification, similar to what is provided in CAMS-REG.

For NMVOC and PM emissions, speciation profiles are provided along with the inventory which provide recommended split factors for distributing these lumped pollutants over specific chemical species. Also, default temporal profiles and default vertical distribution profiles are available with the inventory.

5. Next steps

The currently prepared emission inventory will be shared with the users in RI-URBANS, in particular the modellers in WP3. Some discussions and iterations with the modellers will taking place in the next months to see if the current dataset fits with their needs. This is especially relevant for UFP as a PN inventory is not produced as regularly as for the other pollutants. The feedback from the users will be taken into account in a plan for an improved and final dataset which is due in M28 (January 2024). Work on this improved inventory will start early 2023.

6. References

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