Methodology for estimating atmospheric emissions from residential biomass heating considering technology turnover and real utilization

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Black Carbon Ensemble Emission Map Estimates from national to local level

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Summary

In this presentation is analyzed the impact of residential biomass heating on emissions of particulate matter and its components BC, OC, EC and LG, defining and showing the following indicators:

- Black Carbon (BC) estimates at national and local levels in northern Italy
- Local emission inventories and BC composite map

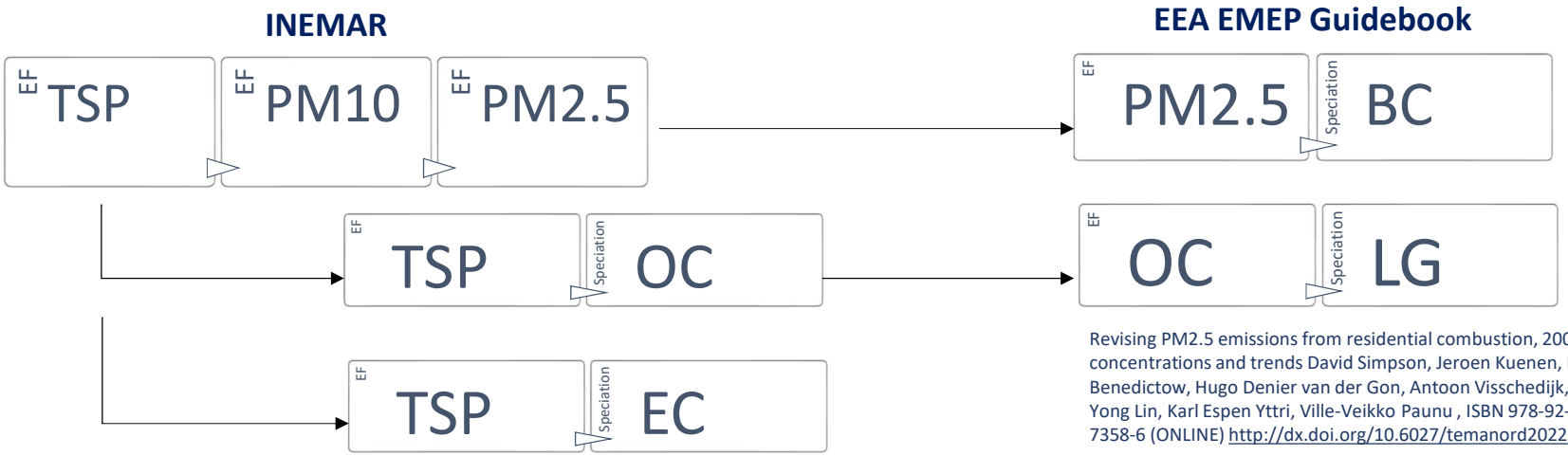
Framework on emission estimates

- **Italian Regions and autonomous provinces** have different functions in the monitoring and management of air quality and must compile and update an **emission inventory** every two or three years on their own territory.
- The **EEA-EMEP Guidebook is the main technical reference** for updating the emission inventories both at national and local levels and plays a fundamental role in the comparability of the estimates.
- The Italian local emission inventories are generally compiled at a **municipal detail** and implement the SNAP source classification.
- This high spatial resolution can allow to better describe the emission intensity on the domain, but sometimes can lead to greater difficulties in ensuring consistent time series due to lacks, gaps and changes in local information availability.
- **LIFE PREPAIR** collected emission inventories in the Po-basin offering an important **benchmark** for comparing Italian and European emission estimates

Methodology Overview

- In Italy, EA EMEP Guidebook is the common reference methodology for National and local emission compilers
- In northern Italy quite all the compilers adopt INEMAR system

Elisabetta Angelino, Alessandro Marongiu, Giuseppe Fossati, Marco Moretti , **AIR POLLUTION MANAGEMENT AND DECISION SUPPORT SYSTEMS: THE IN.EM.AR. EMISSION MODELLING SYSTEM**, 20th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes 14-18 June 2020, Tartu, Estonia

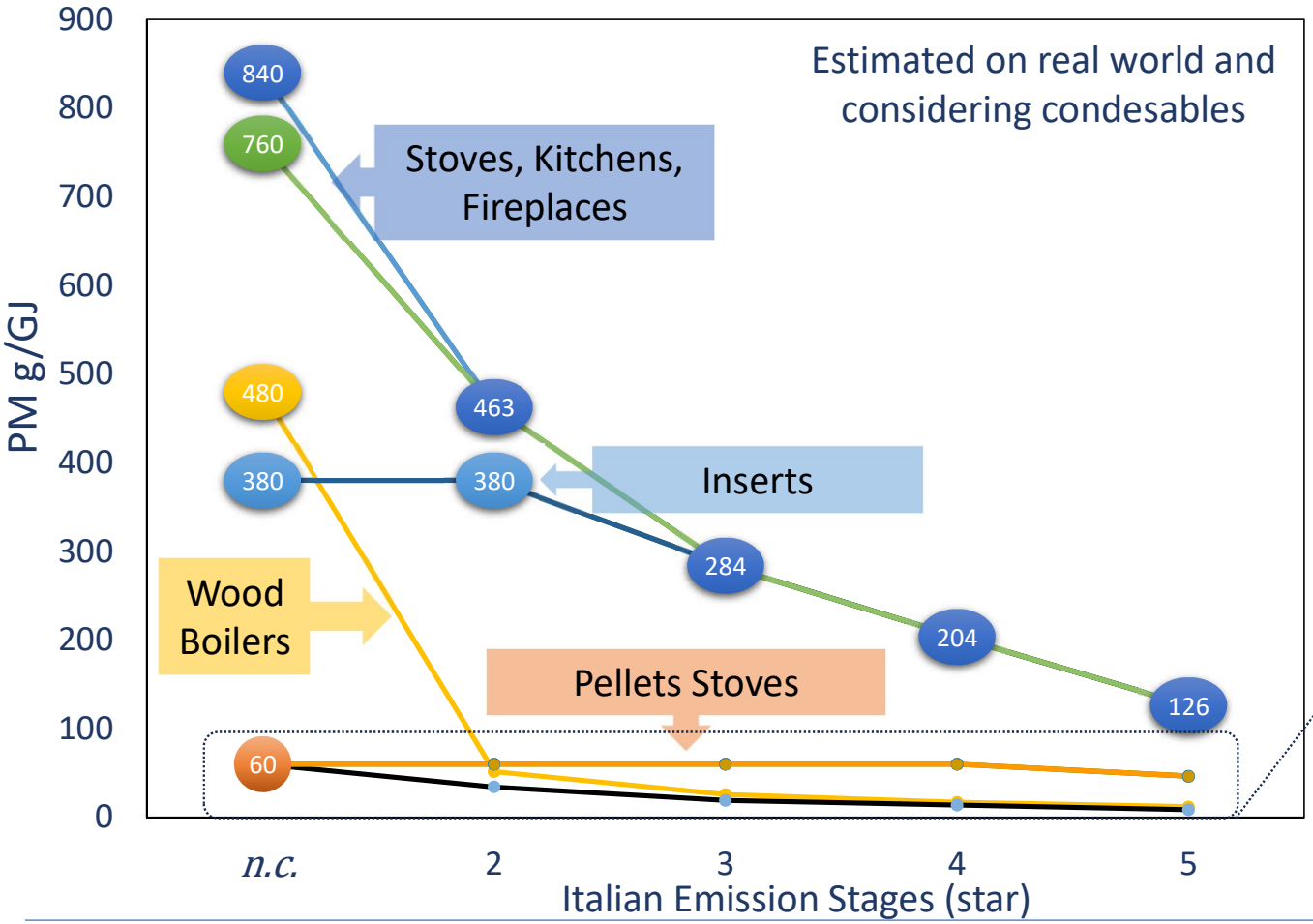


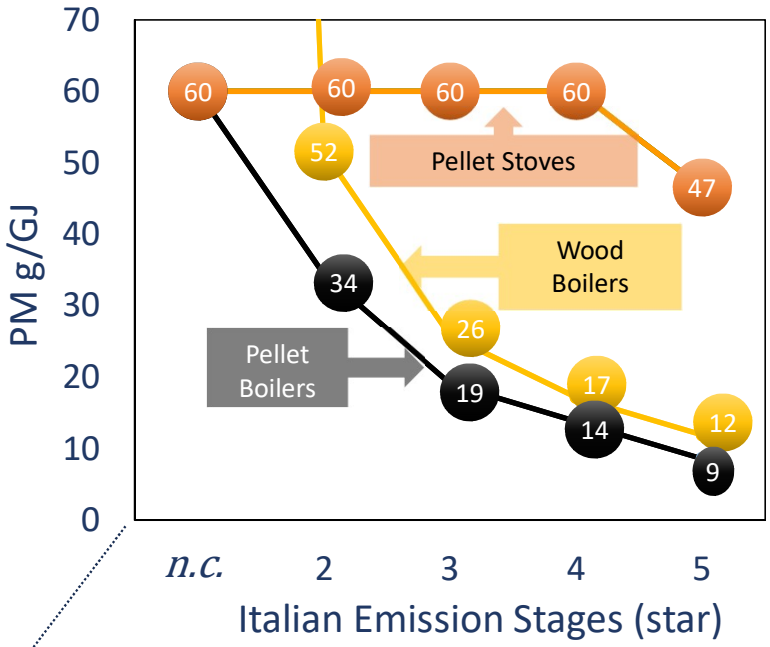
Stefano Caserini, Silvia Galante, Senem Ozgen, Sara Cucco, Katia de Gregorio, Marco Moretti, "A methodology for elemental and organic carbon emission inventory and results for Lombardy region, Italy", Science of The Total Environment, Volumes 450–451, 2013, Pages 22-30, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2013.01.073. (https://www.sciencedirect.com/science/article/pii/S0048969713001289)

Revising PM2.5 emissions from residential combustion, 2005–2019 Implications for air quality concentrations and trends David Simpson, Jeroen Kuenen, Hilde Fagerli, Daniel Heinesen, Anna Benedictow, Hugo Denier van der Gon, Antoon Visschedijk, Zbigniew Klimont, Wenche Aas, Yong Lin, Karl Espen Yttri, Ville-Veikko Paunu , ISBN 978-92-893-7357-9 (PDF), ISBN 978-92-893-7358-6 (ONLINE) http://dx.doi.org/10.6027/temanord2022-540

First High-Resolution Emission Inventory of Levoglucosan for Biomass Burning and Non-Biomass Burning Sources in China; Jian Wu, Shaofei Kong, Xin Zeng, Yi Cheng, Qin Yan, Huang Zheng, Yingying Yan, Shurui Zheng, Dantong Liu, Xiaoyang Zhang, Pingqing Fu, Shuxiao Wang, and Shihua Qi. Environmental Science & Technology 2021 55 (3), 1497-1507 DOI: 10.1021/acs.est.0c06675

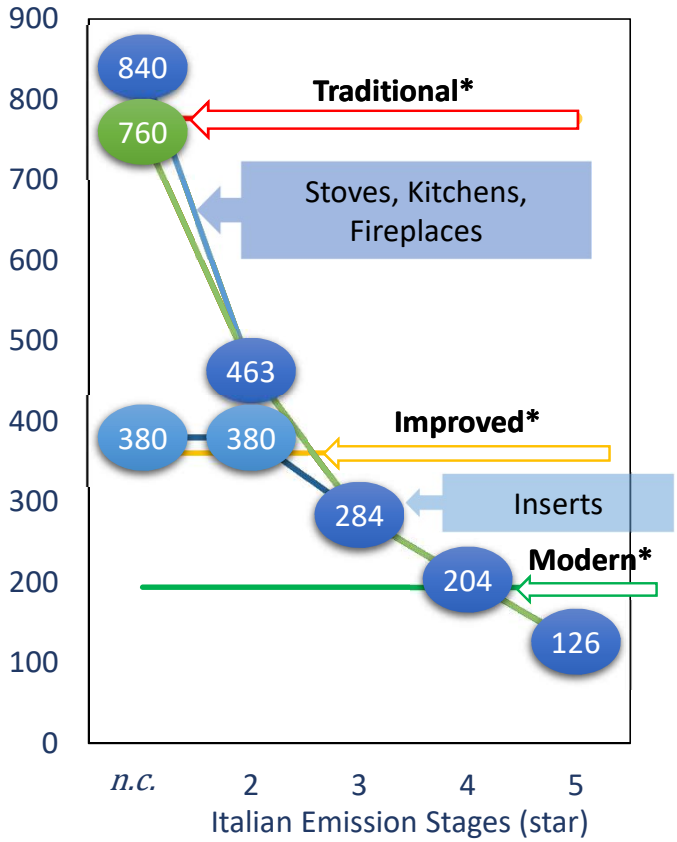
Emission factors for PM – harmonized turnover

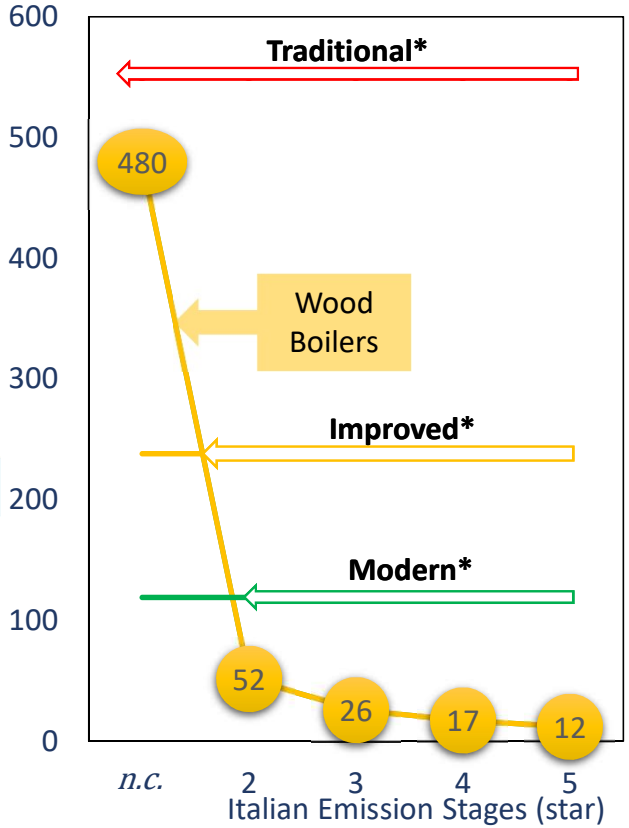


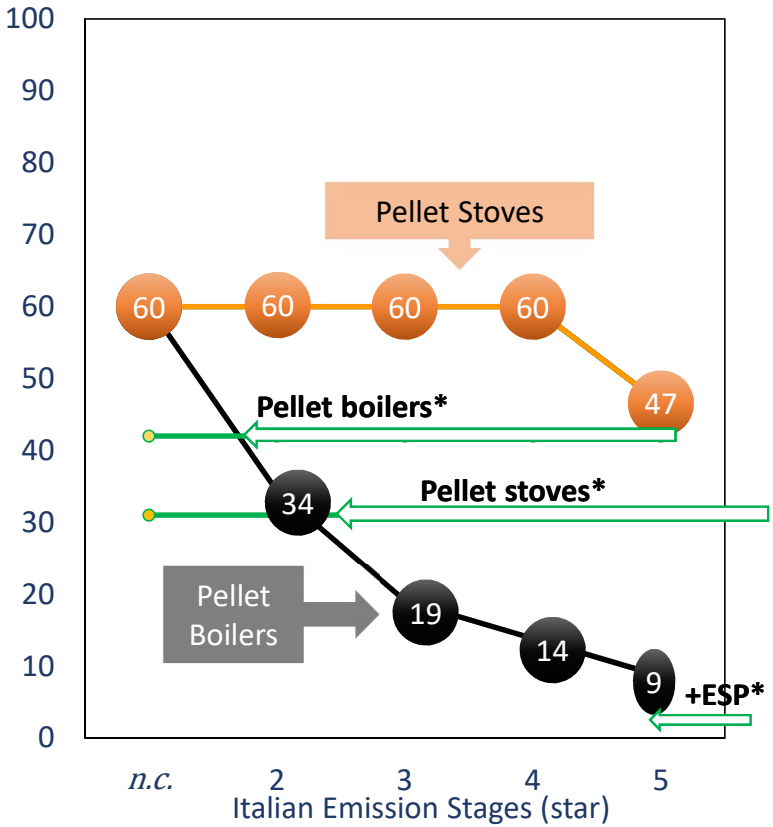


https://www.tfeip-secretariat.org/_files/ugd/e5a9c7_50bad2a5b1a24ae886ddd1d59197a8f4.pdf

Emission stages comparison for PM [g/GJ]



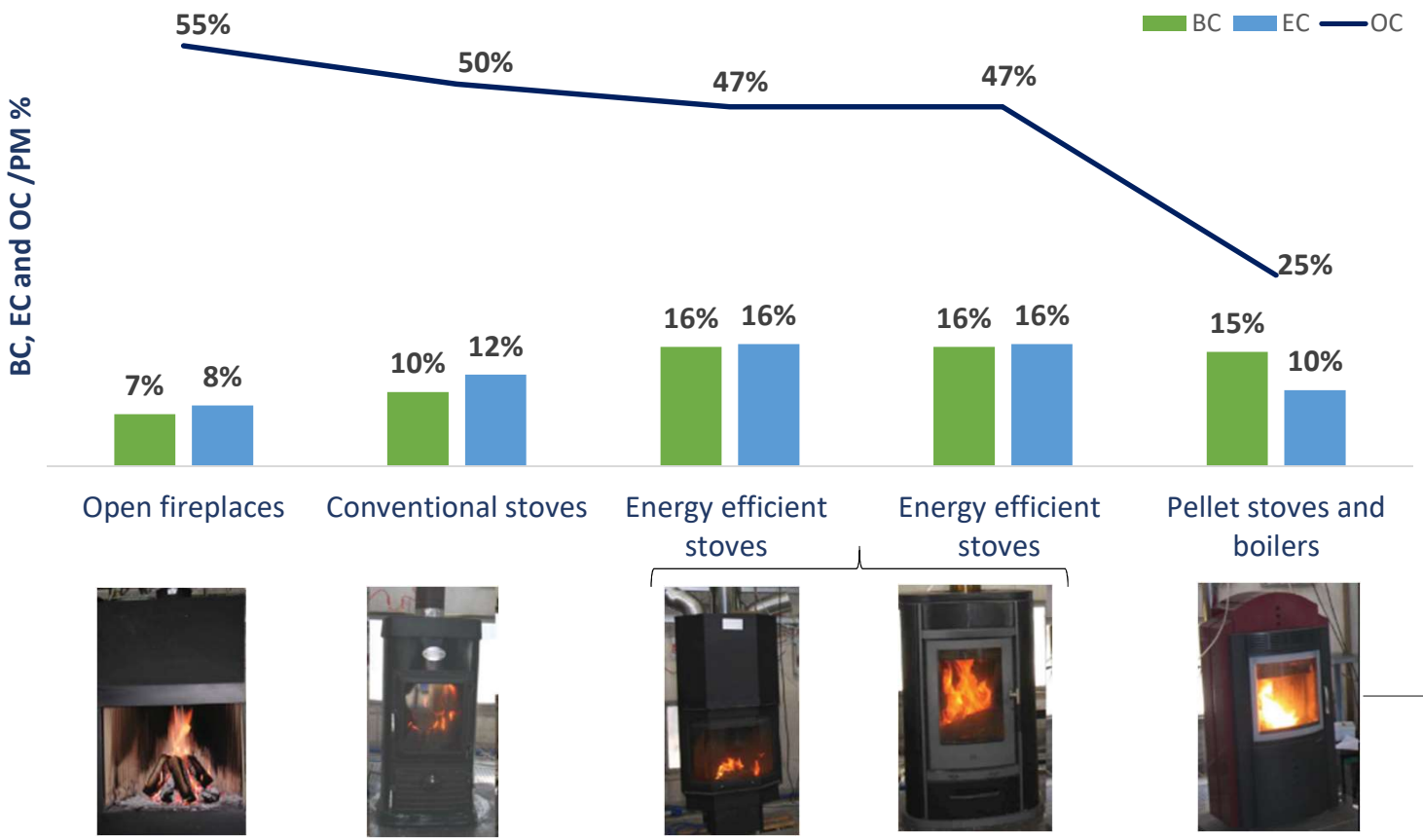




*Revising PM2.5 emissions from residential combustion, 2005–2019 Implications for air quality concentrations and trends David Simpson, Jeroen Kuenen, Hilde Fagerli, Daniel Heinesen, Anna Benedictow, Hugo Denier van der Gon, Antoon Visschedijk, Zbigniew Klimont, Wenche Aas, Yong Lin, Karl Espen Yttri, Ville-Veikko Paunu , ISBN 978-92-893-7357-9 (PDF), ISBN 978-92-893-7358-6 (ONLINE) http://dx.doi.org/10.6027/temanord2022-540

BC from residential wood heating

BC source: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016



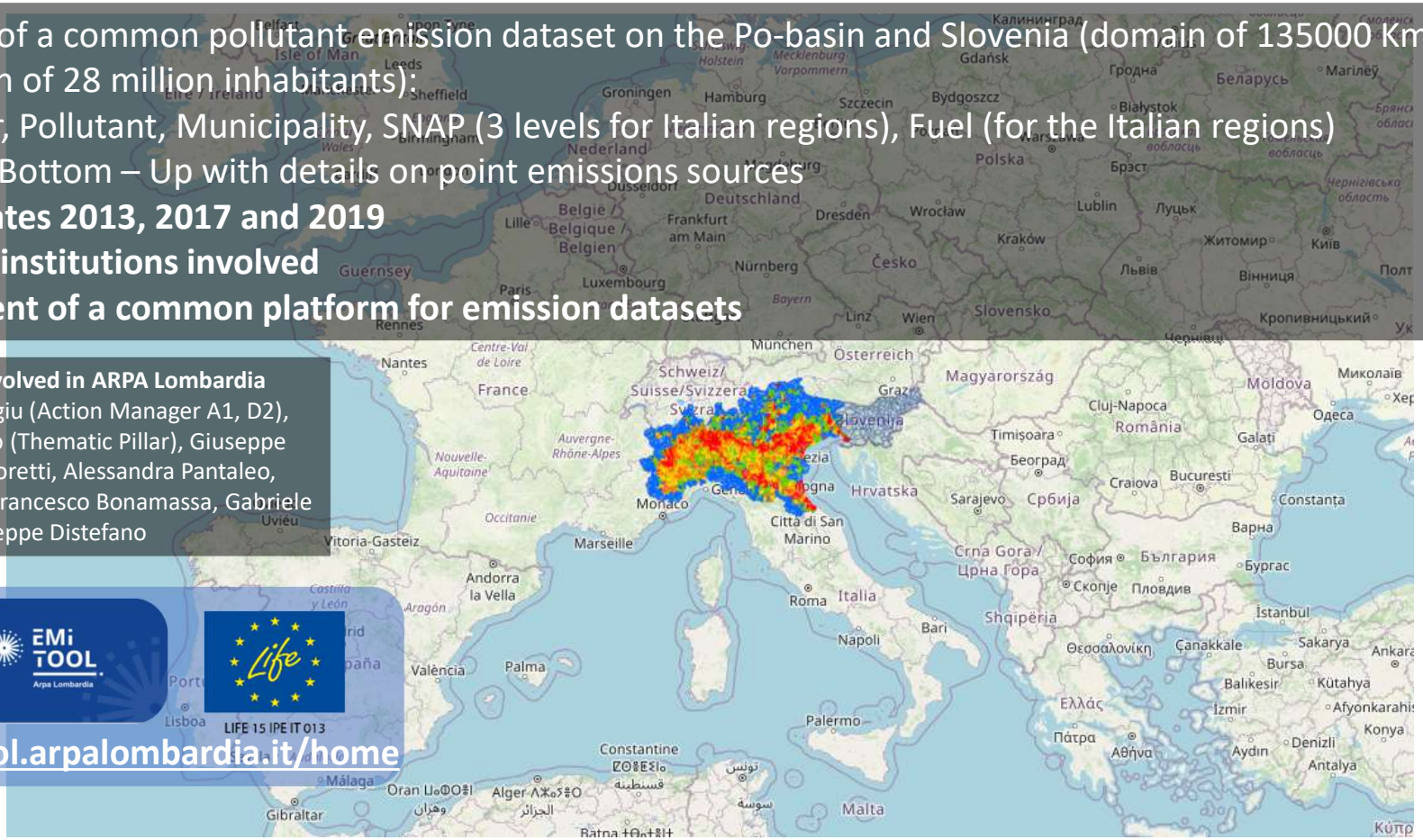
Boilers (< 35 kW) (Water) 1s
Boilers (< 35 kW) (Water) 2s
Boilers (< 35 kW) (Water) 3s
Boilers (< 35 kW) (Water) 4s
Boilers (< 35 kW) (Water) 5s
Boilers (35-100 kW) (Water) 1s
Boilers (35-100 kW) (Water) 2s
Boilers (35-100 kW) (Water) 3s
Boilers (35-100 kW) (Water) 4s
Boilers (35-100 kW) (Water) 5s
Boilers (100-500 kW) (Water) 1s
Boilers (100-500 kW) (Water) 2s
Boilers (100-500 kW) (Water) 3s
Boilers (100-500 kW) (Water) 4s
Boilers (100-500 kW) (Water) 5s
Stoves (Water) 1s
Stoves (Water) 2s
Stoves (Water) 3s
Stoves (Water) 4s
Stoves (Water) 5s
Stoves (Air) 1s
Stoves (Air) 2s
Stoves (Air) 3s
Stoves (Air) 4s
Stoves (Air) 5s

Source of the pictures: Caserini et al., 2014 https://doi.org/10.14672/ida.v1i1.231

Emission dataset in LIFE PREPAIR

Development of a common pollutant emission dataset on the Po-basin and Slovenia (domain of 135000 Km2 and population of 28 million inhabitants):

- **Detail**: Year, Pollutant, Municipality, SNAP (3 levels for Italian regions), Fuel (for the Italian regions)
- **Approach:** Bottom – Up with details on point emissions sources
- **Three updates 2013, 2017 and 2019**
- **9 different institutions involved**
- **Development of a common platform for emission datasets**



9 technicians involved in ARPA Lombardia
Alessandro Marongiu (Action Manager A1, D2), Elisabetta Angelino (Thematic Pillar), Giuseppe Fossati, Marco Moretti, Alessandra Pantaleo, Edoardo Peroni, Pierfrancesco Bonamassa, Gabriele Giuseppe Distefano

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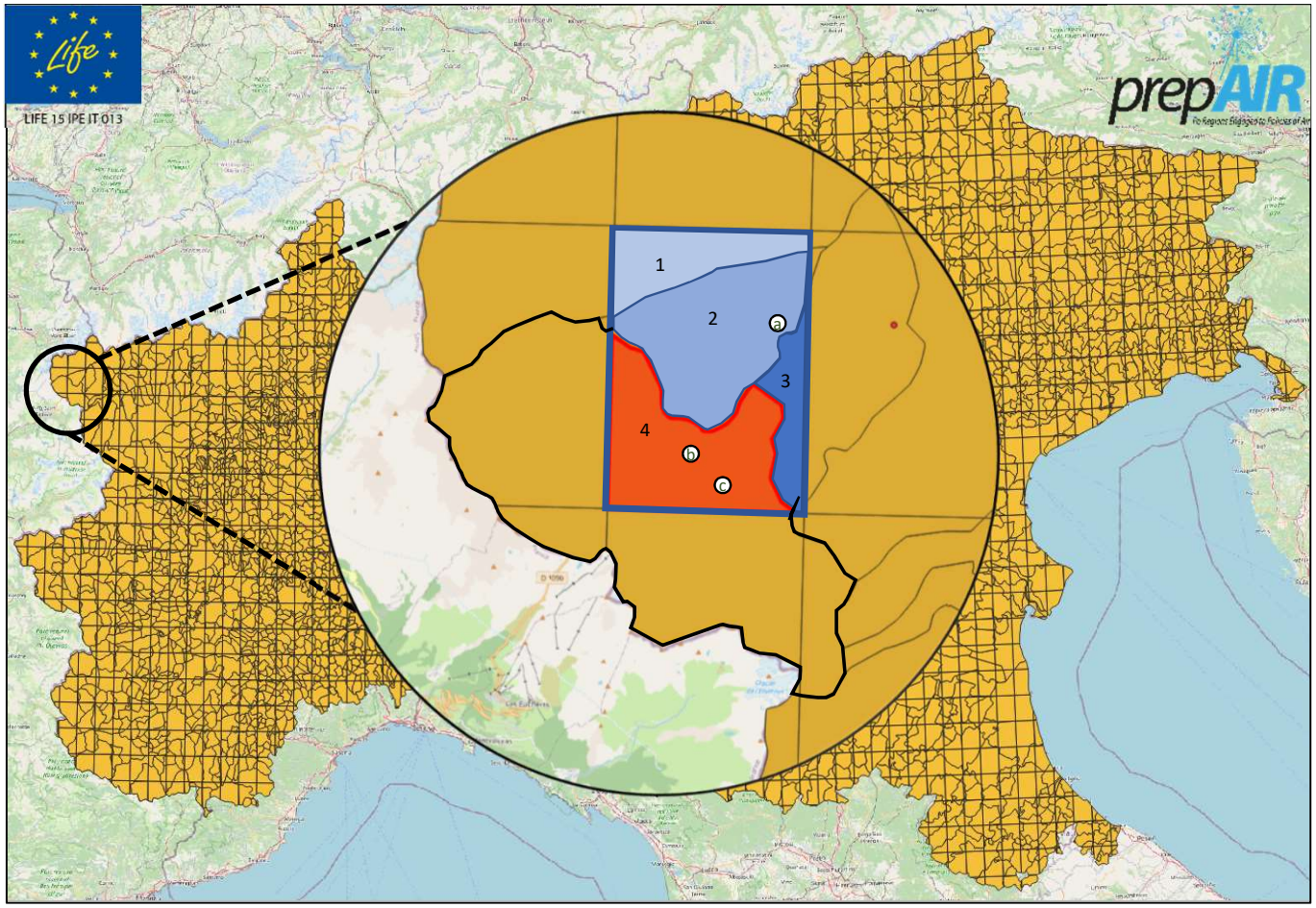
https://emitool.arpalombardia.it/home

Map comparison methodologies



From intersection between map of prepAIR municipal areas and the EMEP grid it's possible calculate the portion of municipal area reported in the prepAIR project which is located within the EMEP-cell.

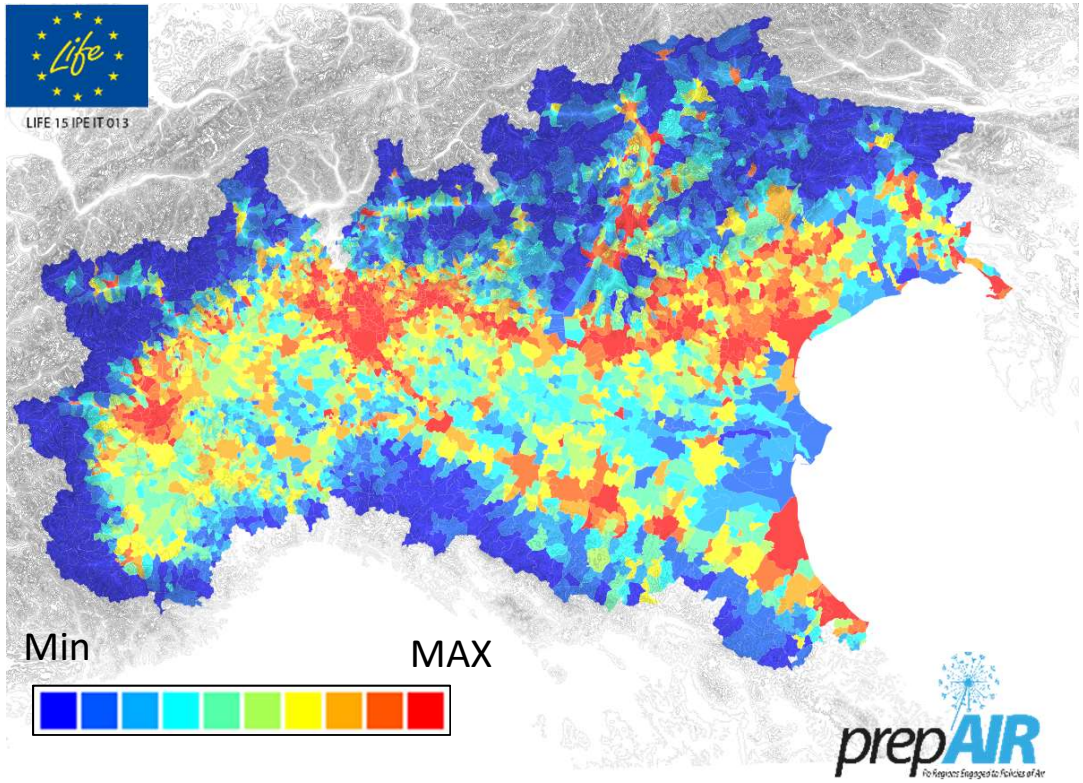
Assuming that the relative diffuse emission of each municipality is proportional to its area within the cell, we calculated the total diffuse emission as the sum of each relative municipal emission within the EMEP-cell.

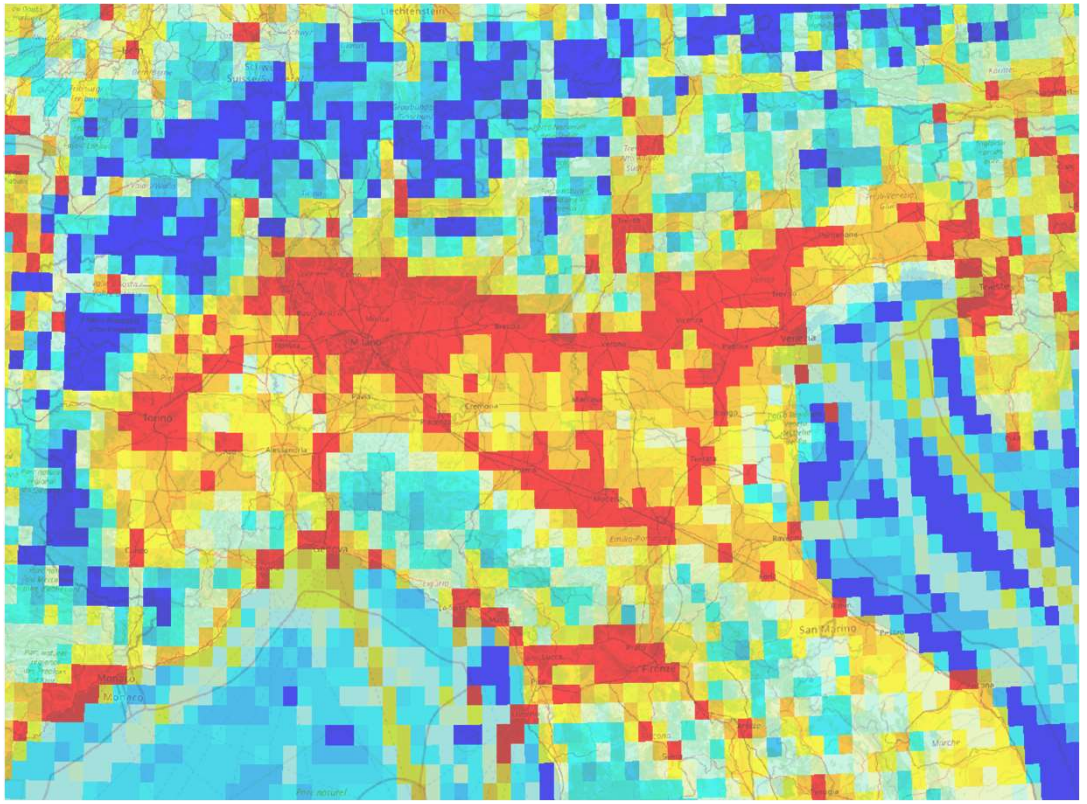
The total emission of cell (E_c):

$$E_c = \sum_{m=1,2..}^{n} \frac{E_{diffuse_m} \times A_{C \cap m}}{A_m} + \sum_{p=a,b..}^{h} E_{punctual}$$

Where:
A_m = total municipal area
$A_{C \cap m}$= municipal area within cell

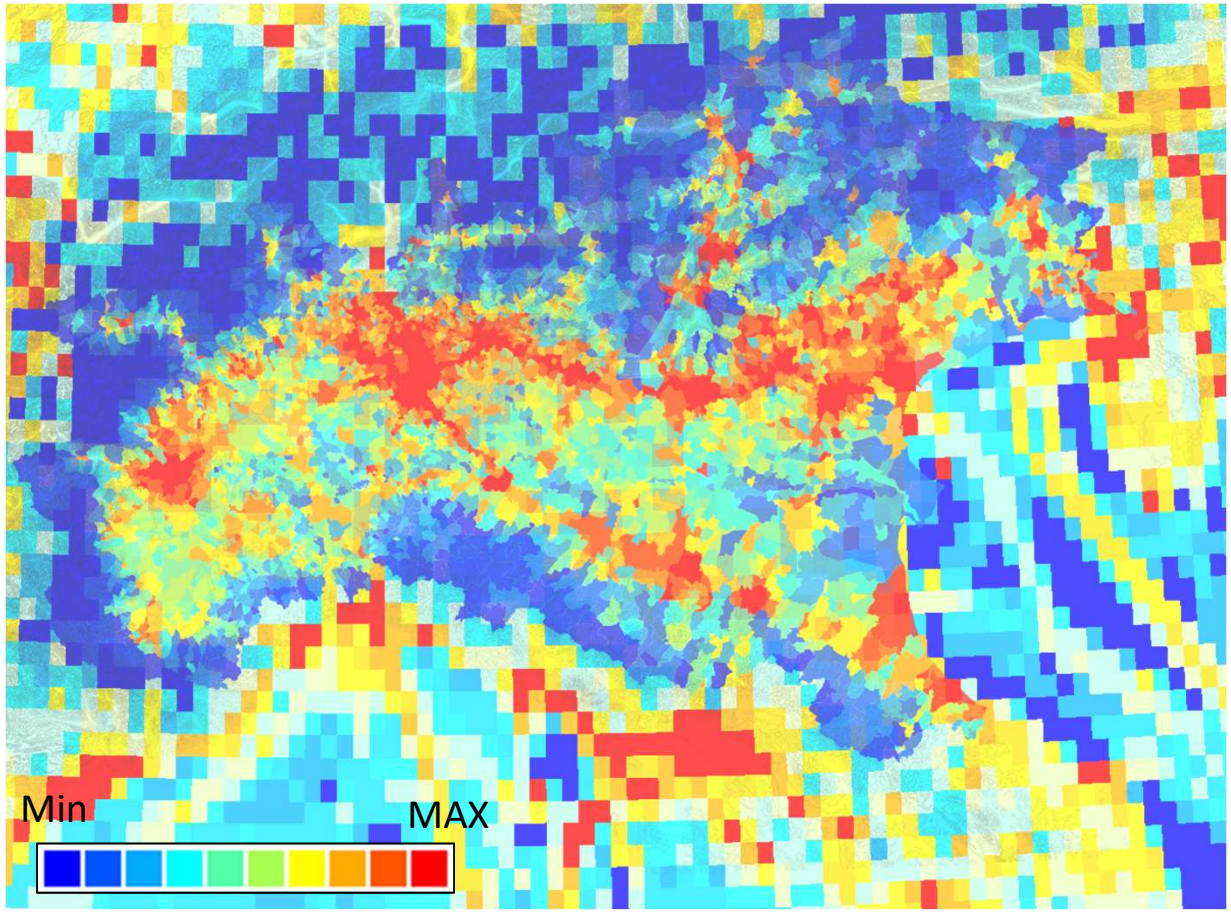
Map comparison LIFE PREPAIR vs EMEP grid on BC

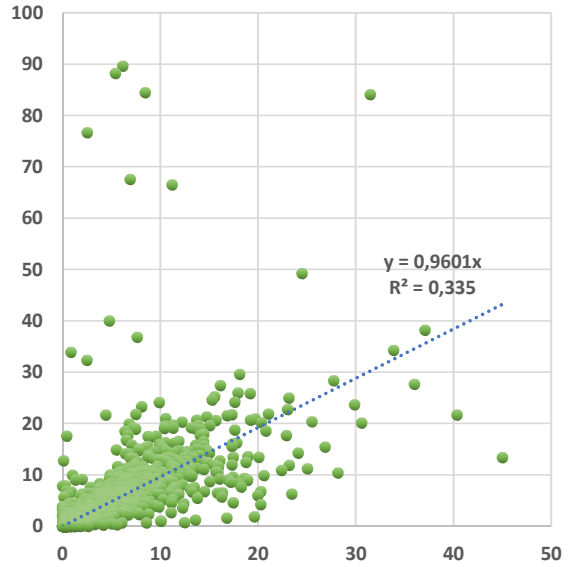




Source: https://www.emep.int/mscw/emep_grid.html

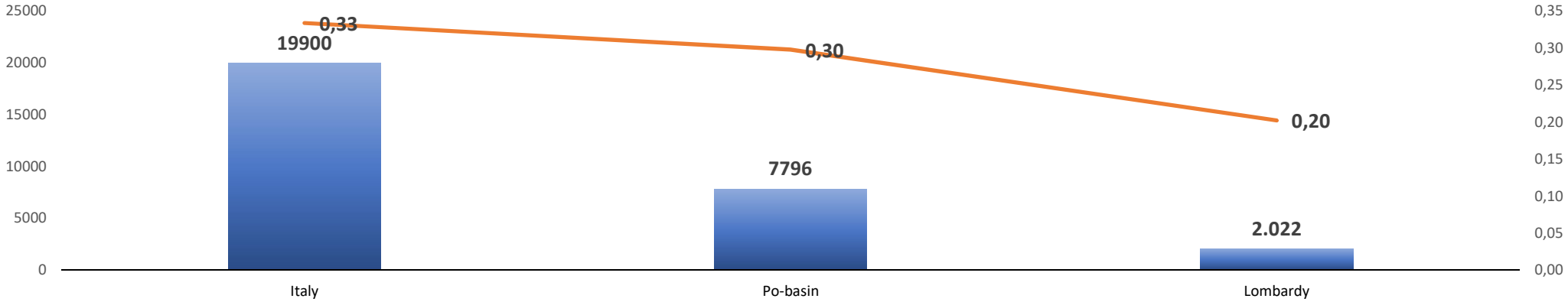
Map comparison LIFE PREPAIR vs EMEP grid on BC

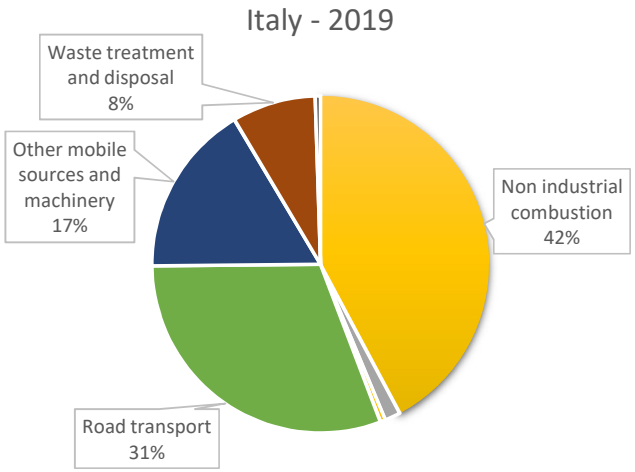


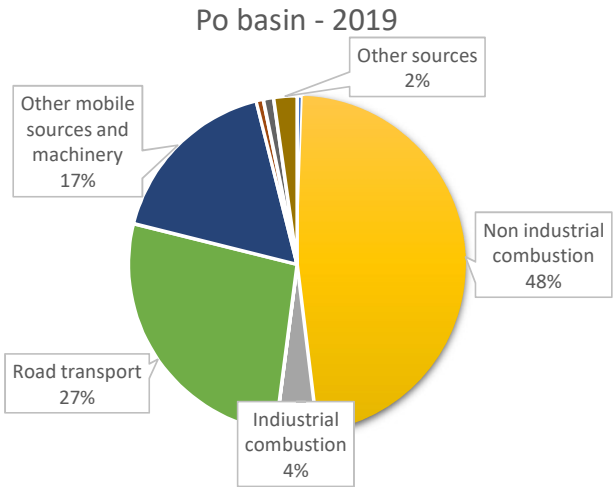


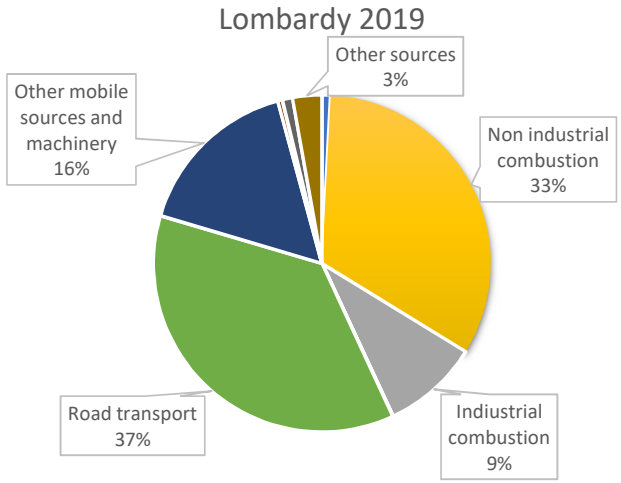
Each point of the scatter plot represents the BC emitted in tons in 2019 for each cell according to PREPAIR and EMEP estimates. All the cells representing the Po basin were compared.

Emission BC on different domains and methodology

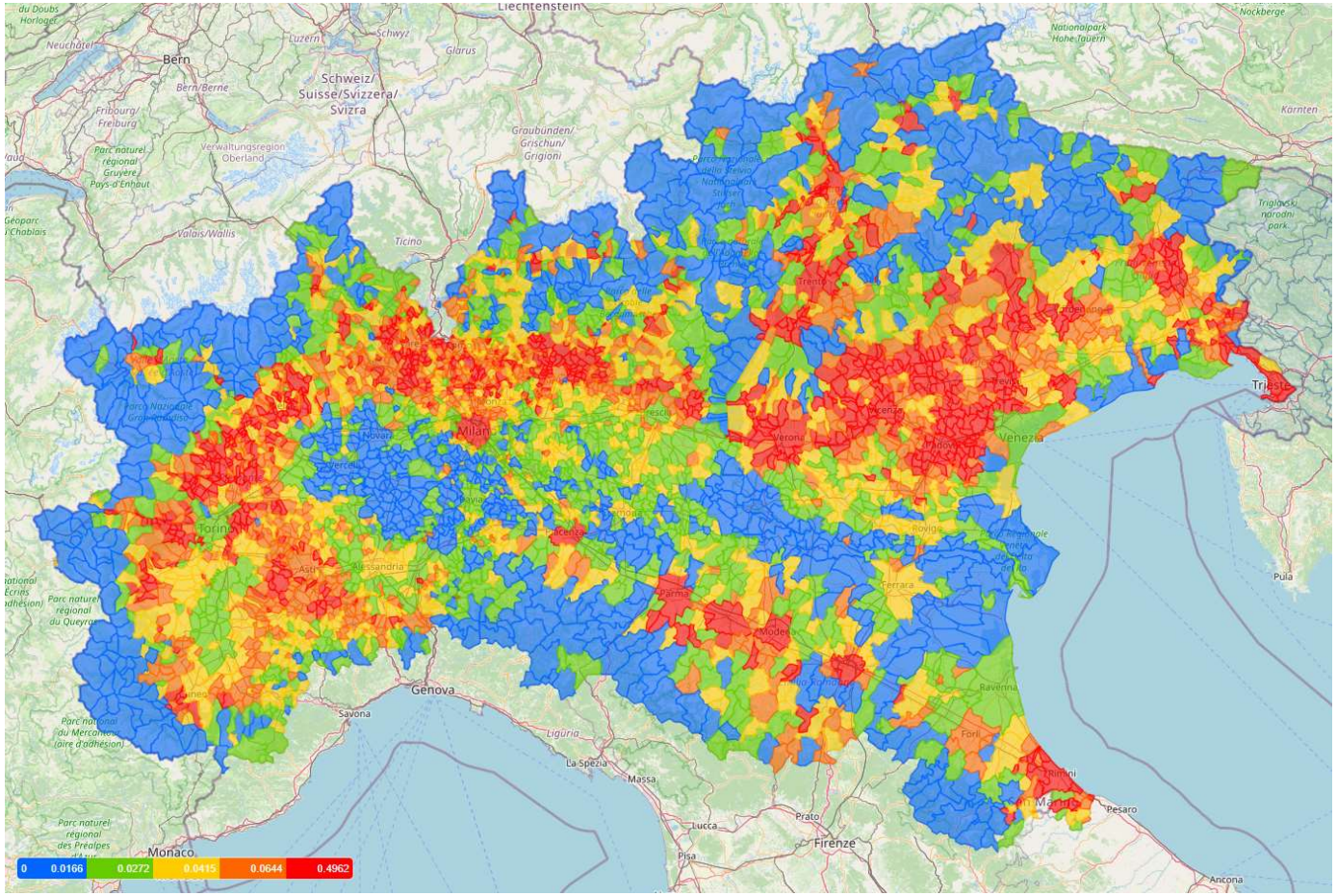


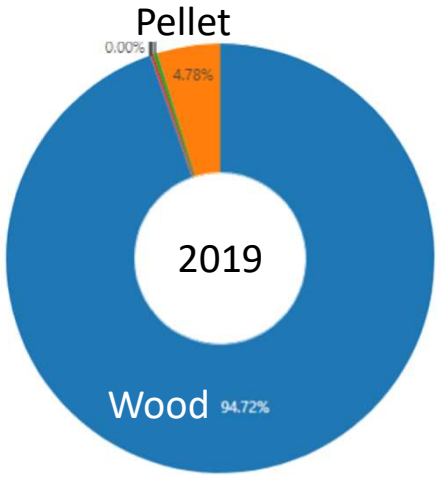






BC from residential heating in the Po-basin





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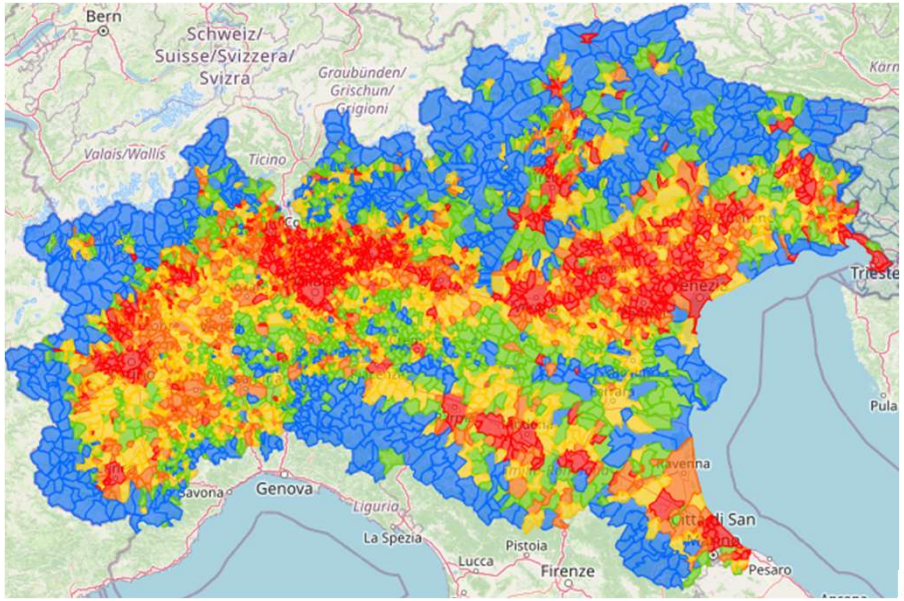
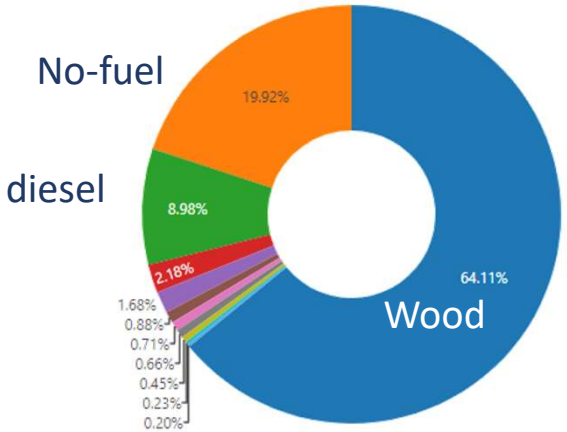
Some interesting pollutant ratio on the Po-basin



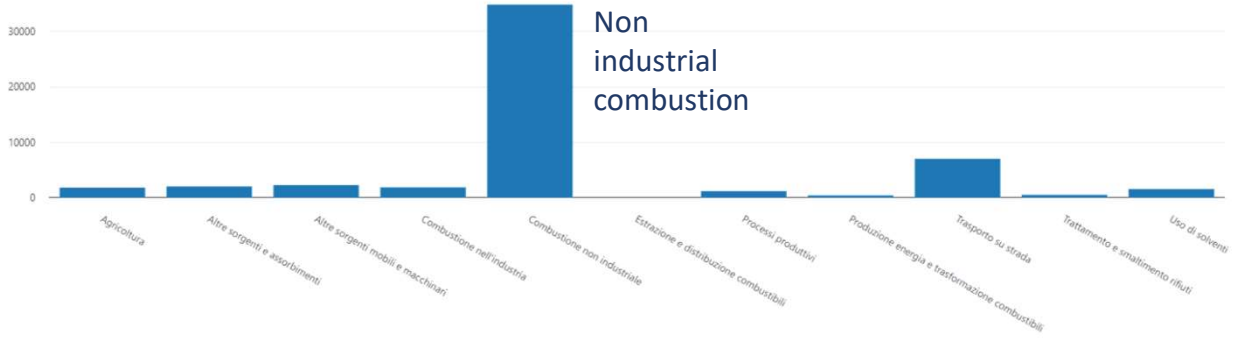


PM2.5/PM10 = 81%

BC/PM2.5 = 15%

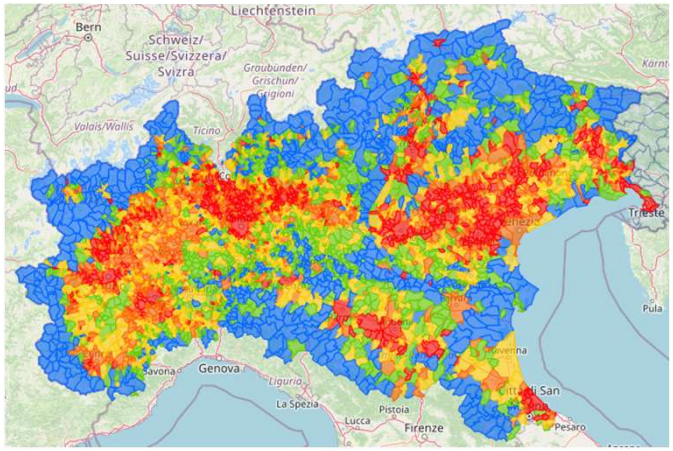
BC/PM10 = 12%

Primary emissions

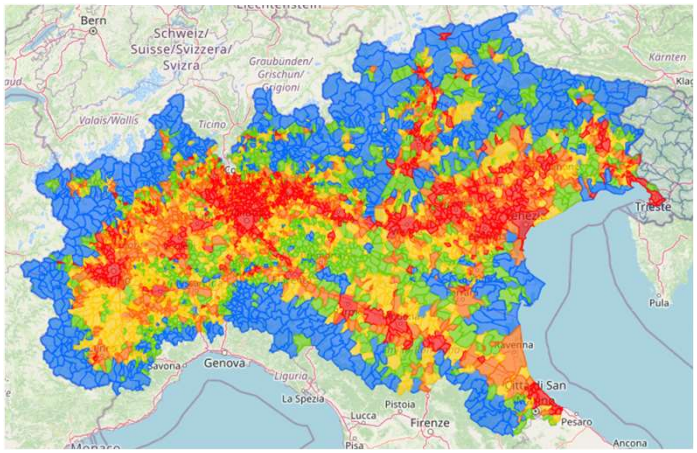


PM fractions and tracers

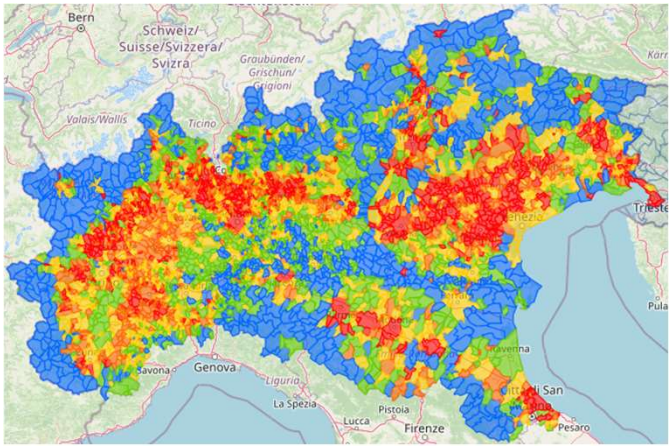
OC/PM10 = 37%



EC/PM10 = 12%



LG/OC = 8.6% **LG/PM10 = 3%**



Conclusions

- Biomass residential heating is a key source of BC in EU, Italy and Po-basin
- Common goal in emission estimates from biomass residential heating is the definition of more details on possible emission stages
- EFs of PM in this work are based on Italian emission stages and shows good comparability with similar studies for technologies at emission stages 2-3. In the comparison, more ambitious are the Italian emission stages 4-5.
- Highest detail in burning appliances need to be comparable to the main classification in EEA EMEP Guidebook
- BC is obtained by the ratio of BC and PM2.5 from the EEA EMEP Guidebook
- The **composite map of BC (Ensemble of local emission inventories) shows a good comparability with EMEP grid**, without relevant gaps and discontinuities and confirm the common technical base between different regions and top-down national inventory; due to the use of same methodological reference (the EEA-EMEP Guidebook) and, in many cases, the same emission modelling system (INEMAR database).

Points of inquiry

- Necessity to extend the details and information on BC/PM2.5 considering other possible technologies for domestic biomass burning.
- There’s a common tendency to use ratio of the measured EC, OC, TC and LG to determine emission sources. How emission inventories are suitable to support these indicators? Are there optimal space and time resolutions?
- LG is commonly accepted as a biomass burning marker. How put into relation LG time series emission with PM levels?
- The time varying LG and emission ratios with other fractions and pollutants can be used for evaluating technology turnover?