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AIR POLLUTION MANAGEMENT AND DECISION SUPPORT SYSTEMS: THE IN.EM.AR. EMISSION MODELLING SYSTEM

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Abstract
The aim of an emission inventory is to provide a quantitative estimate of the contributions to atmospheric emissions from the various anthropogenic and natural sources and how they are distributed over a given territory, in order to have a functional knowledge tool for planning measures for air quality protection.
The IN.EM.AR. system (INventario EMmissioni Aria: www.inemar.eu) is being used in Lombardy for many years to estimate and update the regional Air Emissions Inventory. It has been developed as part of the Regional Air Quality Plan (PRQA) and managed, since 2002, by ARPA Lombardia. The main goal of this paper is the description of the framework of activities for the compilation of the local emission inventory of Lombardy region. The mentioned implemented system was set up in 1998 and is managed since 2002 by Regional Environmental Protection Agency of Lombardy (ARPA). It has been developed over the years in order to take into account: new methodologies, data and information increased availability, user and stakeholder requests evolution, in short, to better face the new challenges in the field of air quality and GHGs. It is also used by other seven Italian ARPAs and Regions. It is able to provide emission estimates deriving from a combination of more than 250 activities and 12 fuels for pollutants of main interest for air quality (SO_2, NO_x, NMVOC, CO, NH_3, PM2.5, PM10, TSP) and greenhouse gases (CO_2, CH_4, N_2O and F-gases) at municipality level. Emission data are also available for the carbonaceous fraction (BC, EC, OC) of particulate, polycyclic aromatic hydrocarbons PAHs (BaP, BbF, BkF, IcdP) and heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn). Emission inventories for Lombardy have been developed using INEMAR for several years: 1997, 2001, 2003, 2005, 2007, 2008, 2010, 2012, 2014 and 2017 (ARPA Lombardia, 2021). The INEMAR system estimates the pollutants emitted by the numerous sources coded according to the international nomenclature SNAP (Selected Nomenclature for Air Pollution), organized hierarchically into macro-sectors (groups), sectors (subgroups) and activities. To each of these classes is assigned a numerical code. IN.EM.AR is in Italian panorama, one of the most functional and data-rich tool for local emission inventories. The results are currently used both by technical-scientific operators for studies, research and environmental impact assessments. The database is essential for the implementation of the environmental legislation, in particular regarding the assessment and the management of ambient air quality, the estimate of the benefits deriving from the measures adopted to reduce emissions pollutants, through the simulation of emission scenarios.

Key words: *INEMAR, emissions inventory*

INTRODUCTION

The estimation of the emissions passes through specific algorithms and methodologies according to the EMEP/EEA Atmospheric Emission Inventory Guidebook, in the most up-to-date version available at the time the inventory was prepared (EEA, 2019), in addition to the further specifications contained in the documents drawn up by ISPRA (https://www.isprambiente.gov.it/it). The estimation is based on the collection of a huge number of information like activities indicators (i.e. fuel consumptions, traffic flows, industrial productions), emission factors and statistical data for the spatial and time-based distribution of the emissions. The periodic updating of the above-mentioned parameters and their level of details (defined as Tier) affect the overall level of uncertainty in emission calculations. An emission inventory must meet the criteria of transparency, consistency, comparability, completeness and accuracy (TCCA). In this direction, one should be able to provide sufficiently detailed reporting to allow replication of the emission estimates based on the data sources, processing assumptions and methodologies. It should be ensured that the estimates of the latest edition of the inventory are consistent with previous releases, identifying the main differences and making estimates accurate enough to ensure as much as possible the reduction of

uncertainties. It is necessary to consider different aspects: 1) the methodology for defining indicators from available data sources, 2) the implementation of calculation algorithms, the choice of emission factors and methodological Tier, 3) the definition of the methodological approach for the representation of different types of source, 4) at least qualitative minimization of uncertainties and 5) the realization of emission estimates and where appropriate, management of their publication. The emission estimates should be carried out allowing to compare the results with those of other inventories, ensuring that the estimates cover all the emission sources for which some methodologies and documenting the sources not considered.

FRAMEWORK IN DEVELOPMENT OF LOCAL EMISSION INVENTORY AND STRUCTURE OF THE INEMAR SYSTEM

The system and methodologies implemented by ARPA Lombardy have been shared with other Italian regions increasing harmonisation in methods and estimates among regional local emission inventories (ARPA, 2021). This latter aim determines an increase in complexity managing local peculiarities. As a matter of facts, the implemented framework seems effective answering to different users' request with a proper codification of standard algorithms and parameters. The implementation of an edition of the regional emission inventory passes through the collection of several data as input. As reported in Figure 1, different methodologies and approaches have been developed in order to: insert emission data with the correct codification, manage input and metafiles in emission inventory and share the methodology with other partners in an open and common space, such as Wiki pages (https://www.inemar.eu).

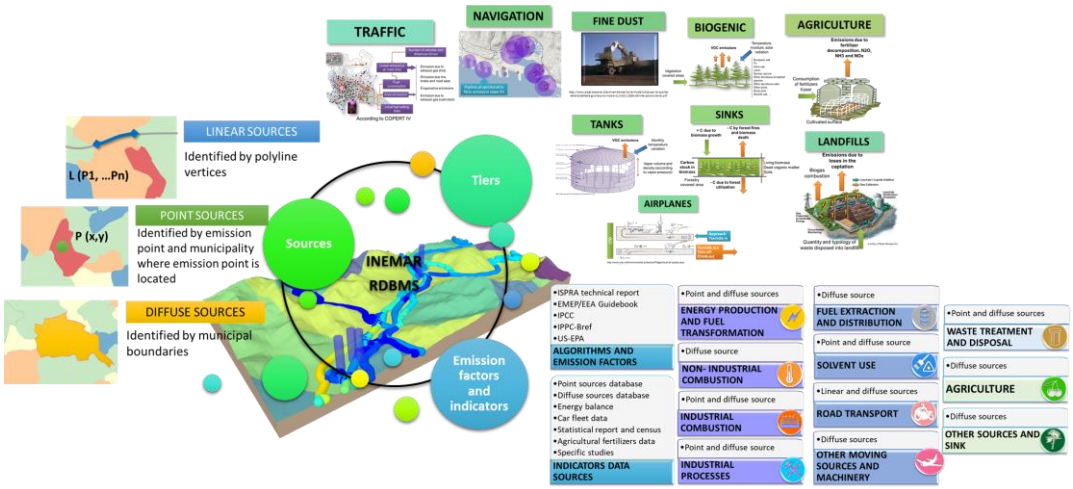

Figure 1. Approaches and mehodologies in Lombardy regional emission inventory.

The highest Tier algorithms have been implemented according to different modules and welded to the database core and the publication policy according to a public review system that have been successfully used. The implemented system is able to identify the uncertainty level of the estimates as a combination of uncertainties of input data, algorithm level of implementation and emission factors. As implemented in different emission inventory editions uncertainty level can be defined considering a multiplier factor defined on qualitative basis (from low to high accurate estimates), determining the amplitude of uncertainties. In IN.EM.AR highest accuracy is performed defining point emission sources when data of concentration are available at stack exit (eg. large industrial plants). With a progressive decreasing of complexities different algorithms are defined, obtained from the highest Tier of the AIEG, where the number of parameters can be relevant (eg. traffic transport). When detailed data are not available or an emission source is characterised by a spread distribution in the territory (eg. domestic heating), a statistical approach is used defining average indicators and emission factors. INEMAR is a database developed in RDBMS Oracle 10i, installed on servers and managed through various client locations. The interface consists of a series of windows that can be viewed via a web browser. It is also possible to access data via ODBC connection. INEMAR consists of a large number of tables grouping the data that are processed by various calculation modules through specific algorithms.

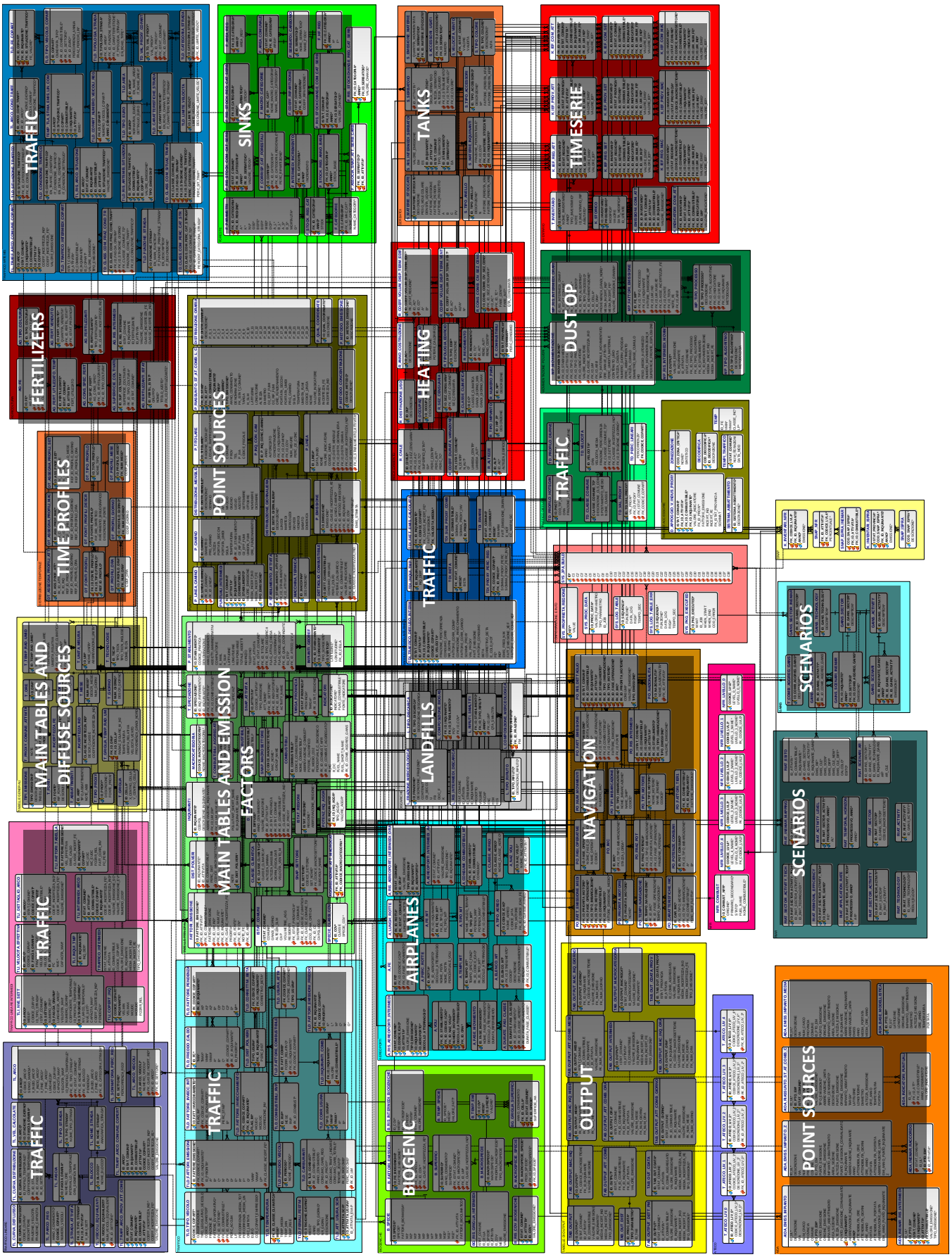

Figure 2. INEMAR database's structural map

The tables are divided into two families: the “general” ones, which contain data used by several calculation modules, and the “specific” ones, which contain data used or produced by a single module. The tables are used for: 1) Definition of parameters, containing the coefficients necessary for the operation of the algorithm (eg emission factors); 2) Storage of the inputs to the inventory, containing the fields defined by the users and necessary for the estimates, ex: the indicators, other local parameters for the operation of the modules; 3) Elaboration of the outputs of the inventory, containing the emissive estimates or the intermediate elaborations necessary to obtain them; 4) Decoding, containing data that describe the numerical code used in extensive form in the database. In the structure of the database there are the following modules: Airports, Agriculture, Biogenics, Areal Sources, Forestry, Landfills, Point Sources, Harbours, Fine Dust, Tanks, Speciation, Traffic, Domestic Heating, Temporal Disaggregation, Recalculation and Scenarios. The outputs of the various calculation modules, that is the result of the algorithmic operations, populate various tables. Each algorithm indicates an emissive type, by means of a 2 or 3 letter code. Figure 2 shows the INEMAR’s structural map, with links connecting the tables of the calculation modules.

EMISSION INVENTORY RESULTS

Total estimates of emissions are also provided for about 1500 municipalities of the Lombardy region,. Regional emissions of macropollutants estimated in the year 2017 are shown in Figure 3 with detail of SNAP group.

	SO_2	NO_x	VOC	CH_4	CO	CO_2	N_2O	NH_3	PM2.5	PM10	TSP	CO_2 eq	O_3 Precurs.	Tot. acidif. (H+)
	t/year	t/year	t/year	t/year	t/year	kt/year	t/year	t/year	t/year	t/year	t/year	kt/year	t/year	kt/year
Combustion in energy and trasformation industries	3.560	8.117	763	1.526	6.665	13.968	262	50	171	177	184	14.084	11.420	291
Non-industrial combustion plants	639	11.308	7.728	4.422	61.045	15.305	583	751	7.384	7.568	7.982	15.590	28.300	310
Combustion in manufacturing industry	4.035	17.294	3.292	697	12.154	11.997	299	396	1.141	1.347	1.608	12.104	25.738	525
Production processes	1.855	1.664	11.247	169	33.260	2.883	55	86	363	602	858	2.903	16.938	99
Extraction and distribution of fossil fuels			10.976	44.572								1.114	11.600	
Solvent and other product use	0	122	75.236	1	53	0		29	669	745	1.104	3.453	75.391	4
Road Transport	110	56.368	15.567	1.139	73.054	17.566	573	1.028	2.857	4.072	5.435	17.765	92.389	1.289
Other mobile sources and machinery	197	12.778	1.270	27	4.866	1.417	47	2	594	595	596	1.431	17.394	284
Waste treatment and disposal	642	2.643	875	66.222	1.104	638	422	544	33	34	38	2.419	5.148	110
Agriculture	43	697	60.791	220.761	2.221		10.265	94.070	548	1.075	2.194	8.578	64.976	5.550
Other sources and sinks	99	484	55.314	5.573	13.805	-2.613	4	157	1.281	1.607	2.154	-2.472	57.501	23
Total	**11.180**	**111.475**	**243.058**	**345.107**	**208.227**	**61.161**	**12.510**	**97.114**	**15.040**	**17.823**	**22.154**	**76.970**	**406.794**	**8.485**

Figure 3. Emissions in Lombardy in 2017 by SNAP group – final data

The map in Figure 4 shows how the largest primary PM10 emissions per unit of surface area of each Lombard municipality affect the main urban areas of the region, the municipalities adjacent to the main motorway arches and some Alpine and pre-Alpine areas characterized by the domestic use of wood biomass. The greatest NOx emissions are estimated near major roads and motorways in relation to vehicular traffic and ammonia is emitted mainly in the plain areas characterized by agricultural vocation.

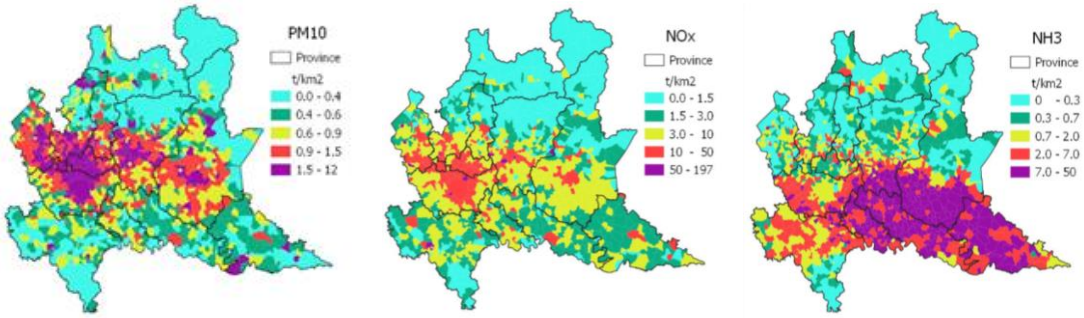

Figure 4. Map of PM10, NOx and NH3 emissions in 2017

The heating sector, mainly due to fuelwood, and the road transport are the main emission sources of PM in Lombardy estimated for 2017 (Figure 5), TSP are also emitted from agriculture sector. The non-industrial

combustion determines 42% of the regional emission of PM10. The heating sector is also the main source of emission of PAHs accounting for 55% of the total emission of BaP, 50% for BbF, 32% for BkF and 44% of IcdP. The use ligno-cellulosic fuels is the main relevant emission source of BaP. The heating sector is also the second main emission source of EC (ca. 33%) and the main emission source of OC (ca. 65%). On the contrary, road transport determines 39% of the total emissions of EC and 10% of the total emissions of OC. EC/OC emissions have been estimated as fraction of PM for each activity and fuel couple (Caserini, 2013). The spatial distribution of the BC/OC emissions results in agreement with the study promoted by IAS (Sandrini et al., 2014). Emission sources of heavy metals show a more complex picture. The industrial sector, both combustions and processes, is a relevant source for all the metals except for Cu emissions. Relative high amount of Cd and Zn can be emitted also from the heating sector.

Figure 5. Lombardy emission estimates for 2017 in t/year (log scale) and emission share among different sectors.

CONCLUSIONS

Regional emission inventory for Lombardy Region is regularly updated considering activity data and new methodology improvements and has been assumed as a reference indicator in regional policy development (PRIA, 2018). The implementation of the system is shared with other local inventory developers, allowing the development of common accepted methodologies and preserving local peculiarities. The methodology is defined in order to obtain the deepest level of estimation minimizing the uncertainty level. Classification of new and diffuse technologies (e.g. small domestic appliances technology turnover), reduction in uncertainties in determination of indicators (e.g wood consumption in domestic heating) and relative fast updating in algorithm and emission factor are common tasks in the update and in the improvement of the emission inventory based on INEMAR systems.

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