

Deliverable D41 (D5.7)

Roadmap: Upscaling sustainable access to RI-URBANS STs (service portfolio, modelling tools, cost/benefit analysis) and solutions



RI-URBANS

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

By

UHEL, CSIC, INERIS, CNR, NOA, VITO, NILU, CNRS, TROPOS, FMI, FZJ, JRC & UW



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Deliverable D41 (D5.7): Roadmap: Upscaling sustainable access to RI-URBANS STs (service portfolio, modelling tools, cost/benefit analysis) and solutions

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1. About this document

This Deliverable (D41, D5.7) “*Roadmap: Upscaling sustainable access to RI-URBANS STs (service portfolio, modelling tools, cost/benefit analysis) and solutions*” resulted from WP5 on “*Developing a Roadmap for Implementation*” (led by UHEL, CSIC) tasks/activities. This WP tasks/ activities developed strategies and solutions for the consolidation of a sustainable access to the RI-URBANS services that enhanced synergies with the Air Quality Monitoring Networks (AQMNs). It developed guidance for upscaling and implementation of the RI-URBANS Service Tools (STs) developed and tested. The carried-out actions defined the methodologies for upscaling, drafting concepts, architecture and engineering plans, along with evaluation of costs for extending and upgrading existing service portfolios of European Research Infrastructures (RIs) and provided guidance to upscaling RI-URBANS STs. Designed conditions for an optimal data and data quality management framework in the project and beyond the project lifetime included necessary knowledge transfer component to ensure that all users, incl. AQMNs have all the necessary skills to operate the RI-URBANS STs. It was realised through: (i) engaging the In-service Aircraft for a Global Observing System (IAGOS, <https://www.iagos.org>) and the Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS, <https://actris.eu>) RIs through their Data Centres and Topic Centres to provide sustainable support to the RI-URBANS STs; (ii) preparing the modelling services for uptake through the Copernicus Atmosphere Monitoring Service (CAMS); (iii) demonstrating feasibility of the RI-URBANS upscaling strategy; and (iii) providing the strategic guidance to a sustainable access to RI-URBANS STs. This WP provided the roadmap for sustainable and interoperable RIs-AQMNs services. This WP5 tasks/ activities included implementation of the data management framework, and establishment of the measurement quality framework and the modelling framework supporting RI-URBANS STs; demonstration of replicability and uptake pathways of urban AQMNs-RIs interoperable services; and development of strategic guidance for European up-scaling STs. The expected impacts included: (i) to ensure that all users, specially AQMNs, have a facilitated access to the STs addressing their specific needs; (ii) to ensure efficient curation, preservation and provision of access to data in line with findable, accessible, interoperable, and reusable (FAIR) principles; (iii) to implement effective knowledge transfer and training sessions so that STs are optimally exploited; and (iv) to favour upgrade of air quality (AQ) monitoring strategy in European cities demonstrating the added value of RI-URBANS STs.

In particular, T5.5 on “*Strategic guidance for European up-scaling RI-URBANS STs*” (lead by UHEL, CSIC, INERIS) was based on the outcome of all RI-URBANS tasks. The roadmap was developed targeting AQMNs and authorities involved in AQ (and health) management at national, regional and local scales, defining the most suited practices for up-scaling and replicating the RI-URBANS solutions. Different stakeholders were engaged early-on providing specific challenges and needs ensuring synergies with existing data structures and services. Based on lessons learnt from the demonstration of such a replication (in Polish cities) ([D40 \(D5.6\)](#)), an upscale of the cost-benefit analysis was conducted. Solutions for sustainable and long-term RI-URBANS STs implementation were offered, either as an upgrade of the RI service portfolio or through other service providers, such as CAMS. RI-URBANS services were also added to ACTRIS and IAGOS portfolios together with modalities for access ([D42 \(D5.8\)](#)). Guidance addressed: (i) best practices for knowledge transfer from RIs to AQMNs, and vice versa, to promote advanced AQ observations, improved use of resources and complement capabilities; (ii) modalities for RI-URBANS STs upgrading; (iii)

modalities for cost-benefit analysis to support decision-making leading to the upgrade of AQMNs; and (iv) updating the RI-service portfolio in ACTRIS and IAGOS to include the urban STs.

This report *“Roadmap: Upscaling sustainable access to RI-URBANS STs (service portfolio, modelling tools, cost/benefit analysis) and solutions”* (D41 (D5.7)) provides summaries on 16 RI-URBANS Service Tools (STs), policy, technology and scientific challenges, referencing in the EC DG for ENV final versions of the technical support documents on *“Air quality monitoring for air quality policy”* and *“Air quality modelling for air quality policy”* (Chapter 2); service portfolio for STs with corresponding data services and open access (through data production, repositories, access platforms, and visualization tools) as well as integration with IAGOS (Chapter 3); modelling tools improvements leading to STs corresponding STs development and application (Chapter 4); results of cost-benefit analysis for a supersite (urban vs. rural background measurements) in accordance with the new AQ Directive for different contaminants for a 5-year period (Chapter 5); replicating AQ monitoring solutions (Chapter 6); training events in support of STs (Chapter 7).

This is a public document that will be distributed to all RI-URBANS partners for their use and submitted to the European Commission as a RI-URBANS Deliverable D41 (D5.7). This document can be downloaded at <https://riurbans.eu/work-package-5/#deliverables-wp5>.

2. RI-URBANS Service Tools (STs)

During the RI-URBANS project lifetime, 16 Service Tools (STs) were developed, tested, and recommended for advanced AQ assessment in urban areas. These STs associated guidance documents (grouped according to their methodologies: surface or vertical profile measurements, source apportionment receptor modelling, health assessment, urban mapping, emission inventories, and modelling for novel AQ pollutants) are publicly available at <https://riurbans.eu/project/#service-tools>. The aim of each RI-URBANS and RI-URBANS/ ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure) guidance document is described in details in the [D55 \(D7.6\)](#) and/or the [booklet](#) published with financial support from the AXA Research Fund and named as the *“Guidance documents on measurements and modelling of novel air quality pollutants in urban Europe: Summary and added value”*. It relates to the New AQ Directive (NAQD) 2024/2881/EC (published in Nov 2024). The NAQD underlines the importance of emerging pollutants for AQ and well-being of citizens. In particular, it is required/ recommended that novel pollutants – such as ultrafine particles (UFP), UFP-number size distribution (PNSD), black carbon (BC), elemental carbon (EC), ammonia (NH₃), volatile organic compounds (VOCs), oxidative potential (OP) of particulate matter (PM) – to be monitored at supersites of both rural and urban areas. It is needed for better scientific understanding of their effects on health and the environment. The RI-URBANS project produced a number of STs for specific advanced AQ measurements and modelling variables, a number of these included in Article 10 and Annex VII of the NAQD.

The RI-URBANS STs are also referenced in the EC DG for ENV final versions of the technical support documents on *“Air quality monitoring for air quality policy”* and *“Air quality modelling for air quality policy”*.

In *“Air quality monitoring for air quality policy”* (Janssen et al., 2025; as technical support document on the use of reference and non-reference methods, and on the quality assurance process to meet relevant data quality objectives for regulated air pollutants), as a result of the RI-URBANS project the document included 29 references to the RI-URBANS project, and in particular, the guidance documents on measurement of NH₃ (with pros and cons discussed), UFP and PNSD (with recommendations for sampling, measurement, data management of UFP, and

reports on the usual concentrations of UFP in urban Europe, recommendations and summarises of the main findings of UFP measurements in Europe.); BC (with guidance to support the harmonization of BC measurements and harmonisation factors, absorption coefficient calculations across different instruments, enhancing comparability); OP (with harmonization on OP monitoring in PM, incl. interlaboratory comparison exercise); aerosol mass spectrometers (AMS) and aerosol chemical speciation monitors (ACSM) (with guidance on use of these instruments and instrument manuals); guidance for online and semi-online methods and instructions/ manuals, and others.

In “Air quality modelling for air quality policy” (Tarrason et al., 2025; as technical support document on the use of modelling for various application domains under the Ambient AQ Directive), among the available EU AQ modelling resources and products, the RI-URBANS/ACTRIS Protocols for measuring novel AQ parameters: Obtaining emission inventories for novel AQ parameters: First UFP-PNSD and non-exhaust vehicle EU PM emission inventories are listed as well STs via RI-URBANS can be used to support chemical speciation.

The RI-URBANS STs are the following (with links to corresponding guidance documents):

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 (NH₃)

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

It should be noted that during the last 20 years the concentrations of most AQ pollutants decreased markedly in European urban areas as a consequence of the European, national, regional and local level AQ policies implemented since the first AQ EU Directive (1996/62/EC). Numerous national to regional level actions took place to implement directives and additional policies. At the local level, low emission zones, congestion charges, policies on domestic sources, among others, contributed also to abate pollution in urban areas. The marked decreases of pollutants were reached mostly by reducing emissions of primary and secondary pollutants e.g., those emitted directly from emission sources and those formed into the atmosphere from the reactions of primary ones, respectively. Continuing decreasing current concentrations of AQ pollutants is a more complex target than before, because the need to decrease secondary pollutants, which is a difficult issue due to the non-linearity of many of their formation

processes. Thus, to devise cost-effective AQ pollution measures a closer collaboration between the scientific community, AQMNs, and policy makers is needed. The RI-URBANS focuses on this gap between science and policy to support developing an advanced AQ assessment to improve AQ in urban Europe. To abate AQ pollutants there are important **policy, technological and scientific challenges** that vary according to the specific pollutant.

Policy challenges: For example, the abatement technologies and measures to be implemented to abate NO₂ pollutant are known and available, hence, there is no need for further research or technology developments, it is a matter of implementation of policies with cost-effective technological and non-technological measures. Another policy challenge is that major AQ policy is developed at European level, but implementation (such as measurements and AQ plans) takes place at national level. EU bodies such as AQUILA (European network of National AQ Reference Laboratories) with the support of ESFRIs (European Strategy Forum on Research Infrastructures) are basic to maintain a harmonised implementation of AQ measurements. However, the policy relevance given in the different EU-17 states to AQ issues varies widely and this should be also harmonised.

Technology challenges: For example, for some sectors, technology development to abate emissions is still a challenge. Examples include: (i) developing and implementing technologies to burn domestic biomass without causing AQ impairments; and (ii) idem for VOCs emissions in biomass-combustion based industrial and power plants.

Scientific challenges: For example, (i) elaborating cost-effective measures for abating secondary pollutants (such as O₃ and PM_{2.5} in urban background of European cities) in a scenario with O₃ and temperature increase due to climate change; and (ii) abating secondary PM_{2.5} under an urban increase of O₃ (that generate more oxidation of gaseous pollutants and, accordingly, more secondary PM).

There is a number of advanced AQ pollutants/parameters that might contribute to a cutting-edge AQ assessment for tackling the above challenges, and also, in some cases, to improve AQ monitoring for a better protection of human health and to support further reviews of AQ standards and parameters to be included in the future AQ legislation.

During the project lifetime, RI-URBANS has produced guidelines for ST1-ST6 (to help implement measurements) and for ST10-ST11 (to perform source apportionment analyses) on advanced AQ pollutants/parameters. These ST1-ST6 should be implemented at urban and rural AQ supersites in EU, as outlined in Article 10 of the NAQD. These ST10-ST11 will support advanced AQ assessment, identification of causes of exceedances of the limit values, evaluation of policy measures effects implemented and assess on future policies. The first emission EU inventory for UFP-PNSD, non-exhaust vehicle PM emissions, and guidance for ST15 (on improving multiscale emission inventories) and for ST16 (on multiscale modelling) were provided for assessing the impact of emission sources in criteria and novel pollutants. The RI-URBANS recommends implementing measurements of vertical profiles (ST7-ST8-ST9), which are not recommended in the NAQD, but might provide essential data for AQ assessment, forecasting and management. These include the boundary layer dynamics, mixing layer height, vertical aerosol profiles, as well as vertical profiles of pollutants (measured by equipped commercial aircrafts) in several European cities. The ST12-ST13 provide guidance on the urban mapping and citizens involvement to obtain accurate spatial and time urban variations of pollution and increase awareness of the problem.

Note that the RI-URBANS and ACTRIS interacted with AQUILA and DG ENV from EC for knowledge transfer and the co-design of the above-mentioned STs. It is also very important to connect these AQ monitoring efforts with those for urban greenhouse gases (GHG), and, when possible, using the same supersites for both types of measurements in connection with the RI-URBANS twin project PAUL-ICOS-cities (<https://www.icos-cp.eu/projects/icos-cities>).

The RI-URBANS STs were presented in numerous stakeholders' meetings/ trainings/ webinars/ etc. (see more details in [D38 \(D5.4\)](#)) and discussed the contents of many of these with AQUILA/ACTRIS. RI-URBANS hopes that the

AQMNs and other AQ stakeholders will find the RI-URBANS STs helpful in implementing the NAQD and further improving AQ across Europe.

3. Service Portfolio

The service portfolio of RI-URBANS represents an expanded set of resources, tools, and datasets that strengthen the capacity of European RIs to address emerging urban AQ challenges. Building on existing infrastructures such as ACTRIS and IAGOS, RI-URBANS developed and integrated [STs](#) that provide standardized protocols, advanced methodologies, and innovative modelling approaches. Together, these tools deliver harmonized, policy-relevant, and high-quality services to scientific users, policymakers, and other stakeholders.

1) Service Tools: STs are any of tools developed by the RI-URBANS that the project has reviewed, in some cases developed, tested, and recommend for advanced AQ assessment in urban areas. These recommendations include protocols for measuring advanced AQ variables (derived from ACTRIS and CEN or, in specific cases, proposed when not available), mapping protocols, emission inventories, modelling tools, and suggested epidemiological approaches to evaluate the health effects of new pollutants. The STs are organized into specific categories that reflect different aspects of urban AQ assessment. **Protocols for the measurement of novel AQ pollutants (ST1–ST6)** establish harmonized procedures for monitoring UFP, BC, NH₃, VOCs, and OP of PM. **Methodologies for vertical profiles of pollutants and meteorology (ST7–ST9)** enable improved characterization of atmospheric dynamics through boundary layer height and vertical profiling measurements, including the use of commercial aircraft. **Source apportionment methodologies (ST10–ST11)** provide receptor modelling approaches to identify pollutant sources and support effective mitigation strategies.

Complementary approaches further strengthen the portfolio. **Urban mapping methodologies (ST12–ST13)** advance high-resolution modelling and citizen science applications to capture pollutant distributions in complex urban environments. **Health evaluation methodologies (ST14)** establish direct links between novel AQ pollutants and health outcomes, offering valuable evidence for public health policy. **Emission inventories (ST15)** provide the first EU-level estimates of ultrafine particle and non-exhaust vehicle particulate matter emissions, while **modelling methodologies (ST16)** enable multi-scale simulations of ultrafine particles and their behaviour across different environments.

Through these STs, RI-URBANS extends the traditional service portfolio of European RIs beyond regulated AQ parameters, addressing pollutants of growing societal concern. All the guidance documents are publicly available on RI-URBANS website (<https://riurbans.eu/project/#service-tools>).

2) Data Services and Open Access: The central component of the service portfolio is the provision of **FAIR and open data**. RI-URBANS participates in the Open Research Data Pilot (ORDP), ensuring the long-term accessibility and interoperability of datasets.

- **Data production:** Over 5000 datasets have been generated within RI-URBANS framework, covering about 150 variables from 125 sites across thirteen countries, including nanoparticle size distributions, particulate matter constituents, and gaseous precursors. All these datasets are available to users, as detailed in Deliverable [D45 \(D5.11\)](#).
- **Repositories:** Data are submitted to three ACTRIS Data Centers (DC):
 - [EBAS](#) (in-situ aerosol and trace gases, hosted at NILU, Norway)
 - [EARLINET](#) (aerosol profiling, hosted at CNR, Italy)
 - [Cloudnet](#) (cloud remote sensing, hosted at FMI, Finland)

- **Access platforms:** All datasets are accessible via the ACTRIS Data Discovery, Virtual Access, and Services (DVAS) portal (<https://data.actris.eu>), as well as through Zenodo ([BC](#), [ACSM](#)) and the RI-URBANS public website (<https://riurbans.eu/results/#open-data>; Figure 1).
- **Visualization tools:** ACTRIS provides web interfaces for data exploration, real-time quality assurance, and source apportionment (e.g., ACSM data at European scale).

Table 1 – quality-controlled data sets

The total number of sites given in parentheses includes those relevant sites that have been reported to other frameworks and those sites expected to be in EBAS soon. It does not include NRT data.

Note that the number of sites and datasets is continuously changing, current information is representative for end of August 2025.

IMPORTANT

The first time you follow the link to the EBAS page, a general disclaimer will appear. Please accept it and follow the link again to visit the pollutant info.

Variable	Instruments	#NRT sites	#sites	# data sets (level 2)	Link to dataset (level 2)
Aerosol absorption coefficient (also used for estimating eBC)	Filter absorption photometers (MAAP, AE33, AE31)	10.0	47.0	288.0	EBAS
particle number size distribution (PNSD)	DMPS, SMPS, CPC, APS	8.0	17.0	2082.0	EBAS
VOC data (111 number of different gas components)	Adsorption, tube, PTR-MS, online-GC, steel canister	-	23.0	1078.0	EBAS
NH ₃	Online absorption, CRDS, online IC, chemiluminescence, passive sampler	-	60.0	65.0	EBAS
Aerosol chemical composition (NH ₄ , SO ₄ , NO ₃ , organic mass)	Aerosol mass spectrometer (ACSM)	2.0	4.0	53.0	EBAS
NO, NO ₂	CAPS, chemiluminescence	-	1.0	8.0	EBAS
SO ₂	UV- fluorescence	-	1.0	4.0	EBAS
Elemental and organic carbon (EC/OC)	High volume sampler	-	1.0	18.0	EBAS
eBC	-	53.0	53.0	-	ZENODO
Non-refractory PM speciation	ACSM	22.0	22.0	-	ZENODO

Figure 1. Snapshot from RI-URBANS open data web portal (<https://riurbans.eu/results/#open-data>) illustrating data, accessed 5 September 2025.

3) Integration with IAGOS

The RI-URBANS portfolio also incorporates the IAGOS services, which provide vertical AQ profiles from commercial aircrafts. These data complement ground-based monitoring and are available through the IAGOS Data Portal. For “RI-URBANS IAGOS”, vertical profiles data can be accessed at: <https://www.iagos.org/products/#/>. Support services allow comparison with Copernicus Atmosphere Monitoring Service (CAMS) models for pilot cities (Amsterdam, Barcelona, Milan, Paris, Zurich). More details can be found in [D37 \(D5.3\)](#).

By combining standardized STs, harmonized datasets, and open access infrastructures, **URBANS service portfolio** establishes a sustainable foundation for monitoring, modelling, and assessing novel air pollutants at both urban and regional scales, ensuring that European RIs remain at the forefront of science and policy support in AQ.

4. Modelling Tools

The RI-URBANS was based on the premise that advanced monitoring and modelling tools developed can be used to supplement current AQMN of regulated pollutants, and that the compiled datasets of observations can be used in health effects evaluation and in improving modelling tools of the RI-URBANS modelling teams. Such improvements are needed for both the modelling tools themselves and for urban scale emission inventories (EIs), and such improvements can be achieved through assimilation of measurements and source contributions.

The model development performed in RI-URBANS has led to several RI-URBANS STs and produced modelling tools for policy support ([D20 \(D3.5\)](#)) that will continuously develop with increasing existing level of knowledge. The improved AQ modelling and EIs were demonstrated on examples of selected cities. For that, first of all, a methodology to improve European urban emission inventories (EI) was devised ([D17 \(D3.2\)](#)). It was realised on the European CAMS-REG EI (spatial resolution of $0.1^\circ \times 0.05^\circ$ or $\sim 6 \times 6 \text{ km}^2$) over specific urban areas of Europe. The first European EI for modelling tools was obtained for PM ultrafine and non-exhaust vehicle emissions distribution was released ([M13, \(M3.2\)](#) & [D18 \(D3.3\)](#)) over Europe and RI-URBANS pilot cities. The RI-URBANS used chemistry-transport models (CTMs) such as PMCAMx and PMCAMx-UF, CHIMERE, EMEP and UEMEP, LOTOS-EUROS, SILAM, and MONARCH as well as ADMS and MUNIC were improved for integrating regional and urban/street scales, respectively ([M15, \(M3.4\)](#)). It led to extending AQ modelling to health and policy relevant indicators down to urban scale. All these led to RI-URBANS STs on obtaining EI for novel AQ pollutants, and in particular, [ST15](#) on the final “First UFP-PNSD and non-exhaust vehicle PM EU emissions”. This was necessary for the RI-URBANS modellers (modelling teams) to introduce in their models the emissions of these key pollutants, and hence, led to [ST16](#) “UFP-PNSD multi-scale modelling” on modelling methodologies for novel AQ pollutants. Other RI-URBANS STs include also methodologies for urban mapping of novel AQ pollutants, and in particular, for [ST12](#) “Deterministic urban modelling of fine PM and PNC” and [ST13](#) “Mapping ultrafine particles and citizen science”.

In RI-URBANS, for characterisation of urban dispersion with advanced observation-based approaches, the methodology was developed which allowed to improve urban aerosol particle emissions ([D16 \(D3.1\)](#)) combining in-situ measurements and novel modelling tools (Large-Eddy Simulation, LES, data assimilation, bottom-up emission models, air quality, and dispersion modelling). The results of the comparison of and crosschecking of methodologies to assess urban emissions and air quality and examine the improvements finer scale simulations can bring in specific case studies made in Barcelona (Spain), Paris (France), Turku and Helsinki (Finland), and Rotterdam (the Netherlands). In particular, the high-resolution modelling was combined to quantify the spatial and temporal dynamics of urban emission fluxes and thus improve the emission data products using PALM LES and SILAM models. The technique was developed for Helsinki and tested for Paris. The street-network model MUNICH, evaluated against PALM, was used to simulate the dispersion processes between the urban surface and atmospheric boundary layer and upscale to city level.

In RI-URBANS, consortium of 8 European AQ modelling teams (INERIS, FORTH, FMI, MET Norway, TNO, CNRS/CEREA, CNRS/LISA, ENPC) involved in the RI-URBANS project (and in a very close collaboration with observation providers), enhanced the above-mentioned CTMs for mapping urban background air quality and mapping high resolution urban air quality in order to quantify source contributions to conventional and novel AQ health metrics (nanoparticles, OP) ([D19 \(D3.4\)](#)). The CTMs were also combined with urban observational data (atmospheric concentrations and 3D profiling and remote sensing).

The RI-URBANS deliverable ([D21 \(D3.6\)](#)) on European health indicators, variabilities, sources, uncertainties, and roadmap in support pilots integrates knowledge acquired with modelling tools and summarizes the methodologies used and the results on reconciling emission estimates at various scales, of the efficacy of the techniques used for source apportionment evaluation in models, elaborates to what extent developed methodologies can be

generalized and exploited to support health impact studies, pilot demonstrations as well as assesses the tools developed that are suitable for feeding a service oriented modelling.

Moreover, the improved modelling tools were used and implemented in specific pilot tests-demonstrations (in WP4) as well as in the roadmap for upscaling (in WP5).

Finally, the RI-URBANS Deliverable (D39 (D5.5)) summarises the Service Tools for modelling novel urban air diagnostics and evaluation of regional AQ models over urban areas. Taking an advantage of developed STs, the modelling tools were also used to describe variability of outdoor exposure of nanoparticles and other pollutants for the European urban areas. Moreover, in relation to AQ mapping, the lessons learnt from mapping pilots showed that NRT data transfer enhances integration with modelling tools (e.g. ENFUSER), enabling insights into spatial pollutant variability.

The developments of RI-URBANS modelling teams were presented in various stakeholders' meetings and frameworks, including FAIRMODE (most relevant for use of modelling in support of policy processes in Europe). The significance of RI-URBANS was also mentioned in the *"Air quality modelling for air quality policy"* technical support document. Moreover, several methodologies developed in RI-URBANS are also being transferred into the Copernicus Atmosphere Monitoring Service (CAMS). Such operational transfer is instrumental for the long-lasting upscaling and wider use by the community.

5. Cost-Benefit Analysis

The effectiveness of Service Tools was demonstrated through cost-benefit analysis for a selected city of Warsaw, Poland based on this city strategic location in Europe, significant pollution levels, low AQMN capacity and low awareness. The benefits for this city are demonstrated and summarized in [D40 \(D5.6\)](#). Considering the lessons learnt from such city the cost-benefit analysis was also performed for a supersite. The implementation costs of a supersite were estimated in accordance with the new AQ Directive and following a structure of estimate required by the Ministry of Environment. These approximate estimates do not include Value Added Tax (VAT) and are for a 5-year period. Note that instrument costs vary greatly depending on the company and country. Operational and maintenance costs also depend greatly on the agreements between networks and companies. In addition, maintenance costs depend on the number of instruments contracted. The same applies to costs of with samples treatments analysis and chemical analysis in laboratories.

For supersites cost estimation, the summary of costs for incorporating sampling points is given in [MS Excel file](#) in separate worksheets by contaminant and in Annex "Complementary Equipment". Note that there are costs (in Euros) listed under the CapEX and OpeEx. The CapEX (Capital EXpenditure) is a main long-term investment in assets, e.g. instruments/equipment. The OpEX (Operating EXpenditure) is ongoing daily costs required to run the installed instruments/ equipment. There are costs breakdown for "housing"/ container. The container is a housing that accommodates all instruments, with an insulated walk-through roof, access ladder, air conditioning, fire extinguishers, a cabinet for dry air pumps and compressors, etc. (estimated price of 70000 € + VAT). The installation of all the equipment requires a larger container than those usually used in air quality monitoring networks. The container also requires: (1) a gas cylinder, e.g. gas bottles for calibration (appx. 1200 € / year); (2) a compressor is recommended for supplying dry air to reduce the relative humidity, for example, for the UFP and BC samples collection (appx. 4500 €); (3) uninterruptable power supply, UPS (2000 €), (4) router for communication as a network device that connects with other networks (100 €); and (5) PC for measurement data management. All these are the CapEX and considered as one-time expenses (300 €).

Among the listed contaminants there are the following: Sulfur dioxide (SO₂); Nitrogen dioxide (NO₂); Carbon monoxide (CO); Ozone (O₃); Particulate Matter (PM) PM₁₀; PM_{2.5}, Ultrafine particles (UFP) Particle Number Concentration (PNC) in a range more than 10 nm; Ultrafine particles (UFP) Particle Number Size Distribution (PNSD) in a range of 10-800 nm; Black carbon (BC), Benzene (C₆H₆) – offline/ online; As, Cd, Ni, and Pb in PM₁₀; Benzo(a)pyrene (BaP) and Polycyclic Aromatic Hydrocarbons (PAHs) in PM₁₀; As, Cd, Ni, Pb and Hg in deposits; Benzo(a)pyrene (BaP) and Polycyclic Aromatic Hydrocarbons (PAHs) in deposits; Organic Carbon Elemental Carbon (OCEC) in PM_{2.5}; Ions in PM_{2.5}; Particulate Matter PM_x – online; Volatile Organic Compounds (VOCs); Ammonia (NH₃) – offline/ online; Oxidative Potential (OP); Levoglucosan; and total gaseous mercury (Hg).

For each of the above-mentioned contaminants there is a cost breakdown detailed in costs for instrument or equipment required (analyzer/ sampler /etc.); installation and startup; comprehensive service contract/ service and operation/ sampling; periodic calibration; filters/sensors; initial training, maintenance; extended warranty; electrical/ power consumption; traceable calibration gases/ needed consumables; and summary of total costs. It is also separated by CapEX/OpEx, required quantity, periodicity of activity/ expense, number of times the expense occur, unit costs and total cost (in Euro), period/ useful life, and assumptions. Note that not all contaminants include detailed breakdown of costs, for example, for the gaseous mercury measurements there is information only for the instrument (the Tekran analyzer), required consumables and power consumption.

In addition, information for *“Pollutants that must be measured at urban background supersites”*, *“Pollutants that must be measured at rural background supersites”*, and *“Recommended pollutants in urban and rural background supersites”* is available in 3 separate [Tables](#), where information for each measured variable, type of measurements, standard to follow, instrument, CaPEX costs (excluding VAT), required consumables and annual operation, and annual costs are included.

6. Replicating AQ Monitoring Solutions: Warsaw, Poland and Applicability to Other Cities

In T5.4 on *“Demonstration of replicability and uptake pathways of urban AQMNs-RIs interoperable services”*, the Polish Stakeholder Meeting ([M35 \(M5.7\)](#)) took place in a hybrid format at the Institute of Geophysics, Faculty of Physics, University of Warsaw on 23rd February 2023. It was arranged to improve awareness, communicate on status, and assess the needs in relation to RI-URBANS STs within the Polish community. The Polish stakeholders representing 23 institutions attended the meeting, including 20 persons onsite from 16 institutions and 11 persons online from 9 institutions. This meeting also attended online 6 representatives of the RI-URBANS and ATMO-ACCESS (Sustainable Access to Atmospheric Research Facilities; <https://www.atmo-access.eu>) projects. During the meeting it was proposed to make upgrades of the ACTRIS-IAGOS-ICOS Polish supersites in order to meet the RI-URBANS urban supersite requirements (to fulfil requirements of the NAQD, 2024/2881, for advanced AQ parameters). The outcomes of the meeting included: contacts between different Polish stakeholders were strengthened; link with RI-URBANS was established; understanding of RIs was improved at national level; relevant information was disseminated websites and to participants of the meeting.

During the RI-URBANS project lifetime, the effort was made to identify suitable candidates for supersites considering the existing infrastructure and locations. In total, 4 were considered, and these are in the Polish cities of Warsaw, Wrocław, Kraków, and Zabrze as representing Metropolis GZM (Górnośląsko-Zagłębiowska Metropolia). The [D40 \(D5.6\)](#) explains in details on how the upgrading of proposed Polish supersites into the ones that include the required advanced AQ parameters (such as UFP, PNSD, BC, PM speciation, NH₃, VOCs, OP) in collaboration with Polish RI-URBANS Partners and other Polish research groups representing these supersites. The results were presented to the Polish AQ stakeholders. Following intensive further work and interaction with ACTRIS-Poland, a report was produced with conclusions/ recommendations on upscaling STs of NAQD in Poland by linking AQMNs,

ACTRIS RIs, other academic RIs, and different national experts. Although it was done for Poland, but this approach as an example of integration of AQMNs with national RIs, ACTRIS and national scientists, can be replicated to other cities in the EU Member States.

7. Training Events in Support of RI-URBANS STs

During the RI-URBANS project lifetime, a series of stakeholders' meetings was organised by the project to offer guidelines for the implementation of the RI-URBANS STs. In particular, during January-February 2025, a series of online training events addressing harmonized measurements of emerging pollutants of the new AQ Directive with the AQUILA, ACTRIS, and the European Environmental Agency (EEA) was organized with focus on aerosol particle number concentration (PNC), aerosol particle number size distribution (PNSD), and equivalent Black Carbon (eBC) measurements. Moreover, on 16 April 2025, 17 Novel Air Quality Documents and 16 Service Tools were launched during RI-URBAN webinar. During 4-5 September 2024, onsite (Warsaw, Poland) mobile monitoring training was provided to volunteers. RI-URBANS participated in the Knowledge & Citizens working group meetings (15 June 2022, 18 November 2022, 13 November 2024, 22 April 2025) arranged by the Green Deal Projects Support Office (GDP-SO) and co-organized Webinar on Dialogue on selected European Green Deal policy priorities (12 January 2023). RI-URBANS jointly with ACTRIS, AQUILA, ATMO-ACCESS co-organized a series of webinars: Phenomenology of new air pollutants (4 December 2023), Instruments and protocols to measure advanced AQ parameters (10 January 2024), Implementing revised EU ambient AQ Directive (4 October 2024), and other events and activities where the RI-URBANS project was also involved.

Materials of the webinars/ trainings were disseminated through the RI-URBANS public website, slides of presentations/talks delivered, and the video recording of the trainings are publicly available (see links provided in [D38 \(D5.4\)](#)) as well as agendas/ programmes are available in Annexes of this deliverable.

8. Summary

This RI-URBANS Deliverable (D41, D5.7) *“Roadmap: Upscaling sustainable access to RI-URBANS STs (service portfolio, modelling tools, cost/benefit analysis) and solutions”* provides summaries on:

- (i) **16 RI-URBANS Service Tools** (STs), policy, technology and scientific challenges, referencing in the EC DG for ENV final versions of the technical support documents on “Air quality monitoring for air quality policy” and “Air quality modelling for air quality policy” (Chapter 2);
- (ii) **service portfolio for STs** with corresponding data services and open access (through data production, repositories, access platforms, and visualization tools) as well as integration with IAGOS establishing a sustainable foundation for monitoring, modelling, and assessing novel air pollutants at both urban and regional scales, ensuring that European RIs remain at the forefront of science and policy support in AQ (Chapter 3);
- (iii) **modelling tools** improvement and enhancement led to several STs development (12, 13, 15, and 16) for modelling methodologies and urban mapping for novel AQ pollutants, and improved emission inventories for urban scales (Chapter 4);
- (iv) **results of cost-benefit analysis** for a supersite (urban vs. rural background measurements) in accordance with the new AQ Directive for different contaminants for a 5-year period (Chapter 5);

(v) **replicating AQ monitoring solutions** was realised on example of Poland, but the approach as an example of integration of AQMNs with national RIs, ACTRIS and national scientists, can be replicated to other cities in the EU Member States (Chapter 6); and

(vi) **training events in support of STs** were organised by the project to offer guidelines for the implementation of the RI-URBANS STs by addressing harmonized measurements of emerging pollutants of the new AQ Directive, mobile training, monitoring, citizen science, mapping and source apportionment and mapping (Chapter 7).

9. References

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10. Annex: Complementary Equipment

Contaminants: NO_x, SO₂, O₃, CO:

Conventional analysers, which require continuous maintenance and calibration.

Particulate Matter (PM₁₀/PM_{2.5}):

Standard method EN12341:2023: gravimetric determination in sampled filters with low-volume collectors. Daily sampling (365 filters/year/size fraction). Maintenance and filter replacement + weighing is required. The PM₁₀ filters can be used to determine metals (As, Cd, Ni, Pb) and/or ions, and/or OCEC, and/or Polycyclic Aromatic Hydrocarbons (PAHs). In this case, the filter must be selected according to the determinations to be made (see section on chemical composition of PM_{2.5}). In supersites, PM_{2.5} speciation (ions, OCEC, is required). The cost estimate does not include the costs of sampling and equipment maintenance.

Additionally, automatic equipment can be installed for continuous measurement of mass concentrations of PM size fractions (PM₁₀ and/or PM_{2.5} and/or PM₁, or more channels) with high temporal resolution. These measurements must be corrected after comparison with manual measurements.

Black Carbon (BC):

Determination of BC from absorption measurements using a photometer (AE33 / AE36, MetOne, etc.). Requires a sampling line with a cut-off head to work at the flow rate of the equipment and drying system. The filter tape must be changed several times a year, depending on the BC concentration (ca. 2 tapes/year in regional background; 4 in urban background and 6 in traffic). The operation and maintenance of the instrument is relatively simple and can be carried out by technical staff from the network. The Excel document indicates the annual maintenance cost offered by the manufacturer, which includes flow calibration, cleaning, equipment inspection, electronics checkout, hardware and software updates, etc.: this cost has not been included in the cost estimate. Although calibration is not required, validation by comparison with offline EC measurements is highly recommended.

Particle number concentration of ultrafine particles (UFP-PNC):

Determination of the number of ultrafine particles in accordance with the standard method in a condensation particle counter (CPC). It requires a sampling line with a PM_{2.5} cut-off head to work at the flow rate of the equipment and the drying system. The same sampling line can be used for four instruments (CPC/SMPS). An external pump may be required. It requires the use of butanol, which can produce odours and interfere with VOCs measurements; an instrument can be purchased to remove butanol vapor from the CPC outlet (included in the cost estimate). A diluter may be required in areas with high concentrations. A highly specialized technician/ research group is required.

Particle number size distribution of ultrafine particles (UFP-PNSD):

A mobility particle size spectrometer (MPSS), which includes a DMA (Differential Mobility Analyzer), a neutralizer, and a CPC, is required to determinate the particle size distribution of ultra-fine particles. It requires a sampling line with a PM_{2.5} cut-off head to work at the equipment flow rate and the drying system. One sampling line can be used for up to four instruments. Therefore, the sampling line is not included in the cost estimate, as it is assumed that it will be installed in parallel with a CPC. An external pump may be required. It requires the use of butanol, which can produce odours and interfere with VOCs measurements; equipment can be purchased to remove butanol vapour from the CPC outlet (included in the cost estimate). It also requires the purchase of a neutralizer; there are different options: Kr85 source (radioactive, license is required), XRF (annual renewal for > 5 K€). Ni63 (exempt and recommended). They require a highly specialized technician/research group.

PM₁₀ PAHs (Benzo-a-pyrene -BaP):

Analysis on PM₁₀ quartz filters collected with samplers (used for PM₁₀ determination). Other PAHs in addition to BaP must be measured for a limited number of sampling points. This includes, as a minimum: benzo(a)anthracene (BaA), benzo(b)fluoranthene (BbF), benzo(j)fluoranthene (BjF), benzo(k)fluoranthene (BkF), indeno(1,2,3-cd)pyrene (INP), and dibenzo(a,h)anthracene (DBaA). It is assumed that the samplers and filters used for gravimetric PM₁₀ determinations will be used, so only the analytical cost is estimated, but not the cost of purchasing the sampler, filters and operational costs. The analytical cost includes fixed measurements (110 days; 30%) and indicative measurements (50 days; 13%).

As, Cd, Ni, Pb in PM₁₀:

Analysis on PM₁₀ quartz filters collected with collectors (used for PM₁₀ determination). It is assumed that the samplers and filters used for gravimetric PM₁₀ determinations will be used, so only the analytical cost is estimated, but not the cost of purchasing the sampler, filters and operational costs. The analytical cost includes fixed measurements (165 days; 45%) and indicative measurements (50 days; 13%).

The same filters or the same sampler (analysing different days) can be used to determine As, Cd, Ni, Pb and PAHs. The two required determinations in PM₁₀ (metals/BaP) can be made with a low-volume sampler, but, in this case, the filter used must be quartz fibre filter, which is the only one suitable for both determinations.

PM_{2.5} chemical composition

PM_{2.5} Ions (SO₄²⁻, NO₃⁻, Cl⁻, Na⁺, Ca²⁺, Mg²⁺, K⁺, NH₄⁺):

Analysis on quartz or Teflon® PM_{2.5} filters collected with collectors (used for determining PM_{2.5}). It is assumed that the samplers and filters used for gravimetric PM_{2.5} determinations will be used, so only the analytical cost is estimated, but not the cost of purchasing the sampler, filters and operational costs. The analytical cost includes fixed measurements (165 days; 45%) and indicative measurements (50 days; 13%).

OC/EC in PM_{2.5}:

Analysis on PM_{2.5} quartz filters collected with collectors (used for determining PM_{2.5}). It is assumed that the samplers and filters used for gravimetric PM_{2.5} determinations will be used, so only the analytical cost is estimated, but not the cost of purchasing the sampler, filters and operational costs. The analytical cost includes fixed measurements (165 days; 45%) and indicative measurements (50 days; 13%).

Both required measurements in PM_{2.5} (OCEC/ions) can be performed with a low-volume sampler and a filter suitable for both, which in this case must be quartz.

Note that the objective of PM_{2.5} chemical analysis is to obtain data for source apportionment studies. In this case, it is also necessary to determine metals and organic tracers (such as levoglucosan; recommended for super-sites). All measurements must be taken on the same day. A large-volume sampler (all analyses on the same filter, which must be high-purity quartz) or several (2 or 3) low-volume samplers must be used to obtain a suitable sample. In source apportionment studies, it is necessary to determine the tracers (metals and organic compounds) as described in RI-URBANS and Amato et al. (2024). To determine the concentration of metals, it is necessary to carry out a total acid digestion of the filters using HF (which allows the digestion of silicates and aluminosilicates) and not the standard method of the directive for the determination of As, Cd, Ni and Pb (EN14902:2005).

Analysis of deposition rates

Monthly to weekly sampling throughout the year is recommended to measure deposition. “Wet-only” or total collectors can be used. To measure PAHs, the global funnel-bottle collector is recommended as the standard collector. Deposition collectors can be located at another nearby site if EMEP requirements are not accomplished. The cost of the deposition sampler is estimated at <5 K€. Measurements can be fixed or indicative. The minimum annual data coverage for indicative measurements is 13% (the percentage for fixed measurements is not specified). We have considered a weekly sampling (56 samples) with an analysis of only 8 samples per year (13% of the days).

It is necessary to check whether the same sample can be used for all determinations; if not, the number of samplers will have to be doubled.

The species to be determined in deposition samples from urban and rural background sites are:

As, Cd, Ni, Pb and Hg: We have estimated an analytical cost for the analysis of As, Cd, Ni, Pb and another for Hg; but these prices are very unrealistic.

PAHs (BaP, BaA, BbF, BkF, BkF, DBahA and INP): As in the case of metals/metalloids, the prices for sample preparation and analysis are highly unrealistic.

Benzene/VOCs

Measurements of benzene and other VOCs (a list of 45 VOC is provided in Annex VII of the Directive) are required, as O₃ precursors. Benzene measurement is relatively simple, but measuring all the required VOCs is very complicated. Two options: (1) Sequential sampling and laboratory analysis: low temporal resolution and low number of chemicals compounds. The cost of sampling equipment has been included, but the cost of analysis has not been included; and (2) Continuous measurement: this requires expensive equipment and specialized technical staff. Equipment can be purchased to measure BTX (approx. 50 K€) or more complex equipment to measure a greater number of chemical compounds (ToF-PTRMS; 400 K€).

Total gaseous mercury

It is required in rural background sites. Tekran price 90 KEu is without VAT, including all necessary parts (calibrator + parts, zero air generator, maintenance package). Cheaper AAS alternatives may have accuracy problems in the low ambient concentration levels. Tekran require argon 5.0 as carrier (annually 4x50L), that is the main drawback of the method.

OTHER RECOMMENDED MEASURES

Oxidative potential (OP):

OP should be determined in PM_{2.5} filters that are chemically analysed. There is no reference method. RI-URBANS/ACTRIS has a working group that is harmonizing the measurement, and differences between laboratories have been observed. It is very important that the analyses are carried out by an experienced laboratory and to continue harmonization efforts.

Ammonia (NH₃):

There is no standard method. Currently, equipment for continuous measurement of NH₃ concentrations has limitations. The most economical option is sampling with passive or diffusive collectors impregnated with an absorbent material, such as citric acid, exposed for 1 week to 1 month. The acid-impregnated grids of the diffusion

tubes are generally extracted in ultrapure water and the NH_3 concentration is determined by an ion chromatography method, for example.

Levoglucosan:

this is a biomass burning tracer. Its measurement is recommended as part of $\text{PM}_{2.5}$ speciation, so it should be analysed in $\text{PM}_{2.5}$ filters where chemical determination is performed. There is a standard method: CEN/TS 18044:2024, based on chromatographic analysis of filters sampled with low- or high-volume pumps.

Particulate and gaseous mercury:

Nitric acid. For nitric acid either as NH_3 (sampling with passive or diffusive collectors impregnated with an absorbent material, such as sodium carbonate, exposed for 1 week to 1 month), or PILS-IC for high resolution measurements.