FINAL CONFERENCE

18/06/2026

cityTRAQ

Medegefinancierd door de Europese Unie

Programme: Morning session – Part 2

Scaling Knowledge into Action: Zagreb as a Replication City in LIFE CityTRAQ

RI URBANS: reshape the way air quality is measured

Panel discussion

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Final Conference LIFE CityTRAQ

SCALING KNOWLEDGE INTO ACTION: ZAGREB AS A REPLICATION CITY IN LIFE CITYTRAQ

Darijo Brzoja

Brussels – 18/06/2026

Co-funded by the European Union

Zagreb – Croatian Capital

- **767 000 residents** (city population)
- **1.1 mil residents** (broader metropolitan area)
- High urbanization
- Strong daily commuting (urban sprawl)
- **Traffic** and **residential heating** as key sources of NO_2 and PM emissions
- Similar enough for comparison, different enough to test the approach

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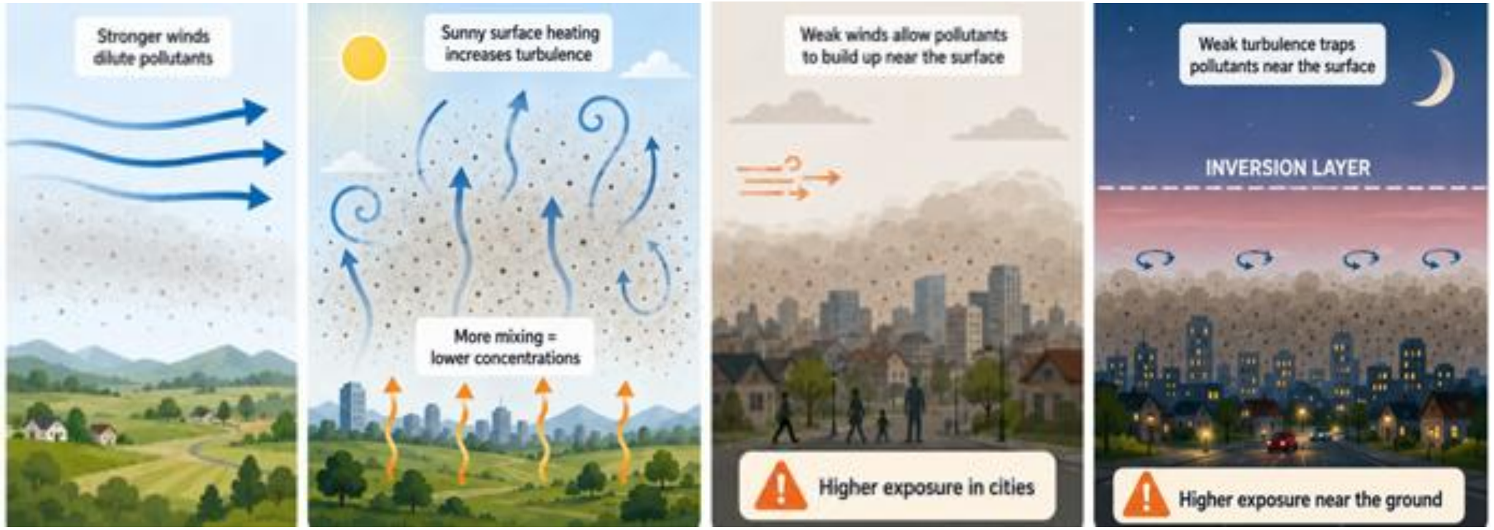
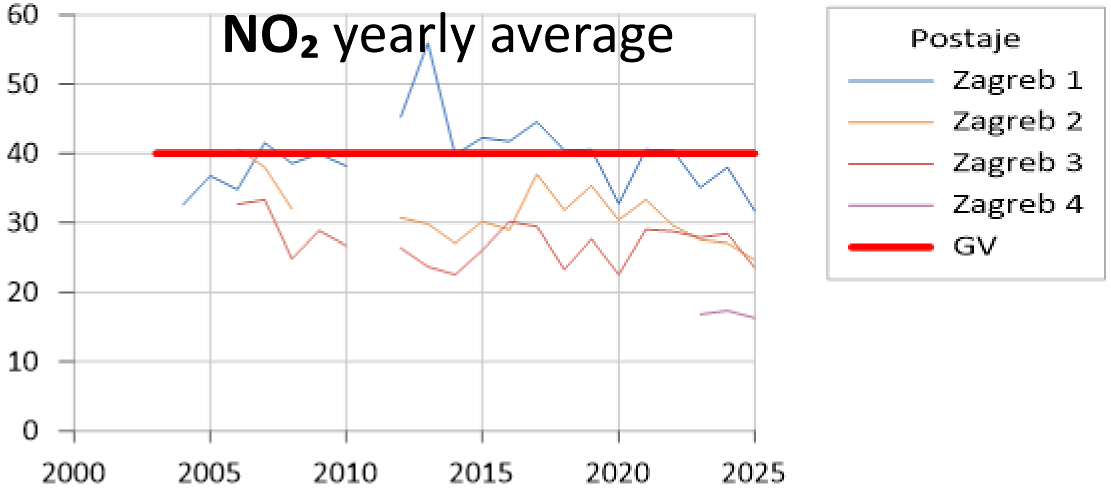
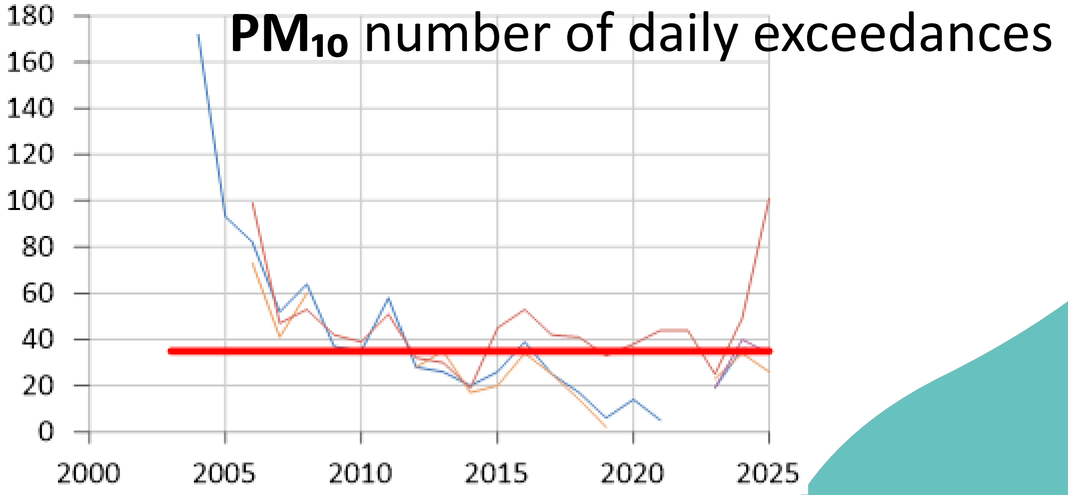
Zagreb – Air Pollution Drivers and Trends

Meteorology as a strong driver

Improvement in cleaner fuels is being **neutralized by** the **increase in vehicles**.







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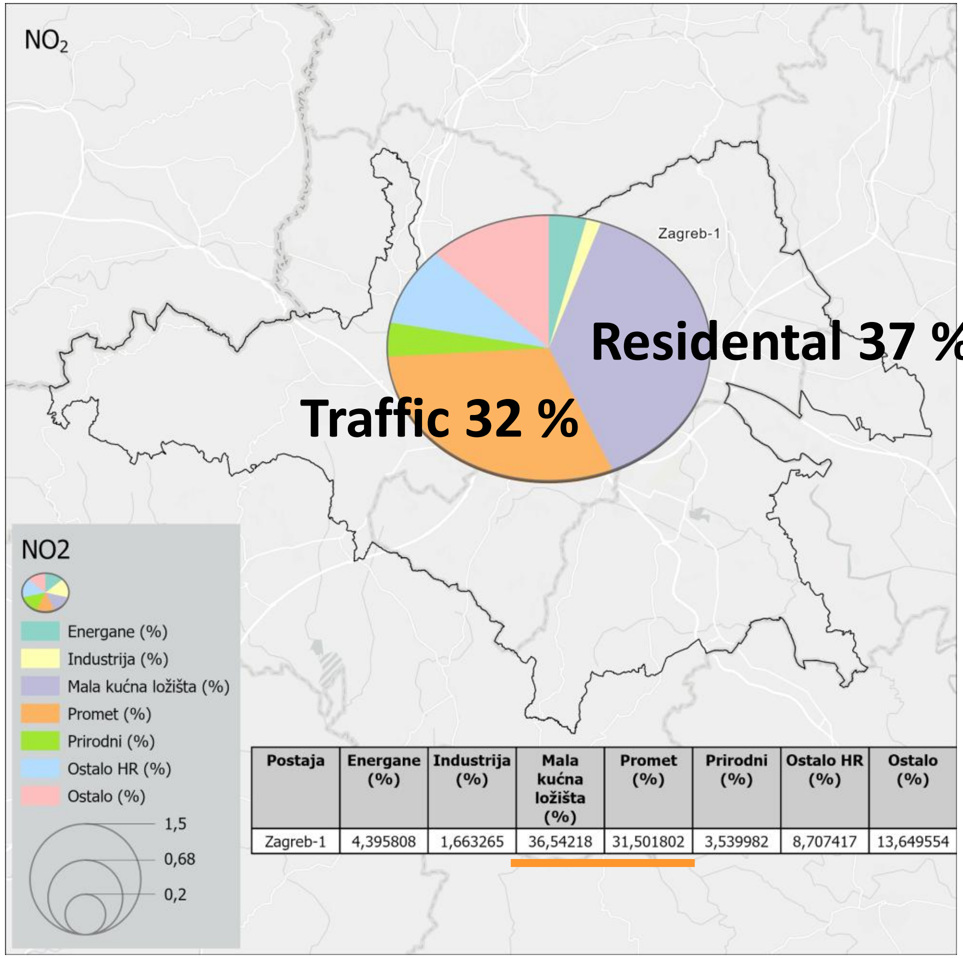
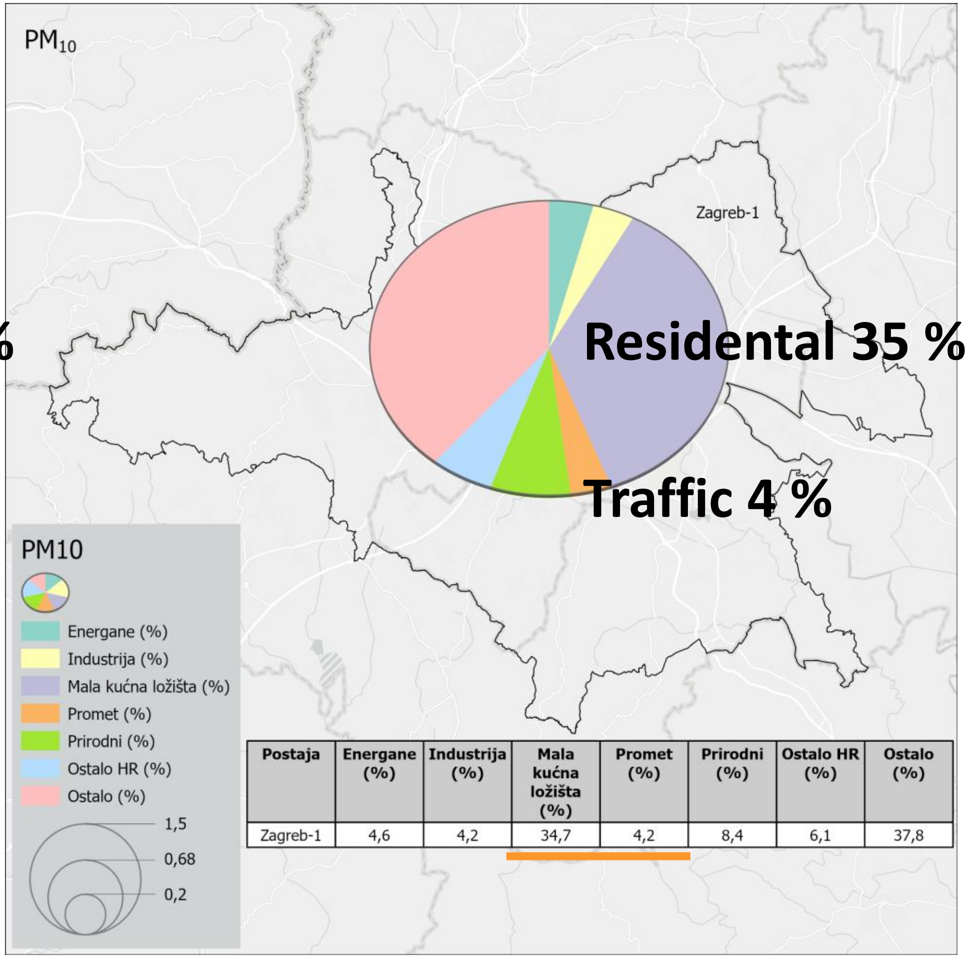
Zagreb – Air Pollution Sources



Postaja	Energane (%)	Industrija (%)	Mala kućna ložišta (%)	Promet (%)	Prirodni (%)	Ostalo HR (%)	Ostalo (%)
Zagreb-1	4,395808	1,663265	36,54218	31,501802	3,539982	8,707417	13,649554



Postaja	Energane (%)	Industrija (%)	Mala kućna ložišta (%)	Promet (%)	Prirodni (%)	Ostalo HR (%)	Ostalo (%)
Zagreb-1	4,6	4,2	34,7	4,2	8,4	6,1	37,8

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Automatic vs. Indicative Air Quality Measurements (Low-Cost AQ Sensors)

Air Quality measurement site

Smartsense aq-sensor box

Zagreb-1 traffic measurement site with additional sensors installed

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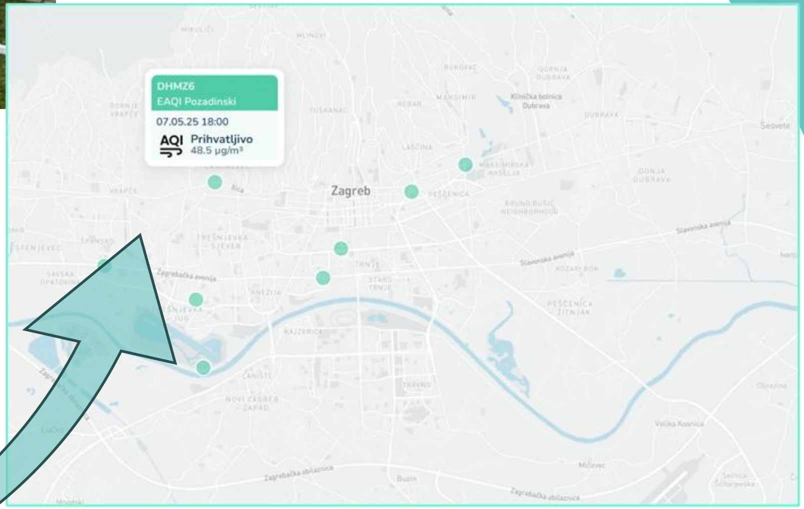
Experimental design

- **8 air quality sensors** were co-located at the **Zagreb-1** air quality urban traffic monitoring station. This setup allowed parallel measurements using both the sensor boxes and the automatic reference-grade analyzers at the station.
- **Sensor Testing Campaign** lasted through **January and February** of 2025. providing a valuable data set of air quality measurements in various meteorological conditions. Focus was on $PM_{2.5}$, NO_2, and O_3.
- **Deployment of Sensor Network** – After the testing period, sensors have been **installed at 8 near-traffic locations** to assess air pollution exposure under real-world conditions.

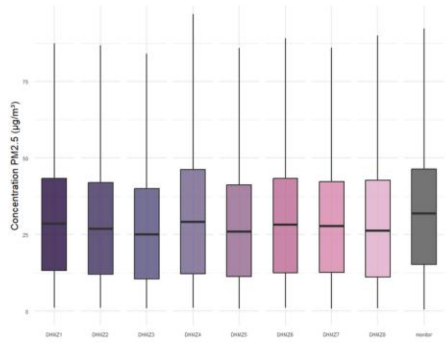
Colocation of 8 sensor boxes

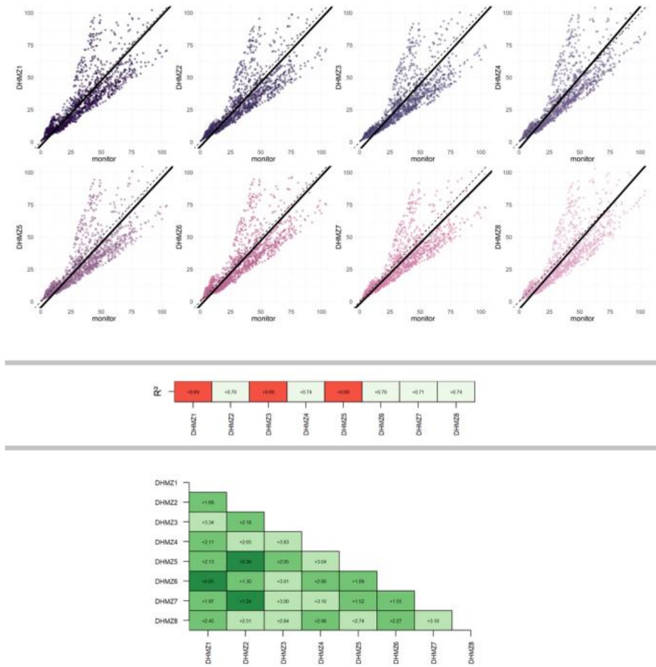


Air Quality Sensor Data Analysis

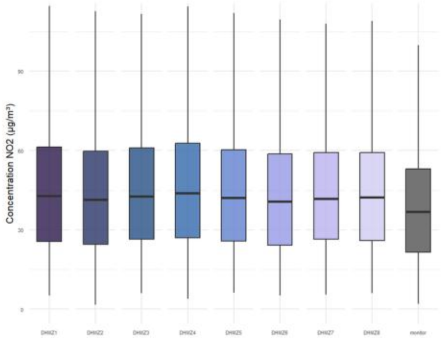
Comparison with Reference Monitor and Inter-Sensor Analysis screening

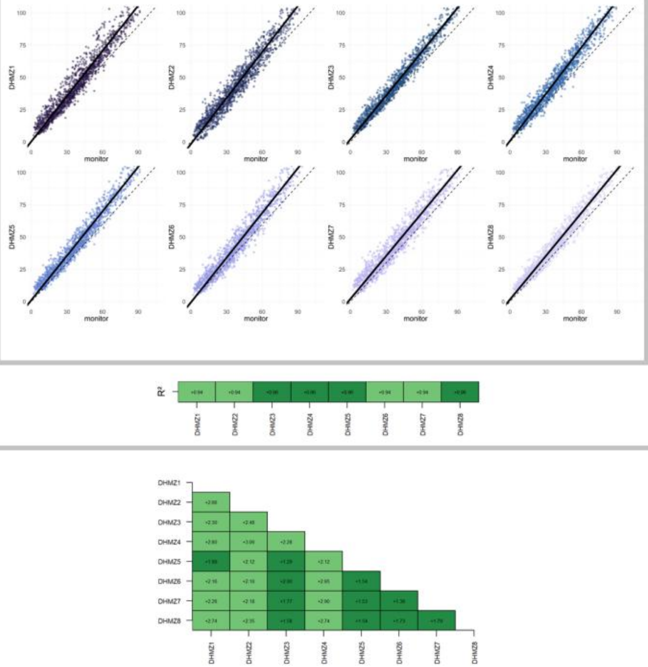
$PM_{2,5}$



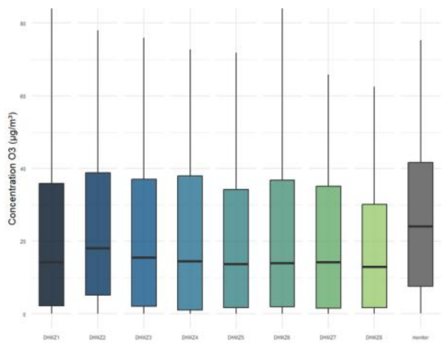


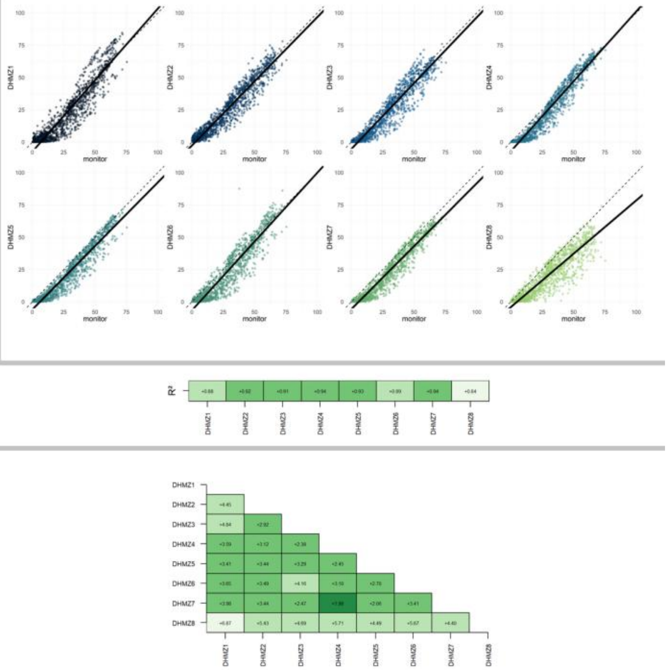
NO_2





O_3





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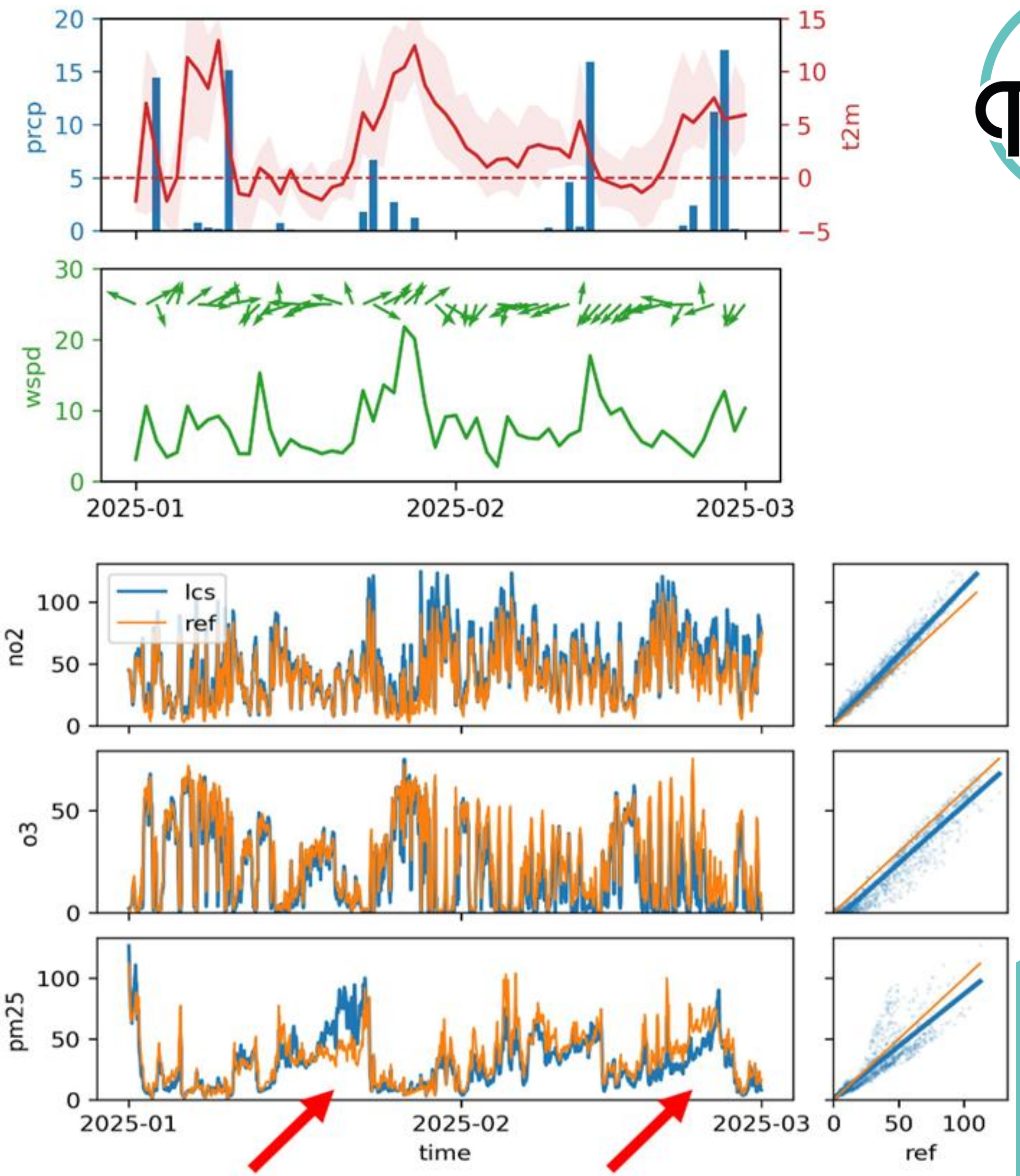
Sensor Performance in Various Weather Conditions – First screening

Focus was on $PM_{2.5}$, NO_2, and O_3.

Ongoing investigation of how **meteorological factors influence sensor accuracy** across different urban settings.

PM sensors perform much better during clear and warm weather, while the data needs an aditional calibration during cold and humid weather



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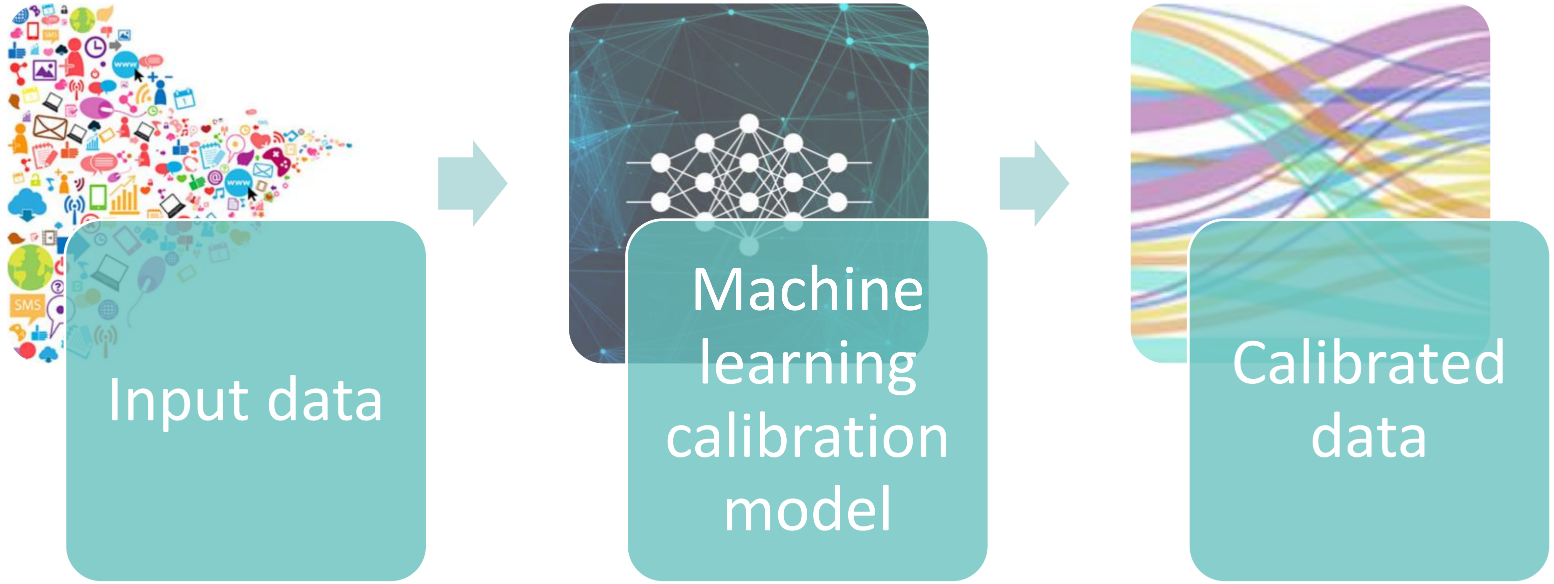
The machine learning calibration model

A machine learning model finds patterns in the data and uses them to make predictions or decisions. The more data it sees, the better it can learn and improve over time.



- Advantage: to efficiently **detect complex patterns** and make **accurate predictions** from large data
- Disadvantage: often **lack transparency** and can be **sensitive to biased or insufficient** data

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Experimental design

- XGBoost model
- Input data:
  - **ECMWF ERA 5 reanalysis** – various variables (e.g. wind, dewpoint temperature, 2 metre temperature, surface pressure, vegetation cover, dust base height, forecast albedo, geopotential, total column ozone, total column water, total column vertically-integrated water vapour, cloud cover, total column cloud liquid water, total column rain water, total precipitation, surface net short-wave (solar) radiation, time-integrated surface sensible heat net flux, surface latent heat flux, long-wave (thermal) radiation, evaporation, surface runoff, snowfall, time-mean surface downward long-wave radiation flux')
  - All the **reference monitoring data** (PM, NO_2, O_3, meteorological data)
  - All the **sensor data** (PM, NO_2, O_3, noise levels)
  - **Traffic proxy**, Julian day, etc.
- The model was **trained on 80%** of the time period, with the remaining **20% used for validation**.

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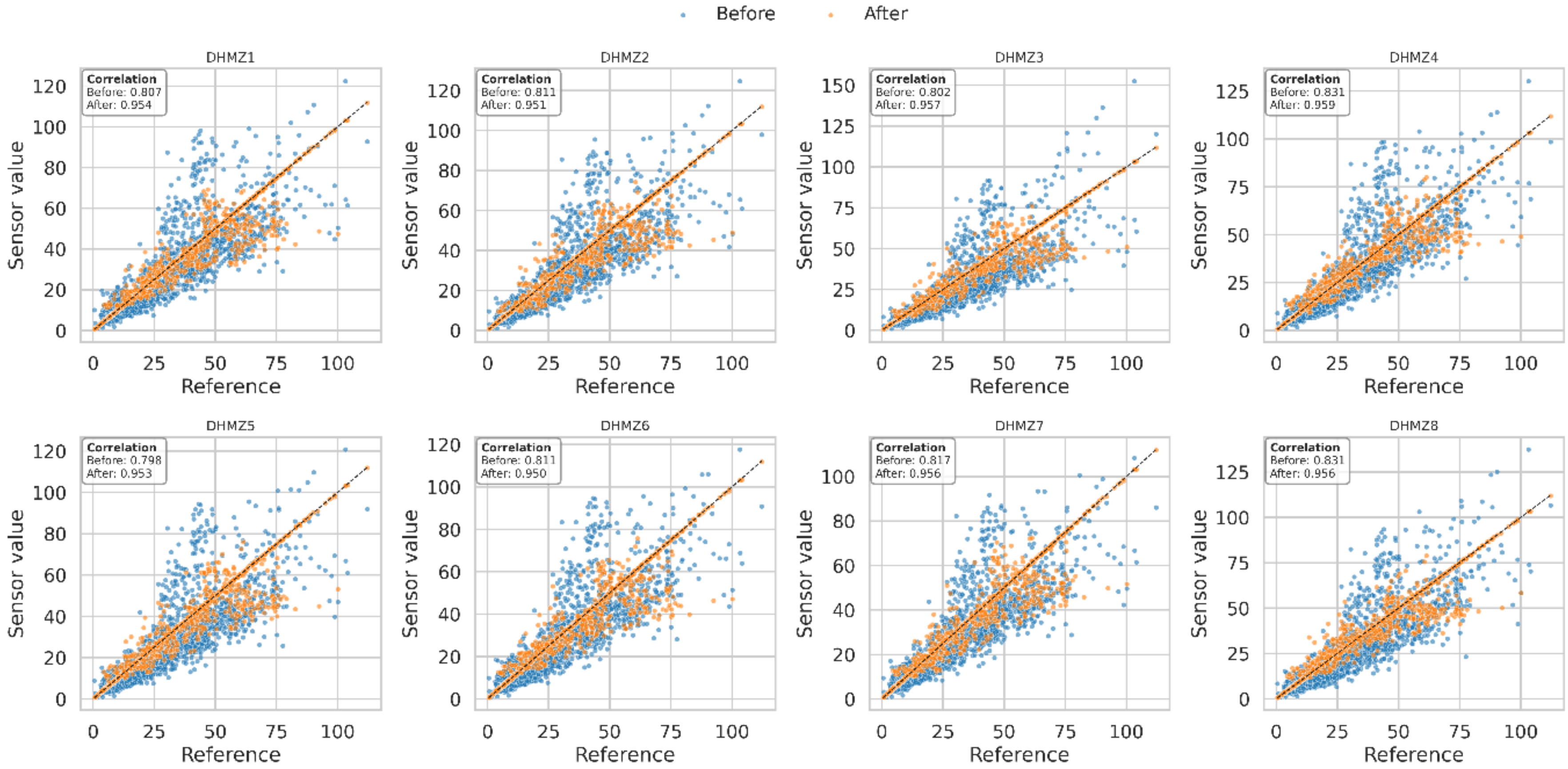
Results – PM$_{2.5}$



Metrics	Value range
R2	0,59 – 0,67
RMSE	10,8 – 12,0
MAE	7,8 – 8,9
Corr_before	0,80 – 0,83
Corr_after	0,95 – 0,96

Improvement in correlation, but the absolute value remains a challenge.

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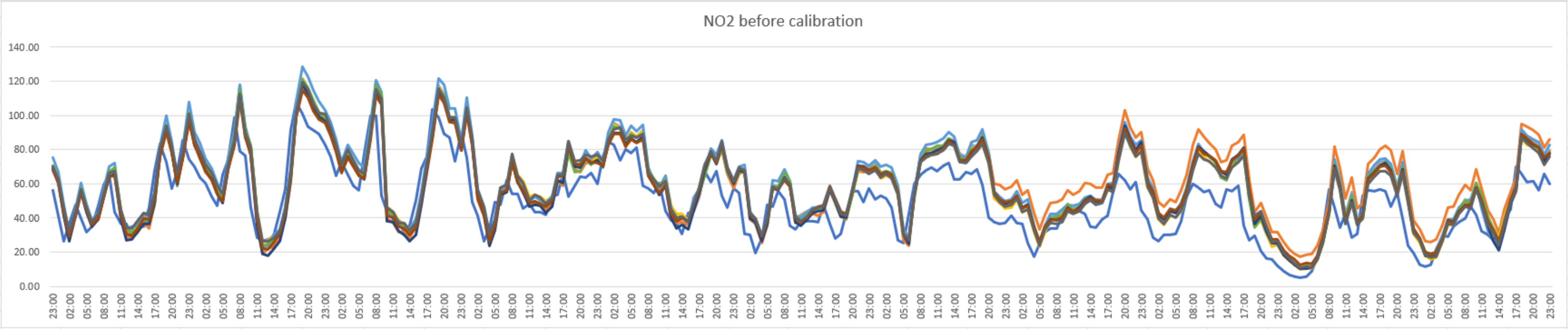
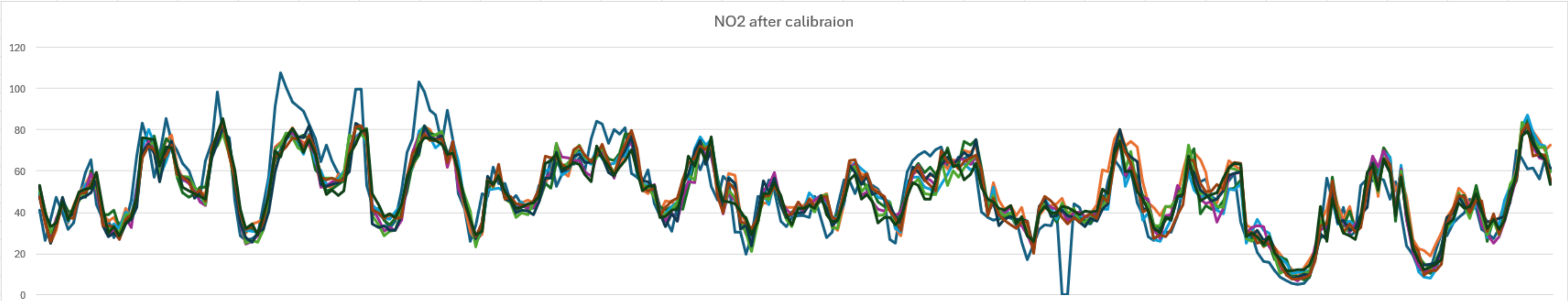
Results – before and after calibration





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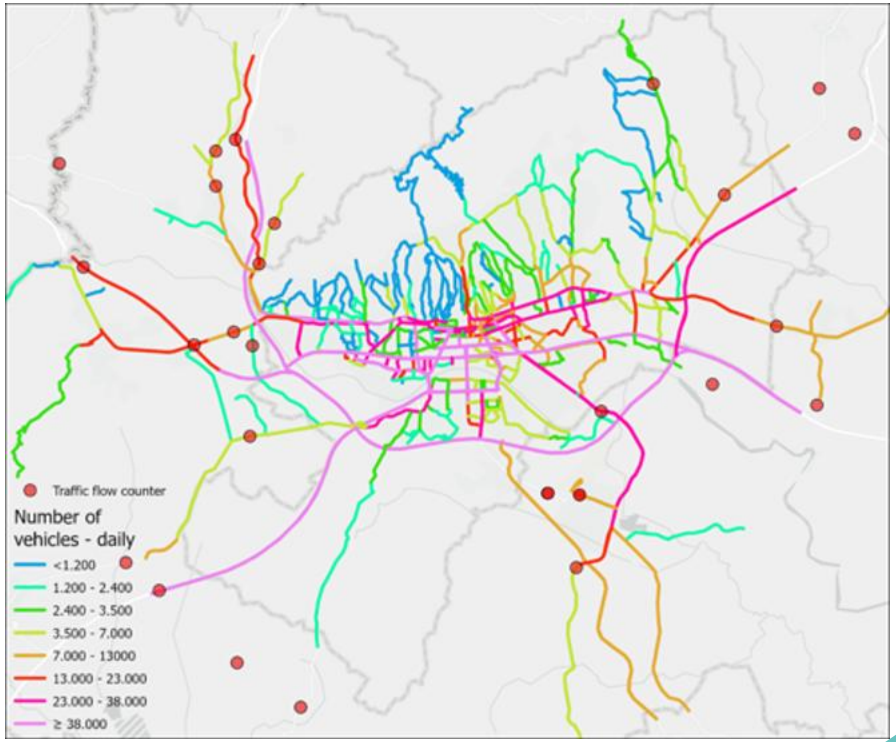
Zagreb – Traffic Emissions Pilot

- The City of Zagreb doesn't have an **official traffic model**
- **200 cameras** are continuously monitoring traffic, but the vehicle count data is **not accessible** to the air quality professionals
- For this pilot, the **Faculty of Mechanical Engineering and Naval Architecture** adjusted the **SUMO** (Simulation of Urban Mobility) model for Zagreb



Three traffic scenarios were produced:

1. Base case
2. Low Emission Zone
3. Planned roads (data from the official city plan)

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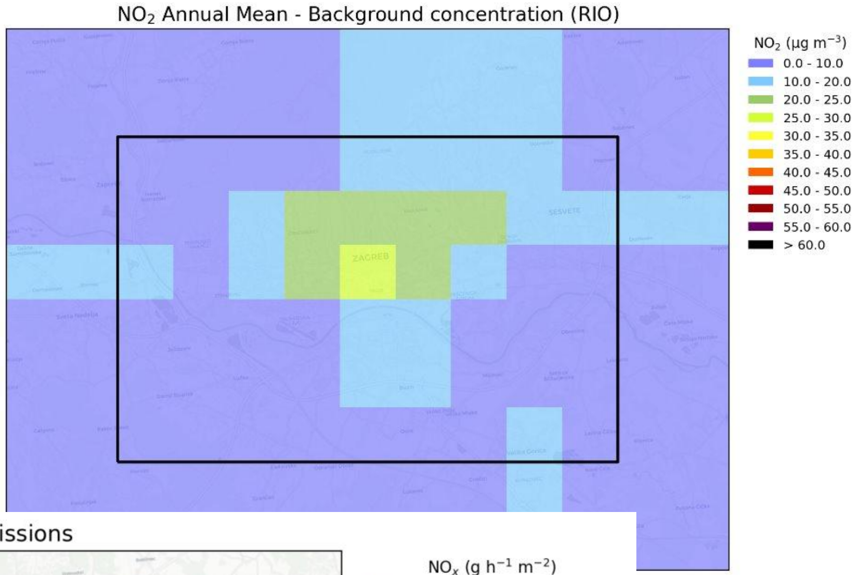
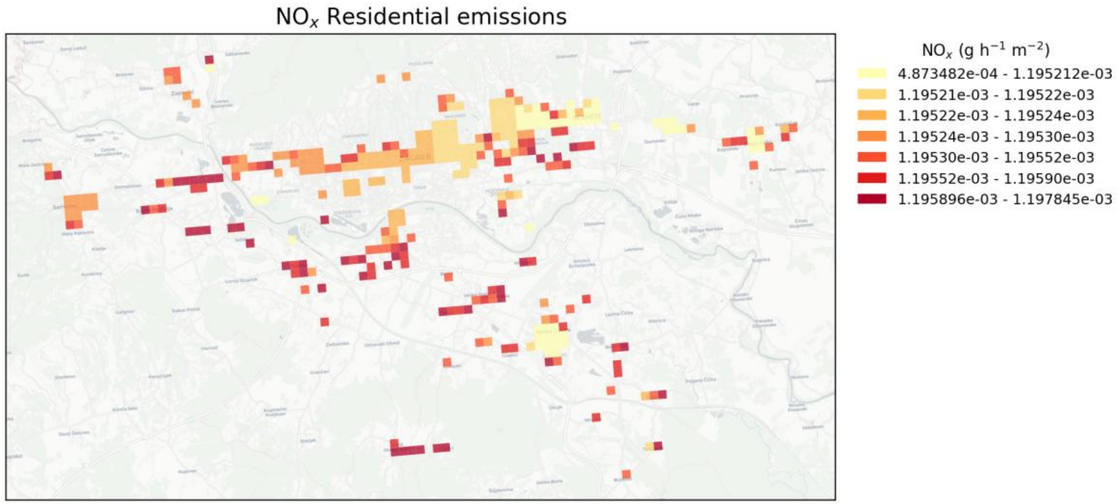
Zagreb – Scenario Modelling

- For this pilot, VITO did the modelling to make sure the methodology is aligned with the Scenario tool developed within the CityTRAQ
- Input data:
  - Background – RIO model
  - Residential gridded emissions
  - Traffic Emissions (Uni Zagreb & FASTRACE)
  - ALADIN meteorology
  - Building heights





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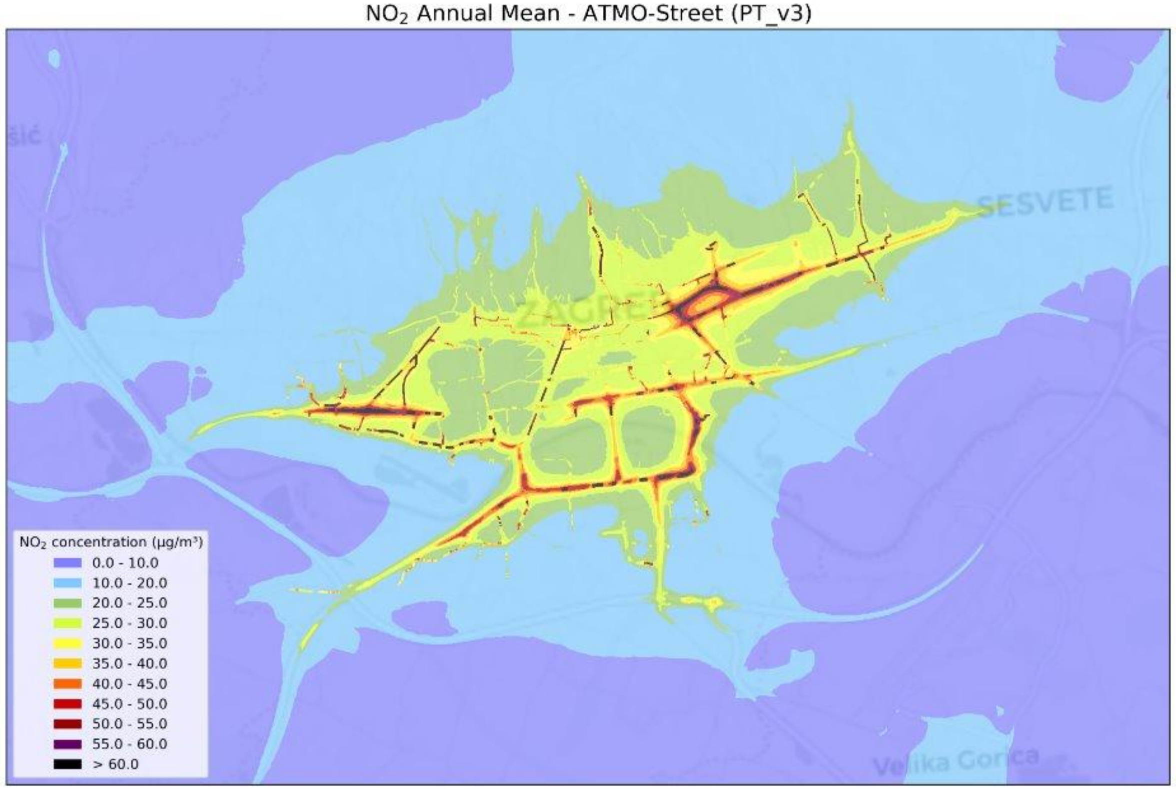
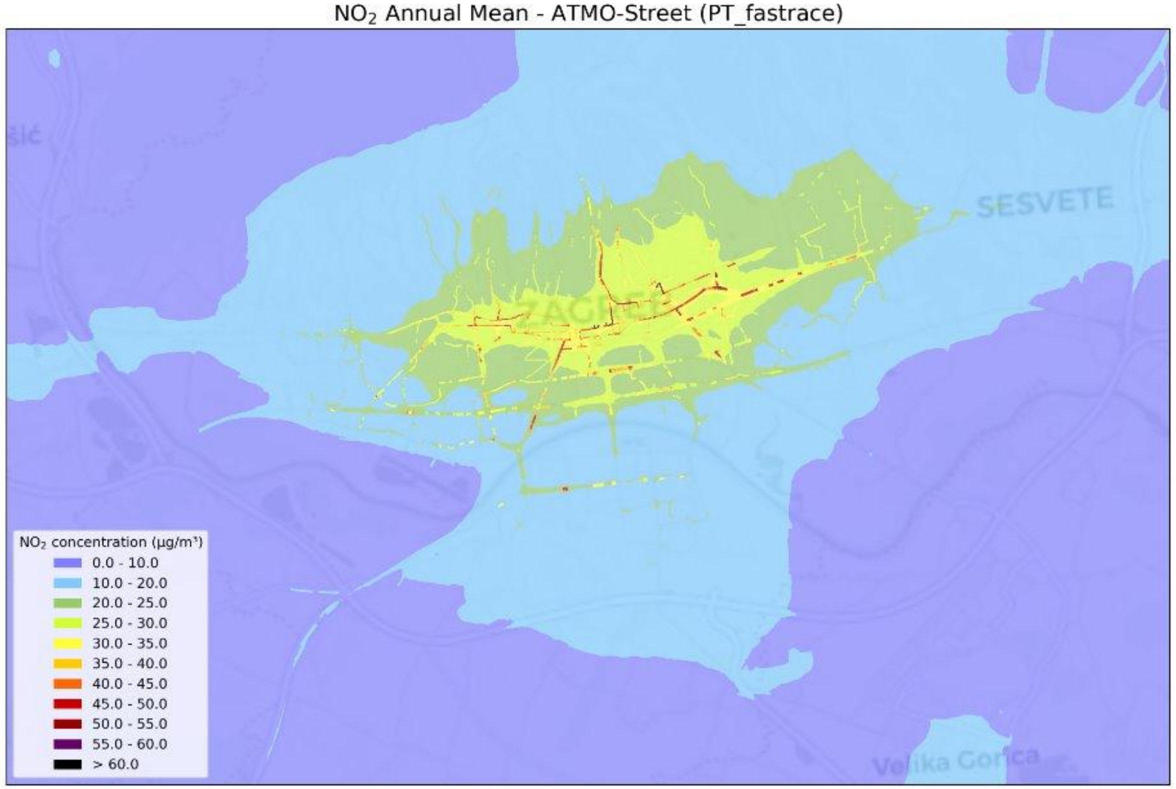
Zagreb – Scenario Modelling

Base case – SUMO



Base case - FASTRACE



SUMO overestimates traffic emissions – needs more calibration

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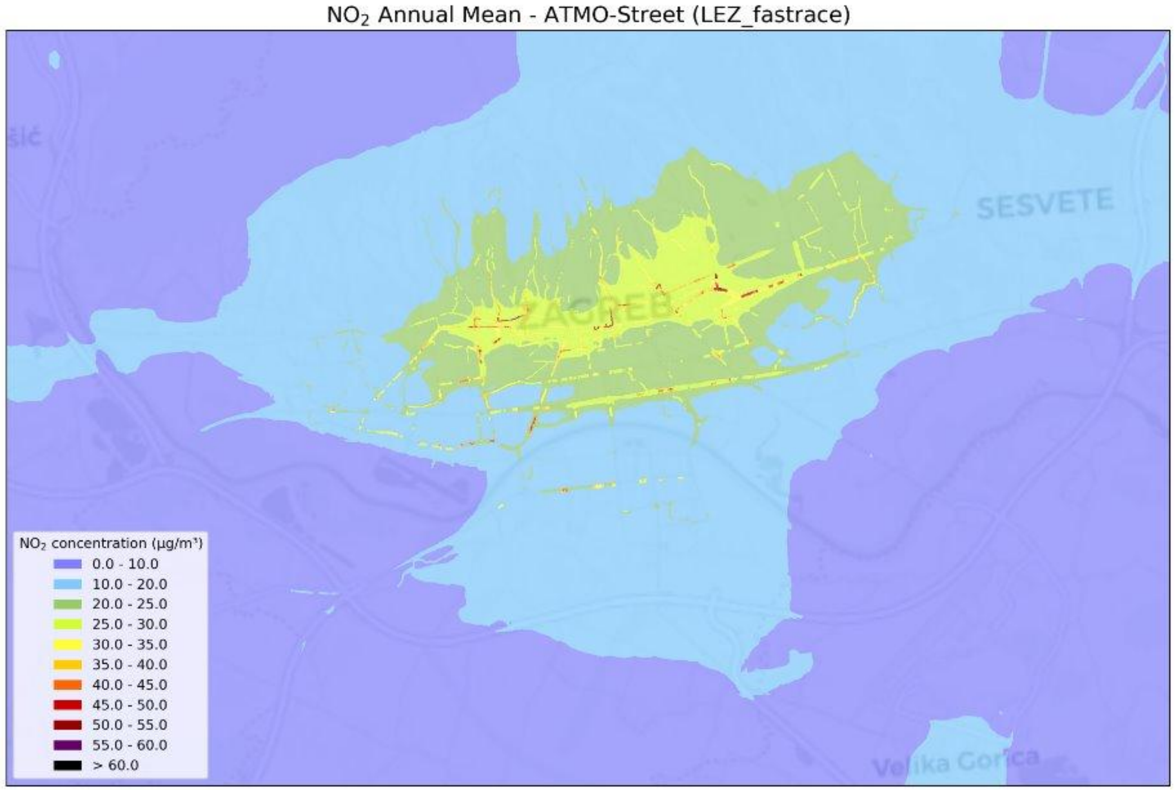
Zagreb – Scenario Modelling

LEZ – SUMO

LEZ - FASTRACE



Improving air quality – needs to take into account behavioral changes

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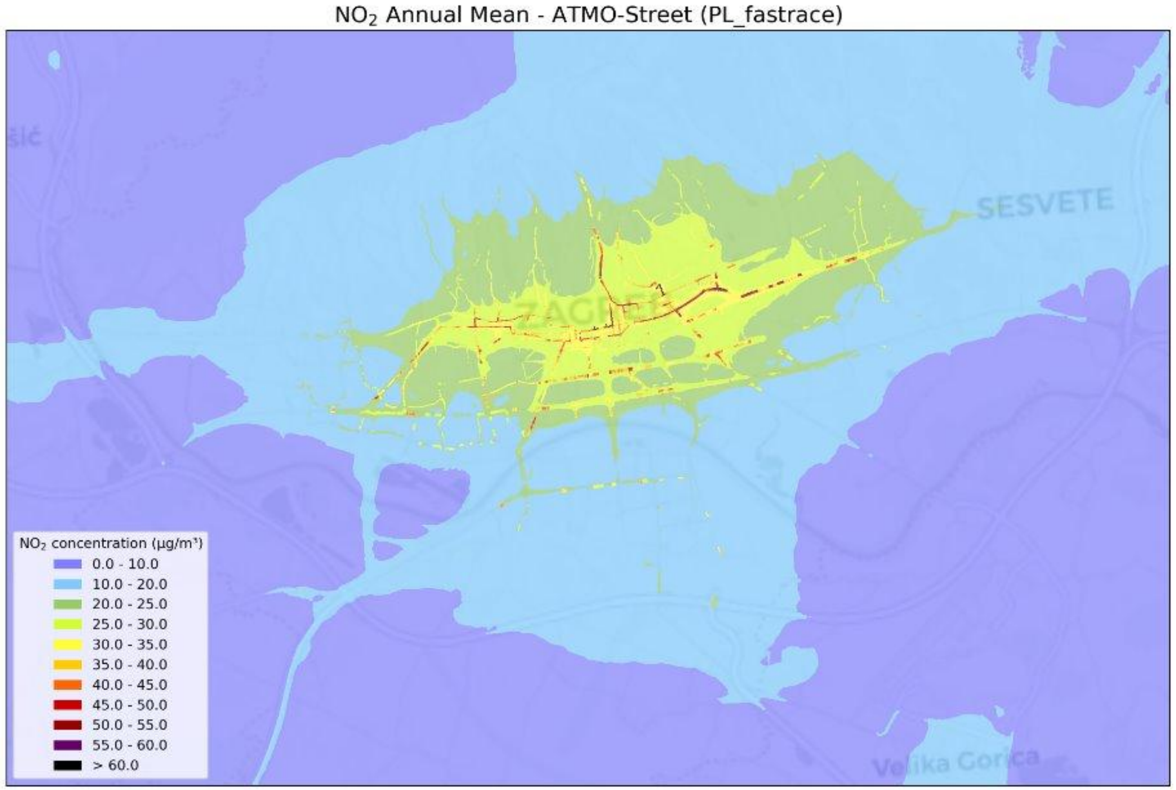
Zagreb – Scenario Modelling

Planned roads – SUMO

Planned roads - FASTRACE



The problem of too many cars can not be solved with new roads.

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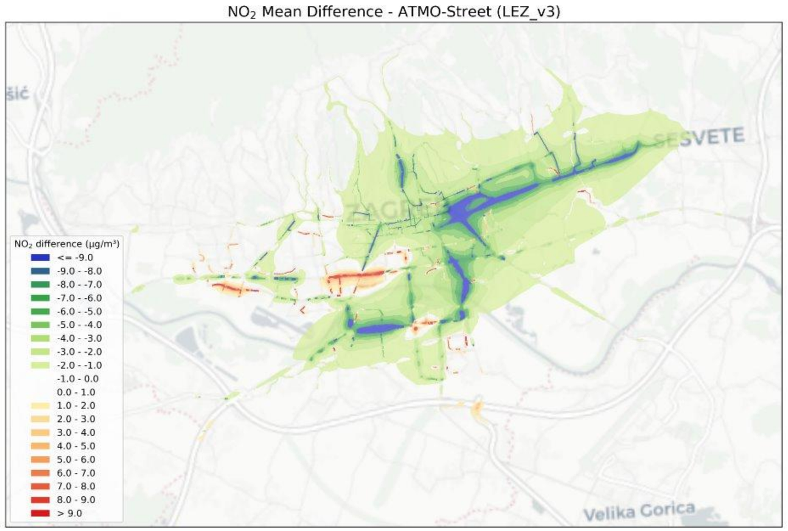
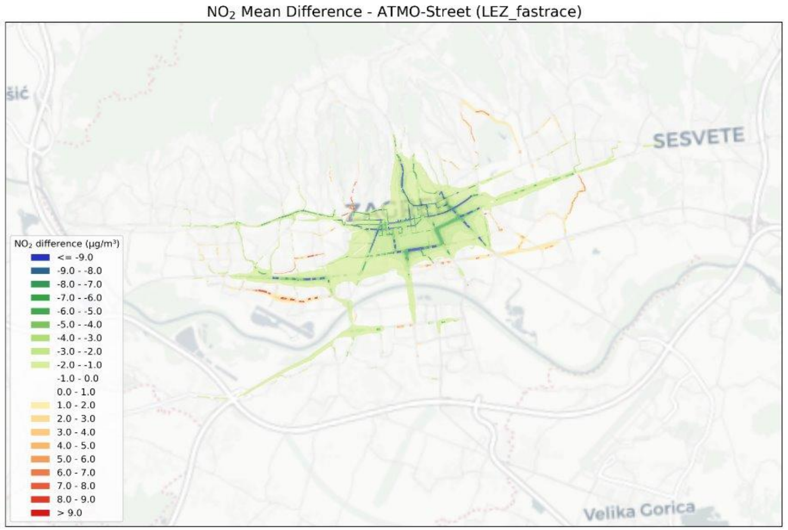
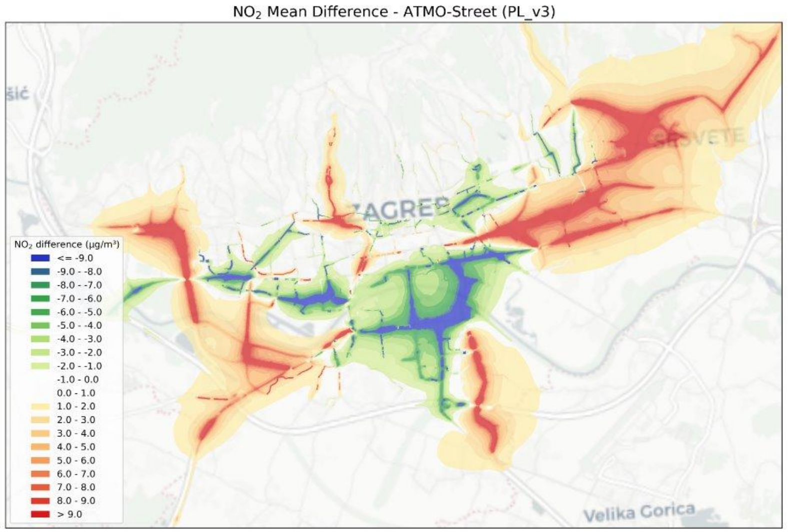
Zagreb – Scenario Modelling

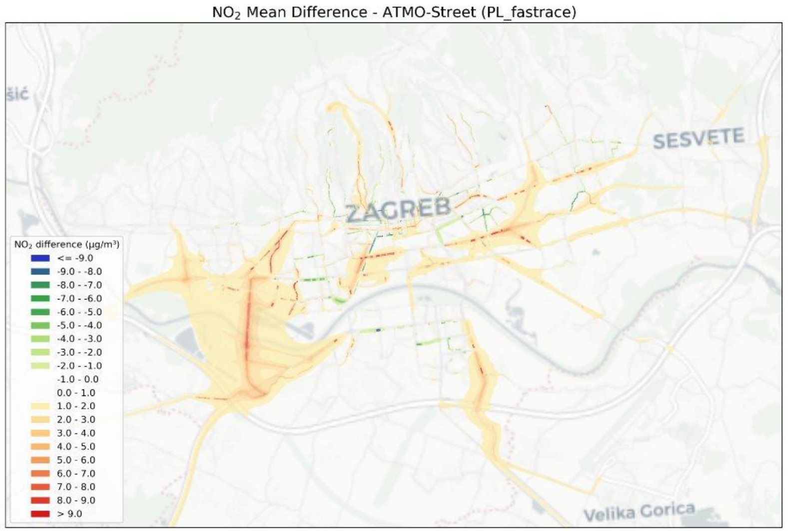
LEZ difference





Planned roads difference





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Conclusions

- Compliance data must always rely on official methods, but validated low-cost sensors can be combined with official networks to improve spatial granularity and public engagement.
- The European Environment Agency (EEA) and the Joint Research Centre (JRC) promote the development of calibration protocols and encourage their integration with official monitoring networks in a complementary way.
- A proper machine learning model can significantly improve the correlation between sensor data and the reference automatic measurement; nevertheless, absolute value correction remains a challenge.
- Informed decision-making depends on reliable data. Calibration of traffic models with real-time vehicle count data is crucial for successful air quality modelling.
- Processes developed within this pilot and lessons learned make a strong foundation for the After-LIFE period, where we will implement tools developed within CityTRAQ across Croatia.

Thank you for your attention.

Questions?

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RI-URBANS

Reshape the way Air Quality is measured

Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (RI-URBANS)

(Project n. 101036245)

project coordinators: Xavier Querol (CSIC) & Tuukka Petäjä (UHEL)

Martine Van Poppel - VITO

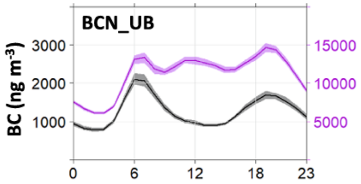
14 countries, 26 beneficiaries, 1 associated beneficiary, starting with 11 cities, 19 associated collaborators
October 2021 – September 2025
Horizon 2020

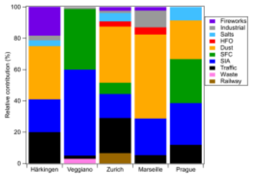
RI-URBANS (101036245)

General AIM

- Improve tools for better AQ assessment and management in EU cities
- Focus on human exposure to outdoor nanoparticles and Particulate Matter (PM), their constituents, sources and precursors

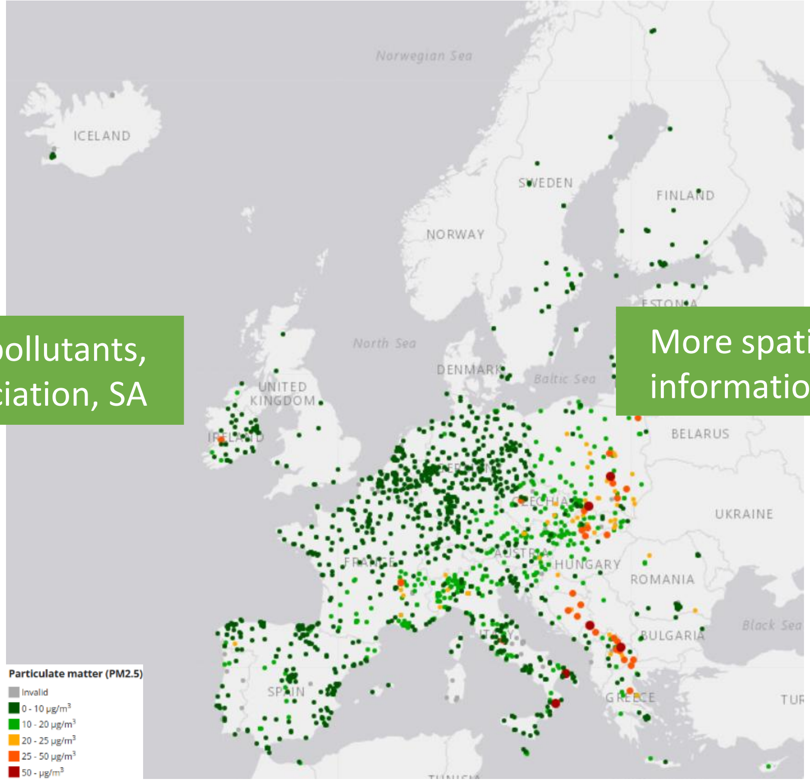
AQ measurements in Europe



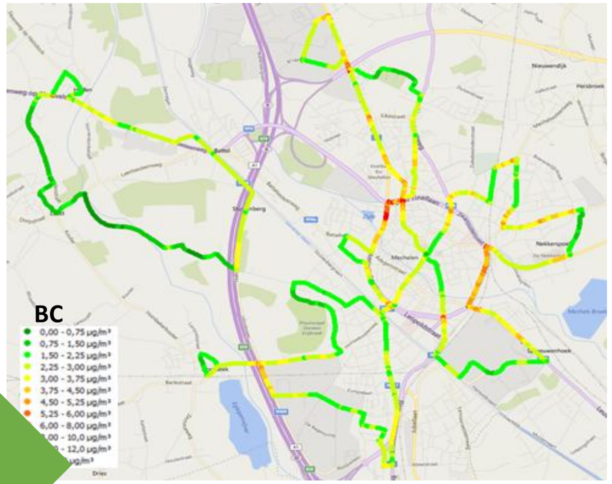


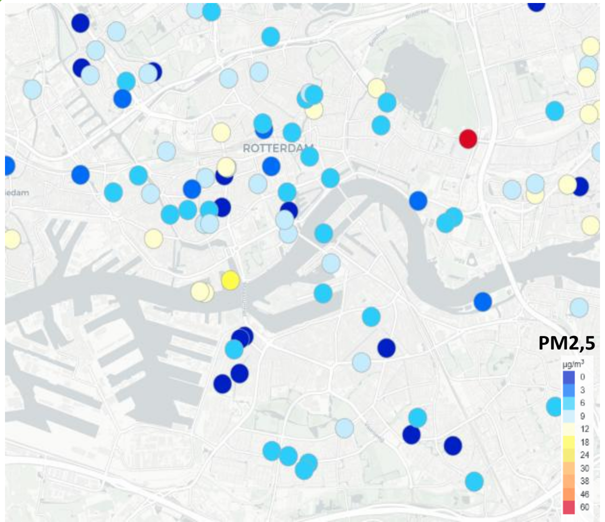
Novel AQ pollutants, speciation, SA

EUROPE



More spatial information





New AQD (2024/2881):
requires/recommends measurements
of UFP (PNC, PSD), NH_3, BC, OP …
at urban background and/or rural supersites

European Commission | HORIZON 2020

vito RI URBANS

Revised Air Quality Directive (2024/2881)

Table 1 – Pollutants to be measured at monitoring supersites at urban background locations

Pollutant	Type of measurement
PM_{10}, $PM_{2,5}$, UFP, BC	Fixed measurements
NO_2, O_3	Fixed measurements
SO_2, CO	Fixed or indicative measurements
Size distribution of UFP	Fixed or indicative measurements
Benzo(a)pyrene, other polycyclic aromatic hydrocarbons (PAH) as relevant (1)	Fixed or indicative measurements
Total deposition (2) of benzo(a)pyrene, and other polycyclic aromatic hydrocarbons (PAH) as relevant	Fixed or indicative measurements
Arsenic, cadmium, lead and nickel	Fixed or indicative measurements
Total deposition (2) of arsenic, cadmium, lead, nickel and mercury	Fixed or indicative measurements
Benzene	Fixed or indicative measurements
Chemical composition of $PM_{2,5}$ in accordance with Section 2	Fixed or indicative measurements

Table 2 – Pollutants to be measured at monitoring supersites at rural background locations

Pollutant	Type of measurement
PM_{10}, $PM_{2,5}$, UFP, BC	Fixed measurements
NO_2, O_3 and ammonia	Fixed measurements
SO_2, CO	Fixed or indicative measurements
Total deposition of benzo(a)pyrene and other polycyclic aromatic hydrocarbons (PAH) as relevant	Fixed or indicative measurements
Total deposition of arsenic, cadmium, lead, nickel and mercury	Fixed or indicative measurements
Benzo(a)pyrene, other polycyclic aromatic hydrocarbons (PAH) as relevant (1)	Fixed or indicative measurements
Arsenic, cadmium, lead and nickel	Fixed or indicative measurements
Chemical composition of $PM_{2,5}$ in accordance with Section 2	Fixed or indicative measurements
Total gaseous mercury	Fixed or indicative measurements

Table 3 – Pollutants recommended to be measured at monitoring supersites at urban background locations and rural background locations if not covered by the requirements of Tables 1 and 2

Pollutant	Type of measurement
Size distribution of UFP	Fixed or indicative measurements
Particulate matter oxidative potential	Fixed or indicative measurements
Ammonia	Fixed or indicative measurements
Levoglucosan to be measured as part of the chemical composition of $PM_{2,5}$	Fixed or indicative measurements
Total gaseous mercury	Fixed or indicative measurements
Particulate and gaseous divalent mercury	Fixed or indicative measurements
Nitric acid	Fixed or indicative measurements

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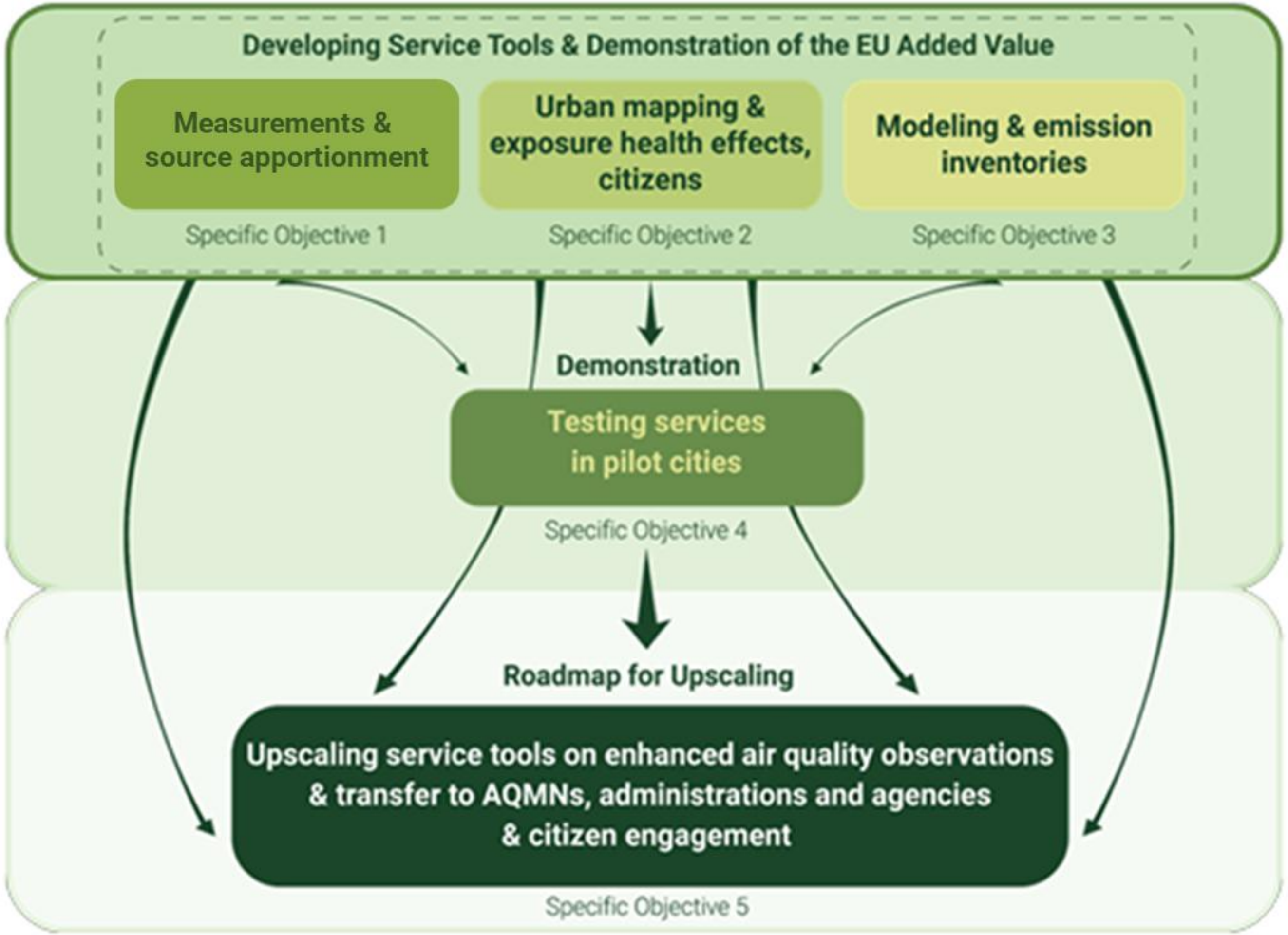
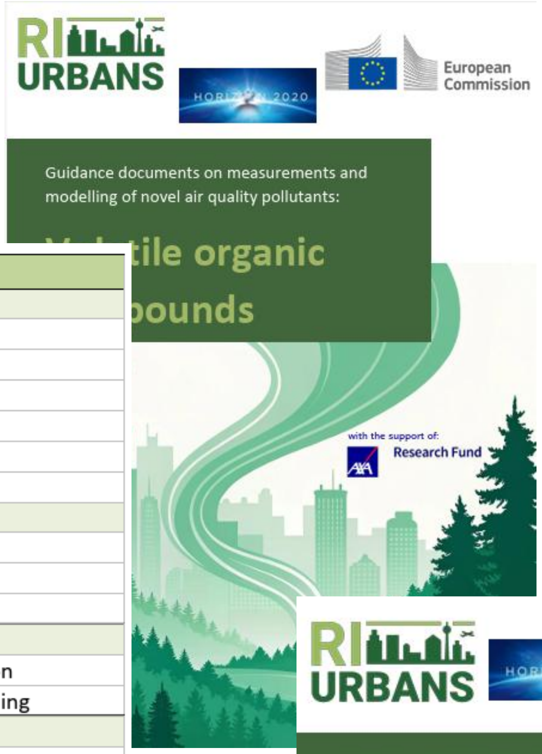
RI-URBANS concepts and Service Tools



Service Tool = any tool in the project that has been reviewed , developed , tested and recommended for advanced AQ assessment in urban areas



Number	Guidance document topic
Protocols for the measurement of novel AQ pollutants	
ST1	Ultrafine-Particle Number Size Distributions (UFP-PNSD)
ST2	Black Carbon (BC)
ST3	Offline and online particulate matter (PM) speciation
ST4	Oxidative potential of particulate matter (OP of PM)
ST5	Volatile Organic Compounds (VOCs)
ST6	Ammonia (NH_3)
Methodologies for vertical profiles of pollutants and meteorology	
ST7	Measurements of boundary level height
ST8	Measurements of vertical profiles of aerosols
ST9	Measurements of IAGOS vertical profiles by commercial aircrafts
Methodologies for source apportionment receptor modelling	
ST10	Source apportionment of PM based on offline and online PM speciation
ST11	Source apportionment of UFP, BC, OP and VOCs using receptor modelling
Methodologies for urban mapping of novel AQ pollutants	
ST12	Deterministic urban modelling of fine PM and PNC
ST13	Mapping ultrafine particles and citizen science
Methodologies for evaluating the health effects of novel AQ pollutants	
ST14	Evaluation of health effects of novel AQ parameters
Obtaining emission inventories for novel AQ pollutants	
ST15	First UFP-PNSD and non-exhaust vehicle PM EU emission
Modelling methodologies for novel AQ pollutants	
ST16	UFP-PNSD multiscale modelling

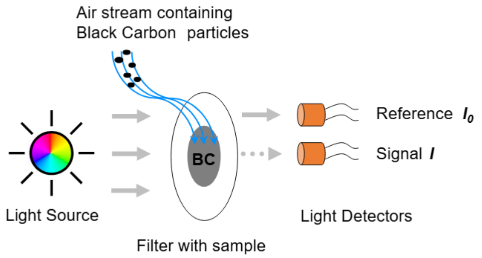
UFP

- Why?
  - Health relevance - can penetrate deeply into the respiratory system – linked to respiratory and cardiovascular diseases
  - Smaller, don't count to mass concentration
- Inconsistencies in reported health effects are partly linked to:
  - differences in measurement methods, lack of representative data (exposure), different sources contributing to UFP concentrations in different cities/regions
- Particle number concentration (PNC) and size distribution (PNSD)
- Harmonized methods for PNC and PNSD (CEN standards)
  - <10 nm; 10-800 nm
  - Sampling method: drying, tube length, dilution,…
- European overview of UFP-PNSD results – relation with other pollutants

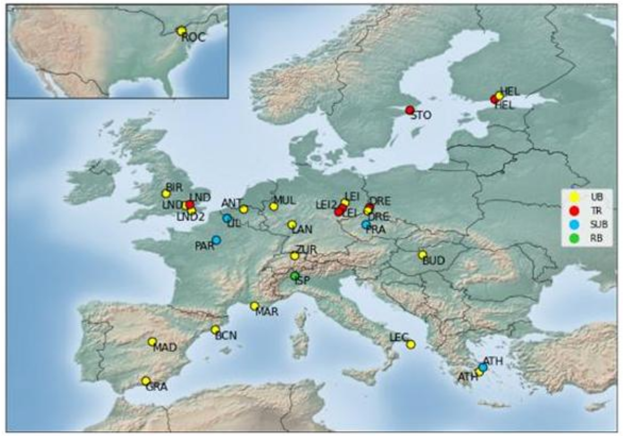
BC

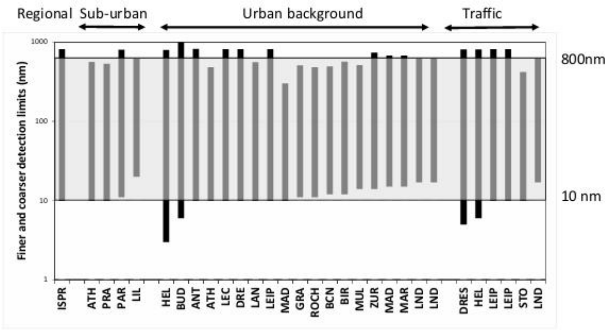
- Why?
  - Impact on AQ, health and climate
  - Combustion related PM
- Harmonized methods needed – standardization on-going
  - BC (Black Carbon) ~ EC (Elemental Carbon)
  - BC is optical method using MAC to convert attenuation to mass concentration
  - MAC can be site/season specific
- SA:
  - Multiple wavelengths: 370 - 950 nm
  - differentiation between Traffic (Liquid Fuel) and Biomass Burning (Fossil Fuel)

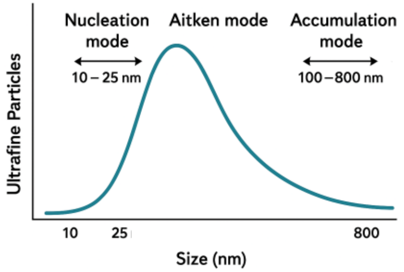
Savadkoohi M., 2024. Environment International
https://doi.org/10.1016/j.envint.2024.108553

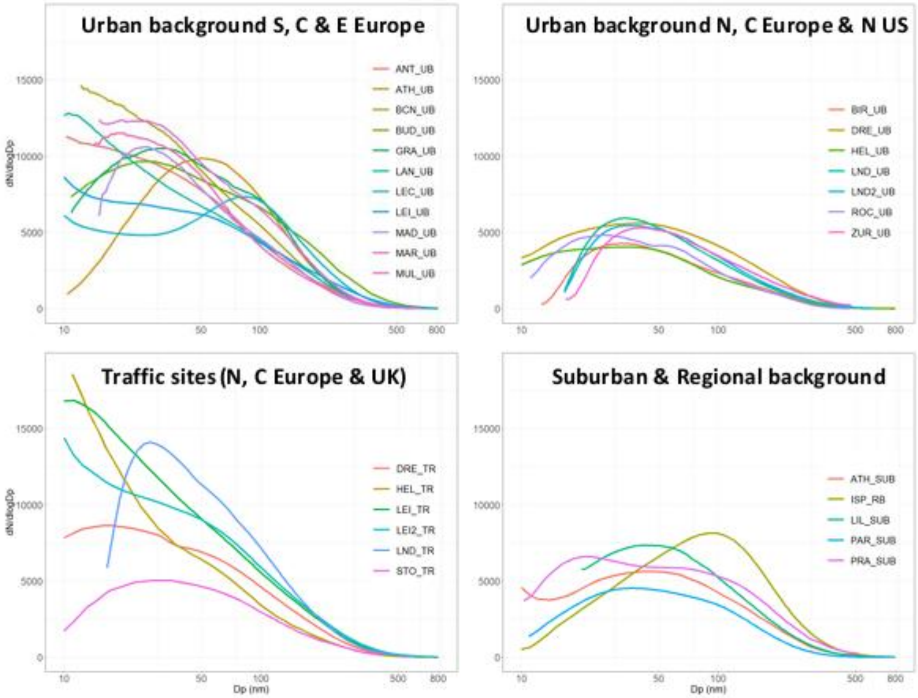


UFP - PNSD



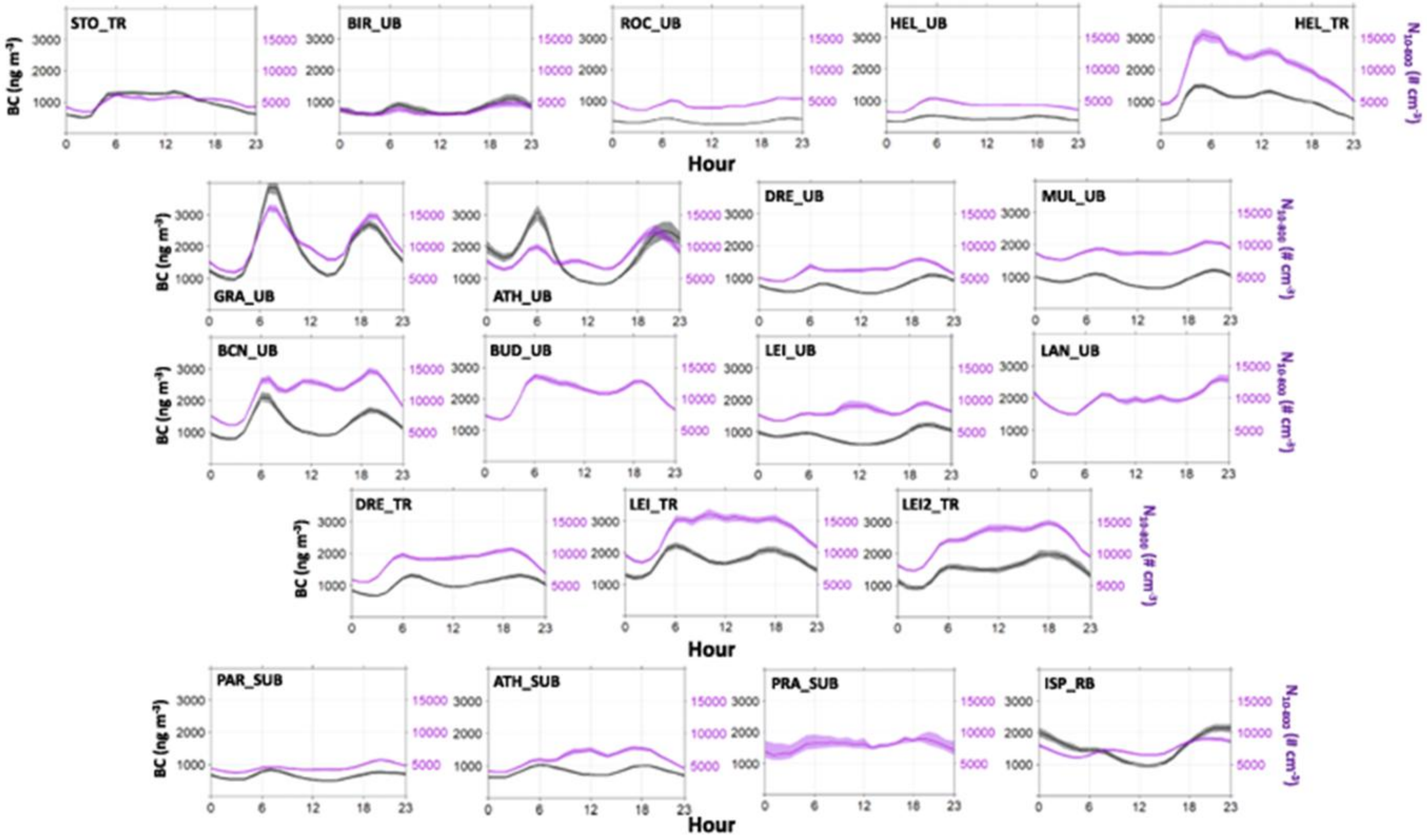






RI-URBANS (101036245)

PNC and BC



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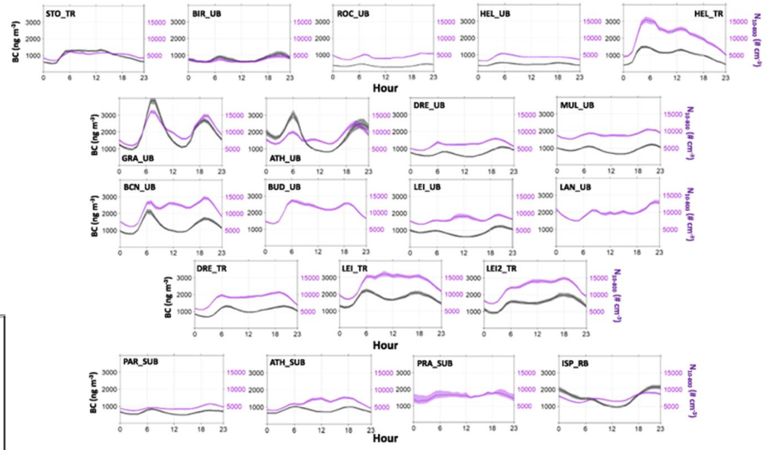
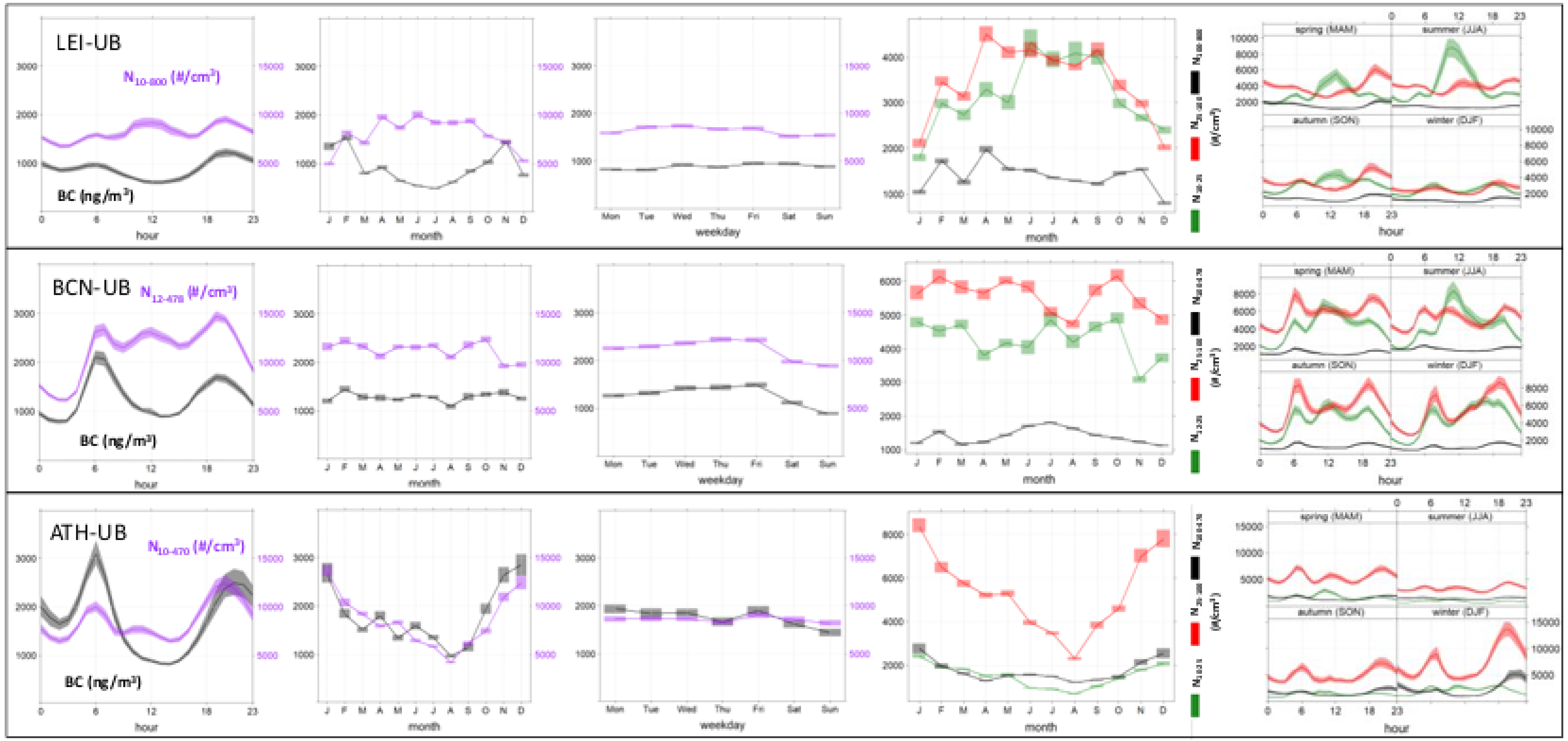
PNC and BC

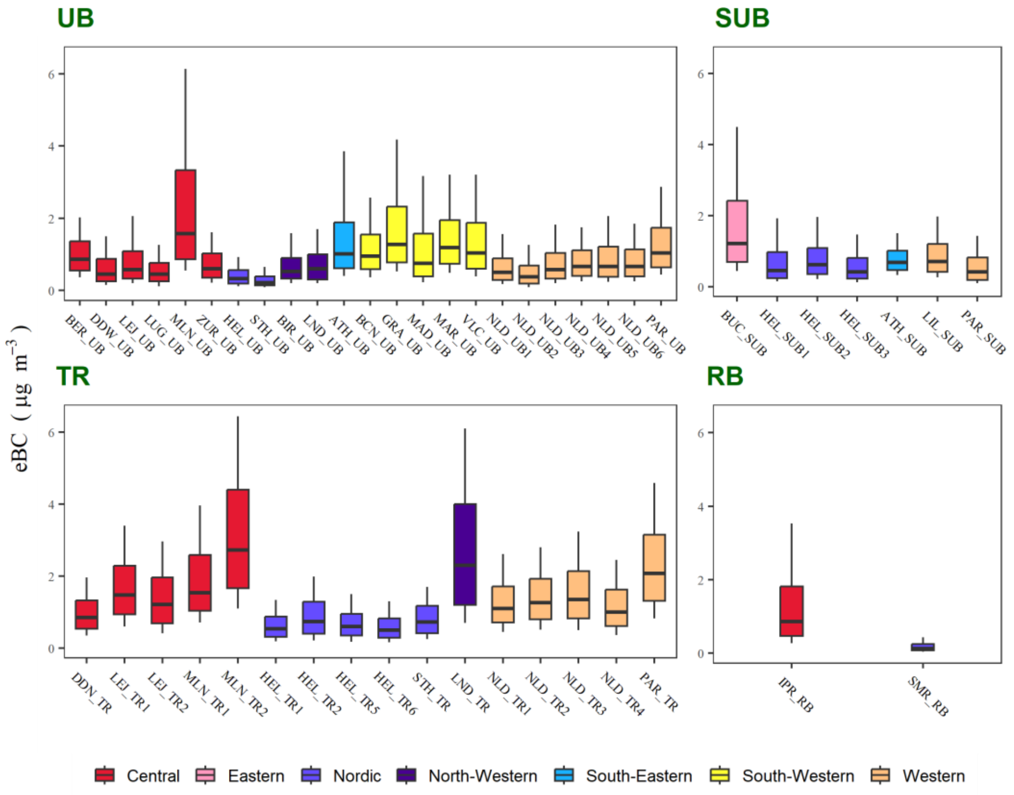


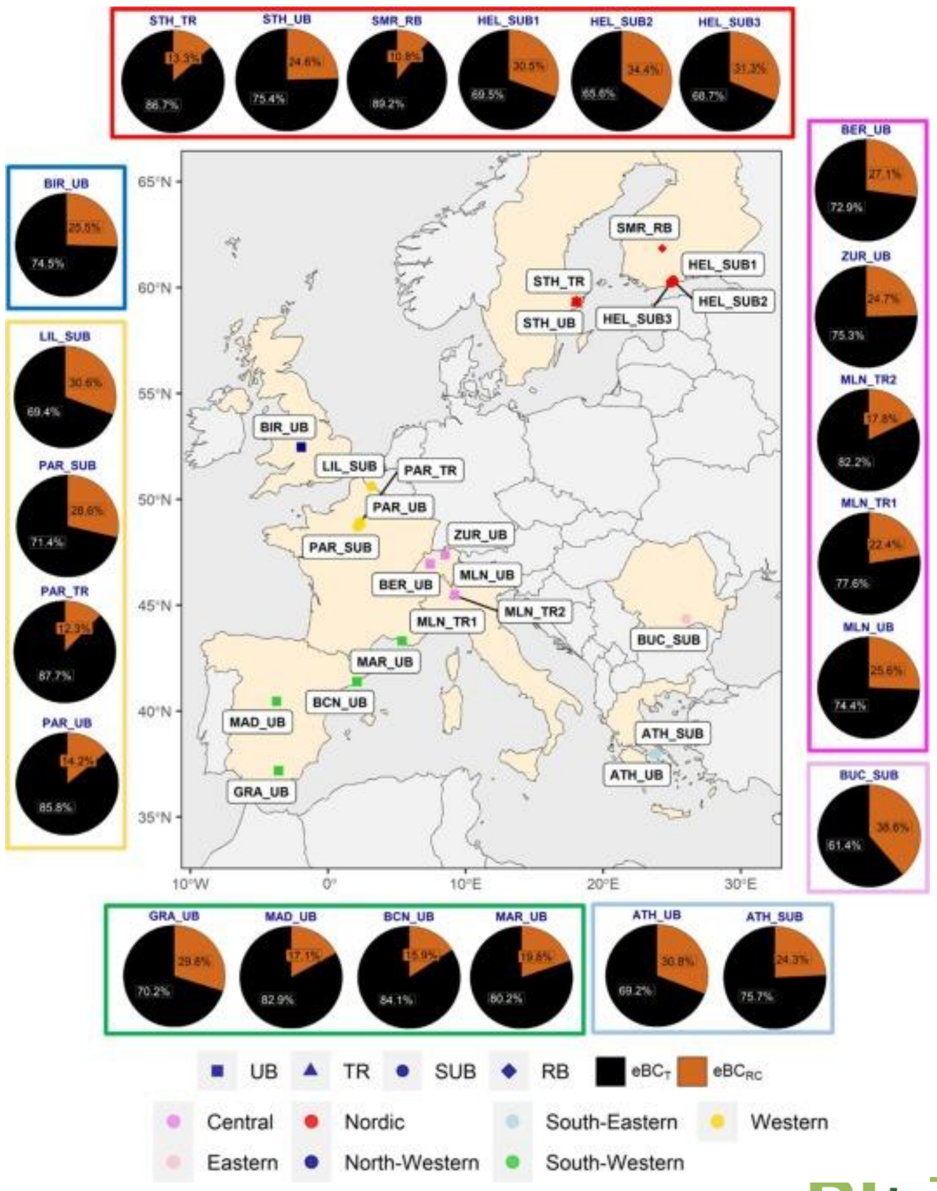


RI-URBANS (101036245)

Trenchera P. et al., 2023. Environment International

BC in urban Europe





RI-URBANS (101036245)

Savadkoohi M., 2023. Environment International
https://doi.org/10.1016/j.envint.2023.108081

European Commission

HORIZON 2020

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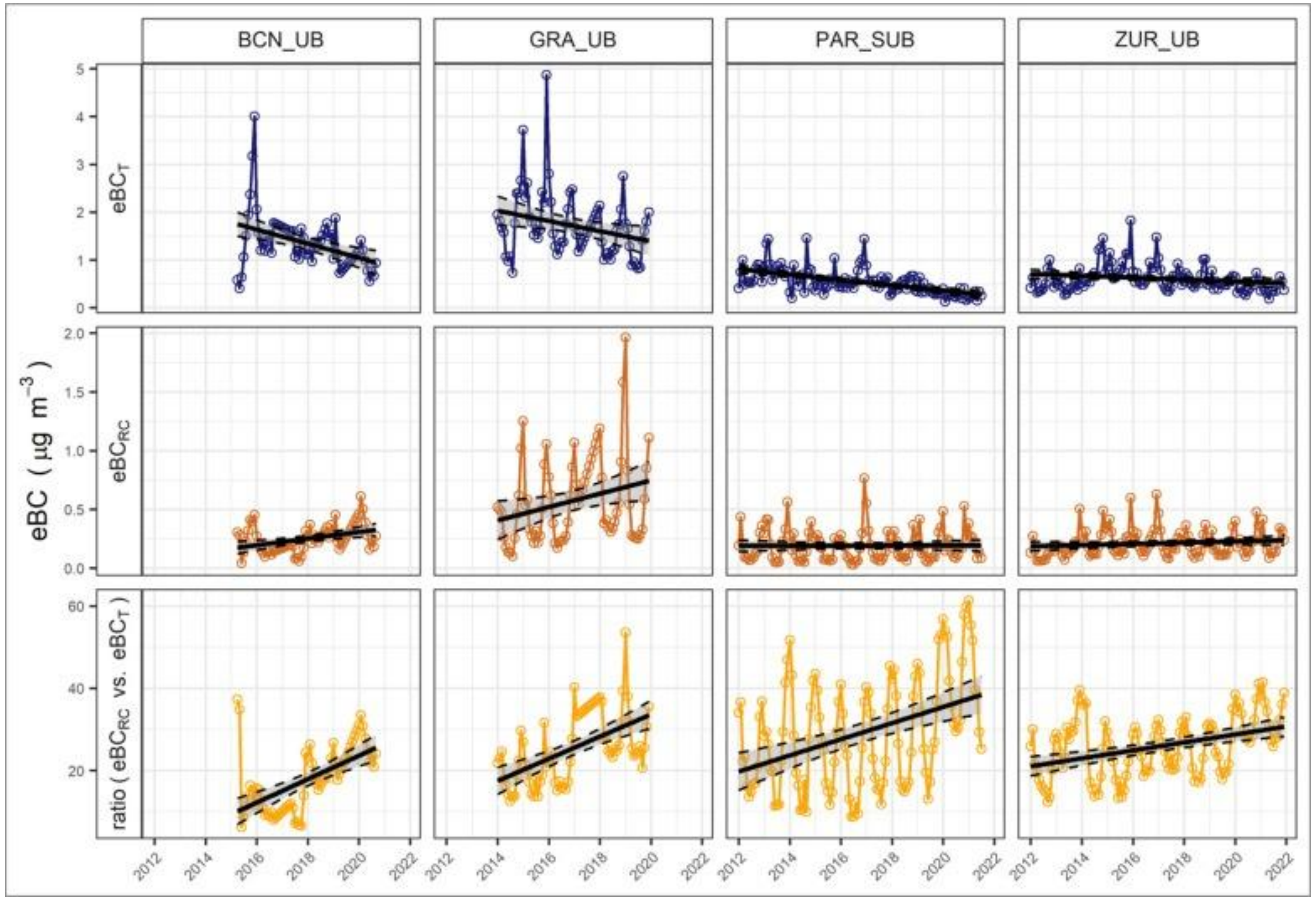
RI URBANS

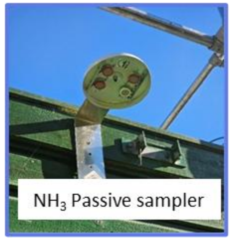
BC in Urban Europe



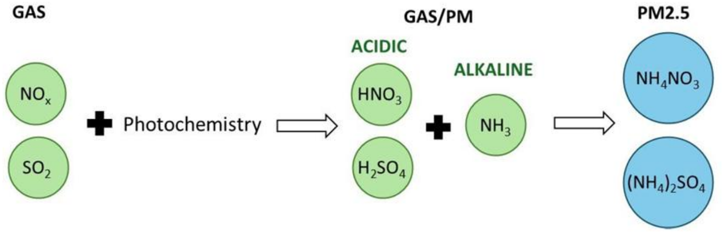
RI-URBANS (101036245)

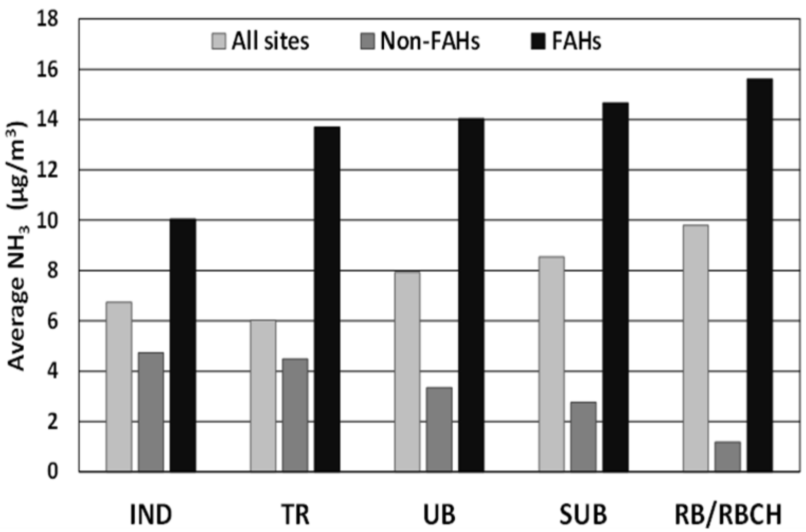
Savadkoohi M., 2023. Environment International
https://doi.org/10.1016/j.envint.2023.108081

Ammonia



- Why?
  - Impact on ecosystems
  - Secondary aerosol formation: PM
- Standard method: Passive samplers
- On-line methods:
  - Needed to understand sources , time trends for effective policy
  - Harmonization needed:
    sampling, measurement technology, operation, …
- First data analysis of European dataset

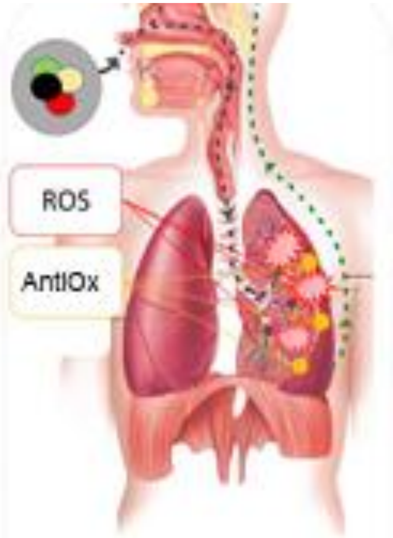




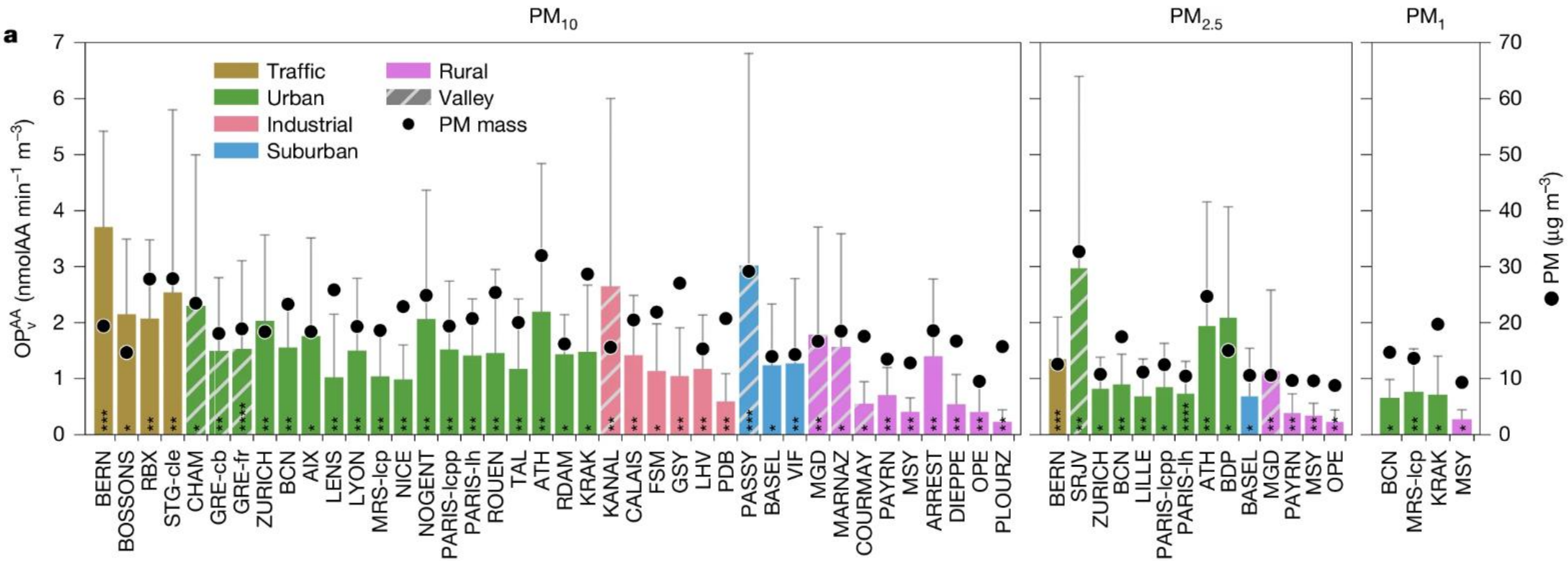
Liu X., 2024. Environment International
https://doi.org/10.1016/j.envint.2024.108519

Oxidative Potential (OP)

- Why?
  - PM is complex mixture with varying physicochemical properties and mass concentration may not fully capture/reflect health impact
  - Oxidative stress (imbalance between Reactive Oxygen Species and antioxidants) -> inflammatory response seems to be the key biological mechanisms involved in PM-induced health effects
  - OP = capacity of PM to induce oxidative reactions/generate ROS
  - OP may better reflect health-relevant particle properties
- Harmonization is needed to measure OP
  - Simplified method was developed
  - Inter-lab comparisons
- Data showed different trends in OP compared to PM mass



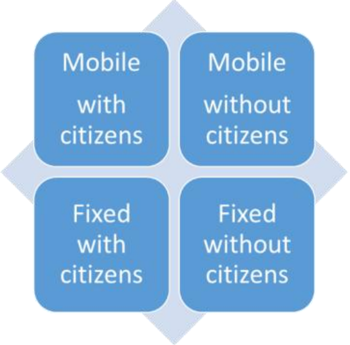
Oxidative potential



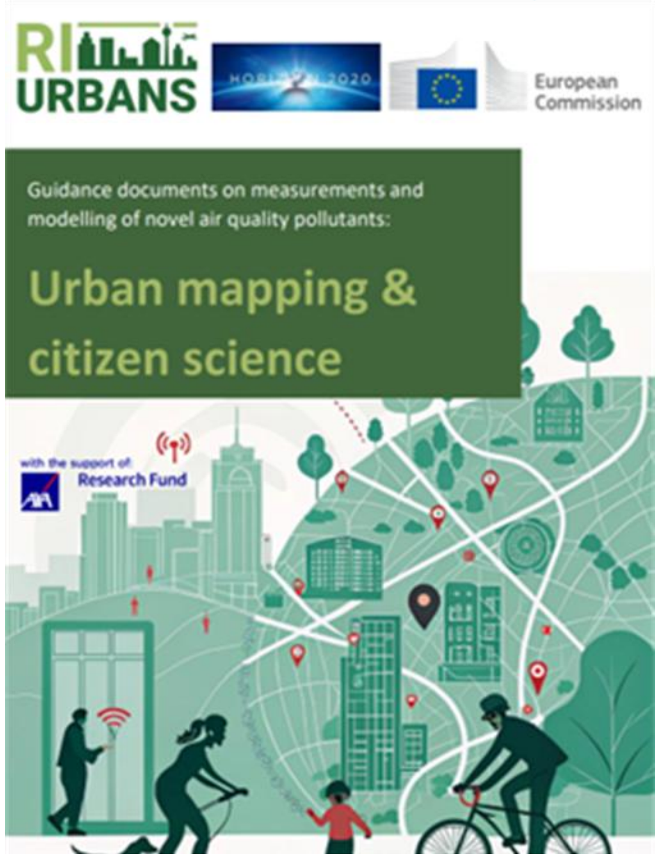
RI-URBANS (101036245)

Tassel et al., Nature 2025

Towards denser AQ data: urban mapping

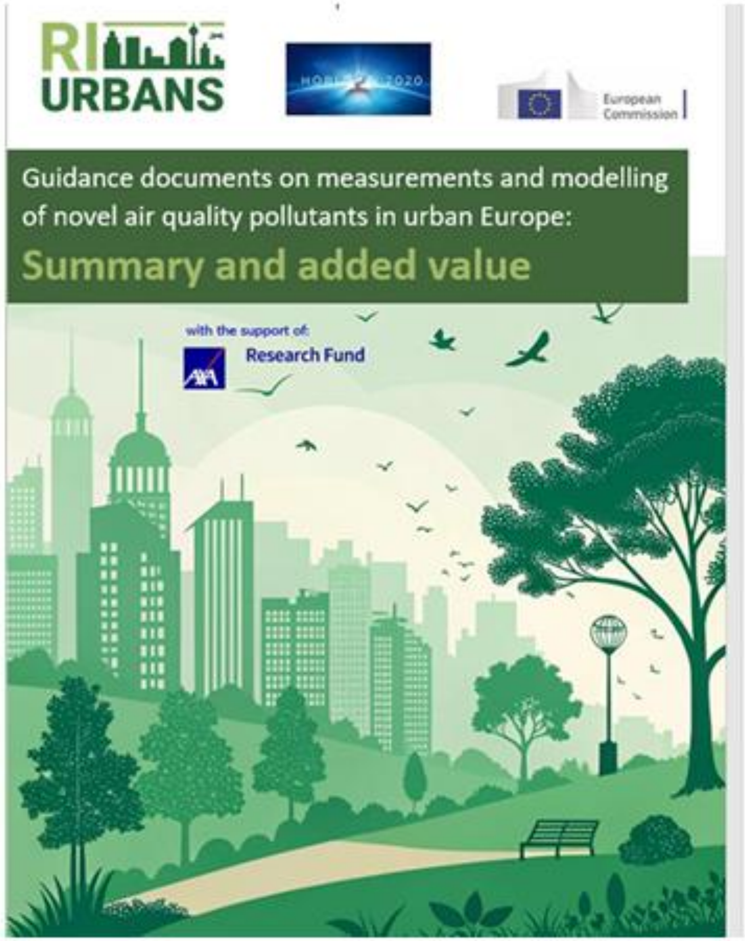


- Service tool developed in RI-URBANS
- New insights from **mobile monitoring** campaigns or **low-cost sensor** (LCS) **networks**
  - limited duration (weeks to months)
  - with a proper design, data processing and quality control
  - different approaches ~ research question
- Complementary to stationary AQMN
  - Longer campaigns can result in more precise estimates of air pollution patterns



RI-URBANS Service Tools

The RI-URBANS booklet




Editors: Xavier Querol (CSIC), Fulvio Amato (CSIC), Andrés Alastuey (CSIC), Tuukka Petäjä (UHEL), Katriina Kyllönen (FMI), Rosa Petracca (CNR)

Authors & Reviewers: See Table 2.2.

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Thank you for your attention!!!

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Questions?

Medegefinancierd door
de Europese Unie

PANEL DISCUSSION

Medegefinancierd door
de Europese Unie

Programme: Afternoon Breakouts

Meeting room	Breakout session 1 - 13:45		Breakout session 2 - 15:15	
1.69	1.1	From Insight to Action: How the CityTRAQ assess-ment & scenario tools strengthen local policy cycle	2.1	Visualizing air quality at the school gate: insights from the process of co-creation to installation
1.70	1.2	Citizen science and air quality measurements	2.2	Learning from mobility policies in Dutch and Flemish front-runner cities
1.71	1.3	From local traffic data to evidence-based environmental policies	2.3	Air Quality Sensors & Mobile Measurements: from Quality Assurance to Quality Control
1.72	1.4	From evidence to policy action: Building robust, data driven air quality plans	2.4	Air Quality Communication That Works: Bridging Science, Sensors and Society

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