COMPAIR

DELIVERABLE

D7.3 Citizen Science and its Potential to Policy Ready Data

Project Acronym:	**COMPAIR**
Project title:	Community Observation Measurement & Participation in AIR Science
Grant Agreement No.	101036563
Website:	www.wecompair.eu
Version:	1.0
Date:	30 September 2024
Responsible Partner:	EAP
Contributing Partners:	AIV, INT3, DAEM, ECSA, IMEC, TELR, UAEG, VMM
Reviewers:	DV (AIV), UAEG, VMM External: Gitte Kragh - Aarhus University (DK) Andrew Stott - Independent (UK) Otakar Čerba - UWB (CZ) Karel Jedlička - UWB (CZ)
Dissemination Level:	Public — X Confidential, only for members of the consortium (including the Commission Services)

This project has received financial support from the European Union's Horizon 2020 Programme under grant agreement no. 101036563

Revision History

Version	Date	Author	Organization	Description
0.1	08/07/2024	Milena Agopyan	EAP	Initial structure
0.2	14/08/2024	Milena Agopyan	EAP	Plovdiv pilot input
0.3	12/09/2024	Dimitra Tsakanika, Ilia Christantoni, Dessislva Todorova	DAEM, SDA	Pilot input
0.4	12/09/2024	Tom Callens	DV	Internal review
0.5	16/09/2024	Gesine Wilbrandt	inter 3	Internal review
0.6	18/09/2024	Gitte Kragh Andrew Stott Otakar Čerba	Aarhus University (DK) independent (UK) UWB (CZ)	External review
1.0	27/09/2024	Milena Agopyan	EAP	Final version

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List of Abbreviations

Abbreviation	Definition
AR	Augmented Reality
CS	Citizen Science
AQ	Air Quality
BC	Black carbon
CO2	Carbon dioxide
CS	Citizen Science
DAEM	Dimos Athinaion Epicheirisi Michanografis
DEVA	Dynamic Exposure Visualisation Application
DEVD	Dynamic Exposure Visualisation Dashboard
DIY	Do It Yourself
DT	Digital Twins
EAP	Energy Agency Plovdiv
EC	European Commission
ECSA	European Citizen Science Association
EEA	European Environmental Agency
EU	European Union
INT3	Institute for Resource Management
IoT	Internet of Things
LSES	Lower Socio-Economic Status
NGO	Non-governmental organisation
NO2	Nitrogen Dioxide
O3	Ozone
PM	Particulate Matter
PMD	Policy Monitoring Dashboard
SDA	Sofia Development Association
SES	Socio-Economic Status
UAEG	University of the Aegean
VMM	Flanders Environment Agency
WP	Work Package
WS	Workshop

Executive Summary

In recent years, citizen science initiatives that use the power of citizens to contribute to research and data collection are rapidly rising. One of the most significant strengths of citizen science is its potential to produce policy-ready data that can inform and shape decision-making. In the **COMPAIR** project, citizen science initiatives focus on issues directly related to local communities - namely air quality, awareness raising, and measures to improve it. The participation of local communities leads to the generation of more fine-grained, accurate, reliable and context-specific data, which in turn can fuel more effective policy interventions.

This deliverable "D7.3 Citizen Science and its Potential to Policy Ready Data" describes the COMPAIR approach for creating data ready for policy making. We began with studies and sharing experiences with evidence-based policymaking and continued with simulations of policy impacts and co-policymaking processes during policy development, implementation and evaluation of specific recommendations. The co-creation process begins with WP5 (Pilot CS Experiments & Co-Innovation) and covers policy and science-related experiments, combining the engagement and design actions. The active participation of citizens in data gathering, collection and analysis helps build trust between them, researchers, and policymakers.

A set of digital tools were developed to ensure the combining of multiple data sources, integration of different data types, visualisation and suggestion formulation. The creation of data ready for policymaking asks for knowledge about the possible use of the data, and mechanisms to calibrate and safeguard quality. The use of CS data by the government as a source for policy decisions (based on historical and live data) needs was tested and evaluated on its potential and was used to formulate best practices and lessons learned.

The participation of various groups of citizens (such as students, elderly persons, etc.) and the integration of diverse types of data (such as traffic volume, and air pollution levels) enable the development of innovative solutions. This, in turn, leads to improved policymaking based on evidence and refinements during policy implementation. Citizen science holds significant potential in providing data that is ready for use in policymaking.

Increasing the number of measurement points for air quality is essential due to the limited availability of official AQ and traffic stations, which provide incomplete information to citizens. Encouraging citizen participation in such experiments can bridge the information gap, leading to more extensive monitoring across various locations. By involving citizens in data generation and analysis, they can contribute to policy decisions related to air quality and mobility, enhancing social inclusion in policy-making processes. The COMPAIR project involved diverse community groups and emphasised the importance of co-creation with citizens for effective policy-making. Personal involvement in air quality experiments raised awareness and knowledge among participants, motivating them to adopt sustainable habits. Replicating these experiments in other EU cities can expand the AQ measurement network and support air pollution mitigation efforts, while serving as a valuable resource for stakeholders looking to address similar challenges.

1. Introduction

In the digital era, the public has more and more access to information. Thus, they can learn about new challenges and solutions or confirm their understanding. Using information helps people make informed choices. For example:

- when choosing a home, in addition to the location and the price (rent), the broker can get information about the conditions in the area - availability of educational and medical facilities, transport connectivity, etc., which would facilitate their daily life. Experts can help them understand how energy efficient the home is and what the air quality is like in the area (whether there is an official air quality measuring station nearby or similar civic networks);

- when buying a new car, they can check whether and how much harmful emissions it emits, how far it can go on a single charge, and regular technical inspections at the workshop help reduce uncertainty about other factors, ensuring that the car is running efficiently.

The examples show how in our personal lives data can be collected to provide valuable information that we rely on to make our decisions. Credible and valid information that is clearly presented, including with the help of experts, allows us to make better decisions that meet our needs and goals.

Similarly, the government is also expected to use information to work effectively and efficiently. With technology development and access to information about citizens' problems, expectations for government efficiency are greater. For decision-making, policymakers need accurate and reliable information, which is only sometimes available. The wider application of evidence in policy-making helps to make the relevant policy decision more quickly.

The project **COMPAIR** is designed to bolster citizens' capacity to monitor, understand, and change their environmental impact at a behavioural and policy level. It unlocks the power of the wider public, including people from lower socioeconomic groups, to provide broad granular data around a central theme of air quality, complementing and improving the quality of official datasets and making new information useful for research purposes, policy-making, and behavioural change.

The main goal of this deliverable is to show the potential of CS data for policy making during the project implementation, including findings and experiences in integrating different types of CS data in the policy data creation and policy-making process. To develop effective policies, policymakers need informed, evidence-based decisions. Collecting large sets of AQ data using traditional methods would take time and money. Citizen science offers timely, innovative and cost-effective solutions.

2. Methodology

Within the COMPAIR project, by 'policy' we mean a set of ideas or a plan of what to do (specifically to improve air quality) that is formally agreed by politicians at local, regional or national level. The pilots have strategic documents through which they have committed to implement such policies:

- Athens - Athens Resilience Strategy for 2030;
- Berlin - Clean Air Plan for Berlin Urban Development Plan Mobility and Transport Berlin 2030;
- Flanders - Local energy and climate pack;
- Plovdiv - Plovdiv Municipality program for improvement of air quality;
- Sofia - Sofia Municipality program for improvement of air quality.

Evidence-based policymaking is a process based primarily on facts and evidence rather than theories and political attitudes. The University of Oxford defines it as “Evidence-based policymaking refers to the method of policy development that consults facts and credible, relevant evidence to make decisions, over political opinion or theory.”[1]

The process involves collecting data and analysing it using science based approaches. This creates evidence on which decisions can be based. Evidence-based policymaking uses knowledge about what works to inform policy deliberations at all stages of the process. Whether determining which policies to advance, setting funding levels or developing regulations, evidence must be generated and available to meet this need. Policymakers can use evidence at different stages of the policymaking process, from defining a problem to identifying a solution.

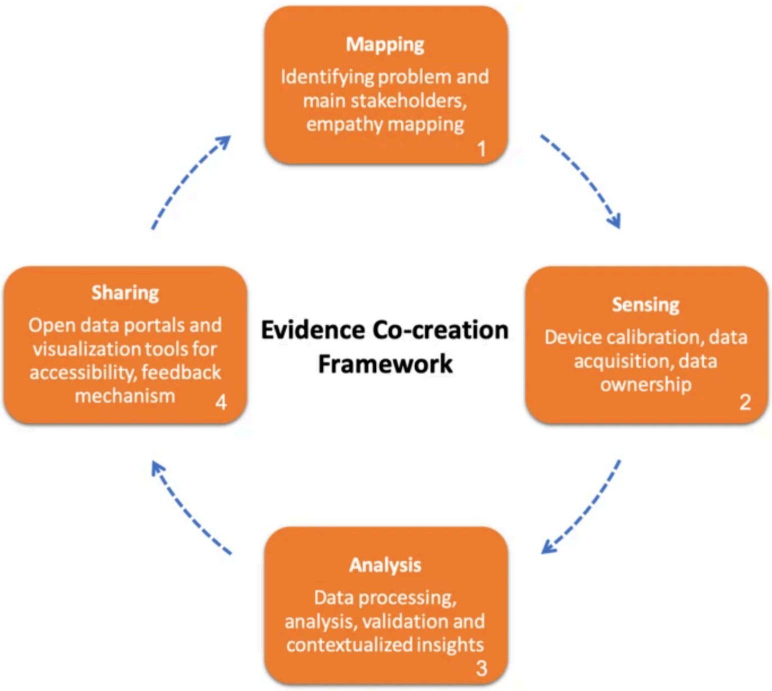
PoliVisu[2] was an EU-funded Research and Innovation project designed to evolve the traditional public policy-making cycle using big data. The aim is to enhance an open set of digital tools to leverage data to help public sector decision-making become more democratic by (a) experimenting with different policy options through impact visualisation and (b) using the resulting visualisations to engage and harness the collective intelligence of policy stakeholders for collaborative solution development. In the frame of the project was created a guideline for Policy making process -how to design, implement and evaluate. The start point is policy design and is implemented in four steps which are 1) problem setting, 2) policy formulation, 3) scenario analysis, and 4) decision.

[1] A guide to evidence based policymaking
[2] PoliVisu

picture source: PoliVisu project

Figure 1: Policy design process

The Evidence Co-creation Framework (ECF) proposed a solution for how citizen-generated data can be used as evidence for policy-making purposes (Mahajan S.,2022)[3].



(picture source: https://www.nature.com/articles/s41599-022-01135-2#notes)

Figure 2: *Evidence co-creation framework*

This framework represents four iterative processes for creating evidence based on citizen-generated data. These processes are: mapping, sensing, analysis and sharing.

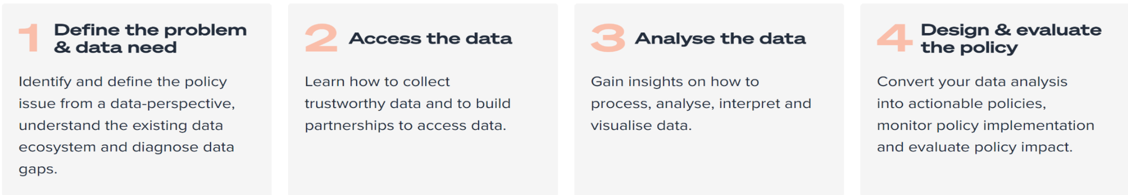
The Data to Policy Navigator[4] is a tool developed by UNDP in collaboration with the German Agency for International Cooperation (GIZ) on behalf of the German Federal Ministry for

[3] Translating citizen-generated air quality data into evidence for shaping policy
[4] Data to Policy Navigator

Economic Cooperation and Development (BMZ) and provides a step-by-step guide and a range of practical examples from across the globe on how to integrate data into policy and programme development. It aims to give policymakers the know-how to systematically integrate new data sources into their decision-making and policy-development processes.

The Navigator offers step-by-step actionable recommendations and examples throughout the policy development process, starting with problem definition to policy design and evaluation. The tool will be used as a base to show the potential of the collected data in the COMPAIR project to be transformed into policy-ready data.

The Data to Policy Navigator recommends 4 steps:



(picture source: https://www.datatopolicy.org)

Figure 3: *The main steps for data-driven policymaking*

By following the sequence of processes from the Evidence co-creation framework and using the Policy Navigator we will show readiness of COMPAIR citizens generated data for policymaking.

3. Policy making data readiness

The creation of data ready for policymaking goes through several stages - problem definition, stakeholder mapping and engagement together with identifying data sources, data collection visualisation and analysis, and dissemination and communication of the collected data.

In the **COMPAIR** project the citizens are empowered in CS Labs (a type of Living Lab) with the skills to co-design and undertake environmental scientific experiments around needs and challenges in their locality. By providing innovative, self-assembly, low-cost sensors, dynamic dashboards, and augmented reality tools for collecting, visualising, and extracting actionable intelligence from data, citizen scientists using the COMPAIR tools can understand their impact on the environment and explore immediate actions to improve it. Beyond helping to mitigate bad environmental habits at an individual and community level, CS (Citizen Science) data could be used to mutually enrich other public and private data sources in official city decision making platforms such as public sector digital twins. This helps to increase civic engagement and influence more effective long-term environmental policy. To ensure the citizen-generated data as evidence for policy purposes the **COMPAIR** project activities were implemented 5 steps:

- ***1st step*** - Problem definition

- ***2nd step*** - Stakeholder Mapping & Engagement
- ***3rd step*** – Identifying the challenges and local needs in each pilot area
- ***4th step*** – Data collection, visualisation and analysis
- ***5th step*** - Dissemination and communication

The 1st, 2nd and 3rd steps are set up activities to develop and prepare CS experiments. Steps 3, 4 and 5 are focused on collecting data and transforming it into evidence-based policies.

3.1. Step 1 – Problem definition

Official measuring stations can provide some data on urban air pollutants, general weather conditions etc., but these are on a macroscale and do not necessarily paint a complete picture of a whole city. However, an opportunity to supplement city data for public sector decision making, in a manner that gives ownership of the data back to the public for actionable change, presents itself in the form of citizen science performed by the people living in the very areas that require change.

Each pilot defined concrete problems in their area related to the lack of enough available data that can be described and analysed in more detail local air quality issues.

The Athens Pilot
The Athens pilot engaged end-users/citizens in participating in the behavioural change towards a reduced carbon footprint and better air-quality. This was achieved through the development of a CO2 Simulation Dashboard available to end-users which was combined with distributed air quality sensors. Also combined the outputs from the first pilot with the Athens Digital City Twin that was used for simulations by using AI and performing "What-if" scenarios to support evidence-based decision making.

The Berlin pilot
The Berlin pilot was focused on citizen engagement to stimulate behavioural change, while filling gaps in official monitoring data with data collected by cyclists, determination of cyclist personal exposure and the impact of a parking ban in the Graefekriez neighbourhood.
There were created more liveable city environments through awareness-raising campaigns and AR app usage. Also were evaluated the effects of local car traffic-free zones and were used DIY traffic count and air quality sensors to measure the modal shift and air quality in the playstreet itself and the surrounding streets. The results were available on project PMD.

The Flanders Pilot
The Flanders pilot enhanced the use of CS initiatives and increased public involvement in them by using citizen science data for policymaking as a way to improve climate quality in urbanised areas and to maximise the impact of evidence-based policy making with special attention to lower SES groups that are difficult to reach. The modal shift and air quality

impact of implementation of school streets (streets that are blocked for cars around a school during the moments that children go to or leave the school) were evaluated. The sensors were installed in people's homes and results were shared amongst policymakers in the city, the school, parents and people living in the neighbourhood. The air quality and traffic CS data were integrated into the Flanders Digital City Twin.

The Sofia/Plovdiv pilots

The Sofia/Plovdiv pilots enhanced citizen science to cope with environmental problems related to commuting behaviour, sustainable mobility for students and choice of transport in general. The pilots organised campaigns for AQ measurement around schools, creating environmental awareness amongst children and their families. In Plovdiv pilots used a mobile air quality laboratory of EAP,which provided independent measurements to validate and verified the official monitoring points and citizen sensors and raised awareness on site through constant display of air quality data. The AQ measurements were combined with Telraam traffic and the impact of the traffic intensity on AQ was evaluated.

3.2. Stakeholder Mapping & Engagement

COMPAIR has adopted the quadruple helix framework for its stakeholder engagement. The pilot areas are five in four EU countries, namely Athens (Greece), Berlin (Germany), Flanders (Belgium) and Sofia & Plovdiv (Bulgaria). For each pilot location, a Policy Network Canvas was created as a basis for stakeholder engagement and co-creation workshops. The main stakeholders belong to the groups of citizens, businesses, researchers and government.

Each pilot organised co-creation workshops to find the stakeholders who wanted to participate in the project and to contribute to each step. The main stakeholders and their engagement are described in D2.1 Value Network Canvas. The goal is to make CS results relevant for decision-making and future research by bringing together representatives of public administrations (municipalities, regional governments), businesses (start-ups, SMEs, corporations), and academia (think tanks, universities, private institutes).

3.3. Identifying the challenges and local needs

3.2.1. Identifying the challenges

In the beginning of the COMPAIR each pilot defined the challenges and local needs in their area through the co–design workshops with stakeholders.

D2.3 Policy Landscape Review identified relevant public measures (strategies, plans, policies etc.) in each pilot location (Athens, Berlin, Flanders, and Sofia/Plovdiv) that can be enriched by citizen science (CS)/ COMPAIR results.

The interaction between different stakeholders was used to understand the issues in detail for each group, what works well for them, what does not, barriers they face etc. These workshops frame specific challenges that will be tackled and draft scenarios for implementation of COMPAIR CS activities, which are aligned with current policy priorities in the pilot areas.

Table 1: *Identified local needs in pilot areas*

Pilot	Local need	Policy
Athens (Greece)	- Creating awareness on air quality among citizens with focus on lowSES group of elderly - Measurements of air quality at street level with civic engagement - Engagement of citizens in environmental data collection for measures and policies support - Calculating carbon footprint using a dashboard	- Rising awareness on air quality - Behavioural change
Berlin (Germany)	- Raising awareness on air quality and traffic with neighbours of two Berlin districts as well as commuting cyclists across Berlin - Diverse usage of sensors/devices and further technical tools - Reconfiguration of parking spaces	- Rising awareness on air quality and traffic - Evaluation of the effects of local car traffic-free zones - Behavioural change
Flanders (Belgium)	- Raising awareness on air quality with kids in schools - Raising awareness on wood burning and air quality with citizens and environmental council - Demonstrating the impact of a mobility plan on traffic and air quality	- Rising awareness on air quality - Rising awareness on wood burning - Evaluation of the mobility plan on air quality and traffic
Plovdiv (Bulgaria)	- Raising awareness of the impact of traffic on air pollution - Raising awareness of the impact of traffic on air pollution and seasonal variation of PM10 - CO_2 calculator usage	- Raising awareness of the impact of traffic on air pollution - Raising awareness of the impact of traffic on air pollution and seasonal variation of PM10
Sofia (Bulgaria)	- School bus service - The importance of room ventilation in kindergarten - CO_2 calculator usage - Raising awareness of the impact of	- Raising awareness of the impact of traffic on air pollution among children in schools, parents and other stakeholders

	traffic on air pollution among children in schools, parents and other stakeholders	

Experiments, called use cases, were created to cover the local needs and meet the concrete challenges in each location.

3.2.2. Identifying data sources

The COMPAIR technical team asked all the pilots if there was an official AQ measurement station on their territory. All official stations were visualised on a PMD and data were collected.

During the Close testing and Open round, the sensors that will be used in each pilot area were selected.

Table 2: *Sensors used in pilot areas*

Pilot	Sensors used
Athens (Greece)	- DIY devices from sensor.community - PM measurement - SODAQ AIR devices - PM measurement - NO2 devices - NO2 measurements - BCmeter sensors - black carbon measurements
Berlin (Germany)	- DIY devices from sensor.community - PM measurement - SODAQ AIR devices - PM measurement - DIY devices bcMeters - black carbon measurement - Telraam S2 devices - traffic measurement
Flanders (Belgium)	- DIY devices from sensor.community - PM measurement - SODAQ AIR devices - PM measurement - bcMeters - black carbon measurement - Telraam S2 devices - traffic measurement - NitroSense - NO2 sensor boxes
Plovdiv (Bulgaria)	- DIY devices from sensor.community - PM measurement - Telraam v1 devices - traffic measurement
Sofia (Bulgaria)	- DIY devices from sensor.community - PM measurement - Telraam v1 devices - traffic measurement

Due to the connectivity issues the pilots in Bulgaria used only devices based on wi-fi data transfer.

The COMPAIR experiences and difficulties connecting IoT devices suitable for Citizen Science and Smart City measurements via narrowband connection systems have consequences for cities and regions without good connectivity. The COMPAIR consortium noticed considerable differences between member states that hinder the future roll-out of smart cities all over Europe. Measures at a European scale to ensure that next to 5G and 6G connectivity and narrowband connections are available are important to allow new IoT innovations across Europe. These networks in countries with a Citizen Science project culture are better available (e.g. Belgium, The Netherlands, and Germany) than in Greece or Bulgaria. The current situation will further widen the gap between member states; recently due to the technologies development there is a shift of the CS projects towards using more IoT-based sensors. The rollout of IoT technologies will optimise the way we live our lives. The number of installed IoT connected devices is projected to increase from some 40 billion in 2023 to 49 billion by 2026, growing at a compound annual growth rate of 7% (International Data Corporation)[5].

Experiences during the COMPAIR project

COMPAIR stands for Community Observation Measurement & Participation in AIR Science and is a citizen science project, using air quality & traffic counting IoT sensors, specifically (among other sensors) SODAQ AIR & Telraam S2. These IoT sensors need constant internet to send data in almost real-time to the cloud. They use common IoT network types, which are available in most cities. The sensors work with two popular standards: LTE-M and NB-IoT. LTE-M is a special low-power network for devices, while NB-IoT is another low-power option for IoT connections. Regular LTE (used in phones) isn't suitable because it uses too much power and is too expensive for simple devices.

Problems experienced

COMPAIR sensors were deployed in cities in Belgium, Germany, Greece and Bulgaria. IoT-connectivity was seamlessly available in all countries, except Bulgaria. Although deployment of sensors was in 2 major Bulgarian cities (Sofia & Plovdiv) where we expect good coverage for at least one of the IoT radio communication technologies (LTE-M or NB-IoT), it was not possible to establish connectivity for any of the sensors.

Actions taken within COMPAIR

We've undertaken a number of actions to resolve the issues, in sequence:

1. Contact local telco operators to activate LTE-M/NB-IoT at least locally in specific areas of interest for the project, either directly or via intermediate service providers ⇒ no impact whatsoever (no leverage over telco operators)

2. Change operators (change SIM-cards) ⇒ no solution, as all operators have the same issue. A1 is the only operator in BG claiming to offer NB-IoT coverage, but none of the sensor-providers in COMPAIR were able to establish reliable NB-IoT connection, due to unavailable coverage

3. Explored retrofit solutions to convert connectivity to (classic) LTE ⇒ while this is a technically working solution, this was considered not feasible as it involves high cost (hardware change, expensive LTE-modem, expensive data communication), which basically makes it unsuitable as a solution for citizen science IoT sensors, aiming for low cost.

[5] Europe's Internet of Things Policy

4. Should we also add the investigation for a router/bridge that could theoretically capture the sensor's connection and connect to 4g?

In the end, insofar as possible, we opted for a roll-back to wifi-connectivity which poses challenges on its own (cumbersome installation, requirement of wifi connectivity nearby, unreliability of wifi,...). Not the solution we hoped to find.

Assessment & recommendation

Lack of NB-IoT AND LTE-M connectivity for connected devices in Bulgaria was an inconvenient surprise for the COMPAIR project. We embarked on this project not expecting we would experience connectivity issues for any of the sensors (at least in urban environments) as long as we made sure sensors used LTE-M and NB-IoT.

This assumption was based on public information from operator's and intermediarie's own coverage maps (example 1 - example 2). Clearly, these coverage maps do not reflect reality on the ground and some operators, while claiming to offer NB-IoT & LTE-M are in fact not providing this service.

For citizen science relying on IoT sensors, data communication using LTE-M or NB-IoT is crucial to keep costs low. To ensure all EU citizens have access to this service, a clear push is needed to force Telco-operators to implement these technologies.

In future development of the European telecommunications regulatory framework consideration should be given to ensuring telecom operators provide LTE-M and NB-IoT. This would enable a future rollout of IoT devices at low cost across Europe. Keeping the connectivity and data exchange costs low is essential for a successful future roll-out of affordable IoT sensor networks to support local smart city initiatives.

3.4. Data collection, visualisation and analysis

3.3.1. Data collection

After stakeholders mapping and creating CS activities design we started with data collection. The process consists of three phases:

1. ***Closed round*** – the consortium partners made internal tests and adjusted CS experiments. The performed activities were described in D5.2 Closed Testing Report;
2. ***Open round*** – narrow circle of stakeholders who have expressed their desire to participate in all phases of the project testing the CS activities and giving feedback for data collection, analysis and visualisation improvements. The volunteers participated in training, games, and used COMPAIR tools to make sense of data. Policymakers had the possibility to compare data from official measuring stations and CS tools. The performed activities were described in the D5.4 Open Round report;

3. ***Public round*** — **COMPAIR** was opened to the wider public. Citizens, policymakers, and other stakeholders contributed to the co-innovation activities, such as data jams and policy hackathons (ideathons). The citizens were encouraged to use CS-generated data and project tools to find useful insights and, through participation in Ideathons, act as policy co-creators. The performed activities were described in the D5.6 Public Round report.

In this step, stakeholders jointly determine how and what data to collect and organise data collection campaigns. Ethical issues related to informed consent and data ownership are addressed. Citizens are made aware of the necessary privacy and anonymity protocols that are part of the data collection and processing process.

Participation in air quality monitoring requires specific knowledge and skills on the part of the participants. They need to be familiar with different pollutant types, characteristics and detection limits, know what a sensor is valid for, and how to use it and/or build it (in the case of do-it-yourself devices). They need to know how to test and calibrate their devices to ensure they are making accurate measurements, as well as how to maintain their equipment to provide stable performance over an extended period. All of this was covered by the COMPAIR project's comprehensive, multi-stage training programme, which included:

- Air quality training;
- Sensor training;
- Data collection training;
- Training on how to use COMPAIR digital tools.

Low-cost sensors collected CS data in accordance with the experiment rules. The data collected by SODAQAir sensors were calibrated with official city sensors to increase their trustworthiness. Calibration was needed to overcome CS Air Quality sensor's limitations concerning accuracy. The calibration process is described in D3.5 Data Processing and Data Calibration of Air Quality Sensors and combines raw (inaccurate) measurements from CS sensors with high-quality data from reference stations and uplifts in real-time the accuracy of the measurements.

The COMPAIR CS Labs are in the centre of the project which offers both a physical and online resource for bringing together all participants. The concrete CS Lab activities were determined in each pilot during co- creation workshops that brought citizens, businesses and policymakers.

The COMPAIR CS Labs are equipped with digital tools that facilitate data collection, analysis and visualisation such us:

- Augmented Reality (AR) App
- Dynamic Exposure Visualisation Dashboard
- Carbon Footprint Simulation Dashboard
- Policy Monitoring Dashboard
- Digital Twin Dashboard

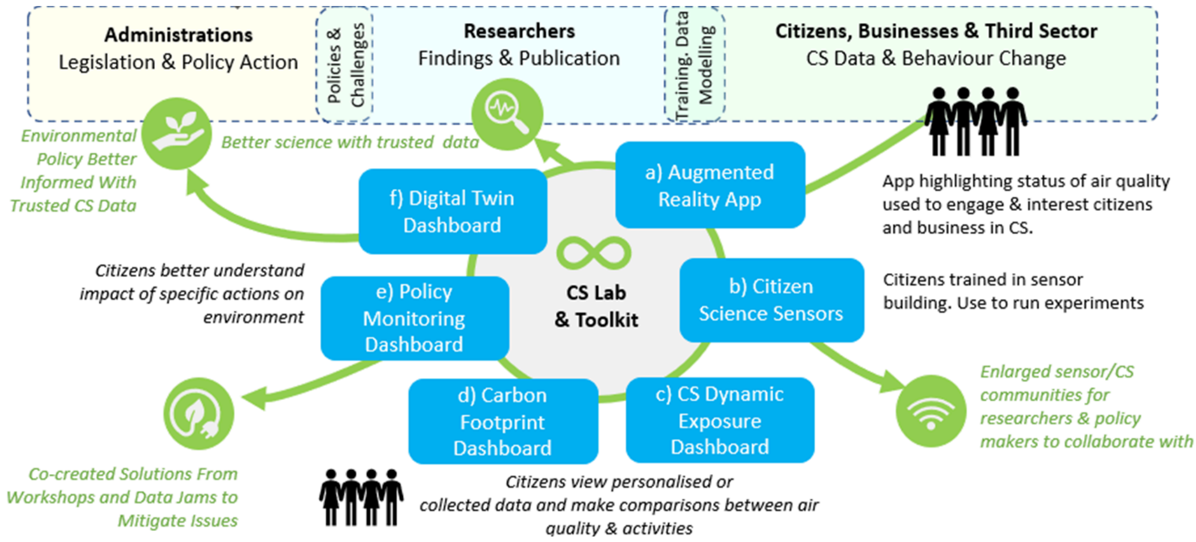


Figure 4: *COMPAIR digital tools*

The digital tools were used in different combinations to fit the experiments and user needs. The guidelines on how to use the sensors and digital tools were created. In each pilot area were organised training dedicated to sensors and digital tools usage. The digital tools, design thinking methodology, and training materials formed a COMPAIR CS Toolkit for experiments. The CS Dynamic Exposure Visualisation Dashboard and Carbon Footprint Simulation Dashboard are integrated into the Policy Monitoring Dashboard.

All of the digital tools are available free of charge online. Anybody can download the collected data from PMD for additional personal analysis.

3.3.2. Visualisation and data analysis

Data collection and analysis often result in the generation of challenging to interpret large data sets. This requires them to be translated and communicated in a way that is easier for everyone to understand. Interactive visualisations and digital tools make sharing evidence and getting feedback from multiple stakeholders easy. Feedback is essential as it allows stakeholders to analyse the experiments and results and provide suggestions for refinement.

To address the user needs, a user-driven approach is being followed in COMPAIR to produce the necessary dashboard screens via a process of paper sketches, visual mock-ups and iterative versions of the new screens until the desired result is obtained. Each pilot organised a series of co-creation workshops with stakeholders to understand their needs and to create tools that cover their needs. Because of different needs, several dashboards were created. Four main dashboards were encapsulated under a common user interface (container UI) that will also realise standard functionalities like page navigation, user login, language selection, etc. All dashboards are available at this link: https://monitoring.wecompair.eu/

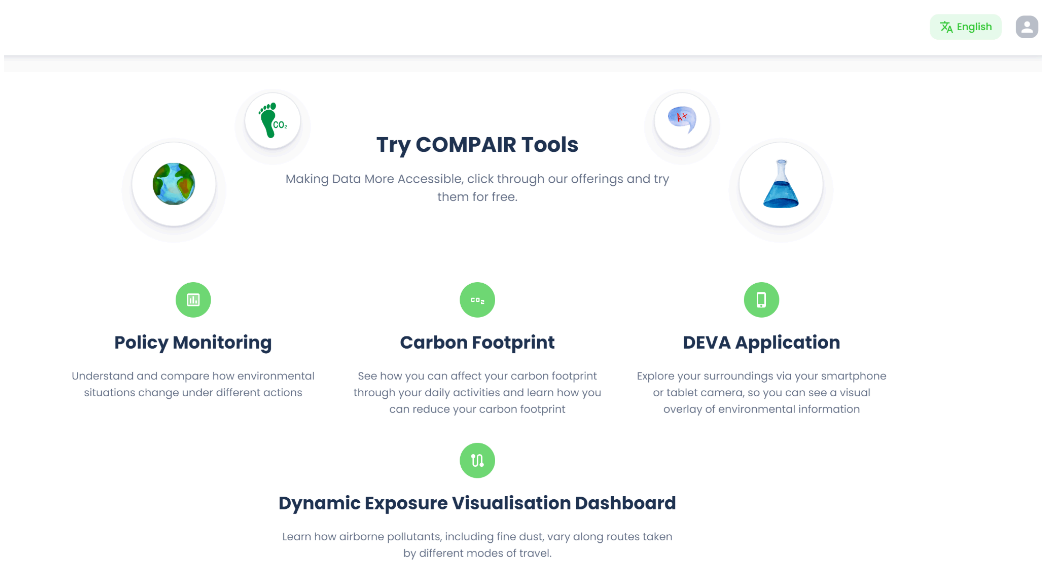


***Figure 5:** COMPAIR dashboards*

The Policy Monitoring Dashboard (PMD) helps users understand and compare how environmental situations change under different actions. By collecting a large amount of Citizen Science (CS) information in a particular setting, the Dashboard simulates future impacts for other variables, e.g., time of road closures, differing routes to school and staggered start times for work or schooling.

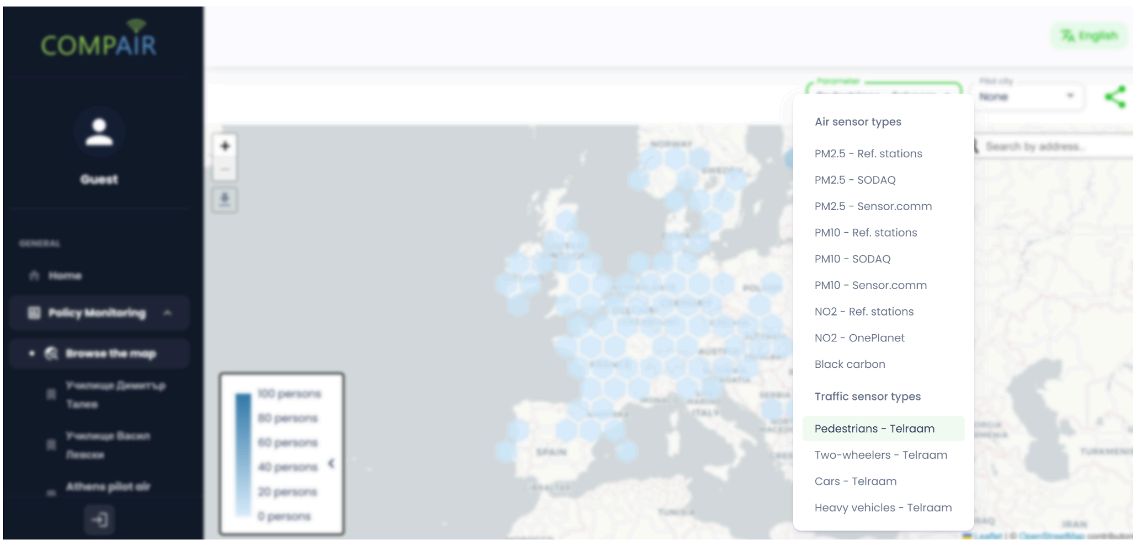


***Figure 6:** COMPAIR policy monitoring dashboard*

Collected data from the official AQ measurement station and all types of used sensors in each pilot area were visualised on a PMD. In Project mode, the user can export the data of the sensors that are part of the project in a csv file (list and pivot table), separated into two periods (1st period and 2nd period). The user can view quickscan and advanced graphs.

In the quick scan graphs, the user is presented by default with the deltas of each group and can show and hide other options as well (before/after each group). In the quick scan box, the user can quickly investigate traffic and air quality data before and after introducing a policy measure for the target and neighbourhood zones. The user can also select <Group Name> -

difference (relative in %) to see relative differences for air and traffic measurements in %. These measurements are depicted as a line with the matching colour of each group.

The advanced graphs can visually compare two vertically aligned graphs combining air/traffic data of the two groups. By hovering their mouse pointer over one plot, the user can reveal detailed information for both graphs at that date, allowing thorough inspection.

In all pilot areas, PMD was used as a primary tool for visualisation of the available data. This is not only a tool for visualisation but manages and processes air and traffic datasets. It enables users to interact with the citizen's generated data from different sensors to help them understand and compare how environmental situations change under different actions. For example, users can compare data before and after policy measure implementation to find the difference.

The online platform gives everybody free access to available data. Users can see the AQ status in different neighbourhoods in all pilot areas and compare it with the situation in their living area. Several versions/iterations of low—and high-fidelity mock-ups were already designed as part of the project's overall agile approach to depict the user functionalities more precisely and assist them in their tasks as best as possible.

The PMD is available in English and pilot country languages, and users can select the language they prefer. This tool is available on: https://monitoring.wecompair.eu/dashboards/policy-monitoring .

Carbon Footprint Simulation Dashboard was created to guide users in improving their behaviours through more environmentally friendly choices regarding their carbon footprint. Visualisations of algorithm results allow users to understand and compare how their daily actions (driving, recycling, etc.) affect future CO_2 levels and guide them to make more environmentally friendly choices like limiting waste and maximising recycling, replacing household appliances with less energy-consuming ones, choosing a more environmentally friendly car use (carpooling). The Carbon Footprint Simulation Dashboard consists of two tools. The first one is the Carbon Footprint Calculator, which calculates the user's carbon footprint and recommends actions on how to lower it. This tool is meant to help users understand how they affect their carbon footprint through their daily activities and provide recommendations on how to reduce their carbon footprint. The second tool is the Scenario Simulation Dashboard. This tool allows citizens to participate in policymaking. It presents a set of actions they are willing to make, as well as actions they are willing to accept from the government to reduce carbon emissions.

The CO2 dashboard is available on: https://monitoring.wecompair.eu/dashboards/carbon-footprint in English and Pilot country languages and users can select the language of their preference.

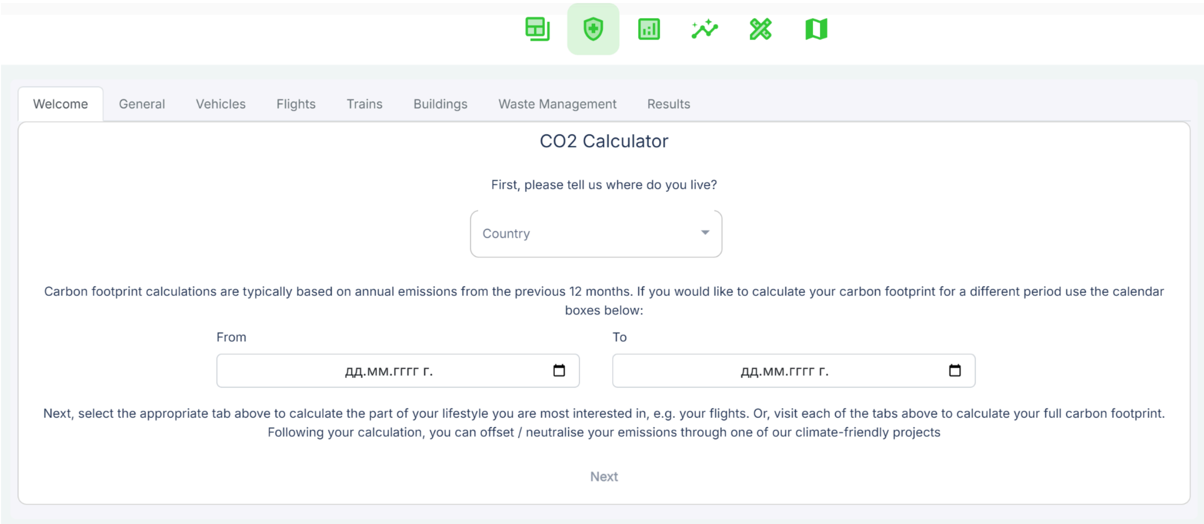


Figure 7: *COMPAIR Carbon Footprint Simulation Dashboard*

The pilots used this tool as:

- ***Athens (Greece)*** -

The CO2 footprint and Scenario Simulation tool is used in Athens pilot under Use Case 3 to measure CO footprint for the households of Athens. It also aims to collect data regarding everyday environmental habits and provide evidence and data for decision making by promoting the dialogue with the city and the opinion mining of citizens regarding the city policies. The Carbon Calculator raises awareness and provides insight on the effect of daily activities to carbon footprint. The tool’s recommendations aim to contribute to reduction of pollution and finally Athens pilot collects the intention of citizens to uptake individual actions and to adopt policies proposed by the municipality, region or government.

The use of the CO2 calculator was launched through campaigns mainly online and included MailChimp campaigns in a database of employees of the Municipality of Athens that included over 5000 individuals. Contacts are invited to create an account in the PMD. Additional online campaigns that took place focused on a diverse set of target groups for the calculation of households CO2 footprint in Athens, indicatively actively citizens groups, private companies, professionals in the field of energy efficiency and buildings, academia, public authorities, ministries, environmental NGOs, energy auditors for buildings etc

The Athens pilot activities on the CO2 footprint are supported by the Vice Mayor of Climate Change, the Department of Public Relations and the Department of Resilience and Sustainability.

Moreover the tool is promoted in the Synathina platform of the city, a common space for citizens’ groups engaged in improving the quality of life in Athens. Finally, the Co2 tools was used by followers of the National Documentation Center that promoted the tool in its newsletter.

For the next weeks of the project, an important campaign is designed and will be launched in 3 national online newspapers through banners in their first pages and their social media pages, as well as promotion from the Municipal Radio Station Athens 9.84.

- ***Plovdiv (Bulgaria)*** - due to the connectivity issues and a limited number of installed sensors in Plovdiv, the CO2 dashboard was one of the most used tools. We work mainly with students (from 11 to 14 years old) and volunteers from the LSES group. For them, it was more suitable to use the CO2 calculator. For the students, we organised a "train the trainers" campaign. We asked the school directors and teachers to find students from LSES households (students with disabilities, from families with low incomes, with more than 3 kids, with single parents) and our team trained them how to use the CO2 calculator. After training, they presented the calculator to their classmates and encouraged them to try it. For the volunteers, active citizens, and municipalities, we organised meetings and workshops as a part of our rising awareness campaign. We asked them to use it and share the results with us.

- ***Sofia (Bulgaria)*** - due to connectivity issues and a limited number of installed sensors in Sofia that led to a limited ability to use the other digital tools provided by COMPAIR, the focus of pilot activities was mainly on CO2 dashboard. An awareness-raising campaign was organised to promote the tool mainly outdoors but also an online media campaign was conducted. Over 40 locations on public transport stops, metro stations and billboards were spread among the whole city promoting the digital tool as an instrument citizens to check their personal carbon footprint and to track it over time supporting them to build sustainable living habits

The CO2 calculator was not used in Flanders (Belgium) and Berlin (Germany).

Dynamic Exposure Visualization Dashboard (DEV-D) is an easy-to-understand visual dashboard that assists users in comprehending and interpreting data gathered from a diverse range of mobile air quality sensors. This tool visualises a combination of geometric information from trips/routes recorded by the trip recorder, a key component of the Dynamic Exposure Visualization App (DEVA), and air quality data collected by mobile sensors like the SODAQ fine dust sensor measuring PM1.0, 2.5 and 10

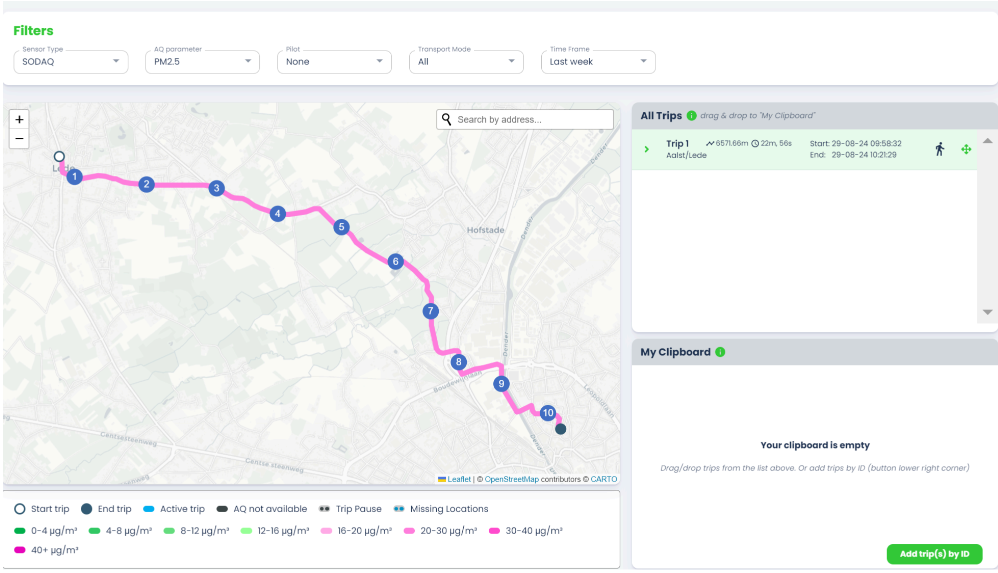


Figure 8: *COMPAIR Dynamic Exposure Visualisation Dashboard*

The tool is available on https://monitoring.wecompair.eu/dashboards/dev-d

In the Athens pilot the air quality measurements were static in the households of volunteers hence the tool is not applicable.

The DEV-D was used in **Berlin (Germany)** by the participants of the mobile measurement campaign - commuting cyclists across Berlin. Due to the fact that the dashboard was only usable for users with an Android smartphone and not an iphone and additionally the difficulties with the tool DEVA which needed to track the commuting path in order to be shown on DEV-D only 14 participants were able to test and use this tool. For some of the users the handling of this tool appeared convincing. Others criticised the app's complicated display of route documentation.

Flanders (Belgium) -
The students of a College of Geel & the University of Leuven started working with the SODAQ sensor, DEVA app & DEV-D dashboard. First, they were explained about air quality, the SODAQ sensor and the tools developed within CompAIR. Afterwards, they walked themselves to a VMM measurement station with the sensor and took measurements for another 3 weeks. The measurement period was extended due to difficulties with the DEVA app.

Due to the connectivity issues in Plovdiv and Sofia (Bulgaria) this tool was not used.

Dynamic Exposure Visualisation App - DEVA - Augmented Reality (AR) app, which allenable citizens to explore the environmental conditions in their surroundings via their smartphone or tablet using Augmented Reality (AR). So they see a visual overlay of environmental information such as air quality or traffic information.

***Figure 9:** Screenshot DEVA*

DEVA is planned to be used and demonstrated in the final activities of the Athens pilot that will take place at the end of September in order to showcase the effects of air quality and exposure to air pollution.

The DEVA was also used by the **Berlin (Germany)** pilot; concretely by the commuting cyclists across Berlin. Due to the fact that the app only works for Android users and the first version faced some bigger usage difficulties hardly any participants had used the app until the end of the measurement period. Around 26 participants tried the app at the beginning but only a few continued using it because the app drew too much battery and had overstrained the users with the complicated menu navigation. The second version was able to resolve the errors so that users could be won back and were satisfied with the usage. In general, many users only used the SODAQ device and not any other tracking or visualisation tools. This also explains the poor utilisation in terms of numbers.

In Flanders (Belgium) this tool was not used.
Due to the connectivity issues in Plovdiv and Sofia (Bulgaria) this tool was not used.

Digital Twins—Digital Twins are virtual representations of physical systems and their associated environments and processes. Flanders and Athens already had those created. The citizens generated data from COMPAIR air quality (Particulate Matter (PM), Nitrogen Dioxide (NO2), and Black Carbon (BC)), and traffic counting sensors were integrated into Athens and Flanders' Digital Twins.

Athens (Greece)—The CS data from the Athens pilot was integrated into the Athens digital twin to evaluate the impact of implementing green routing in Athens Stadiou Street, allowing only pedestrians and cyclists. This included evaluating citizen feedback and the impact on daily mobility using traffic modelling.

Flanders (Belgium)—Citizen Science APIs from the Flanders pilot area were integrated into the Flanders Digital Twin to visualise the most recent measurement data and provide a view of the historical data. In addition, the tool was used for traffic modelling.

The Flanders and Athens Digital Twin pilot cases show how a Digital Twin supported evidence-informed policy-making by integrating Citizen Science data and how a Digital Twin, including complex traffic modelling, involved citizens by allowing geo-tagged feedback to optimise decision-making in the smart city and urban planning field.

3.3.3. Data analysis

Each of the pilots encourages citizens to interpret the collected data and also the pilot teams prepared their analysis as follow:

Table 3: *Performed analysis by pilots*

Pilot	Performed analysis
Athens (Greece)	- Compare air quality indexes PM10, and PM2.5 within Kispeli area - Compare air quality indexes PM10, and PM2.5 within Neos Kosmos area from the measurements of SODAQ - Compare air pollution conditions between two areas in Athens (Kipseli and Neos Kosmos) - Analyse NO2 measurements from the two areas - Analysis of extraordinary conditions affecting the air quality e.g. works taking place - Analysis of external conditions that affect the quality of air due to weather extremes. - Compare the total collected data on the categories of CO2 emissions (transportation, flights, trains, waste, buildings) - Identify categories that affect mostly the overall CO2 pollution - Compare CO2 results from the 7 districts of Athens
Berlin (Germany)	- Comparison of air (PM 2.5) and traffic quality within two Berlin districts in Mitte and Neukölln (static campaign) - Comparison of PM 2.5 with traffic values and analysis of the connection between the two values for each district to detect potential effects of traffic calming measurements (static campaign) - Average exposure of PM 2.5 by all commuting cyclists (mobile campaign) - Number of measured days, and number of measurements of each commuting cyclists (mobile campaign) - Maximum amount of measured PM 2.5 per hour to detect hotspot times between the commuting cyclists (mobile campaign)

Flanders (Belgium)	- the variation in dynamic exposure of two groups of students in Ghent - Data validation/calculations - Daily profiles for each location during the Sint-Niklaas campaign - Comparing bike traffic count from manual counts, Telraam and pneumatic tube (per direction) - average concentration of NO2 for each hour of the day for each sensor individually, comparing the situation before and after the change - hourly averaged and cleaned bcMeter data (black carbon measurements)
Plovdiv (Bulgaria)	- Analysis of data from measurements with mobile AQ laboratory - PM10 and NO2 and pick values - Analysis of data from official AQ measurement stations - PM10 and NO2 and pick values - Analysis of data from traffic sensors - Comparison of AQ data with traffic intensity
Sofia (Bulgaria)	- Analysis of data gathered from the sensors installed at kindergarten and schools - Analysis of data gathered from the surveys spread among the parents users of the school bus municipal service

Athens pilot

Use cases 1 and 2

The analysis for the Athens pilot is mainly focused on comparing the data from the 2 areas of Kipseli and Neos Kosmos.In use cases 1 and 2 the analysis of the PMD data focused on:

- Browsing in the map of sensors' locations and measurements and
- from the projects' creation feature.

Three projects are created for experimental analysis, namely: a project to compare air quality indexes PM10, and PM2.5 within Kispeli area, a project to compare air quality indexes PM10, and PM2.5 within Neos Kosmos area and a project for the analysis of NO2 measurements from the two areas. Additional analysis in the Use cases 1 and 2 include:

- Comparison of air pollution conditions between two areas in Athens (Kispeli and Neos Kosmos)
- Analysis of internal conditions in each of the two areas by comparing sensors located in different streets and landscape e.g. hills and traffic roads
- Analysis of extraordinary conditions affecting the air quality e.g. works taking place is an area for a specific time period. An evident example are the works for the new metro station in Kipseli that is currently under construction.
- Analysis of conditions that affect the quality of air in the city and are external due to weather extremes.

Use case 3

In Use case 3 for the CO2 calculator tool and the Scenario Simulation Dashboard provides data that are studied as follows:

- Comparison the total collected data from citizens of Athens on the categories of CO2 emissions – transportation, flights, trains, waste and buildings
- Identification of the categories that affect more the overall pollution of the city.
- Each category analysed in terms of its distribution to CO2 emissions for the 7 districts of Athens.
- Comparison of CO2 results from the 7 districts of Athens

Berlin pilot

Use case 1 - mobile measurement campaign

The analysis for the Berlin pilot (mobile) was mainly focussed on identifying the individual exposure profiles of PM 2.5 by the participating commuting cyclists across Berlin. More concrete it addressed the following aspects:

- cumulative exposure of PM 2.5 across a cyclist's route
- Hotspots of PM 2.5 along the route
- individual participant's exposure of PM 2.5 related to the other participants
- Potential gain of knowledge of air quality after the project

To analyse the data of the SODAQ sensors the DEVA for tracking, the knowyourair.net website for tracking, visualising and analysing as well as the PMD for visualising and analysing was used. On the knowyourair.net website as well on PMD the cyclists could see their cumulative exposure of PM 2.5 on their commute and even see hotspots because the values of PM 2.5 were shown by different colours on a map. This individual feedback by the map (as well as the direct feedback of the device itself while cycling) helped the participants to understand and interpret the data because they were the experts. They were able to give us interpretations such as that they were at an intersection or had passed a truck that caused the PM value to shoot up.

Use case 2 - static measurement campaign

The analysis for the Berlin pilot (static) was mainly focussed on measuring and raising awareness on air quality and traffic with citizens in two Berlin neighbourhoods from their homes. The participants used the SODAQ sensors to capture PM 2.5, the DIY device bcmeter to measure black carbon and the Telraam device to track the traffic. Concretely, the static campaign measured:

- The potential differences between the traffic-calmed neighbourhood and the non-traffic-calmed neighbourhood in terms of PM 2.5, black carbon and traffic
- The linkage between the PM 2.5 and the intensity of traffic
- Potential gain of knowledge of air quality after the project

For the analysis the DEV-D was helpful for the participants. Here they could directly see the different values for PM 2.5 and traffic in direct comparison within a neighbourhood as well as in comparison between the two Berlin districts. On the Telraam website the participants had a great and organised visual overview of all the values related to the counted traffic within a measured street. Since the graphs and data provided on the DEV-D were quite limited the project team also used the collected SODAQ data by the knowyourair.net website to analyse the data.

Flanders pilot

For each use case a project was created on PMD.

Use case 1 - a primary school in Ghent

The students from three 5th grade classes explored air quality in their surroundings with the SODAQ PM sensors. They measured their daily route from home to school. Each morning the results were discussed in class and noted in the logbook.

Use case 2 - a secondary school in Herzele

The measurement project was carried out by two 5th secondary school classes (15 & 19 students), covering a time frame of 8 weeks, with a weekly time commitment of 1 hour. The SODAQ sensor, the air pipe sensor, the DEVA app and DEV-D - tools they would use for their measurements were explained. The project concluded with a presentation by the students on the results of their project. Based on the students' feedback, the DEVA app was modified. The Environmental Council students also got to work with the SODAQ sensors after the Easter holidays (own initiative- unaccompanied). This was to find the cleanest route from home to school.

Use case 3 - students of a College of Geel & the University of Leuven

With 5 students from the master in life sciences-food industry, we started working with the SODAQ sensor, DEVA app & DEV-D dashboard. They walked themselves to a VMM measurement station with the sensor and took measurements.

Use case 4 - citizens in Herzele

4 Citizens in Herzele measured black carbon with the BC sensor to evaluate the effect of the school street in Herzele.

Use case 5 - environmental council in Hove

Between January and March 2024, 8 members of the environmental council walked, cycled or ran in the streets of Hove, Belgium collecting roughly 9000 measurement blocks of PM2.5-data (each block is about 100x70m and implies at least one measurement during a single hour). Two different datasets were used in the analysis. One with the publicly available data from knowyourair.net and one with the raw sensor data. PM2.5-data were corrected for background regional pollution levels to be able to focus on the local contributions only. Data analysis was performed with statistical software R.

Use case 6 - circulation plan Ghent

There are 23 TELR-sensors, counting on 19 road segments (a few replacements and streets with 2 devices). The 4 NO2-sensors have been measured since the 1st of March 2024. The measurements were used for evaluation of the district circulation plan, which started on April 29th 2024.

Use case 7 - circulation plan Sint-Niklaas

The impact of traffic is measured by 10 TELR sensors since February 2024 and air quality by 4 NO2 sensor boxes to evaluate the effect of the circulation plan, which started 10 of June 2024.

Plovdiv pilot

Use case 1 - Raising awareness of the impact of traffic on air pollution - primary school Dimitar Talev

The mobile laboratory, situated in a school yard, measured NO2 and PM10 on an hourly basis. The analysis covered comparing the PM10 and NO2 concentration during school and non-school days; observed concentrations were lower than on school days. One PM DIY and one Telraam v1 traffic sensor were installed in one classroom in the school. The traffic intensity and hourly peaks were analysed and compared with PM10 and NO2 concentration.

Use case 2 - Raising awareness of the impact of traffic on air pollution and seasonal variation of PM10

The data for PM10 and NO2 concentration were collected from the official AQ station, Kamenitsa, and covered the period from April 2023 to the end of 30 May 2024. The data were analysed to find that PM10 has a seasonal variation and that there is a correlation between traffic intensity and NO2 concentrations. 10 PM DIY sensors were installed in the area by volunteers. The area is covered by the official AQ station. The data from the one DIY sensor closest to the station was compared with the official data.

Initially, the analysis of PM10 concentration was distributed in three categories: average concentration for the period (May 2023—May 2024), average concentration during the heating season, and average concentration outside the heating season. For better understanding, the EAP team made deeper analyses depending on the days of the week—whether they were school days or vacation days, working days or weekends.

The same approach was used to analyse NO2 concentrations, but the seasonal variation of NO2 is not so clearly visible as the PM10. The highest concentrations of NO2 were observed during the heating season, on working days during the school year. The lowest concentrations were observed out of the heating season on a school vacation. It's normal because during the vacation, students do not go to school, and traffic is reduced. The first peak of NO2 concentration is in the morning in the 7 to 9 am time slot, as classes start at 8 am. Some students finish their studies at noon, while others stay for extracurricular activities until 4 - 5 p.m. In the immediate vicinity, there are two secondary schools whose lessons end after 7 pm. A large, well-visited city park is located in the area. There is a football stadium and sports halls nearby. The attendance of these facilities likely contributes to the observed higher concentrations of NO2 from 19:00 to 21:00.

Analysis of data from the official air quality station shows that peak values for NO2 concentrations coincide with the activity hours of schools and gyms, while PM 10 levels are relatively constant.

Use case 3 - Raising awareness of the impact of traffic on air pollution, primary school Knyaz Alexander I

The measurements were done by a mobile AQ laboratory situated in the school yard and covered the period from December 2023 to the end of May 2024. The collected data covered 6 months, and the data is not sufficient to draw a conclusion for the whole year. Only in December 2023 was there a significant deviation in NO2 concentrations.

The measurements were done by a mobile AQ laboratory situated in the school yard and covered the period from December 2023 to the end of May 2024. The highest concentrations of NO2 were observed during the heating season, on working days during the school year. The lowest concentrations were observed outside of the heating season, on a school vacation. This is normal because during the vacation, students are not going to school, and traffic is reduced.

The first peak of NO2 concentration is in the morning at 7 to 9 am, as classes start at 8 am. Some students finish their studies at noon, while others stay for extracurricular activities until 4 - 5 p.m. In the immediate vicinity, there are two secondary schools whose lessons end after 7 pm. The school is situated near the city centre and this is probably the reason for more intensive traffic, respectively higher concentrations of NO2 from 19:00 to 21:00.

During working days, traffic is significantly higher than on weekends. The students were given a task to analyse data for the period from 11/01/2024 to 18/04/2024.

The key findings were summarised, presented as graphics, and conclusions formulated. They were disseminated during a rising awareness campaign and included in a report to the municipality of Plovdiv.

Sofia pilot

Sofia use case 1 – School bus service

The aim of this use case was to introduce school bus routes on the outskirts of the LEZ and to create a community-building exercise with schools and stakeholders affected by air pollution - kids, parents, teachers, and to start raising awareness on every citizen's behavioural choices along with testing new municipal service of the school busses, providing an alternative to the widely established model of driving your children to school by car.

In order to assess the effectiveness of this measure, the SDA team installed 4 DIY COMPAIR-provided sensor devices around the two main schools and also spread 3 surveys among parents in the 5 schools around and conducted several workshops with students and their parents to raise their awareness on the air quality and to get feedback on how the service can be improved, popularised and being preferred by the citizens compared to the usage of individual cars.

However the most effective way of assessing the service quality occurred to be the direct communication and the surveys we spread among parents. With the workshops and the feedback we get from the parents we managed to identify the impact and the positive effects according to the stakeholders, mainly parents, and to discuss the development of the project for the next school year and ahead.

Parents shared this information anonymously in the surveys we prepared during the different testing periods. Then we made 2 analyses and reports to the local authorities - one at the end of each testing round of the school bus service. The report aimed to summarise the feedback and the data gathered from the parents users of the service and to recommend future steps for developing the school bus service. Thus citizens were involved on every stage of developing the service and were part of the policy making.

Sofia use case 2 – Kindergarten
In this case we were working in close collaboration with the Digitalisation Department of Sofia Municipality and their Canary system - an existing indoor air quality monitoring system at one of the kindergartens in Sofia used for the pilot area. The initial planning of this use case was aimed at measuring indoor air quality in the kindergarten.

We installed 2 sensors of the DIY sensor.community sensors that gathered data during the winter and the summer period. The analysis we made shows seasonal, weekly and daily correlations that helped us to support our hypothesis that when kids enter the room and move more actively the PM levels in the room rises and in these cases teachers were instructed to make some ventilation in order to improve the indoor air quality.

Our initial plans were to make a comparison with data gathered from the Canary system but due to lack of budget for maintenance and due to technical issues of the provider of the Canary system, it turned out the data was not available for the measuring period and we cannot compare the results from the Canary system with the COMPAIR-provided DIY devices from *sensor.community*.

Sofia use case 3 – CO2 calculator usage
The Sofia pilot recognised the CO2 calculator and Carbon Footprint Simulation Dashboard as a suitable tool for engaging citizens and supporting them toward their climate neutrality and put a priority on this tool. The SDA team put an effort to popularise the platform and gather some initial data to start the tool testing and also to present the features of the tool in several workshops and campaigns promoting the CO2 Calculator and Dashboard to experts from Sofia Municipality.

The SDA team is using Matomo - an internal platform to track the users' performance and also is using the features of the tool to make analysis from the gathered data from the users. This analysis could be provided to local authorities at a later stage when we have enough data gathered.

Sofia use case 4 – Awareness raising campaign

One of the main focuses of the SDA team was raising awareness of the topic of traffic and air quality. Thus a media campaign was conducted on positive examples of people living sustainably aiming to call to action to change behaviour. The campaign presented attractive visualisations of some of the digital tools of COMPAIR like CO2 Calculator and other policy measures of Sofia Municipality aiming at promoting sustainable living habits. The main message was "It's cool that you care". Some of the visuals promoted the COMPAIR-provided tools, others promoted pilot projects of the SDA team and also programs, projects and policy measures of Sofia Municipality calling to actions like planting new trees, recycling and unplugging devices when not used to save energy. An online campaign was also launched at the beginning of September 2024.

As the campaign is still ongoing an analysis of its effectiveness is about to be provided.

3.5. Dissemination and communication

A communication and dissemination strategy is essential to the success and impact of citizen science projects, as they rely on public participation. The Deliverable "8.1 Impact Enhancement Roadmap" outlined communication and dissemination strategy for effective engagement of stakeholders.

The key channels for COMPAIR project communication were the project website, social media channels, newsletters, and brochures. The pilots also used their own channels for communications and Sofia pilot made an outdoor awareness-raising campaign including billboards and posters on public transport stops and metro stations in 40 locations of the city.

The dissemination was based on press releases, organisation and participation in the events (through presentations, brochures, postcards, and posters), webinars, conferences and publications.

Each pilot team organised co-creation workshops:

- In the beginning of the project-for stakeholder mapping, engagement, identification of the local needs and stakeholders requirements for digital tools and design of experiments.
- after the Open and Public round to share the results and collect feedback from the stakeholders. The main idea was to communicate findings to different audiences and to allow networking with other similar organisations engaged in Science for Policy activities to advance processes and methods.

The Flanders and Bulgarian pilots prepared reports with key findings for the local authorities.

4. Creation of data ready for policy-making

Transforming data to be ready for usage in policy making requires knowledge as it relates to creating new formats more amenable to analysis, raising awareness, and guiding strategic decision-making. Data must be reliable and usable by different stakeholders—citizens, academia, and government.

The pilots designed and implemented citizen science experiments with citizens to improve public knowledge about local air quality and collect valuable data for policy making.
All of the experiments (use cases) followed the 5 step approach:

- 1st step – Problem definition
- 2nd step – Stakeholder Mapping & Engagement
- 3rd step – Identifying the challenges and local needs in each pilot area
- 4th step – Data collection, visualisation and analysis
- 5th step – Dissemination and communication

Table 3: *Performed analysis by pilots*

Steps Pilot	1st step	2nd step	3rd step	4th step	5th step
	Problem definition	Stakeholder Mapping & Engagement	Identifying the challenges and local needs	Data collection, visualisation and analysis	Dissemination and communication
Athens	Engaging end-users/citizens in participating in the behavioural change towards a reduced carbon footprint and better air-quality	**Mapped and engaged stakeholders:** -Municipality of Athens -Department of Resilience & Sustainability - Municipality of Athens -Athens Digital Lab -Office of Deputy Mayor for Climate Change and green spaces -Department of green spaces management -PANhellenic infrastructure for Atmospheric Composition and climatE chAnge (PANACEA) -DevelopAthens -Climate Resilient Regions through Systemic Solutions and Innovations (ARSINOE) -National Observatory of Athens -SynAthina -Institute of Communication and Computer Systems ICCS, NTUA	- Creating awareness on AIR quality among citizens with focus on lowSES group of elderly - measurements of AIR quality at street level with civic engagement - Engagement of citizens in environmental data collection for measures and policies support - Calculating carbon footprint using a dashboard	**Data collection** - Official AQ stations; - DIY devices from sensor.community - PM measurement - SODAQ AIR devices - PM measurement -NO2 devices NO2 measurements - BCmeter sensors - black carbon measurements **Data visualisation** -Carbon Footprint Simulation Dashboard -Policy Monitoring Dashboard -Digital Twin Dashboard **Data analysis** -Compare air quality indexes PM10, and PM2.5 within Kispeli area -Compare air quality indexes PM10, and PM2.5 within Neos Kosmos area from the measurements of	**Co-creation workshops**: - In the beginning of the project for stakeholder mapping, engagement, identification of the local needs and stakeholders requirements for digital tools and design of experiments. - after the Open and Public round to share the results, to communicate findings and collect feedback from the stakeholders. **Dissemination** - press releases, organisation and participation in the events (through presentations, brochures, postcards, and posters), webinars, conferences and publications. **Communication**- each pilot has a person, responsible for communication with citizens, stakeholders, local partners and media.

		-DRAXIS ENVIRONMENTAL SA -EASA (European Architecture Students' Assembly -National Centre For Scientific Research Demokritos -Natural Environment & Climate Change Agency (NECCA) -SCIENCE FOR YOU PNPC "SCIFY"		SODAQ -Compare air pollution conditions between two areas in Athens (Kipseli and Neos Kosmos) -Analyse NO2 measurements from the two areas -Analysis of extraordinary conditions affecting the air quality e.g. works taking place -Analysis of external conditions that affect the quality of air due to weather extremes. -Compare the total collected data on the categories of CO2 emissions (transportation, flights, trains, waste, buildings) -Identify categories that affect mostly the overall CO2 pollution -Compare CO2 results from the 7 districts of Athens	

Berlin	Improvement of the AQ and enhance the use of CS initiatives and increase public involvement.	Mapped and engaged stakeholders: -District Office Mitte Berlin -Office for Urban Greenspace and Mobility Planning in Mitte -Office for Environmental and Nature Protection in Mitte -Senate Department for the Environment, Transport and Climate Protection -District Office Charlottenburg-Wilmersdorf Berlin -Office for Urban Greenspace and Mobility Planning in Charlottenburg - Wilmersdorf -Office for Environmental and Nature Protection in Charlottenburg - Wilmersdorf -VCD -KiezConnect -Changing Cities -Temporäre Spielstraßen -Berlin 21 -Training Institute of the Heinrich Böll Foundation -ADFC-TK -Grüne Liga (Green League) Frauenalia -Frauencafé Berlin Global -Mamis en Movimiento e.V -BOX66	-Raising awareness on air quality and traffic with neighbours of two Berlin districts as well as commuting cyclists across Berlin -Diverse usage of sensors/ devices and further technical tools -Reconfiguration of parking spaces	**Data collection** - Official AQ stations - DIY devices from sensor.community - PM measurement - SODAQ AIR devices - PM measurement - DIY devices bcMeters - black carbon measurement - Telraam S2 devices - traffic measurement **Data visualisation** -Augmented Reality (AR) App -Dynamic Exposure Visualisation Dashboard -Policy Monitoring Dashboard **Data analysis** -Comparison of air (PM 2.5) and traffic quality within two Berlin districts in Mitte and Neukölln (static campaign) -Comparison of PM 2.5 with traffic values and analysis of the connection between the two values for each district to detect potential effects of traffic calming measurements (static campaign)	**Co-creation workshops**: - In the beginning of the project-for stakeholder mapping, engagement, identification of the local needs and stakeholders requirements for digital tools and design of experiments. - after the Open and Public round to share the results, to communicate findings and collect feedback from the stakeholders. **Dissemination** - press releases, organisation and participation in the events (through presentations, brochures, postcards, and posters), webinars, conferences and publications. **Communication**- each pilot has a person, responsible for communication with citizens, stakeholders, local partners and media.

		-Migration hub -s27 -Refugees on rails -Berlin Willkommen Zentrum -LAFI NK e.V -Technik Museum -Naturfreunde Berlin -Schreberjugend Berlin -BUND friends of earth Germany -Flicken -Flotte -Avocargo -Free University of Berlin, Institute of Geographical Science -Berlin Institute of Technology, Institute for Ecology, Department of Climatology Berlin Institute of Technology, Geoinformation in Environmental Planning -Humboldt University Berlin, Institute for Climate Geography, Department of Urban Climate and Air Pollution		-Average exposure of PM 2.5 by all commuting cyclists (mobile campaign) -Number of measured days, and number of measurements of each commuting cyclists (mobile campaign) -Maximum amount of measured PM 2.5 per hour to detect hotspot times between the commuting cyclists (mobile campaign)	

Flanders	Improvement of the AQ, enhances the use of CS initiatives and increases public involvement.	Mapped and engaged stakeholders: -Agency for internal affairs (ABB) -Agency for innovation and entrepreneurship -Agency for education -Agency for roads and traffic -Environmental agency VMM (partner) -Digital Flanders (partner) -Department for mobility and public works -Umbrella organisation for community education (gemeenschapsonderwijs) -Umbrella organisation for catholic education -Knowledge Center Flemish major cities -300 Local communities -13 major cities in Flanders (KVS) -Flanders intermunicipal companies (VLINTER) -Organisatie representing lokaal onderwijs -Umbrella organisation of the Flemish Provinces (VVP) -Flemish Provinces -VSV (Flemish foundation for mobility education)	- Raising awareness on air quality with kids in schools - Raising awareness on wood burning and air quality with citizens and environmental council - Demonstrating the impact of a mobility plan on traffic and air quality	**Data collection** - Official AQ stations - DIY devices from sensor.community - PM measurement - SODAQ AIR devices - PM measurement - bcMeters - black carbon measurement - Telraam S2 devices - traffic measurement - NitroSense - NO2 sensor boxes **Data visualisation** -Augmented Reality (AR) App -Dynamic Exposure Visualisation Dashboard -Policy Monitoring Dashboard -Digital Twin Dashboard **Data analysis** -the variation in dynamic exposure of two groups of students in Ghent -Data validation/calculations -Daily profiles for each location during the Sint-Niklaas campaign -Comparing bike traffic count from manual counts, Telraam and pneumatic	**Co-creation workshops**: - In the beginning of the project-for stakeholder mapping, engagement, identification of the local needs and stakeholders requirements for digital tools and design of experiments. - after the Open and Public round to share the results, to communicate findings and collect feedback from the stakeholders. **Dissemination** - press releases, organisation and participation in the events (through presentations, brochures, postcards, and posters), , webinars, conferences and publications. **Communication**- each pilot has a person, responsible for communication with citizens, stakeholders, local partners and media.

		-VVSG (Flemish organisation of local communities) - Smart city representative -Research institutes and universities -Individual schools -Umbrella organisation of parents and parents organisations (VCOV) -Local police zones -Grassroots organisations -Citizen science data providers (Mobility) -Citizen science data providers (Air quality) -Netwerk voor duurzame mobiliteit - Pedestrians movement -Cyclists movement -Public Space Info Point -Umbrella organisation of the Flemish Urban and Spatial Planners (VRP) -Schools for Clean Air (Grassroots organisation) -Heroes For Zero (Grassroot organisation) -Leuven Climate 2030 (city partnership) -Umbrella organisations of family doctors -Umbrella organisations of		tube (per direction) -average concentration of NO2 for each hour of the day for each sensor individually, comparing the situation before and after the change -hourly averaged and cleaned bcMeter data (black carbon measurements)	

		pharmacies -Flemish Agency for Care and Health -Department of Welfare, Public Health and Family -Health Insurance Funds -Bicycle shops -Umbrella organisation of social bicycle companies (Bicycle points) -Public transport company - buses -Public transport company - trains -Public transport company - tram -Car sharing service (Cambio) -Umbrella organisation of the Flemish nature and environmental organizations -SCIVIL -Free University of Brussels -Ghent University -Catholic University of Leuven -University of Antwerp -Hasselt University -Flemish Institute for Technological Research -IMEC -Provincial Center of Expertise on Environment and Health			

		-Flemish Center of Expertise on Environment and Health			
Plovdiv	Improvement of the AQ through changes in commuting behaviour, choice of sustainable transport and enhance the use of CS initiatives, increase public involvement	Mapped and engaged stakeholders: -Municipality Plovdiv -Sofena Energy Agency -Regional Education Management Agency - Plovdiv -Association of Bulgarian Energy Agencies -Primary school Dimitar Talev -Primary school Vasil Levski -Primary schools Knyaz Alexander I -Primary schools Vasil Petleshkov -Primary schools in Plovdiv -Regional Inspectorate of Environment and Water - Plovdiv -Directorate "Ecology and waste management", municipality Plovdiv -BG BeActive -Directorate Education, municipality Plovdiv -EVN Bulgaria -Medical University of Plovdiv -Agricultural University of Plovdiv -University of Plovdiv	- Raising awareness of the impact of traffic on air pollution - Raising awareness of the impact of traffic on air pollution and seasonal variation of PM10 -CO2 calculator usage	**Data collection** - Official AQ stations - DIY devices from sensor.community - PM measurement - Telraam v1 devices - traffic measurement **Data visualisation** -Carbon Footprint Simulation Dashboard -Policy Monitoring Dashboard **Data analysis** -Analysis of data from measurements with mobile AQ laboratory - PM10 and NO2 and pick values -Analysis of data from official AQ measurement stations - PM10 and NO2 and pick values -Analysis of data from traffic sensors -Comparison of AQ data with traffic intensity	**Co-creation workshops**: - In the beginning of the project-for stakeholder mapping, engagement, identification of the local needs and stakeholders requirements for digital tools and design of experiments. - after the Open and Public round to share the results, to communicate findings and collect feedback from the stakeholders. **Dissemination** - press releases, organisation and participation in the events (through presentations, brochures, postcards, and posters), webinars, conferences, Ideathon and publications. **Communication**- each pilot has a person, responsible for communication with citizens, stakeholders, local partners and media.

		-Green Synergy Cluster -Business for Plovdiv -Public Council for Air Quality Plovdiv			
Sofia	Enhance citizen science to cope with environmental problems related to commuting behaviour, sustainable mobility for students and choice of transport	Mapped and engaged stakeholders: -Sofia Municipality -Environmental Department -Climate, Air and Energy Department -Urban Mobility Department -Sofiaplan -Urban Mobility Department - Climate, Energy and Air Quality Department -AirBG Foundation -Za Zemiata -Bulgarian representative for the EU Climate Pact - Gorichka -The Small Steps Foundation -Junior Achievement Bulgaria -Sofenhagen	-School bus service -The importance of room ventilation in kindergarten -CO2 calculator usage -Raising awareness of the impact of traffic on air pollution among children in schools, parents and other stakeholders	**Data collection** - Official AQ stations - DIY devices from sensor.community - PM measurement - Telraam v1 devices - traffic measurement **Data visualisation** -Carbon Footprint Simulation Dashboard -Policy Monitoring Dashboard **Data analysis** -Analysis of data gathered from the sensors installed at kindergarten and schools -Analysis of data gathered from the surveys spread among the parents users of the school bus municipal service	**Co-creation workshops**: - In the beginning of the project-for stakeholder mapping, engagement, identification of the local needs and stakeholders requirements for digital tools and design of experiments. - after the Open and Public round to share the results, to communicate findings and collect feedback from the stakeholders. **Dissemination** - press releases, organisation and participation in the events (through presentations, brochures, postcards, and posters), webinars, conferences and publications. **Communication**- each pilot has a person, responsible for communication with citizens, stakeholders, local partners and media.

Based on the above mentioned 5 steps, corresponding activities and local stakeholders involved (including local politicians) in each pilot, we can assume that the data generated by the COMPAIR project are ready to be used for policy making.

4.1. Mechanisms to calibrate and safeguard quality

Two procedures were implemented to guarantee the quality of data: standardisation and calibration.

The input data were generated from different sources (DIY sensors, SODAQAir devices, Telraam v1 & v2 devices, and official AQ stations) with other formats. To be correctly interpreted, the data has to go through a standardisation procedure. COMPAIR used the OGC SensorThings API (OGC-STA) data model to address the interoperability challenge. The modal provides an open, geospatial-enabled, unified way to interconnect Internet-of-Things (IoT) devices, data and applications. OGC-STA covers two main modules: sensing and tasking. The sensing module provided a standard way to manage and retrieve observations (sensor measurements) and metadata from differently configured IoT sensor systems. Additionally, the tasking module can be used to parameterise sensors and trigger IoT actuators.

Sensor data calibration is crucial to ensure accurate and reliable measurements, which helps end users make well-informed analyses and interpretations. In COMPAIR, a novel sensor calibration approach called “distant calibration” was applied and evaluated to calibrate PM and NO_2 sensor data. The approach combined high-end reference station data with low-cost sensor data to account for sensors' sensitivity to environmental conditions and the changes they undergo during their deployment outdoors. The approach enabled automated near-real-time calibration of sensor data without requiring lengthy and labour-intensive laboratory or field testing.

D3.5: Data Processing and Data Calibration of Air Quality Sensors provides detailed information regarding standardisation and calibration procedures.

For the citizen's training, training material (“D5.1 Guide to Air Quality Monitoring”) was developed. This material supports the COMPAIR pilots and provides them with some basic information on air quality and low-cost air quality sensors. The students and volunteers were trained on how to install and maintain their sensors.

4.2. Joint use of CS data, government and private sector

The collaborative use of citizen science data by local governments and the private sector enables complex societal challenges to be addressed. Through citizen science, individuals contribute to scientific research through observations, data collection, and analysis, providing valuable insights that complement traditional scientific methods. Harnessing the collective efforts of engaged citizens, government and private organisations enables access to vast amounts of real-time data on everything from the environment to urban development, enabling more responsible and informed decision-making.

Citizens-generated data and making data relevant for policy-making face several challenges. For example, the lack of trust or engagement between politicians and the citizens of the state, mistrust of the quality of data generated by citizens, the lack of knowledge and capacity to process citizen data, etc. Data generated by citizen science can complement, but not replace, official data. Citizen-generated data initiatives empower people to engage in political processes. In March 2024 during the 55th session of the UN Statistical Commission, The Copenhagen Framework on Citizen Data[6] was set. The citizens data were defined as " data originating from initiatives where citizens either initiate or are sufficiently engaged, at the minimum, in the design and/or collection stages of the data value chain, irrespective of whether these data are integrated into official statistics."

The citizens' participation in data generation allows them to decide what data is important to collect, how to collect and use it for policymaking and an impact on their lives. If the citizens undertake initiatives themselves or in partnership with local decision-makers they achieve sufficient participation in data.

The access to more AQ data, especially in "blind spots" (areas not covered by official AQ stations or other networks) enables the making of better-informed decisions and develops new insights and innovative ideas that can generate social and economic benefits, improving the lives of people. The data can be compared, and combined to show the connections among different datasets. The effectively combined and compared data highlight trends, identify social and economic challenges, and benchmark progress in policy creation and implementation.

The COMPAIR project offers free access to citizen-generated data through PMD. It enables users to interact with data from different sensors, helping them understand and compare how environmental situations change under different actions. The users can generate data reports, visualise and share the data. The Policy Monitoring dashboard is customisable to specific user requirements. It presents an easier way to apply analysis to data, interprets data from different sources and disseminates data appropriately - all of which assist with critical policy decision-making.

The experiments in Athens were focused on AQ measurement and CO2 calculator usage by senior citizens. For the seniors, it was easy to install the sensors but some difficulties to

[6] The Copenhagen Framework on Citizen Data

maintain them. They can fill in the information in the CO2 calculator but have difficulties interpreting the results. The elderly can contribute to data collection and local policy-making. The data generated from the seniors could provide more information about their needs and habits.

The experiments in Berlin were conducted in dynamic and static modes. The dynamic mode gives more information about the personal exposure to the air pollution of the cyclist in the city, AQ in “blind spots” not covered by measurements, but also can support policymakers with information such as cyclists' preferred routes, average length of journeys and could be used for improvements in the urban mobility plans. The static mode compares the air quality in a district with low and higher traffic intercity and evaluates the measures for traffic reduction.

The experiments in Herzele (Flanders pilot) were dedicated to implementing school street—the street near the school was closed for vehicles when the students went to school and when they returned home. The results show a reduction in traffic and air pollutants and an increase in safety.

The experiments in the Plovdiv pilot were dedicated to raising awareness of traffic's impact on air pollution and seasonal variation of PM10. The traffic intensity was monitored by Telraam v1 sensors. The highest traffic intensity was registered when the students went to school and when they returned home. The highest NO2 concentration measured by the mobile AQ laboratory in the school corresponds to the highest traffic intensity.

Collaboration between citizen scientists, policymakers, and the private sector unlocks vast potential for advancing scientific knowledge and public engagement.

4.3. Design the policy by using collected data

The common need in all pilots was to fill the gap in available AQ data with the conditions in concrete areas of interest. In most cases, the areas were not covered by official AQ measurement stations and there was no data about the air quality there. The new AQ data were collected, which complement the existing ones, analysis and conclusions were made. The experiments in pilot areas were used for monitoring of the current policies, to suggest improvements and to inform citizens about new policies.

The **Athens pilot** focuses on the engagement of citizens in the dimension of behavioural change regarding reducing their carbon footprint and improving air quality. The citizens measured AQ by sensors. The scientists support them in analysing collected data and focus attention on pick values. The outcomes could be used by the local authorities to enhance environmental strategies, develop concrete policies on climate mitigation and empower citizens' active engagement.

The **Berlin pilot** performed activities for dynamic (cyclists on their daily commutes all over Berlin) and static (citizens from their homes), measuring and raising air quality awareness.

To a little extent the local authorities could use the outcomes by getting an imagine of where more of such measurements are still needed and how such a civil measurement process could be designed. A specific policy was not introduced, but impulses were given to the responsible administrative authority. Especially local initiatives that are active in lobbying for more sustainable air and mobility were able to use and publish this data in relation to so-called neighbourhood blocks (Kiezblock/Superblock), citizen science participation approaches and to raise the political awareness of air and traffic quality issues.

The **Flanders pilot** performed activities in seven sites, to raise awareness of air quality among children in schools, citizens, and environmental councils and demonstrate a mobility plan's impact on traffic and air quality.

The **Plovdiv pilot** performed activities showing the connection between traffic intensity and levels of PM and NO2 around the schools and the seasonal variation of PM10. The results from the Public and Open rounds were widely disseminated during the workshops and meetings. The Plovdiv team prepared a Google form to collect proposals from citizens for measures to improve air quality. The collected measures were analysed and the most suitable ones were included in a proposal to the Plovdiv municipality. The proposal contains the results from experiments, key findings, and proposed solutions, but it also incorporates good practices from the other pilots in the COMPAIR project - school streets and school buses.

The municipality of Plovdiv is currently developing a new program for AQ improvement, and we hope that the proposed measures will be included.

The **Sofia pilot** implemented a scaled-up school bus service developed with the active citizen engagement and raising awareness in the dimension of behavioural change regarding reducing their carbon footprint and improving air quality around school areas. The routes of the school buses were adjusted using data provided by parents of the students from 1st to 4th grade that helped to validate and define more precisely the routes and bus stops they wanted to use and preferences of the service features. The data gathered both by the sensors installed and from the surveys conducted in the schools was used first to establish the school bus service as a resistible policy measure and then to monitor the effectiveness of the implementation. During the duration of the project, the SDA team conducted several testing rounds and with every iteration the school bus service was adjusted to the users' feedback and needs.

5. Behavioural aspects

The behavioural public policy is a policymaking process, focused on people, affected by policy and used research methods. Citizens, academia, and policymakers in a partnership may create an environment that supports behavioural public policy by increasing the probability that relevant evidence will be found, generated, and taken into account.

The raising awareness is one of the policy measures that could lead to the behavioural changes. Citizens collected data on the KAV and traffic in their neighbourhoods. Using the project's digital tools, the data was visualised. The results of the measurements were explained at workshops. In this way, citizens could understand how their daily behaviour affects the environment. On the other hand, politicians could better understand what and why is happening in the pilot areas.

The PMD tool visualised collected data and offered opportunities for data comparison, graphics creation and trend analysis. But not all collected data could be visualised by COMPAIR digital tools. Using the CO2 calculator, citizens can calculate their footprint by providing data on their energy consumption and find ways to reduce it through behaviour change. Awareness campaigns and pointing out the sources of air pollution can lead to behavioural changes.

Citizen science is a significant data source of information. The citizens with their participation in data collection, analysis, CO2 calculator usage and rising awareness campaigns allow policymakers to understand how their motivations and behaviour relate to their willingness to change.

In **Athens**, citizens were engaged in calculating their carbon footprint, providing feedback, and testing different scenarios/recommendations to achieve lower emissions at a household level, mostly by changing their everyday habits. This process is already inline with the city’s strategic goals referring to environmental policies, especially the objective of Athens to reduce air pollution and emissions. Hence the data collected enhanced the latter directions of the city. Furthermore, the outcomes could be used by the city authorities to further enrich environmental strategies that are now under development e.g. the energy efficiency of municipal buildings, to develop concrete future policies on climate mitigation and empower citizens' active engagement.

In **Berlin** citizens were engaged in dynamic and static measurements. Dynamic measurements aim to evaluate the exposure of cyclists on their regular commute to work, school, care work or other activities. The SODAQAir sensors and DEVA gave the participating citizens information about the air quality during their daily commute. The static measurements focused on comparing air quality and traffic in different neighbourhoods - intensive vs low traffic (Kiezblock) areas. The participants from both campaigns - mobile and static - gained knowledge, were highly sensitised by the topics of mobility, air quality and Citizen Science approaches and thus learned an impulse to change their behaviour and acted as a multiplier for their immediate environment. A person from the Berlin administration was present at the closing event so that the participating Citizen Scientists from the COMPAIR project could enter into dialogue with each other about their experiences, changes in behaviour as a result of the project and policy requirements. The administrator was thus able to feed ideas back into her work.

In **Flanders** - the students were involved in the experiment creation of mobile and static measurements. The results were used to demonstrate the impact of a school street in Herzele and Ghent on both traffic and air quality and the effect of wood burning in Herzele and Hove and to evaluate a mobility plan in Ghent and Sint-Niklaas. The circulation plan was evaluated by measurement of the traffic intensity, car speed and emissions (NO2 and black carbon). 95% of observed local peaks of PM concentrations could be attributed to wood smoke and 5% to other sources. After experiments in Herzele students answered the questions, 20% less would take a car and 7% more used bus, train or carpooling. The results show the effect of the circulation plans but more time and data were needed for any definitive statements.

In **Plovdiv** - the students were involved in an experiment, volunteers and students were involved in data analysis, and the results were disseminated through a rising awareness campaign with the aims of showing the relationship between traffic and air pollution in 2 school areas to raising awareness of the impact of traffic on air pollution and seasonal variation of PM10. The students and citizens were encouraged to use the CO2 calculator. After the raising awareness campaign citizens suggested to local authority measures for AQ improvement.

In **Sofia**, an assessment of the effectiveness and the impact of the introduction of new school bus routes on behavioural choices and air quality was made. The service was recognised by parents and local authorities as an important measure that needs to be put on a strategic level and developed further. The use of a CO2 calculator was promoted to raise awareness of individual carbon footprints and the ways citizens can take to decrease them and track them over a long term period. Thus all the gathered data from the CO2 calculator and especially from the Scenario Simulation Dashboard could be also used by local authorities as the tool maps the intention of citizens to take diverse actions and their intention to adopt initiatives proposed by the municipality, region or government.

6. Good practices and lessons learned

The experiments in each pilot have generated good practices. Knowing better than the local authorities what the situation is in their neighbourhoods, specific needs of the area, participants were willing to contribute.

The complex maintenance of the equipment for regular work or not covering citizens' expectations might lead to disappointment and reluctance to participate in AQ related data generation. The lack of participation can lead to limited area covered, data generated and lack of willingness of citizens to participate in the co - creation policy making process.

6.1. Athens

The policy measures targeted in Athens were raising awareness and contribution to air quality measurements from citizens - reduce air pollution (PMs) in Athens specifically the data collected for PM2.5, PM10 and NO2.

The good practice is engaging elderly people. This was facilitated by "Friendship Clubs" (community centres administered by the city dedicated to seniors). The engagement procedure includes on-site introductory meetings, workshops, and follow-up visits to ensure active participation. This method aimed to integrate seniors into the air quality monitoring process and build a supportive community around the project.

The number of sensors is limited, but digital tools can be used by many people. The online communication channels were used to involve a diverse group of stakeholders, including the Ministry of Environment, NGOs, and academic professionals, in using the CO2 calculator and contributing to climate policy discussions. The engagement of stakeholders and authorities, the modes of communication and their involvement in the Athens is reported in the deliverables related to the pilot execution and evolution hence D5.2, 5.4 and 5.6.

6.2. Berlin

The policy measures targeted in Berlin were measuring and raising awareness on air quality with cyclists on their daily commutes all over Berlin (mobile measurements) and measuring and raising awareness on air quality with citizens in two Berlin neighbourhoods from their homes (static measurements).

The good practice is combining static with dynamic AQ measurements. Citizens leading a more active lifestyle were included in the dynamic measurements. The experience from other well-established initiatives focused on mobility, cycling, and sustainability, leveraging their social media platforms, newsletters, and mailing lists to attract participants was used.

For the static measurements, the volunteers were identified locally in the concrete neighbourhood through flyer distribution and publication in neighbourhood newspapers. Regular communication through workshops and emails was maintained to keep participants engaged and motivated.

During the COMPAIR project, there were several exchanges with Berlin administrative authorities about the project, the measurements and the citizen science approach. At the final project event in particular, the key results of the measurements and, above all, the participatory approach were presented to the participants, local initiatives and the administrative staff. This ensured that impulses could be set at a political level and a contribution made to the Berlin air and mobility debate. Specifically, the measurement results collected could not be used by the administration due to their insufficient validity with regard to the official administrative standard, but nevertheless served as an impulse for where there is still a need for research and measurement and how this can be organised in a co-creative and innovative way (e.g. through citizen science).

The stakeholder engagement, involvement, communication, experiments and results were detailed described in D5.2, D5.4 and D5.6.

6.3. Flanders

The policy measures targeted in Flanders were:
- Raising awareness on air quality with kids in a primary school in Ghent
- Raising awareness on air quality with kids in secondary school in Herzele
- Raising awareness on wood burning and air quality with citizens in Herzele
- Raising awareness on wood burning and air quality with environmental council in Hove
- Demonstrating the impact of a mobility plan on traffic and air quality in Ghent
- Demonstrating the impact of a mobility plan on traffic and air quality in Sint-Niklaas

The good practices covered the implementation of school streets, and the new innovative approach was to close the nearest street for vehicles only during peak hours when the pupils come to school and go home.

The stakeholder engagement, involvement, communication, experiments and results were reported in D5.2, D5.4 and D5.6.

6.4. Plovdiv

Good practices include engaging students in experiments, involving the LSES group, collecting AQ-improving measures from citizens, and launching an awareness campaign.

The policy measures targeted in Plovdiv were raising awareness of the impact of traffic on air pollution and raising awareness of the impact of traffic on air pollution and seasonal variation of PM10.

The deputy mayor of Education and deputy mayor of Ecology in Plovdiv signed the invitation letter for schools to participate. This facilitated the engagement of local authorities and schools.

To include representatives of the LSES group and not to put the children in an uncomfortable position or make them feel ashamed, we turned to the directors of the schools and teachers. We asked for information on whether there are children in the classes who fall into some of the following categories - raised by single parents, orphans, families with 3 or more children, etc. These children were given personal tasks. For example - to introduce the CO2 calculator to other students, regular checking of the data on the PMD, to undertake some analysis, etc.

The Plovdiv team prepared an on-line template of Proposal with a list of possible measures for reduction of traffic and improvement of AQ around schools for the municipality of Plovdiv. The collected proposals were presented to the municipality. The report contains good practises from other pilots - engagement of the elderly persons, school street implementation in Flanders and school bus service in Sofia. Now the municipality of Plovdiv is developing a new program for improving AQ and the measures could be included.

The stakeholder engagement, involvement, communication, experiments and results were reported in D5.2, D5.4 and D5.6.

6.5. Sofia

The policy measures targeted in Sofia were the development of the school bus municipal service during the public round, connected also with the implementation of the first LEZ in Sofia and indoor air quality in kindergartens.

Good practices include engaging both students in workshops and raising awareness on air quality topics and parents as decision makers in one family. They sometimes worked together and shared their feedback, making it possible to adjust the features of a municipal service to the exact needs of the users - parents and students. Through the survey parents were asked how their children commuted to school before the implementation of the school bus service and the common answer was that they were driven by parents via their personal car. After the initiative was conducted another survey showed that some of the parents already changed their behaviour from using personal cars to using school bus service and preferred it compared to car or public transportation. All the gathered data and feedback were summarised into a report to local authorities that was used as s starting point for the discussions to prolong the service and to start creating a strategy how to expand it among other districts of the Sofia Municipality making it a more important part of the Air Quality Improvement Programme of Sofia Municipality and probably also part of the Sustainable urban mobility plan.The implementation of the school bus service for the whole school year 2023-2024 and its prolonging for 2024-2025 as recognised as an important measure for reducing air pollution was a success and a starting point for more strategic policies integrated with other pilot policies such as the LEZ introduction.

The stakeholder engagement, involvement, communication, experiments and results were reported in D5.2, D5.4 and D5.6.

7. Recommendation for CS for policy making

1. Clear identification of local needs:

    - The citizens understand the process better in their neighbourhoods. They can support local authorities in identifying the needs at the neighbourhood level;
    - The local authorities can map some challenges and ask citizens how to overcome

Both processes can be successful if they are implemented in a co-creation way. Cooperation between policymakers, scientists, and citizens should be established at the beginning of the project to ensure that the results are ultimately usable and useful to the administrations and policymakers.

2. Clear identification of the stakeholders and development of engagement strategy - different stakeholder involvement will facilitate trust, credibility, understanding, collaboration, and cooperation in designing and implementing policies.

3. Using the power of CS - citizens can generate big data for a short period, which is impossible in traditional ways. Evidence and stakeholder participation are essential for the policymaking process and fostering ownership for its implementation.

4. Clear definition of citizens' contribution - for the citizens it will be helpful to know to which aspects they can contribute (data generation, data collection, data analysis, policy creation). The active involvement of citizens in the policy-making process allows them to contribute to decisions that may have an impact on their lives.

5. Provision of technical support and training for participants, particularly in case of troubleshooting of sensors in parallel with easy-to-follow guidelines and readiness to invest time in house visits to amend matters. The technical support and training facilitate the processes of data collection, analysis, policy formulation and implementation.

6. Establish efficient feedback mechanisms to collect specific insights on sensor types and usability. This feedback can guide improvements in sensor technology. Consider involving participants who are actively cooperating on these technical aspects in project meetings. The feedback enriches policy analysis by explaining how policy designs affect citizens and what are the expectations and obligations towards politicians.

7. Use the valuable role of local champions in engaging and organising participants within their communities. Community involvement in the policymaking process encourages the making of sustainable decisions by recognising and communicating the needs and interests of the stakeholders, increases acceptance of decisions and community commitment to outcomes as local knowledge from diverse groups shapes and creates inclusive, effective solutions.

8. Maintenance of an open and honest communication with participants, providing clear information on device functionality and limitations. To guarantee that evidence is incorporated into policies, it is crucial to effectively communicate information with policy makers and other stakeholders.

9. Data reliability—Politicians need reliable data as a base for policy making. Such data is often not available. The fastest way is to use CS's potential to generate the necessary data, but with the mechanism for calibration and methods for comparison

- Soft measures—sometimes, it is enough to find the source of air pollution or see the trendline in the process, and then it is unnecessary to make investments.

8. Conclusion

The project, with its activities and developed digital tools, connected citizens and policy makers. Citizens participating in science-oriented activities understand how their behaviour affects the environment. Such practices have the potential to influence policy making processes by local authorities. Empowerment of citizens contributes to more efficient and transparent governance, supports monitoring and evaluation of policies. Within the project, awareness-raising campaigns were carried out to encourage behavioural changes.

Although the experiments carried out within the project are replicable, they cannot always be applied directly. For example, limiting the speed to 30 km/h or prohibiting the passage of certain vehicles. In different settlements, they may vary and the levels of pollutants will be different. Local climatic conditions are also important. Temperature inversions prevent the air from rising in height, pollutants accumulate near the ground and this leads to higher pollutant concentrations. Good air circulation helps disperse pollutants. PM10 DIY sensors are widespread and easy for citizens to use. NitroSence's NO2 and bcMeter (black carbon) devices require more complex maintenance. Devices based on IoT technology could not be used in Bulgaria due to connectivity issues. A very important condition for conducting experiments is the availability of a platform for sharing the results.

The project has accumulated vast experience with the citizens involvement in civil AQ and traffic measurements and, thus, has come to the following conclusions:

The number of measurement points must be increased. The number of official AQ and traffic stations is limited. So, citizens receive information about the status of urban air quality at very few points in the city. This is highly insufficient to cover their demand for AQ awareness. By encouraging the citizens to participate in and test civil sensors for air quality and traffic, the information gaps can be filled in, ensuring measurements in multiple points, and covering larger observed territories. The active involvement of citizens in data generation and analysis allows them to contribute to decisions that may have an impact on their lives in the policy-making process.

Civil measurements are live AQ data that must be exploited. Through citizen participation in experiments, data generation, data analysis, AQ monitoring and rising awareness campaigns, a better understanding of the issue of air quality and the origins of pollution was achieved. During the experiments, numerous data sets were captured and analysed; incl. for air pollution blind spots. This data is with high granularity and great territorial coverage, making it real-life evidence data for policy-making. The best use of such massive datasets is for informed decision- and policy-making on local, national and EU level.

Social inclusion is a must in civil AQ policy making. During the COMPAIR project, various community groups were included - pupils, university students, elderly persons, low social/economic status groups. All of them were interested to join the project out of curiosity, but consequently started to gain deeper understanding and knowledge on the topics. Thus, they become a good source of argument for the public policies to be changed for the better.

Co-creation with the citizens is key for adequate policy making. The citizens who were part of the AQ and traffic experiments and tested the digital instruments acquired a critical mass of knowledge and experience in the AQ domain; furthermore, they were also knowledgeable of their local circumstances. Their personal involvement in the experiments brought about their personal vision and attitude for public policy making. Thus, they become a valuable source of information and feedback for local policy making. The partnerships between schools, pensions clubs, universities, local authorities, NGOs should be further developed.

Citizens need to be shown their personal benefits in AQ civil measurement and experimentation. The citizens were involved in static and dynamic measurements and could see their personal exposure due to air pollution. Through their participation in these experiments, they became more aware of the air pollution problem. They became more critical of themselves and the others, and acquired new skills and knowledge on how to change their habits to more sustainable ones.

Replication is key to scaling up and expanding the AQ measurement network. All experiments in the COMPAIR project are highly replicable and can be used for knowledge and experience transfer to other EU cities. This will strengthen the air pollution mitigation actions and raise the public awareness to the topic. Their results can be used as lessons learned by other stakeholders.

More data and knowledge could be collected and turned into evidence with the CS. The participation of various groups of citizens (such as students, elderly persons, etc.) and the integration of diverse types of data (such as traffic volume, and air pollution levels) enable the development of innovative solutions. This, in turn, leads to improved policymaking based on evidence and refinements during policy implementation. Citizen science holds significant potential in providing data that is ready for use in policymaking.