COMPAIR

DELIVERABLE

D5.6 Public Round report

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COMPAIR

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List of Abbreviations

Abbreviation	Definition
PM	Particulate Matter
CS	Citizen Science
(L)SES	(Lower) Socioeconomic Status
NO_2	Nitrogen dioxide
BC	Black Carbon
PMD	Policy Monitoring Dashboard
DEV-D	Dynamic Exposure Visualisation Dashboard
AQ	Air Quality
GA	General Assembly
DEVA	Dynamic Exposure Visualisation App

Executive Summary

The COMPARE Citizen Science project, under the EU Horizon 2020 initiative, organised experiments in Athens, Berlin, Flanders, Sofia & Plovdiv in which we provided technology to citizen scientists with the aims of measuring traffic and air quality to improve urban quality of life by affecting local policy decisions and citizen behaviour.

This report summarises the activities, results and lessons learned during the Public Round of the COMPAIR project. In the Public Round COMPAIR organised experiments in Athens, Berlin, Flanders, Sofia & Plovdiv in which we provided technology to citizen scientists with the aims of measuring traffic and air quality and with that affecting local policy decisions and citizen behaviour. The Public Round ran from November 1st 2023 to 30st of June 2024. The Public Round follows COMPAIR's Closed and Open Round in which we worked on a smaller scale a) internally with only project partners to test the different devices and b) with a small group of citizens to gain feedback and improvements for the Public Round.

The increasing urbanization and associated air pollution pose significant health risks and environmental challenges. Motivated by the need for accurate, localized air and traffic quality data and enhanced public awareness, the COMPAIR project engaged citizens, schools, local authorities, and researchers to collaboratively address air quality and mobility issues in urban settings.

The **primary goal of the Public Round** was to test and validate citizen science methodologies for monitoring air quality and traffic and influencing urban policy. The project sought to explore how community engagement by the approach of Citizen Science can lead to better environmental outcomes and sustainable urban living. Pilot projects were conducted in Athens, Berlin, Flanders, Sofia and Plovdiv to assess the feasibility and effectiveness of these approaches.

The Public Round **methodology** was built on the success of the Open Round. It involved:

- Adapting the LIFE VAQUUMS air quality sensor roadmap.
- Conducting detailed pilot interviews to develop experimental design tables.
- Implementing a living document approach to manage and adjust the experimental designs.
- Engaging citizens through workshops, sensor deployments, and collaborative activities such as hackathons.

Each pilot was tailored to local conditions, ensuring relevant and impactful outcomes.

Key findings from the pilot projects include:

- **Athens**: Citizen science innovatively introduced in Athens through COMPAIR aiming to measure air quality at street level and to calculate CO2 footprint of citizens. Elderly citizens engaged to participate with sensors and showed remarkable interest on the impact of air quality to their health.

- **Berlin:** Contribute to the gaps (simulated data) in the official measuring stations in Berlin through mobile bicycle exposure profiles and data from residential areas; technical and participatory experiences from a neighborhood block (Kiezblock/Superblock)
- **Flanders:** Identification of "Local Champions" and successful community engagement, particularly in schools, despite ethical challenges regarding traffic redistribution.
- **Sofia & Plovdiv**: Emphasis on clear communication and robust partnership management, demonstrating the scalability of results based on user needs.

The pilots demonstrated that citizen engagement can lead to measurable behavioral changes and provide validated, localized air and traffic quality data. These insights are crucial for shaping urban policies aimed at reducing pollution and enhancing public health.

The COMPAIR project's Public Round underscores the potential of citizen science to contribute to urban air quality management. The **success of the project** hinges on:

- Robust experimental designs and innovative technologies, such as low-cost devices and interactive dashboards.
- Strategic partnerships with local authorities, stakeholders and initiatives.
- Continuous support and tailored engagement strategies for participants.

Recommendations for future initiatives include:

- Start cooperation with administrations as early as possible in the course of the project in order to generate usable citizen-generated data that can be incorporated into municipal decision-making processes.
- Developing comprehensive engagement plans to maintain participant motivation.
- Scaling successful pilot strategies to other urban areas facing similar challenges.

By leveraging the power of community involvement and advanced technologies, the COMPAIR project offers valuable lessons and strategies for enhancing urban air quality and fostering sustainable mobility.

1. Introduction

This report summarises the public round of the COMPAIR project. Based on the learning from the Open Round, this report delves into the multifaceted pilot projects conducted during the Public Round, offering a detailed exploration of the activities, results, and valuable lessons learned throughout our experiments. The Public Round extends the innovative approaches put into practice during the Open Round and which can be looked up in the public deliverable D5.4 – Open Round Report.

The Horizon 2020 project COMPAIR was driven by the overarching goal of advancing urban quality of life through a citizen science approach on traffic and air quality. Through a collaborative effort involving multiple stakeholders, including citizens, schools, local authorities, and researchers, COMPAIR sought to address critical questions in this public round related to air quality and mobility in urban environments. The Public Round of COMPAIR featured pilot projects in different locations across Athens, Berlin, Flanders, Sofia and Plovdiv.

This report provides an overview of the pilot projects conducted during the Public Round, summarising their key objectives, methodologies, findings, and the valuable insights gained. As in the Open Round, the pilot projects encompassed a wide range of topics, from assessing the impact of school streets on traffic to exploring the dynamics of urban air quality in diverse European cities. Despite the varying nature of these initiatives, they all shared a common thread: a commitment to harnessing citizen science, innovative technologies, and interdisciplinary collaboration to enhance our understanding of air quality and its associated challenges. Each pilot approached this objective in a way tailored to their local situation. Throughout this report, we aim to summarise the key aspects of these pilot projects, providing a view on the activities undertaken, the results obtained, and the lessons that can guide future endeavours in urban air quality and traffic management. By sharing these experiences and insights, we hope to contribute to the broader discourse on air quality, sustainable mobility, and the vital role of citizen science in shaping the future of urban living.

2. Public testing methodology

The success of the Open round experiments, as laid out in D5.4, has legitimised the approach taken with regards to experimental design during the Open round. The phase leading up to the implementation of experiments was marked by a string of interviews conducted by VMM, which resulted in thorough and elaborate experimental design tables for each pilot.

The document containing the experimental tables will hence be extended to the Public round. Just as in the Open round, the Public round experimental design document will be a living document that pilots will use to define and manage their experimental design. The tables within the document provide a foundation for all pilot experiments and, ultimately, Section 3 of this deliverable.

A critical factor in achieving both a sustainable environmental impact and behavioural change through our pilot experiments is proper experimental design. VMM, WP6 as well as open and public round task leader, has built elaborate expertise in guiding cities through the experimental design process. A simplified version of the EU-projects LIFE VAQUUMS' air quality sensor roadmap and INTERREG Zuivere Lucht's guidelines on citizen science experiments (Dutch only) was developed as part of COMPAIR's WP6 and applied in pilot discussions.

The Open and Public round experiment designs were drafted based on pilot interviews conducted by VMM (experimental design expertise) and IMEC (technical development expertise). VMM and IMEC summarised the results of these interviews in a draft experimental design table which was reviewed and approved by all partners.

The Public Round experimental design summary provides a backbone to the Public Round report and envisaged intermediate monitoring results, which will in turn provide the basis for the environmental impact benefits assessment and conclusions in D6.3. During the Public Round, lessons will be learned on this process and a final reflection will take place in this report.

2.1 Adaptation of LIFE VAQUUMS air quality sensor roadmap

As already used for the Open round and its report, in the following sections we briefly describe the roadmap and guidelines that were used as a starting point, argue the relevance of several elements for COMPAIR's pilot cases and finally list the key aspects of the interview guide used by VMM and IMEC as focal point of this methodology.

The **standard LIFE VAQUUMS roadmap** consists of three journeys, each encompassing three elaborately described steps. The first journey is on assessing needs by developing a persona description of the key stakeholders. It describes how you can empathise with potential users of an air quality sensor network and other stakeholders. The outcome of this journey is a set of problems and wish statements relevant to your sensor network. In the second journey you'll start envisaging solutions by determining key areas in a city that require monitoring in light of stakeholder needs and from that defining key concepts on technical aspects of the sensor network. These key concepts can later be trialed or prototyped in the ensuing experiments. At this stage you end up with use cases linked to stakeholder challenges and technical parameters. In the final journey you'll map any assumptions made and define experiments that allow you to validate those assumptions and start building your sensor network through experimentation. Typical assumption categories used are desirability, feasibility and viability. At the end of this journey you prioritise experiments, put them on a timeline and develop that into a project plan.

INTERREG Zuivere Lucht's guidelines on setting up citizen science experiments on air quality are aimed at local authorities and/or citizens designing their own experiments. It therefore provides a much more practical and simplified framework than the LIFE VAQUUMS roadmap. This simplification comes at the cost of not considering stakeholders, complex technical solutions, etc. It is built around a set of questions that a citizen scientist should ask before starting their own experiment:

- Step 1: define a research question by building a statement based on the following questions:
  - What (effect, phenomenon, etc) do you want to measure and why?
  - What type of experiment do you need? (comparative, descriptive, evaluation)
  - When, for how long and where will your experiment take place?
- Step 2: define the actual experiment you will undertake based on the following questions:
  - What (pollutant, meteorological parameter, traffic mode, etc) do you need to monitor? Consider the sources relevant to your research question and potential confounders influencing pollutant levels (e.g. weather, traffic, etc)
  - Where do you need to perform measurements? Plan your locations as a function of your research question (i.e. breathing level, chimney, indoor/outdoor, etc), hypothesis (downwind of potential source) and practical considerations (accessibility, ventilation, etc)
  - When do you need to perform measurements? Depending on your research questions a certain season might be more applicable (e.g. wood burning in winter) or you want to exclude certain periods (e.g. holidays or weekends due to changes in traffic) or you are interested in only a specific time of day (e.g. rush hour)?
  - How do you need to measure? Consider both active (e.g. sensor) and passive (e.g. Palmes tube) methods depending mostly on the temporal resolution needed to answer your research question.

Zuivere Lucht's hands-on approach using trigger questions provided the inspiration of using a **semi-structured interview** as the method of choice for drafting our open round experimental designs. The questions marked in green were copied as a starting point for our interview guide. The other questions were omitted as they would follow from the interview and discussion results and the answers to those questions could be brought up by the interviewers based on their experience in scientific experimentation.

As for the LIFE VAQUUMS roadmap we decided on incorporating elements of the following key aspects in our interview guide:

- **Empathising with stakeholders**: Given the specific nature of COMPAIR pilots and the predefined aim of experimenting on local policy effect and behavioural change, we explicitly limit this journey to 3 stakeholders. Only pilot leads, citizens and local policy makers were considered in the interview and no other stakeholder identification or prioritisation was undertaken.
- **Envisaging solutions**: as COMPAIR's implementations are already centered on a very specific region of interest within each city, we could not use the generic VAQUUMS-approach (e.g. identifying "school districts" as a zone of interest) as it was. We therefore adapted this approach to a map-based discussion of the local situation on the cases at hand during the interviews. Allowing the interviewers to identify where key activities take place, where the main effect is expected, where potential side effects can take place, etc. In order to follow this approach, we decided to also reverse the order of this journey and first define the use case using Zuivere Lucht's example on defining the research question. This allowed for a much more specific map based discussion. The map based discussion followed the technical parameterization as described in the VAQUUMS roadmap.
- **Managing implementation**: this journey was used to implement checks & balances in the interviews. We mainly focus on feasibility assumptions here. Desirability has been checked through stakeholder workshops and involvement earlier on, which are also reflected in the stakeholder elements. Viability is less of an issue given the project based nature of our pilots, although we did include checks on whether stakeholder involvement plans match the experimental design. The focus on feasibility and therefore also technical aspects, triggered the involvement of IMEC in the interviews to manage these assumptions by liaising with the technical team and describing the link to sensor and dashboard solutions provided in the experimental round document.

This approach led to the following semi-structured interview guide:

1. Use case definition (combination of research question & empathise with stakeholders)
    a. Context:
        i. What challenges does your pilot face in light of air quality and traffic?
        ii. Is there a policy change planned? If so, which one?
        iii. What data is currently available in your pilot? (both air quality and traffic)
        iv. What stance do citizens take on air quality and traffic policy?
        v. How would you describe the current level of participation in light of traffic and air quality policy?
    b. Motivation:
        i. What outcome or change would you like to achieve? (more than just results)
        ii. What effect do you think the policy change will have on traffic, air quality and behaviour?
        iii. What effect do you think the measurements will have on traffic, air quality and behaviour?

   iv. Why do you feel these citizen science measurements are required? What value do they add to the already existing data?
   c. Solution:
      i. What will you try to measure and why?
      ii. What are important locations for your pilot?
      iii. What are relevant moments for your pilot?
2. Experimentation
   a. Which citizens will you work with?
   b. What pollutants and modes of transport are relevant to monitor?
   c. At which exact locations should you monitor these parameters?
   d. When do you perform measurements and for how long? Do you require data at a high temporal resolution or at an aggregated level?
   e. What analyses will you need to perform to test your hypothesis? Does it require comparing parameters, relative or absolute values? Is there a before/after distinction?
   f. What analyses will you need to perform to communicate results to participants & citizens?
   g. Will the data collected this way sufficiently support your hypothesis?
3. Checks & balances
   a. Do the ordered amounts of devices and their properties (e.g. temporal resolution) match the experiment design? Describe how each device ordered will be used -> these questions were posed on each sensor separately
   b. Have you considered power and network connectivity requirements at the desired locations?
   c. What is the timeline for recruitment and participant workshops? Does it match the timing in the experimental design?
   d. How are you handling citizen engagement and lower SES representation?
   e. General check whether the required analyses will be possible in the COMPAIR dashboard (Policy Monitoring Dashboard (PMD) or Dynamic exposure Visualisation Dashboard (DEVD)) and if not, whether they can be done in other ways (internally or external).

2.2 Structuring and key elements of experimental design

Based on the above COMPAIR elucidated an experimental design summary focus on the 3 main topics:

1. Use case definition: purpose, research question(s) and hypothesis
2. Experimentation: type of experiment, design
3. Checks & balances: planned analysis, remarks

Experimental design for XXXXX - use case YYYY					
Purpose	Change to be realised, desired outcome				
Research question(s)	Questions to be answered through experiment				
Hypothesis	Expected results				
Type of experiment	Comparative Descriptive Threshold testing				
Design	What, Where, Who, When and How Devices (type and #), locations, participants, timing				
Planned analysis	**Analysis**	**PMD**	**DEVD**	**Ext.**	**Int.**
	How will data be processed? Does PMD suffice? Is in house data science capacity available?				
Remarks	Concerns, points of attention …				

3. Pilots public testing

3.1. Athens pilot

3.1.1. Activities

3.1.1.1. Purpose, research questions & hypothesis

The Athens pilot in the COMPAIR project, focuses on the engagement of citizens in the dimension of behavioural change regarding reducing their carbon footprint and improving air quality.

These two dimensions are depicted in three use cases scenario that includes behavioural change of citizens on environmental habits, by distributing air quality sensors to end-users (low cost and energy) and in the third scenario by citizens' participation on the Carbon Footprint Simulation Dashboard that calculates the carbon footprint and provides feedback and recommendations in order to achieve lower emissions at a household level. Also, activities related to the use cases are performed during Open Round and are ongoing in the Public Round too.

The main objective of the Public Round in Athens is to continue to raise awareness on air quality among citizens targeting elderly inhabitants in a second identified area, Kipseli, to monitor the results of sensors' measurements from both areas, Neos Kosmos and Kipseli. Also, through the participation of citizens that live in Athens, they calculate their CO2 footprint in the domains of household, public transport use, recycling and other habits and to receive recommendations according to their individual calculation.

The outcomes of this Round could be used by the city authorities in order to enhance environmental strategies, develop concrete policies on climate mitigation and empower citizens' active engagement.

Athens use case 1 and 2

The main research focus of the use cases 1 and 2 is to evaluate whether citizens are willing and have the ability to provide efficient and stable air pollution measurements or other environmental data, especially citizens that have a lowSES profile. This is researched through the distribution of air pollution sensors (initially sensor.community and then were replaced by SODAQ). In parallel, the aim is to experiment on whether citizens change environmental behaviour when they gain awareness of the air pollution factors, participate actively in measurements and receive insights on the environmental burden of the city. The introduction of the citizen science concept within Athens, more specifically through the engagement of a high percentage of lowSES groups is innovative and important results can be derived. Finally, another research point to highlight was the intention of citizens to take part in the city's actions

for environmental neutrality by providing data and the city's trust in data provided by citizen science.
Both use cases share the same aforementioned targets, however the involvement of two areas of Athens provides the opportunity to gather data from two diverse localities of the city, to correlate them and exclude comparative outputs. Finally, the feed of data in the Digital Twin tool aims to support decision making and easy to comprehend visualizations.

Regarding the recruitment and engagement for use case 1 and 2, their planning started from the main research question that is behavioural change of Athens citizens on environmental habits by distributing air quality sensors to volunteers. Since COMPAIR is a citizen science project, the engagement of citizens was very crucial. The process for successful results both on citizen science perspective and on air quality issues include:

- Design of the process to engage Low SES population
- Communication with the Municipality of Athens in order to identify the areas and the respective Friendship Clubs
- Sensors distribution
- Recurrent workshops for end-users support and address any concern.

Athens use case 3

Use case 3 for the Athens pilot refers to the CO2 footprint measurement for the households of Athens, the collection of data regarding everyday environmental habits and the exploitation of the results for analysis and decision making. The proposition of interventions according to the declared way of life and habits was also foreseen for the pilot in the form of advice for a greener behavior and reduction of the footprint at a household level.

Additionally, the use case aims at promoting the dialogue with the city and the opinion mining of citizens regarding the city policies. This purpose is served through the Scenario Simulation Dashboard tool that is integrated in the carbon calculator and facilitates the process of policy formulation for the target of climate neutrality to be achieved by European cities.

More specifically the Carbon Calculator tackles the research topics of raising awareness since it supports the citizens to understand how they affect their carbon footprint through their daily activities with graphic data and reports that compare their households' results with national and European data. Another research goal is that of citizens' contribution to the reduction of pollution footprint through the provision of recommendations according to the inserted data. On the other hand, the scenario simulation tackles the participation of citizens to policy making since the tool maps the intention of citizens to take diverse actions and their intention to adopt initiatives proposed by the municipality, region or government.

The points to address through the activities in the Athens pilot aim to research the level of change in individual behaviour when more insights on the impact of their behaviour is gained, the level of increase in civic participation when it is communicated that environmental goals are reached through collective actions and the level of acceptance of data collected by citizens from the policy makers and city officials.

3.1.1.2. Experimental design

For use case 2, the experimental design is depicted in the Table 1 below including all the respective information regarding the design and the hypothesis to be addressed:

Table 1: *Experimental design for Athens - use case 2*

<table>
<tr><th colspan="6">Experimental design for Athens - use case 2</th></tr>
<tr><td>Purpose</td><td colspan="5">Creating awareness on air quality among elderly habitants of Kipseli</td></tr>
<tr><td>Research question(s)</td><td colspan="5">Focus on awareness</td></tr>
<tr><td>Hypothesis</td><td colspan="5">Collect variations in PM, humidity and temperature across Kipseli of varying temporal frequencies such as daily, monthly, seasonal, etc</td></tr>
<tr><td>Type of experiment</td><td colspan="5">Comparative
Descriptive
Threshold testing</td></tr>
<tr><td>Design</td><td colspan="5">What:
31 SODAQ sensors (PM2,5, PM10, temperature, humidity)
11 sensor.community devices
1 BC meter
1 NitroSense
Where:
Deployed within the district on the balcony of individual residences (apartments preferably on lower floors) of elderly participants in the area of Kipseli, engaged 2 Friendship Clubs in Kipseli
BC meter and NitroSense are installed in the building of the Friendship Club.
Who:
Elderly, as a low SES group, 65+, majority retired
Take part in socialising centers of Municipality of Athens, namely 2 friendship clubs in the area of Kipseli
When:
Sensors are delivered with assembly workshops starting from October 2023 and will be maintained until the end of the project.
Friendship clubs have activities every day, mostly in the morning. In previous times this was typically done on a monthly basis, but frequency can be increased. Senior citizens reduce their activities in the summer period.
How:
Device monitoring initially distributed sensors.community, then retrieved back to be send to Sofia and Plovdiv pilots and SODAQ sensors were re-distributed
Logbook (example) = elderly citizen keeps track of outdoor activities that could help correlate to sensor data? Y</td></tr>
<tr><td rowspan="2">Planned analysis</td><td>Analysis</td><td>PMD</td><td>DEVD</td><td>Ext.</td><td>Int.</td></tr>
<tr><td>How will data be processed? Does PMD suffice? Is in house data science capacity available?</td><td>x</td><td></td><td></td><td></td></tr>
</table>

The following Table 2 includes the experimental design for the use case 3, namely the CO2 Dashboard:

Table 2: *Experimental design for Athens - use case 3*

<table>
<tr><th colspan="6">Experimental design for Athens - use case 3</th></tr>
<tr><td>Purpose</td><td colspan="5">Calculating carbon footprint using dashboard</td></tr>
<tr><td>Research question(s)</td><td colspan="5">Raising awareness on daily activities and on the carbon footprint that is produced at a household level</td></tr>
<tr><td>Hypothesis</td><td colspan="5">Expected results</td></tr>
<tr><td>Type of experiment</td><td colspan="5">● Comparative
● Descriptive
● Threshold testing</td></tr>
<tr><td>Design</td><td colspan="5">What:
CO2 Dashboard promoted for the calculation of footprint by each user

Where:
Online campaigns through diverse communication and networking channels

Who:
CO2 Dashboard is used be residents of Athens that volunteer to sign in, create account and answer the tool

When:
the campaigns launched in April 2024 ant it is on going

How:
CO2 Dashboard Calculator and Scenario Simulation Dashboard is used by online volunteers</td></tr>
<tr><td rowspan="2">Planned analysis</td><td>Analysis</td><td>PMD</td><td>DEVD</td><td>Ext.</td><td>Int.</td></tr>
<tr><td>How will data be processed? Does PMD suffice? Is in house data science capacity available?</td><td>x</td><td></td><td></td><td></td></tr>
</table>

3.1.1.3. Workshops

Use case 1 and 2

In this section, the activities performed regarding citizens engagement for the 2 above mentioned use cases are summarized below.

Firstly, two areas of Athens are selected for Open and Public round, Neos Kosmos and Kipseli, areas with environmental issues addressing also socioeconomic criteria. Mainly, the tasks of Open Round included workshops, meetings in the Friendship Club of Neos Kosmos, but also in this area activities were continued during the Public Round. In the Public Round activities in 2 Friendship Clubs of Kipseli take place.
In this section, a summarised description of the engagement process follows that includes:

- Meetings with group of citizens in order to be informed on the objectives of the pilot implementation and their role and contribution
- Recruitment and benefits for the citizens
- Distribution of sensors
- Training sessions on sensors' functionalities and operation.

In total, so far, 10 engagement workshops and follow up meetings have been organized to present the scope of air quality measurements and train end users in installing and using the sensors. From these workshops, 54 end-users are engaged, 51 out of them are lowSES population (94% of the volunteers), namely senior citizens, members of Friendship Clubs. It must be noted that each Friendship Club of the city has on average 50 registered members, and 35 of them are usually active in daily participation. As per the demographics, most of them are women, thus 44 women and 10 men. To these end-users 54 sensors are distributed, but also 2 NitroSense and 2 BC Meters installed in the respective premises.

The outputs of the workshops are very positive taking into consideration that COMPAIR's scope and objectives encourage citizens behavioral change regarding energy consumption and initiatives for air pollution. It is a challenge to convince citizens to participate in a pilot project by installing sensors in households, and more so senior citizens. However, the completion of several tasks up to now, indicates exactly the above-mentioned point, that the project's challenges are addressed and citizens, even of low SES groups, are eager to participate and contribute to improvement of air quality and on environmental issues in general.
Moreover, the comparison of air quality of the two areas that have different characteristics is also remarkable. On one hand, the two areas have different socioeconomic characteristics, meaning that in Neos Kosmos citizens have better living standards and quality of Life than of Kipseli, while the area of Kipseli is less green, hence of worse air quality.

By the end of the project, final workshops are scheduled with the members of the Friendship Clubs and their administration in order to present the outcomes of sensors' measurements. This could be of utmost importance since seniors are eager to learn about air quality and to participate in activities related to healthier conditions of living. The outcomes of these experiments are planned to be presented to city officials in order to take them into consideration and include them in their future policies and environmental strategies.

Use case 3
The campaigns for the CO2 calculator and policy simulator were organized at the first stage of the actions online. The initial communication was launched through recurrent MailChimp campaigns in a database of contacts that are all employees of the Municipality of Athens. This list includes more than 5000 individuals and a percentage of which are also residents of Athens. Of course, a diffusion campaign for the use of a tool resides to the volunteer intention of each contact, hence contacts are invited to sign in with their email accounts in the PMD and

were directed to use the CO_2 calculator. Figure 1 below depicts the graphic design of the first campaign to municipal employees.

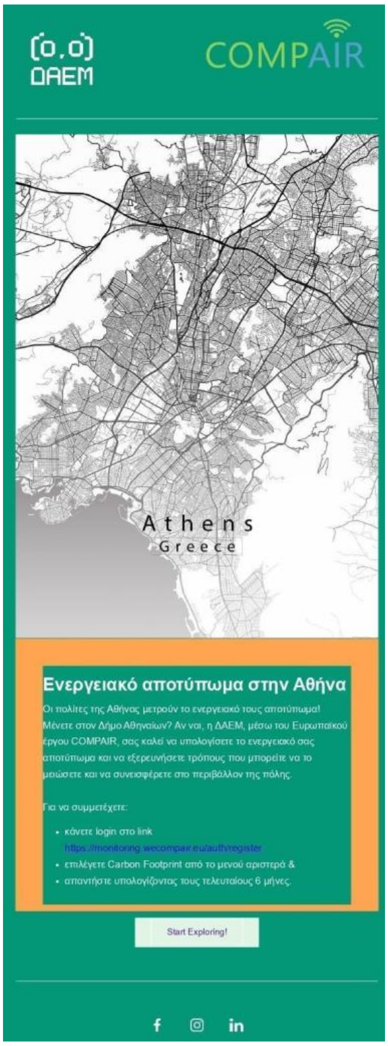


Figure 1: *CO_2 calculator campaign to municipal employees of the City of Athens*

The other online campaigns focused on a diverse set of target groups for the calculation of households CO_2 footprint in Athens and followed the quadruple helix:

- Citizens, NGOs, active groups
- Industry, companies, private sector
- academia and research
- public authorities.

More specifically, each group of organizations was contacted by adopting the approach to each profile and scope and below there are summarized the organizations that are invited to participate:

- Greek NGOs that are located in Athens and have a focus on the prevention of pollution, promotion of environmental challenges, sustainability and well-being
- Technical companies with offices in the Athens Municipality from the registry of companies that are active in the field of architecture, civil engineering etc

- Professional auditors for energy related matters located in Athens and members of the Technical Chamber of Greece
- Professional inspectors for energy certifications in buildings located in Athens and certified by the Ministry of Environment
- Academia personnel, university professors and research in the National Technical University of Athens in the fields of architecture, civil engineering, environmental, mechanical and chemical engineering that have relevant energy related activities in their curricula
- Contacts from the Ministry of Environment and Energy
- University professors from the National Kapodistrian University of Athens, the School of Pedagogical and Technological Education, the Technical University of West Attica, the University of Piraeus, the Harokopio University that include related technical and energy faculties
- Energy auditors in the field of tourism that are located in Athens
- Members of HELLASCO the Hellenic Association of Consulting Firms, non-profit organisation for companies that provide consulting services for design, planning and implementation of technical and development projects
- Members of EITEK the Greek Institute for Building Technology and Science
- The Energy Institute that is an initiative of the Public Power Cooperation of Greece
- Members of IENE the Institute of Energy for South-East Europe located in Athens
- Members in Athens of HELAPCO the Hellenic Association of Photovoltaic Companies
- The Greek Association of Electrical Providers and Renewable Sources of Energy – ESHAPE
- Contacts in the Centre for Renewable Energy Sources and Saving (CRES) a Greek national entity for the promotion of renewable energy sources, rational use of energy and energy conservation
- Athens members of the Greek Atomic Energy Commission
- The environmentally active Institute of Forest Research
- The Organization of Earthquake Planning and Protection
- Contacts of policy makers from the Region of Attica
- Public bodies that are located in Athens and have responsibilities in the field of environmental and generally public protection e.g. the Civil Protection and the Hellenic National Meteorological Service
- The Decentralized Administration of Attica
- The Energy Coop Electra
- The officer of Green Fund, the national contact point for LIFE projects from the Ministry for the Environment and Energy
- Contacts in N.E.C.C.A. the Natural Environment and Climate Change Agency that is a private body administered by the Ministry of Environment and Energy with the responsibility to implement the policies of the Ministry on the fields of sustainability and response to climate change
- Professionals in the construction industry and evaluators of buildings located in Athens, companies in the field of new energy systems, EMS, BMS etc
- Associations sustainable buildings professionals e.g. insulations, energy systems etc
- Members of POMIDA the Hellenic Property Federation a national organization of building owners

- Contacts in the Hellenic Recycling Agency and HERRCO the Hellenic Recovery Recycling Corporation
- Officers of ELIAMEP the Hellenic Foundation for European and Foreign Policy with activities related to Climate and Sustainability
- Officers in the Programme “Environment and Climate Change” that was launched in 2022 as the main program of the NSRF National Strategic Reference Framework
- HSPN the Hellenic Society for the Protection of Nature
- Citizens groups volunteering in Athens indicatively: Elix volunteer groups, Save your Hood, Greek Eco Project, All for Blue, the group Ev Zin for well-being, ARSIS NGO, the Green Tank, the Impact Hub Athens, the Group of Storytelling for the city of Athens
- Environmental NGOs that are in the contacts of the Municipality of Athens through the SynAthina Platform
- Groups of citizens that are active in their neighbourhoods and have formed an organizational structure for their coordination e.g. local discussion groups and local activists. Their groups are located in the neighbourhoods of Athens: Ardittos, Petralona, Filopappou, Thisseio, Kerameikos, Gkazi, Rouf, Koukaki, Patisia, Academy of Plato.
- Finally, a specific communication was established with NGOs and other bodies that have an important role in Athens such as the Goulandri Foundation, the Bodosaki Foundation, the Foundation QualityNet, the Association of Engineers Without Borders, UEHR the Institute of Urban Environment and Human Resources a public body launched by the Department of Economic and Regional Development of Panteion University, the Biopolitics International Organisation, PA.KOE the National Centre for Ecological Research, the Ecological Library Eyonimos, AEF the Athens Environmental Foundation, MEDASSET, Greenpeace Hellas, WWF Hellas, Archelon NGO, HSPN the Hellenic Society for the Protection of Nature, MedSOS, the Earth Organization, the organization We4All, the environmental NGO Center for Development of the Mediterranean and the Environmental Education Laboratory (EEL) of the National and Kapodistrian University of Athens.

The COMPAIR Athens activities are promoted also in collaboration with the City of Athens from the Vice Mayor of Climate Change, the Department of Public Relations and the Department of Resilience and Sustainability. Finally, the action was promoted in the Synathina platform of Athens (Figure 2), a common space which brings together, supports and facilitates citizens’ groups engaged in improving the quality of life in Athens. The platform has served the coordination of citizens’ groups and the support of their activities since 2013.

Figure 2: *Promotion of CO2 footprint calculator in SynAthina platform*

The actions reported in this document are ongoing since use case 3 will remain active until the end of the project. Thus, next steps are already designed and some organized. Indicatively, use case 3 is communicated to the National Contact Points of European projects in Greece and the National Documentation Center will include COMPAIR campaigns in its next newsletters with invitations for the citizens of Athens to take part in citizen science. More actions are planned with the Municipality of Athens and a synergy with the C40 network – where Athens is a member - on Friendship Clubs. Actions are planned to contact associations of parents of students in the 7 districts of the municipality. Finally, presence and promotion of use case 3 is planned for July in online newspapers, websites and blogs utilizing contacts of the city.

3.1.2. Results

3.1.2.1. Analyses

Use cases 1 and 2
For the analyses of the use cases 1 and 2 the PMD dashboard of the project was exploited in various ways, including:

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

Three projects are created for experimental analysis, a project to compare the measurements of SODAQ sensors in the area of Neos Kosmos[1] that were initially distributed in the Open Round (Figure 3). This project was also updated by adding the additional sensors distributed to citizens in the area during the Public Round. A second project was created for the measurements of the Kipseli2 area that was launched in the Public Round (Figure 4). Finally, the third project refers mainly to the NO2 measurements[3] from the 2 areas (Figure 5).

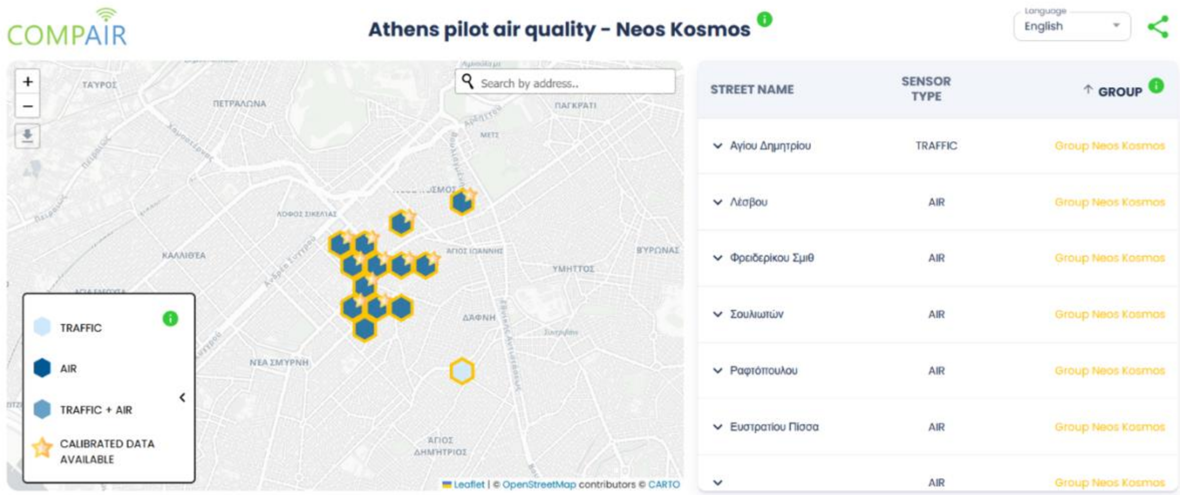


Figure 3: *PMD project for air quality in Neos Kosmos*

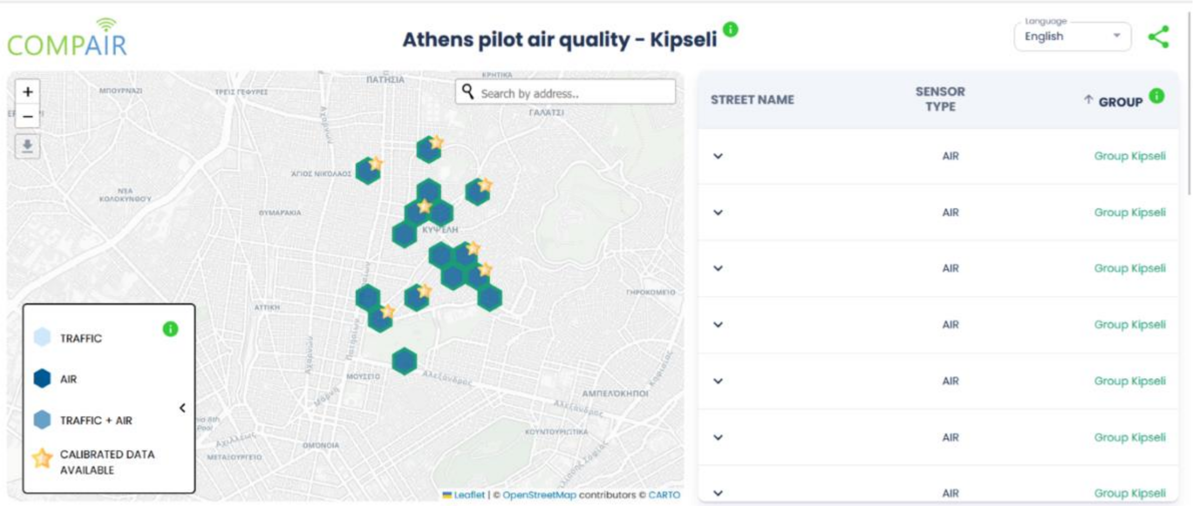


Figure 4: *PMD project for air quality in Kipseli*

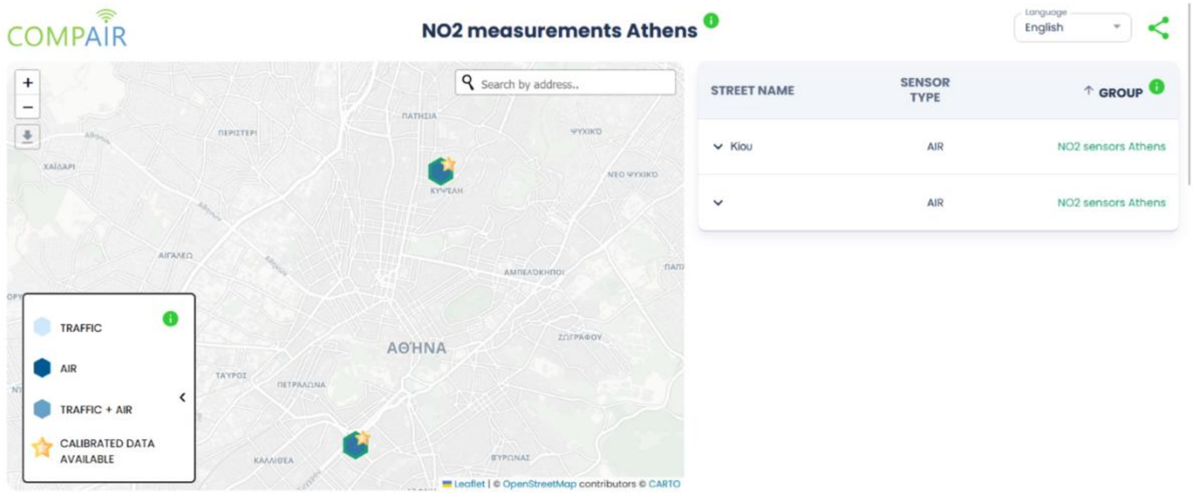


Figure 5: *PMD project for NO2 measurements in Athens*

Other important analysis took place from the Use cases 1 and 2, indicatively:

- The 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
- Comparison of results for the two areas to extract valuable output
- 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.

Outputs and results of such analysis are mentioned in the next session.

Use case 3

Use case 3 refers to the CO2 calculator tool and the Scenario Simulation Dashboard that is integrated. The analyses that have been performed so far on the received answers are initially the following:

- comparing 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.
- Then each of these categories is aimed to be analysed in terms of its distribution to CO2 emissions for the 7 districts of Athens. Each district has a different contribution to each category and valuable outputs can be derived by these analyses.

3.1.2.2. Results

Use cases 1 and 2

Regarding the NO2 data collection in the two areas of Athens, it is depicted in the Figure 6 below the measurements from December 2023 until today. It is evident from the data collected that the NO2 concentration for the areas of Athens follow the same trend of measurements. The data from the sensor in Kipseli is the lower line in the graph, so the location of the sensor measures less NO2 in Kipseli than in Neos Kosmos. A parameter to take into account is that the sensor in Kipseli is in a building located in a very small street with less traffic than the sensor in Neos Kosmos that is installed in a small park, but the park is adjacent with a large avenue of Athens. The latter has extensive traffic jams, 4 lanes of traffic and vehicles crossing almost all day.

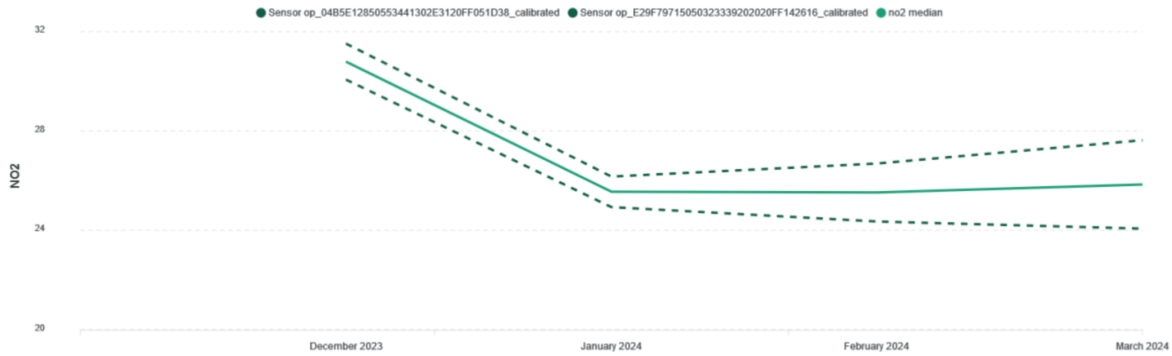


Figure 6: *NO2 measurements*

Another result that analizes the effect of extraordinary conditions on air quality is the case study of the central square of the Kipseli area. This location is covered by the PM sensor 350457790905051 that one of the elderly citizens has installed in his/her home and it is directly over the square. As depicted in the Figure 7 below from the beginning of the installation 26/10/2023 relatively acceptable levels of PM2.5 were measured in the area until 18/12/2023. The levels were between 5.6 - 20.56 μg/m³. On this specific date the square was closed for traffic and the excavation for the new metro station started in the month of December 2023. It is evident from the figure that the 10 days of excavation works created a peak in the PM2.5 measurements due to the dust produced and the pollution spiked to very high levels peaking at 27.29 μg/m³. Then other underground works started taking place and the area remained restricted from vehicles so the PM2.5 reduced slowly and remained low due to no traffic in the neighbouring streets. The same trend applied also in the values of PM10.

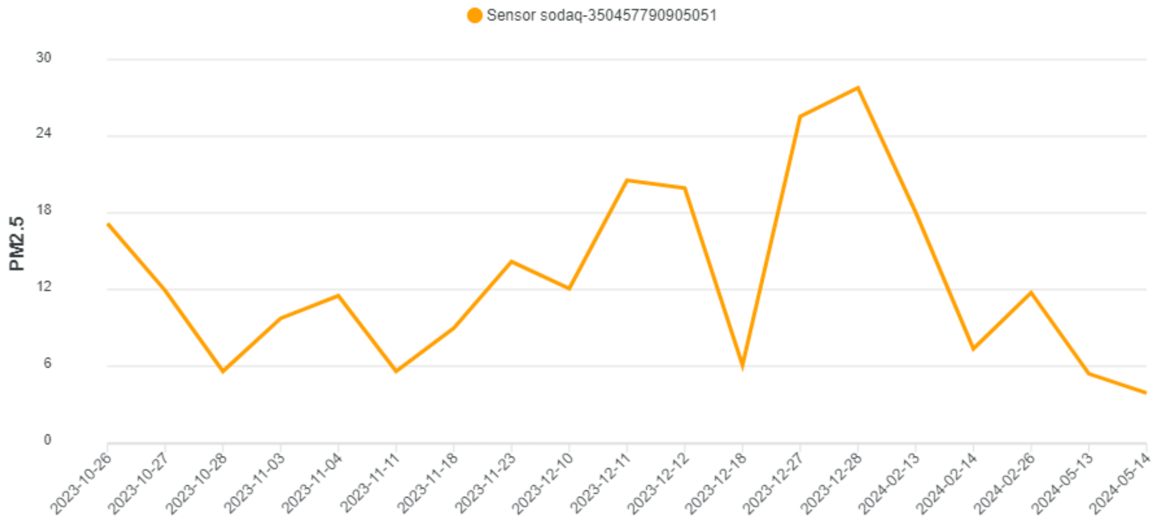


Figure 7: *PM2.5 measurements in Kipseli*

The Figure 8 below depicts the output for analysis of conditions that affect the quality of air in the city and are external caused by weather extremes. The graph shows the measurements of a sensor located in Neos Kosmos and it is used as an example of the extraordinary event of african dust that covered almost all the area of Athens in the days 17-19/5/2024 spiking the values of PMs. From the figure it is clear that the general trend in the last months is to have values lower than 8 μg/m³ and it increases over 16 μg/m³ during the period that the phenomenon of african dust appeared.

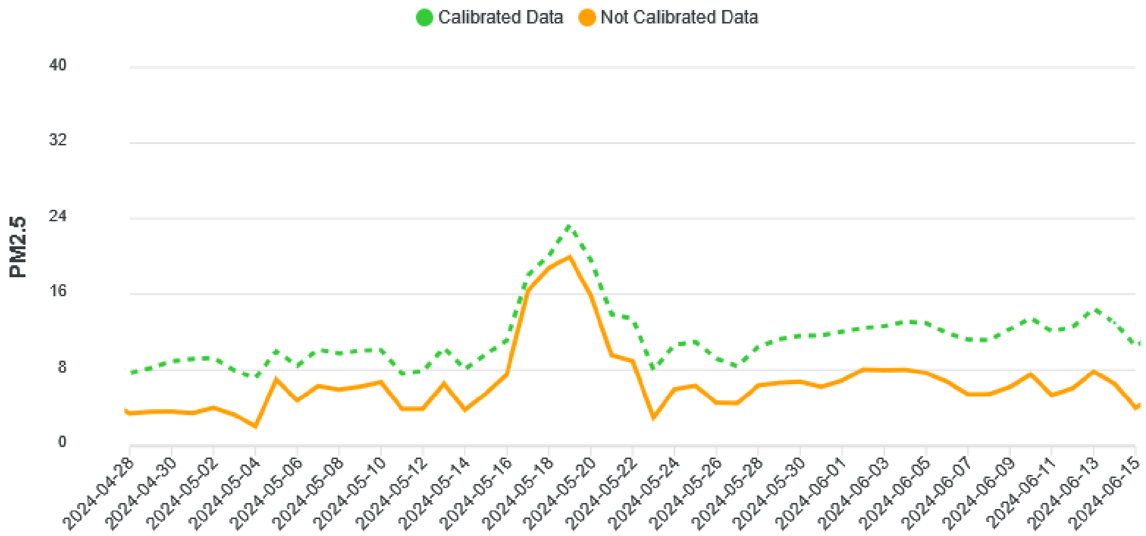


Figure 8: *PM2.5 measurements in Neos Kosmos*

Internally in the area of Neos Kosmos, the average values of PM2.5 are around 10-12 μg/m³ that is a rather healthy result. Grouping a number of sensors in the Figure 9 it is evident that during the winter months of December there is a rise in the pollution due to wood burning used for domestic heating. One of the sensors that measures profoundly high levels is also located right next to a restaurant's chimney and it was indicated by the end-user of the pilot that installed it.

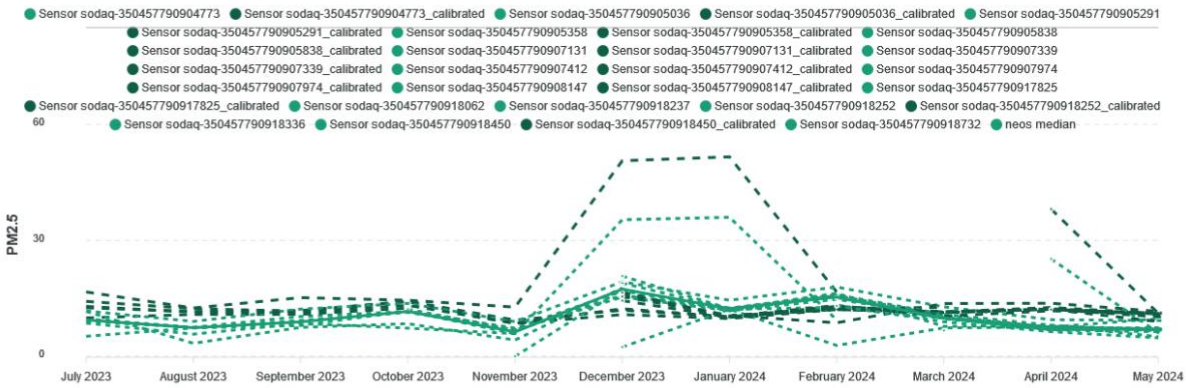


Figure 9: *PM2.5 measurements in Neos Kosmos due to wood burning*

The diagram for a group of sensors in the area of Kipseli is presented in the Figure 10 below. The general mean value of this area is higher than that of Neos Kosmos, approximately 15 μg/m³. Higher air pollution was expected in Kipseli since it is an area more densed with roads and traffic, with less green spaces and closer to the city center.

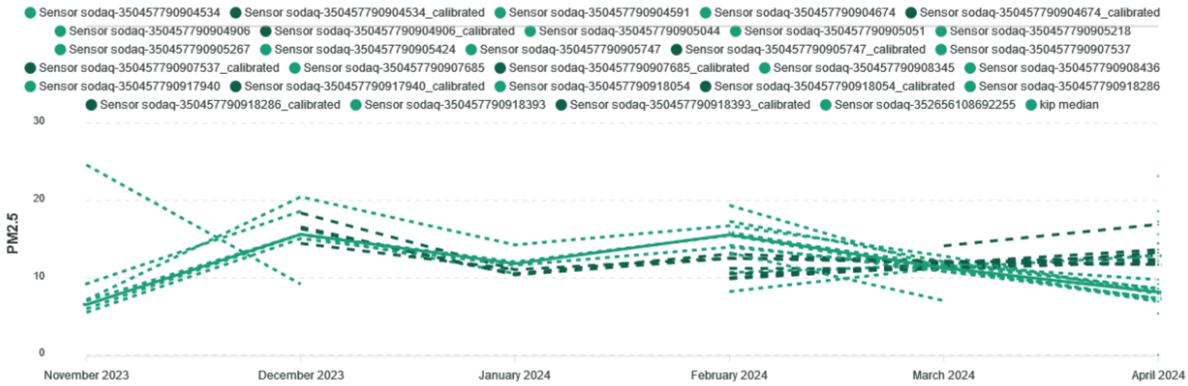


Figure 10: *PM2.5 measurements in Kipseli*

Finally performing analysis internally in positions within each area is indicatively depicted in the Figure 11. The sensor 350457790918450 is measuring higher values of PM10 for a common week period than the other one. The first sensor is located in a crossroad with a lot of traffic jams in the Neos Kosmos area, while the other sensor is in a small road.

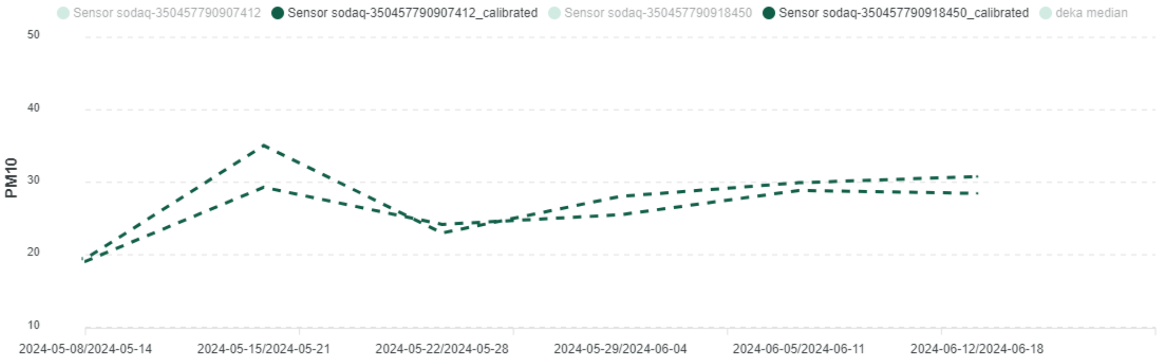


Figure 11: *PM10 measurements in Neos Kosmosi*

Since the Athens pilot is still ongoing until the end of the project, it is planned in September to perform more analysis on the gathered data from the use cases and to exercise of extracting valuable outputs for the formulation of policies at a neighbourhood and district level. Also, the Digital Twin representation of the data that is planned for the next period will provide a tool to further support policy making.

Use case 3

Until 11 June 2024, the CO2 calculator was visited by 173 users, 83 created accounts and 80 replied to on their household footprint. These numbers are approximate since this is an ongoing communication, and users are replying even after they have been contacted. Also, as mentioned in the previous section, the use case 3 of Athens pilot will remain active until the end of the project and next activities are already planned.

Figure 12 depicts a distribution of the sources of CO2 pollution from all the data inserted to the tool by the users. The main categories of CO2 emissions are the buildings, flights and the use of vehicles. The rail sources and waste emissions are rather low, revealing that so far citizens of Athens are not keen to use the train or it is not convenient to daily life and also that waste management and recycling habits are already at an advanced level.

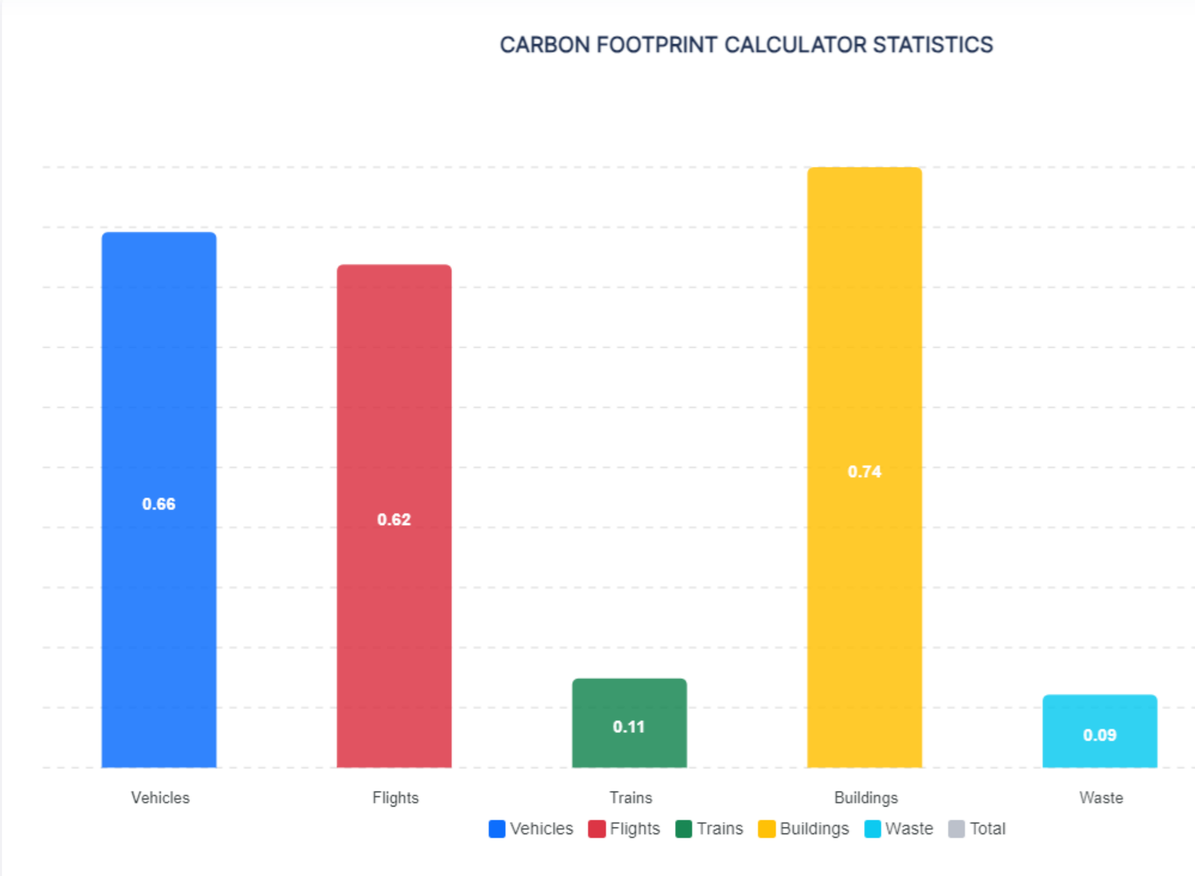


Figure 12: *CO2 Calculator statistics for Athens*

Also, the CO2 calculator has the feature for Athens to group the answers from citizens according to the area that they live to the 7 municipal districts of Athens. Thus, summarized data are also reported in the view depicted in Figure 13, where the 7 districts are pinned. By clicking in each pin the average data from the citizens of this district are shown in the map.

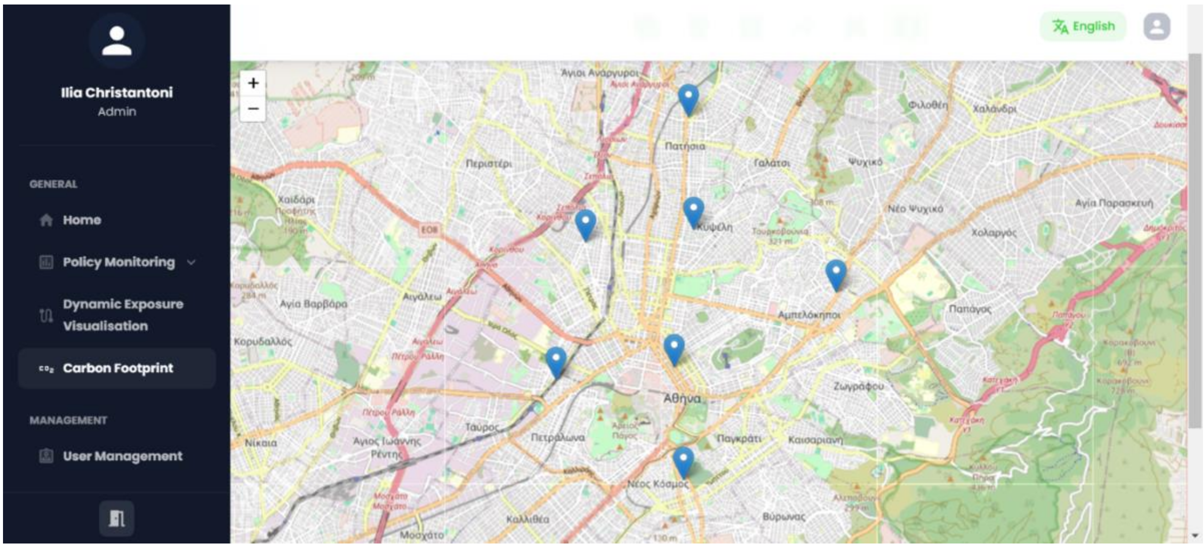


Figure 13: *CO2 measurements for 7 municipal districts of Athens*

In the table 3 the data collected are presented for each municipal district in 5 different categories, namely the average emissions calculated from the answers for transportation, flights, trains, buildings and waste.

Table 3: *Total results for CO2 sources for the 7 districts*

Municipal District	Average CO2 from Transporation	Average CO2 from Flights	Average CO2 from Trains	Average CO2 from Buildings	Average CO2 from Waste
1st	0.0411	0.8877	0.0422	0.8394	0.0855
2nd	4.1558	0.5558	0.2050	1.2208	0.1008
3rd	0.0433	0.5700	0.0200	1.5800	0.0766
4th	0.0366	1.0833	0.6749	0.4350	0.0733
5th	0.0566	0.4186	0.0000	0.4460	0.0946
6th	0.0190	0.1689	0.0000	0.8170	0.0779
7th	0.0271	0.8814	0.0000	0.3400	0.0999

From the analysis of each category, has resulted that the 2nd district contributes highly to the pollution from transportation, so the use and number of cars, the use of fuel, the frequency of car mobility etc, while the other citizens in other districts have greener habits of transportation. An outcome from this observation is that within the 2nd district of Athens a part is well connected with mass means of transportation and also close to the center, however a large part of the district is served only by tram that is very slow-speed and not convenient for the majority of the residents.

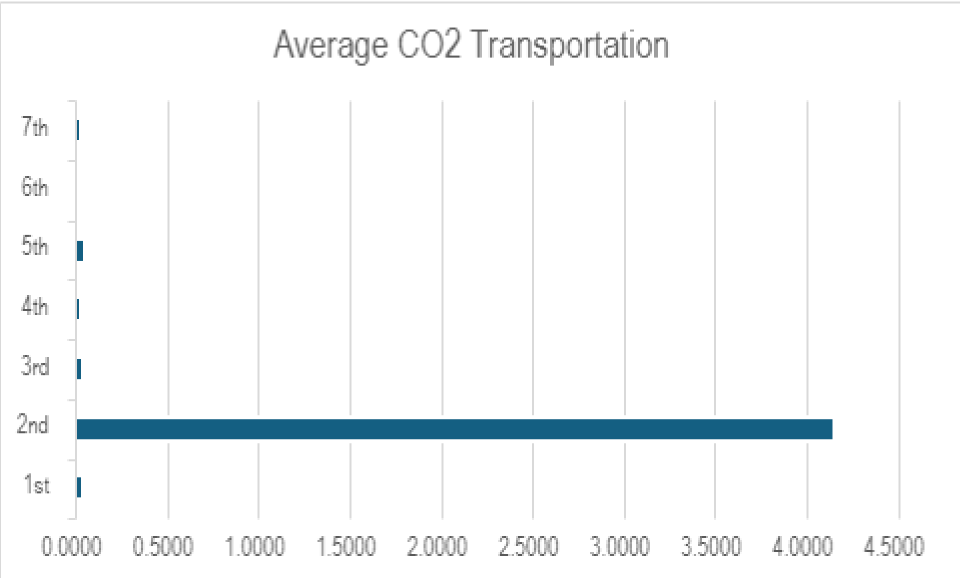


Figure 14: *CO2 from transportation*

The average pollution from flights has a rather equal distribution from the districts 4, 1 and 7. The flight habits are connected with the professional and other travelling habits of the citizens and not strictly related with the city.

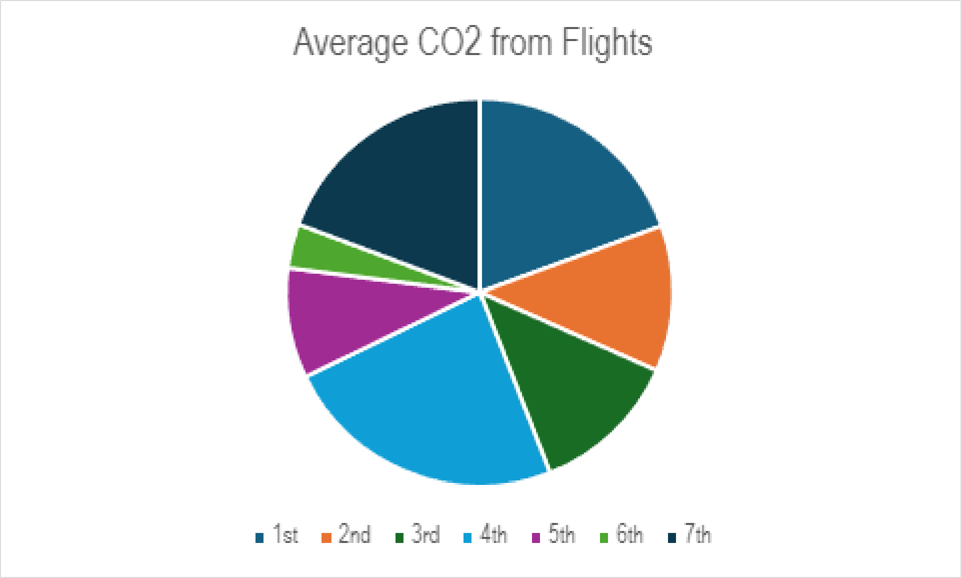


Figure 15: *CO2 from flights*

Figure 16 depicts the train habits and average CO2 data from rail use. It is expected to have high numbers from the citizens of 4th district since within this area is located the central railway station of Athens.

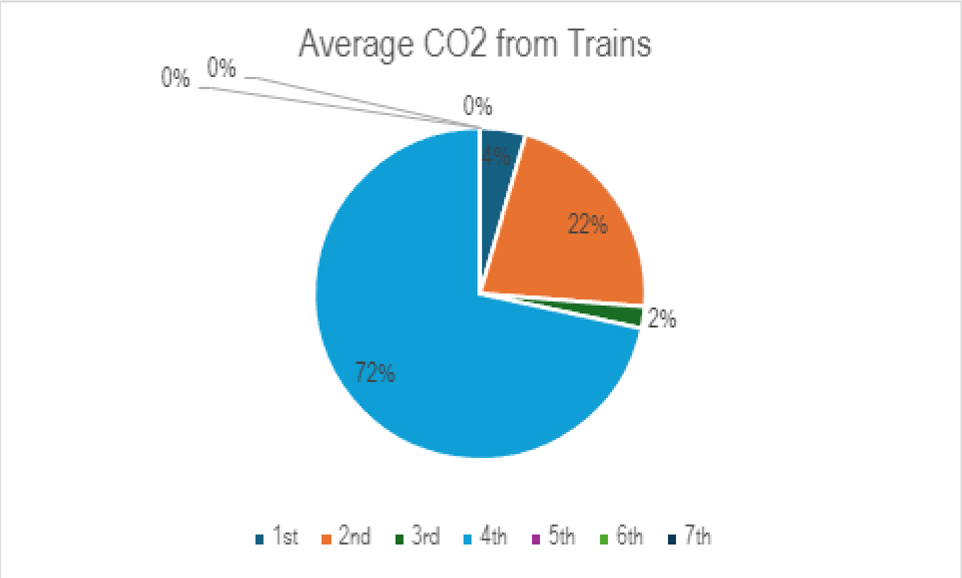


Figure 16: *CO2 from trains*

Regarding the emissions from buildings that are also the main source of CO2 from the citizens data so far, the main contributions are from the 3rd and 2nd district of Athens each one contributing more than 20% for the emissions.

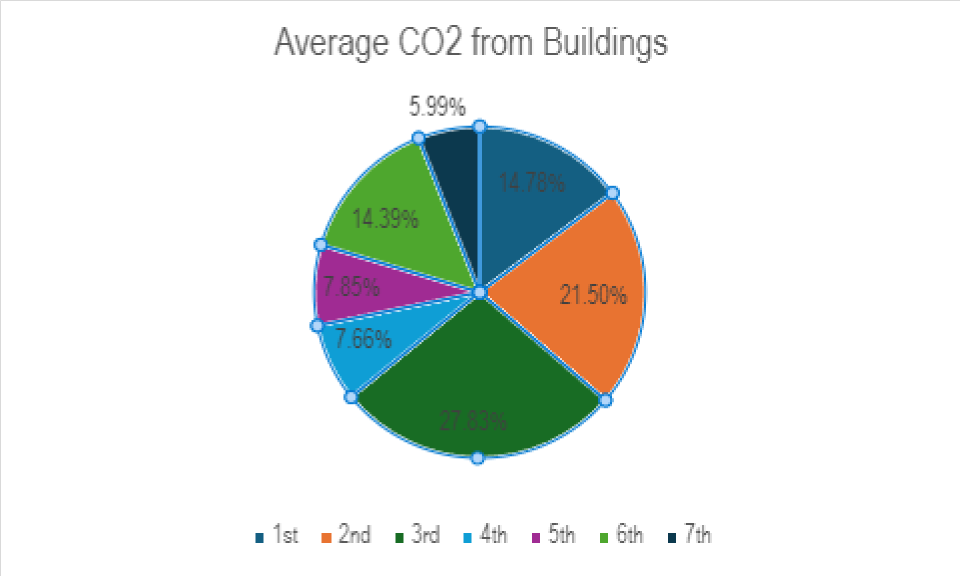


Figure 17: *CO2 from buildings*

Finally, as also mentioned in the general results, the waste emissions from the citizens of Athens have an approximately equal distribution and relatively low contribution to the pollution. The recycling habits in Greece are sufficiently widespread and effective.

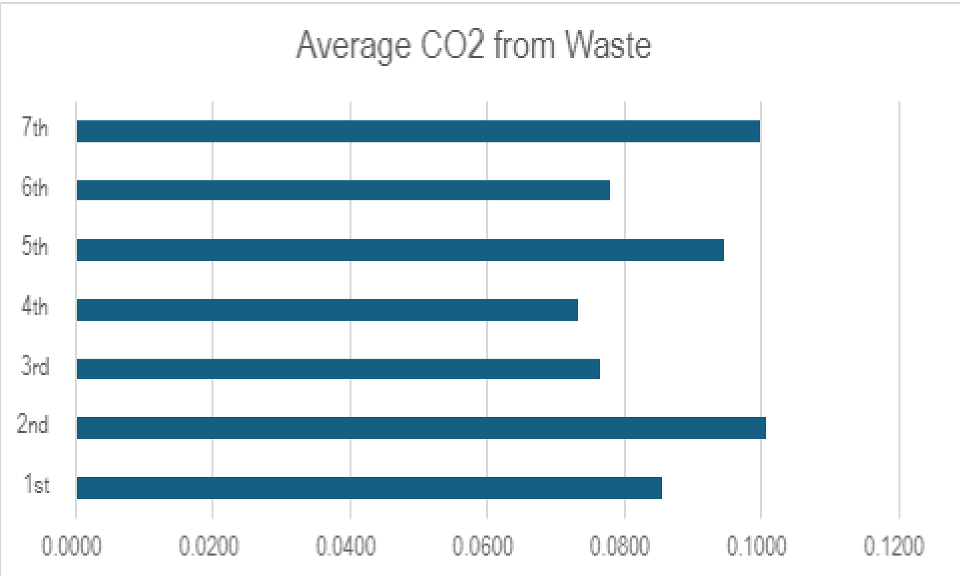


Figure 18: *CO2 from waste*

Reviewing the results from the Scenario Simulation Dashboard feature of the CO2 calculator, the end-users through their answers have declared their intention to adopt a new habit in their daily life that will reduce their domestic footprint and the city's footprint. Also they have stated their perception on the proposed policies on a municipal, local and governmental level. The overall outputs are depicted in the figure below and will be further analyzed in this section.

It is important to highlight that the data collected and analyzed here from the Scenario Simulation Dashboard, are the replies from volunteers that all declared to have an education level of postgraduate degree. The tool did not receive answers by volunteers of other education backgrounds. Also the end users age groups were between 25-34 and 45-54. The sample also stated their gender only as male and “rather not say”, so in case the volunteer was a female or non-binary this was not declared in the tool. Finally, it must be reported that the answers in the first part of the tools referring to the CO2 calculator were received from users that had stated more educational levels, genders and age groups. This could suggest that the first part of the tool was completed easily by more users, while not all users proceeded to the Scenario Simulation since it is more complicated to understand and submit answers.

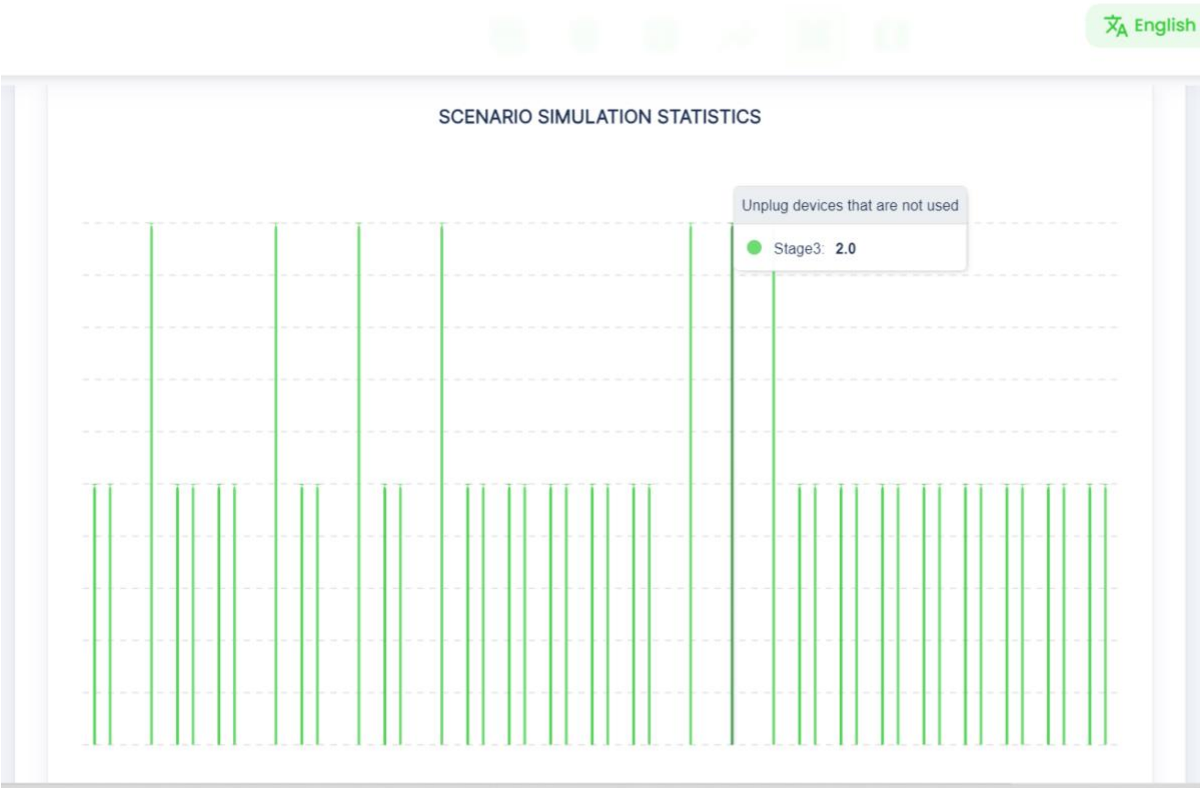


Figure 19: *Scenario Simulation statistics*

In order to provide more insights on the outputs, interventions, changes and other adoptions that the users stated would be willing to uptake in order to change their footprint are summarized. Below there are listed the most preferable actions:

- Improve everyday mobility in Athens
- Unplug devices when not in use
- Introduce composting in everyday life
- Improve recycling habits
- Improve insulation habits
- Improve habits on use of appliances
- Improve lighting habits

Other changes at household level that were proposed but less preferred by the end-users are the following. The volunteers saw a small level of improvement on those, possibly because they are not feasible to implement, or the users are less willing to adopt:

- Change and improve flying habits
- Change travelling habits

- Improve transportation habits
- Replacement of car with electric.

Finally, as outputs of the Scenario Simulation, end-users stated their preferred policies to be applied and decided by the municipality, the region and/or the government:

- Start creating bicycle lanes, where there are not available in Athens (regional/municipal)
- Introduce bike sharing programs at convenient locations (regional/municipal)
- Increase the number of composting stations (regional/municipal)
- Financial support program to improve domestic heating (governmental)
- Financial support program for home insulation systems (governmental)
- Creation of green ports (governmental)
- Increase the existing bike lanes in Athens (regional/municipal)
- Establish a speed limit of 30km/h (regional/municipal)
- Improve energy efficiency of households through a government support program (governmental)
- Improvement of rail efficiency service (governmental)
- Increase the production of wind energy (governmental)
- PV parks in petrol stations (governmental).

3.1.3. Lessons learned

In this section, lessons learned from the workshops and sensors distribution and from the campaigns for the CO2 calculation are presented.
Regarding the sensors' distribution the general feedback is very positive since the interest from the seniors in learning more is high and their interest to contribute to measuring pollution. Although the targeted group is citizens over 65 years old, their intention to participate in these activities is worth mentioning. Elderly people are a citizen community eager to learn and sensitized to environmental issues, making their engagement successful, since the percentage of their participation is about 95% from the overall volunteers.
Moreover, the fact that the SODAQ sensors are easy to use made the recruitment of seniors more efficient. Similar reactions from users in the Open Round were observed to Public Round. In more details, the first sensors distributed and then retrieved back were the sensors.community. These devices were difficult to assemble by seniors, elderly citizens did not manage to transmit data effectively, wifi details were necessary and seniors gave them wrongly. That's the reason the troubleshooting wasn't easy, and they were finally replaced by SODAQ sensors.
The negative point that was also noted in the Open Round was that there is no indication that the battery is low and the charging of the devices remained an issue. To tackle this challenge, plugs for continuous charging are distributed to end-users in the Public Round.

The end users of the Friendship Clubs of Kipseli expressed their concerns on the power that is necessary for the charging and transmission of data for both the sensors.community and the SODAQ devices. All doubts were answered in this Round too.
Finally, a remarkable lesson learned is that Citizen Science projects, since the actual participation of citizens groups is mandatory, require recurrent face to face meetings. Thus,

personal contact is necessary and an effort for field work must be foreseen to the success of such projects.
Another point that was highlighted by seniors is that it is quite difficult for them to comprehend the measurements depicted in PMD, hence the need for extra time and activities allocation is needed. Also in some cases the visualizations are not easy to interpret and this depends on the educational level of the volunteer.

Regarding the CO2 Calculator the general feedback from the participants so far is positive as well, taking into consideration that the campaign process is still ongoing and it will be completed by the end of the COMPAIR project. The number of registered participants indicates that citizens are sensitized on environmental issues and the climate change affects them. Also, the alternative use of mobility means is of their interest and depending on the neighbourhood they live in, the use of public transport means is increased. Moreover, citizens are eager to contribute to energy saving by unplugging devices and by improving their habits on their use, as well as and by improving insulation habits.
After the end of the indicative campaigns and the project, city officials can include the results of citizens' replies in respective strategies in order to improve not only the climate conditions in the city, but also improve the quality of life.

3.2. Berlin pilots

In Berlin, inter 3 – the Institute for Resource Management - organised two experiments for the Public Round campaign:

- Measuring and raising awareness on air quality with cyclist on their daily commutes all over Berlin (mobile measurements)
- Measuring and raising awareness on air quality with citizens in two Berlin neighborhoods from their homes (static measurements)

3.2.1. Activities

3.2.1.1. Purpose, research questions & hypothesis

Use Case 1 - Mobile measurements across Berlin
The goal of the mobile measurements was to ascertain the exposure of cyclists on their regular commute to work, school, care work or other activities. In addition, the aim was to fill the gaps of the official high-end air quality monitoring network in Berlin with data through the mobile survey. These "blind spots" between fixed measuring stations have been fed with simulated data. Our mobile campaign allowed us to check and compare the quality of the mobile sensors and data collection with those official and simulated data. And, of course, our goal was also to raise citizens' awareness of air quality and show them leverage points using the citizen science approach. The overarching aim is to carry this experience to other cyclists across Berlin.

Table 4: *Purpose, research questions and hypothesis for Berlin use case 1*

Overview of Berlin's experiment - use case 1	
Purpose	Measuring and raising awareness on air quality with cyclist on their daily commutes all over Berlin.
Research question(s)	The following questions will be addressed through experiments: ● What is the cumulative exposure across a cyclist's route? ● Where are hotspots along the route? ● How does an individual participant's exposure relate to his/her peers? ● Is cyclists' knowledge of air quality increasing? ● Are they more aware of air issues after the project (link between air quality & health)?
Hypothesis	● Cyclists will encounter PM hotspots along their individual routes ● Cumulative exposure at the group level follows a normal/Gaussian distribution ● They gain more knowledge about air quality ● They are more aware of air issues after the project

Use Case 2 - Static measurements in two Berlin districts

The the static measurement campaign took place in the Bellermannkiez in the district Mitte in Berlin as well as in the Donau- and Flughafenkiez in the district Neukölln in Berlin. The Bellermannkiez is a neighbourhood block (in German “Kiezblock”), an area where traffic calming measures reduce the high volume of through traffic. The Donaukiez and Flughafenkiez neighbourhoods are not neighbourhood blocks. Together with the residents of these three neighbourhoods, it was our goal to compare them and find out what effects traffic calming has on air quality and traffic. It was also of interest to us to back up the rather sparse air data in residential areas (gaps) with data through our project and, in addition, to test the inexpensive and partly DIY measuring devices using the citizen science approach. In this way, we were able to pursue the goal of raising citizens to air and mobility issues and familiarising them with technical measuring devices and research.

Table 5: *Purpose, research questions and hypothesis for Berlin use case 2*

Overview of Berlin's experiment – use case 2	
Purpose	Measuring and raising awareness on air quality with citizens in two Berlin neighborhoods from their homes.
Research question(s)	The following questions will be answered through the experiment: • Are there differences between the traffic-calmed neighbourhood and the two non-traffic-calmed neighbourhoods in terms of particulate matter (PM 2.5)? • Are there differences between the traffic-calmed neighbourhood and the two non-traffic-calmed neighbourhoods in terms of soot (BC)? • Are there differences between the traffic-calmed neighbourhood and the two non-traffic-calmed neighbourhoods in terms of traffic flow? • Is the participants´ knowledge of air quality increasing? • Are they more aware of air issues after the project (link between air quality & health)?
Hypothesis	• Lower lower traffic volumes in the neighbourhood block in contrast to the Neukölln neighbourhoods without traffic calming measures • No noticeable differences in particulate matter and soot pollution and a lower volume of traffic in the neighbourhood block in contrast to the Neukölln neighbourhoods without traffic calming measures • The occurrence of certain elevated levels (e.g. PM) could be explained by things like wood burning and BBQ • They gain more knowledge about air quality • They are more aware of air issues after the project

3.2.1.2. Experimental design

Use Case 1 - Mobile measurements across Berlin
Air quality measurements in Berlin are conducted by an extensive network of 17 high-end measurement stations (BLUME)[1] located across the city, encompassing different types of urban topographies. The three types of stations - traffic, urban background and city outskirts - are distributed in such a way so as to take representative measurements that are applicable

[1] BLUME stands for "Berliner Luftgüte-Messnetz" and means the Berlin air quality monitoring network with permanently installed official measuring stations.

to other areas in the city with similar characteristics. In addition, there are over 40 small active sampling devices (RUBIS)[2] attached to street lamps and passive samplers that supplement the measuring network.

Despite all those stations and sensors there are still gaps in certain areas where the extent of air pollution levels is not fully accounted for. Identifying potential pollution hotspots, especially in the second most polluted city in Germany[3], is crucial for informing public actors and laying down targeted public health policies.

This is where the mobile measurements campaign in Berlin comes into play. It pursues two goals, one prioritising data collection on particulate matter (PM) especially within those "blind spots"/gaps and another on the meta level which concerns citizens' knowledge of air quality issues.

[2] RUBIS stands for "Ruß- und Benzol-Immissionssammlern" and means soot and benzene emission collectors which expand the Berlin BLUME monitoring network.

[3] https://www.eea.europa.eu/themes/air/urban-air-quality/european-city-air-quality-viewer

Table 6: *Experimental outline for Berlin use case 1*

Experimental design for Berlin - use case 1	
Type of experiment	Comparative Descriptive Threshold testing

Design	**What**
	• Mobile $PM_{2.5}$
	• 45 SODAQ AIR devices
	
	Where
	• Citizens/cyclists living or working in city outskirts with few or no official monitoring stations. For more detail see map below
	
	Who
	• Device(s) assembly:
	  ○ Participants, initially helped by pilot staff
	• Device(s) installation:
	  ○ Participants by following translated instruction manuals
	
	When
	• From February 1 to May 31, 2024
	
	How
	• Devices provided to participants and assembled at workshops
	• Device(s) monitoring:
	  ○ By citizens (only for Android v10-User) via Dynamic Exposure Visualisation App (DEVA) to track the ride
	  ○ By both pilot staff and citizens (only for Android v10-User) via Dynamic Exposure Visualisation Dashboard (DEV-D)
	  ○ By both pilot staff and citizens (Android and iphone) via SODAQ's knowyourair.net platform
	• Pilot lead will host an interim workshop with participants to discuss ongoing results, observations and to get feedback on measurement campaign.

In the context of the data collection network of official measurement stations, the mobile measurement campaign aimed at closing air quality and PM data gaps and involving citizens to foster new knowledge around air pollution. This way, citizens were infused with new knowledge and provided with the right tools (air quality sensors) to collect meaningful data that, coupled with IMEC's calibration of SODAQ devices, could provide a strong leverage in a dialogue with policymakers regarding the utilisation of citizen data for public policy purposes.

There were a total of 45 citizens participating in the mobile measurement campaign in Berlin during the Public Round. The participants were selected so that their commuting routes covered the outskirts of the city and/or the gaps, meaning the gaps between the measuring stations, as much as possible. The distribution of the participants' places of residence and work can be seen on the map below.

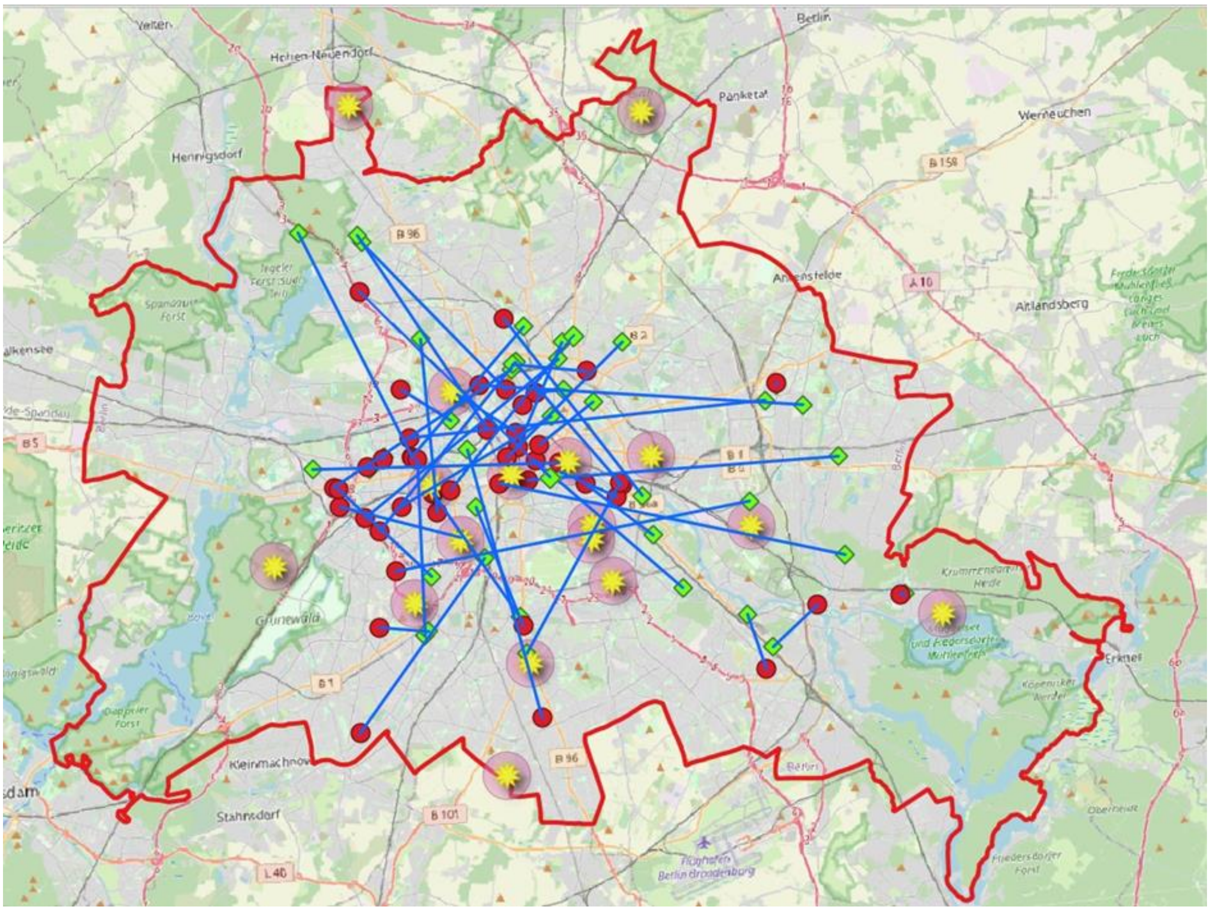


Figure 20: *Map outline - GREEN: Residence locations of participating citizens; RED: Work locations of participating citizens; BLUE LINE: Commuting route of participating citizens; YELLOW: Official stations along high traffic roads, in urban background locations and at city outskirts*

Citizens were given guidelines on how to approach measurements with the SODAQ AIR device and how to make sense of the data on different platforms during the introductory workshop on February 1. The SODAQ knowyourair.net platform was useable for all the participants, while Dynamic Exposure Visualisation App for tracking and the Dynamic Exposure Visualisation Dashboard was only accessible for Android v10-User. Participants collected data between February and May 2024, 3 - 5 days a week for at least 2-3 weeks along their regular commuting routes. They were told to regularly consult one of the provided maps/dashboards to familiarise themselves with the collected data in order to get a better understanding of their own air pollution exposure. An online workshop was organised on April 22 to provide a more fine-grained picture on individual and cumulative exposure patterns. A final workshop on June 10 engaged the citizens in a more interactive way, providing more insights into the collected data and encouraged citizens to discuss their perceptions on air quality, traffic and public policy measures.

Use Case 2 - Static measurements in two Berlin district

Table 7: *Experimental outline for Berlin use case 2*

Experimental design for Berlin - use case 2	
Type of experiment	● Comparative ● Descriptive ● Threshold testing
Design	**What** ● $PM_{2.5}$, BC and traffic ● 16 *SODAQ fine dust* ($PM_{2.5}$) sensors ● 3 bcMeters devices ● 6 Telraam traffic devices **Where** ● Bellermannkiez in Wedding ○ mixed zone area of small stores/coffee shops/restaurants and schools on the lower floor and residences in the upper floors ○ so called Kiezblock: traffic-calmed neighborhood with 5 diagonal barriers ○ 10 *SODAQ fine dust* devices ○ 1 BCmeters ○ 3 Telraam · Donau- and Flughafenkiez in Neukölln ○ mixed zone area of small stores/coffee shops/restaurants and schools on the lower floor and residences in the upper floors ○ not a traffic-calmed neighborhood, but characterized by a lot of through traffic ○ 6 *SODAQ fine dust* devices ○ 2 BCmeters ○ 3 Telraam ● Reference station on Frankfurter Allee, Friedrichshain ○ 1 *SODAQ fine dust* devices **Who** ● Device(s) assembly:

- *SODAQ*, bcMeter and Telraam: Participants, initially helped by pilot staff
- Device(s) installation:
    - *SODAQ*, bcMeter and Telraam: Participants by following translated instruction manuals

When

- From February 12 to May 31, 2024

How

- Devices provided to participants and assembled at workshops
- Device(s) monitoring:
    - SODAQ, bcmeter and Telraam: monitoring of the data via Policy Monitoring Dashboard (PMD)
    - SODAQ: via SODAQ's knowyourair.net platform
    - bcMeter: regular check-ups via email, asking citizens to send .csv files
    - Traffic: Telraam dashboard
- Pilot lead will host an interim workshop with participants to discuss ongoing results, observations and to get feedback on measurement campaign.

In addition to official air quality measurement gaps on a spatial level, Berlin's air quality stations cannot provide sufficient insights on a temporal level either. Concretely, air quality improvements resulting from changes in individual neighbourhoods' public space (re)configurations, often short-term, often go under the radar and cannot be picked up by the official stations. The main cause for this is the aggregation to the hourly averaged level by the reference networks, making it difficult to track any effect within the hourly frequency.

In the Bellermannkiez in Wedding the concept of a Kiezblock - traffic calming measures using diagonal barriers - started in 2019 by a phase of various participation formats to actively involve citizens in the development of a transport concept; followed by the introduction of the first of five diagonal barriers and greening measures. The mobility measure aimed primarily at reducing the strong through traffic of this neighborhood. The following figure shows the distribution of the five diagonal barriers (red and green circles).

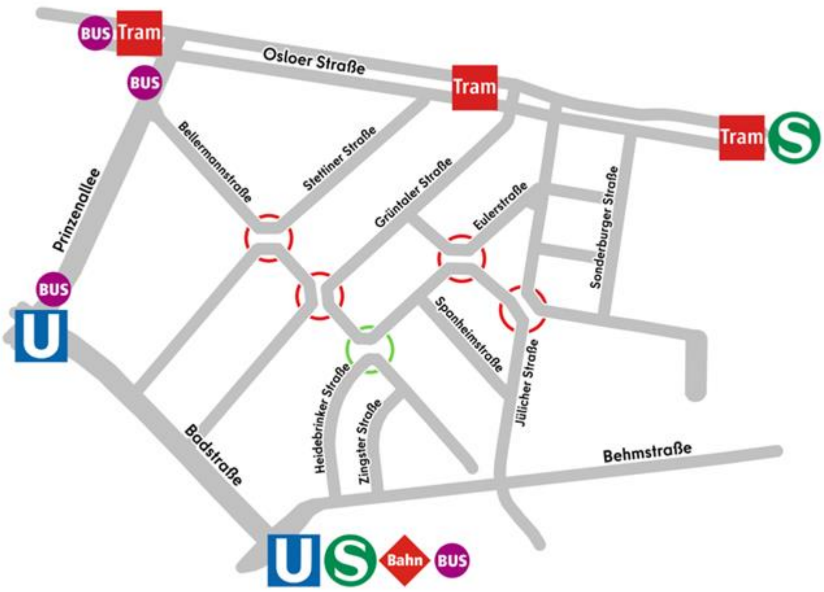


Figure 21: *Map of Bellermann-Kiezblock with five diagonal barriers (red and green circles)*

COMPAIR became part of the project in the late days of 2023 by getting in touch with the neighborhood management as well as the mobility initiative Changing Cities which coordinates those Kiezblocks in Berlin and even Germany. In addition to the neighborhood block in Bellermannkiez, we also contacted the neighborhood management offices in Donaukiez and Flughafenkiez in Neukölln at the end of 2019. These two neighborhoods are quite similar to Bellermannkiez in terms of their socio-cultural, structural and infrastructural character, but have no traffic calming measures and are therefore confronted with a lot of through traffic. The original idea was to compare the traffic flow and air quality of the Bellermann Kiezblock with the Neukölln neighborhoods in terms of the effects of traffic calming measures. In both districts we aimed at involving local residents to not only assess the effect of the mobility measure on traffic and air quality but also to find out how well the citizen science approach works in this context to reach and mobilize citizens.

The engagement campaign started in December 2023 and successfully involved 19 citizens by the beginning of the measurement campaign in February 2024. The participants were scattered around the neighborhood and measuring the flow of traffic with Telraam devices and two types of pollutants - black carbon with bcMeter, an experimental sensor, and particulate matter with *SODAQ* devices; distribution of the participants is shown in **Figure x**. Measuring black carbon was particularly interesting because the DIY measuring device is still in the development phase and we wanted to find out how well the participants cope with a rather sophisticated device. The data was of secondary importance at this point since the values are generally well below the former test values.

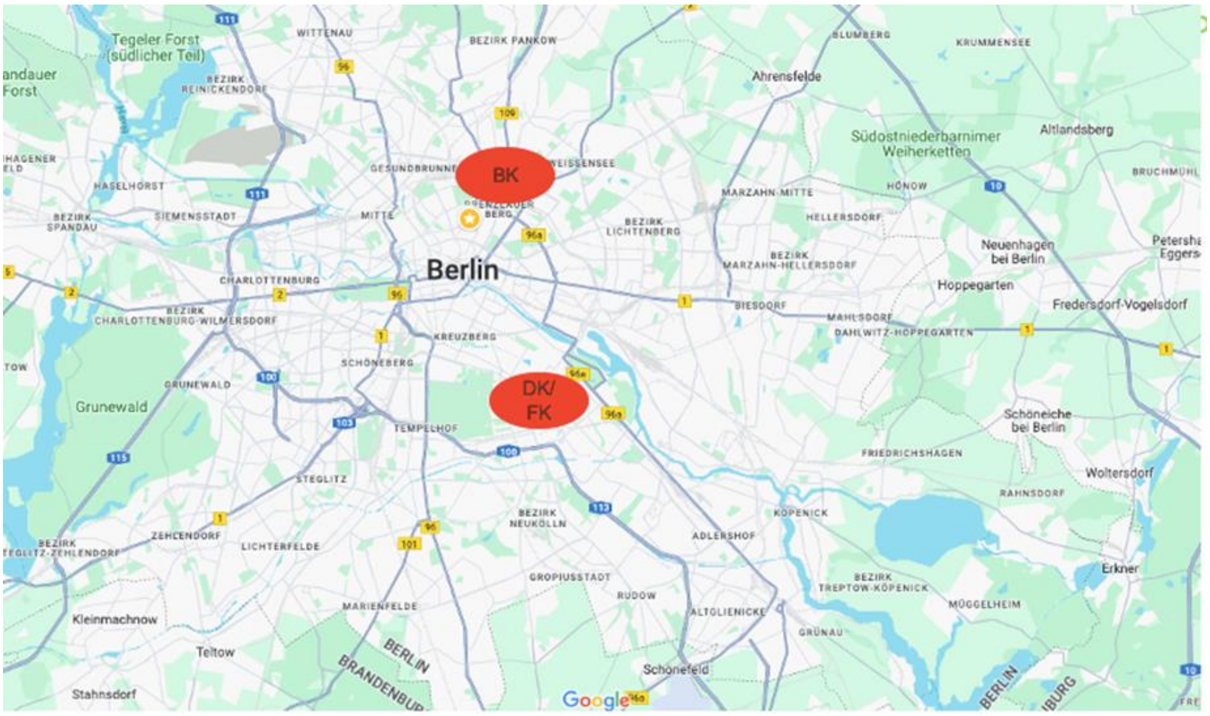


Figure 22: *Map of Berlin showing the two static measurement locations in red circles; BK meaning Bellermannkiez and DK/FK meaning Donau- and Flughafenkiez*

This map shows the location of the two static measurement neighborhoods in the Northern part of Berlin – Bellermannkiez (BK) and the Mid-Southern part of Berlin Donau- and Flughafenkiez (DK/FK).

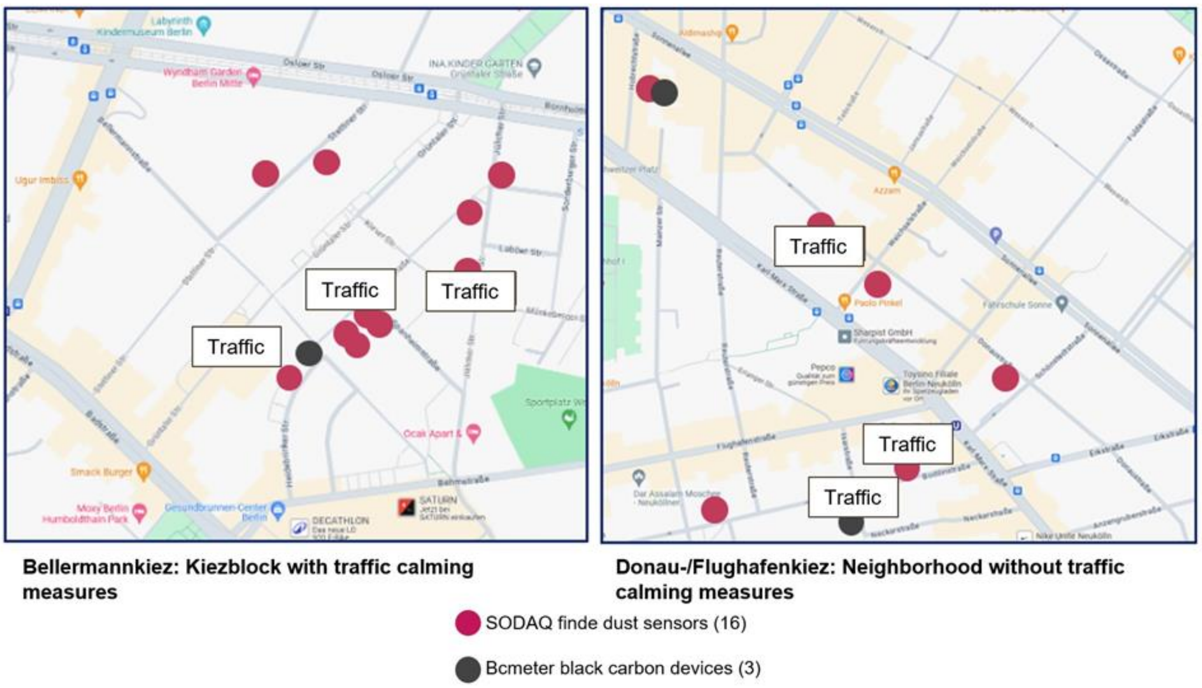


Figure 23: *Map showing the measurement locations and type of sensors placed in Bellermannkiez as well in Donau- and Flughafenkiez, Berlin*

The measurement campaign began on February 12 and ended on May 31, 2024 and were conducted during the entire period to assess whether the mobility measures had an effect on traffic, black carbon and particulate matter in comparison with the neighborhood without traffic calming measures in Neukölln.

3.2.1.3. Workshops

Use Case 1 - Mobile measurements across Berlin

There was a total of three workshops that took place during the mobile measurement campaign. The first workshop, organised on February 1, was attended by 45 citizens and introduced the participants to citizen science and COMPAIR and provided an overview on the air quality situation in Berlin, its developments and how air pollution is generally measured. A practical training session followed thereafter, where the citizens were taught how to properly measure air quality, what rules to follow during the measurement phase and how to utilise the SODAQ AIR devices.

The second workshop on April 22, which took place online together with the mobile measurement campaign participants, aimed at providing a clearer overview on the collected data and ascertaining individual and collective cumulative exposure. Citizens were asked to discuss their own experiences and sharing what they learned until then.

The final workshop took again place with the participants of the static measurement campaign. There all the collected data of both campaigns were analysed and discussed with the participants. Special features included a brief input from a representative of the Senate Department for Mobility, Transport, Climate Protection and the Environment on the subject of Berlin's clean air plan and policy, as well as a panel discussion. The panel discussion also included the representative from the Berlin Senate and a spokesperson from a civil society mobility initiative that deals with neighborhood blocks and bicycle traffic, among other things, as well as a person from the field of citizen science, which networks such projects nationwide. In addition to the measurement results, the panel discussion also focused on the role of citizens in research projects and how such citizen science data can also be made usable for civil society and administration. In a further block, the participants were able to share their experiences from the COMPAIR project in a small survey via the online participation tool Mentimeter where they contributed to a fruitful discussion on what the issue of air quality means to them after the measurement campaign and how the new insights had or hadn´t changed their behavior as well as a general feedback on the organization and structure of the project.

Use Case 2 - Static measurements in two Berlin districts

The second measurement campaign began with a workshop on February 12. Similarly to the mobile measurements training workshop, the participants were introduced to the idea behind citizen science and COMPAIR, the importance of measuring air quality in Berlin and the particularities of the measurements in a Kiezblock and two comparison neighborhoods. In the interactive session, citizens learned how to assemble and use the three devices - bcMeter (black carbon) and the SODAQ devices (PM) as well as the traffic device Telraam. After the workshop, citizens were given additional information on sensor usage, management and data retrieval.

The second workshop on April 22, which took place online together with the mobile measurement campaign participants, aimed at providing a clearer overview on the collected data in the Wedding and Neukölln neighborhoods. Citizens were asked to discuss their own experiences and sharing what they learned until then.

Content of the final workshop see above (mobile measurement).

3.2.2. Results

In general, where it was possible and useful, we analyzed the data with reference values from the extensive network of 17 high-end measurement stations (BLUME) and our specially calibrated SODAQ sensor (Frankfurter Allee) in order to increase our validity and to be able to better interpret and compare the collected data.

3.2.2.1. Analyses

Use Case 1 - Mobile measurements across Berlin

The analytical approach in the first use case was fairly simple. Citizens were asked to ride their bikes and collect PM data along their usual commuting routes. An overview of the average exposure by all participants was presented. In addition, an analysis of average PM values based on hours of the day was presented as well in order to determine rush hour exposures. Information on the measurement frequencies at each hour of the day was provided as well.

As citizens gathered data over the course of several weeks, individual exposure profiles were compared to the average exposure by all other participants. Moreover, their exposure at particular times of the time (e.g. morning or evening rush hour) were also contrasted against the average exposure of other participants. Finally, the frequency at which individual values were measured was clustered into different categories (from low to high) in order to present the exposure intensity of individual participants compared to the average exposure.

The PM data was set in relation with the official threshold value of fine dust of the European Union as well the more strict but not binding value of the World Health Organisation as well as the calibrated SODAQ sensor at the Frankfurter Allee.

Use Case 2 - Static measurements in two Berlin districts

The main purpose of the second use case was to test the effects of traffic calming measures (Kiezblock) on air and traffic quality in comparison with two neighborhoods without traffic calming measures. A network of traffic, PM and black carbon devices was placed around the neighborhood. Local residents started measuring air quality and traffic flows in their respective streets in February 2024 and continued collecting data until the end of May. Apart from the comparison analysis, a correlation analysis was conducted to compare car traffic with pollutant concentration levels in both neighborhoods.

In the static measurement, the PM data was also set in relation with the official threshold value of fine dust of the European Union as well the more strict but not binding value of the World Health Organisation as well as the calibrated SODAQ sensor at the Frankfurter Allee.

3.2.2.2. Results

All the results and data presented follow the same structure. Whenever possible and useful, we analyzed the fine dust (PM 2.5) data with reference values from the BLUME measuring stations and our specially calibrated SODAQ sensor (Frankfurter Allee) in order to increase our validity and to be able to better interpret and compare the collected data. Of the 17 BLUME measuring stations, we selected three stations that we considered particularly suitable for comparison with our static and mobile data. The two measuring stations Karl-Marx-Straße and Wedding, which are not far from the neighborhoods of the static measurement campaign and thus provide good comparability. We also included the Müggelsee measuring station. This is a measuring station on the outskirts of the city where, due to the quieter traffic situation and the very green, wooded surroundings close to the lake, lower particulate matter levels are often recorded than at the measuring stations (e.g. Karl-Marx-Straße and Wedding) in the city center.

Use Case 1 - Mobile measurements across Berlin

The results of the collected data are presented as individual exposure profiles of the participating citizens.

As can be seen in the example below, citizens were informed about the number of measurements they have conducted during the measurement campaign from February 1 to May 31. The number of measurements results from a) the distance of the commuting route; the sensor measures in motion every ten seconds (corresponds to 1 measurement) and b) the frequency with which the sensor was used (number of days). As can be seen, the number of measurements varies widely between the participants – ranges from 22 measurements to 23.859 measurements by so called "power users", participants who provide a large proportion of the total data collected and are very important for the project. The comparison with the BLUME measurement stations wouldn´t have added value to the graph and was therefore kept empty in this one. Our calibrated SODAQ sensor measured 2.693; here it is important to know that the sensor was permanently installed over the entire measurement campaign (static) and thereby only measured every five minutes. As a result, the value here is significantly lower.

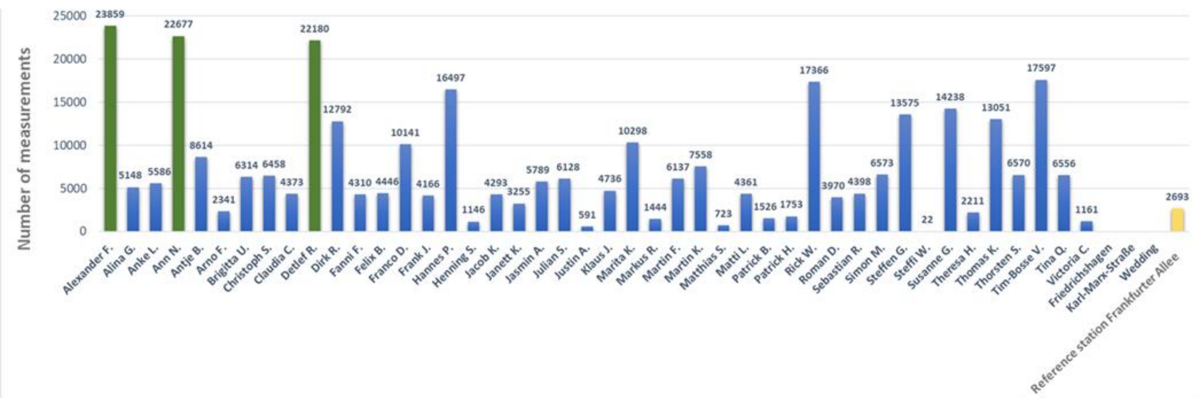


Figure 24: *Number of measurements conducted by each participant (left axis) and the different participants (blue and green bars) (lower axis) in the period 01/02 to 31/05 2024 ;*

including three BLUME measurement stations (empty) and the number of measurements of the reference station at Frankfurter Allee (yellow bars)

In the following figure, the number of days measured by each participant are shown. The three BLUME measuring stations show the highest possible value (four months of measurement); the Frankfurter Allee reference station was removed nine days before the end of the measurement campaign (therefore 111 days). As in the graph above, the range varies greatly between one day and 93 days. 93 measured days is an extremely high value if you consider that measurements were "only" taken on working days and at least the weekend must be excluded. Once again, we see "power users" contributing an enormous amount to the total pool of data.

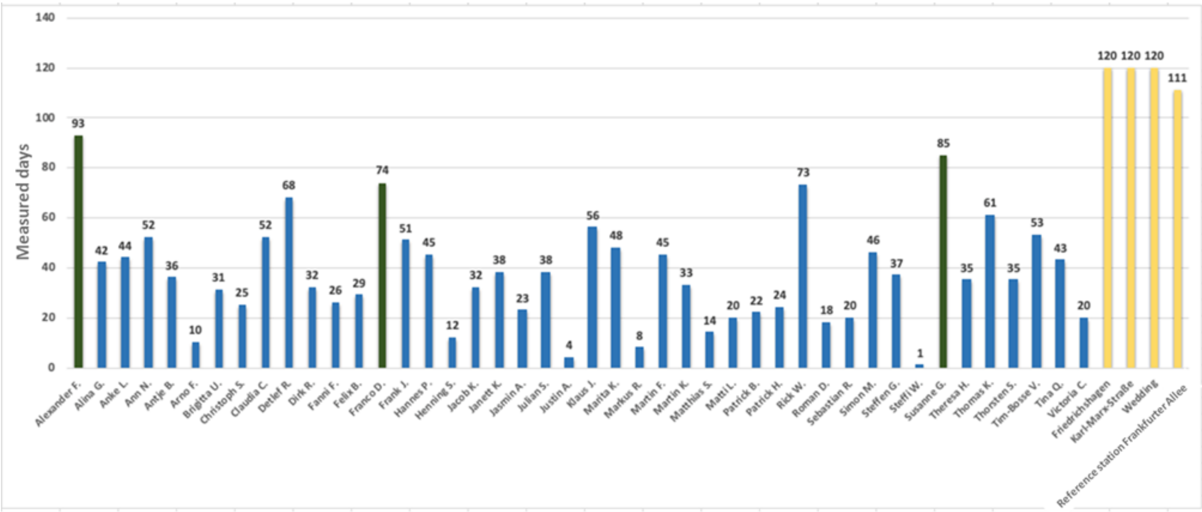


Figure 25: *Number of days measured by each participant (left axis) and the different participants (blue and green bars) (lower axis) in the period 01/02 to 31/05 2024 ; including three BLUME measurement stations and the number of measurements of the reference station at Frankfurter Allee (yellow bars)*

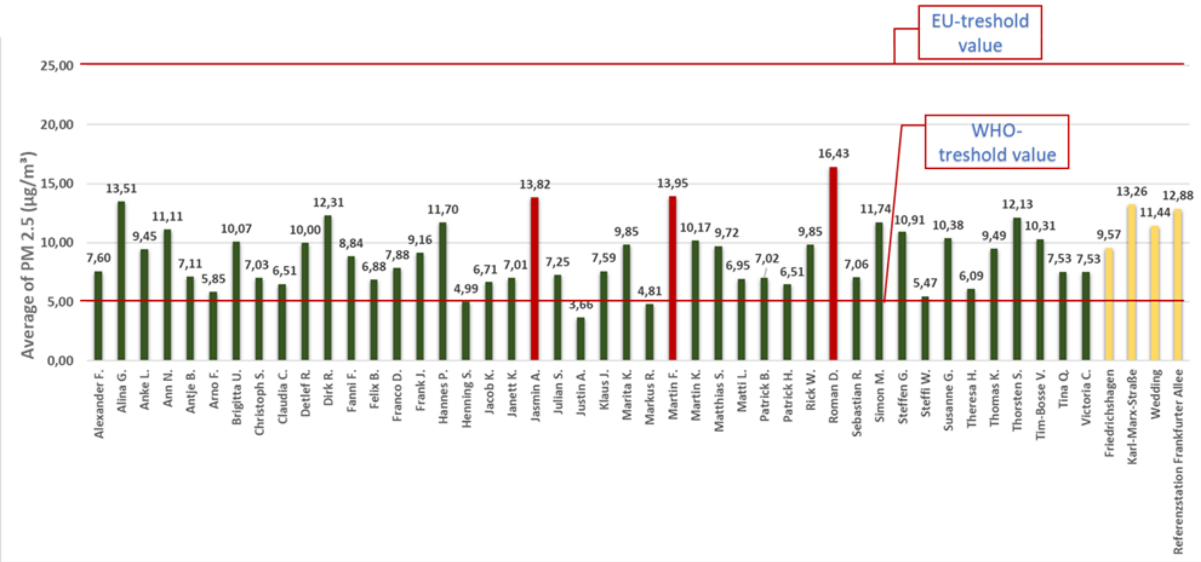


Figure 26: *Average PM 2.5 values (left axis) and the different participants (green and red bars) (lower axis) in the period 01/02 to 31/05 2024 ; including three BLUME measurement stations and the number of measurements of the reference station at Frankfurter Allee (yellow bars) as well as the threshold values for PM of the EU (legally binding) and the WHO (recommended).*

In this figure the average PM exposure over the course of 12 weeks for each participant is shown in green bars; the three red bars show the participants with the highest average of PM 2.5 exposure. If one compares the values of the participants with the three values of the BLUME measuring stations and the reference station on Frankfurter Allee, it is noticeable that the data collected by the citizens fits in well with the official measurement data and can be said to be valid. The fact that the values from the BLUME measuring station in Friedrichshagen are lower than those in Wedding and Karl-Marx-Straße makes sense because Friedrichshagen is located on the outskirts of the city in a green area and the fine dust pollution here is lower. What is interesting is the comparison between the two limit values of the EU and the WHO. The annual average value for PM 2.5 in the EU is 25µg/m³, while the WHO value is 5µg/m³. All of the participants' average values are therefore below the EU value, while all but one of the participants' average values for PM 2.5 are above the limit value recommended by the WHO. It is also interesting to note that the EU wants to reduce the annual average value of PM 2.5 from 25µg/m³ to 10µg/m³ by 2030. This would mean that the value would still be twice as high as recommended by the WHO and 34% of participants would also be above the "new" EU value.

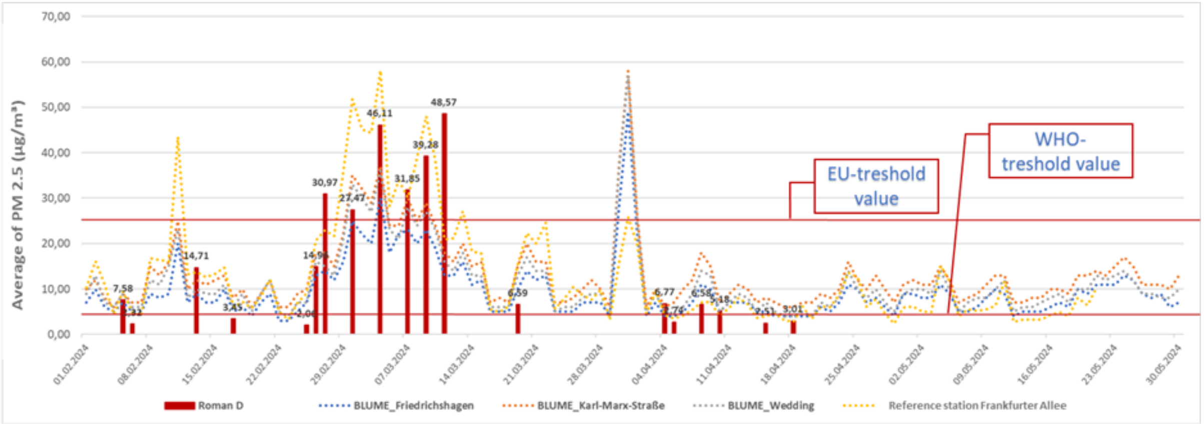


Figure 27: *Test person with highest average PM2.5 value in the period 01/02 to 31/05 2024 ; range of PM 2.5 (left axis) and the measurement period with highlighting of the days on which the test person measured (red bars) (lower axis); including three BLUME measurements of the reference station at Frankfurter Allee (dashed lines) as well as the threshold values for PM of the EU (legally binding) and the WHO (recommended).*

The graph above shows the exposure profile of the participant with the highest PM 2.5 average value in the entire measurement period. The red bars, the person's measurements, correspond to the course of the official measurement data (dashed lines). The extremely high values at the end of February to mid-March are striking - both for the test person and for the official measuring stations. This can be explained by the Sahara dust, which also led to a sharp spike in particulate matter levels in Germany. During this period, the values were even significantly higher than the EU limit value, in some cases twice as high, and ten times higher than the WHO limit value.

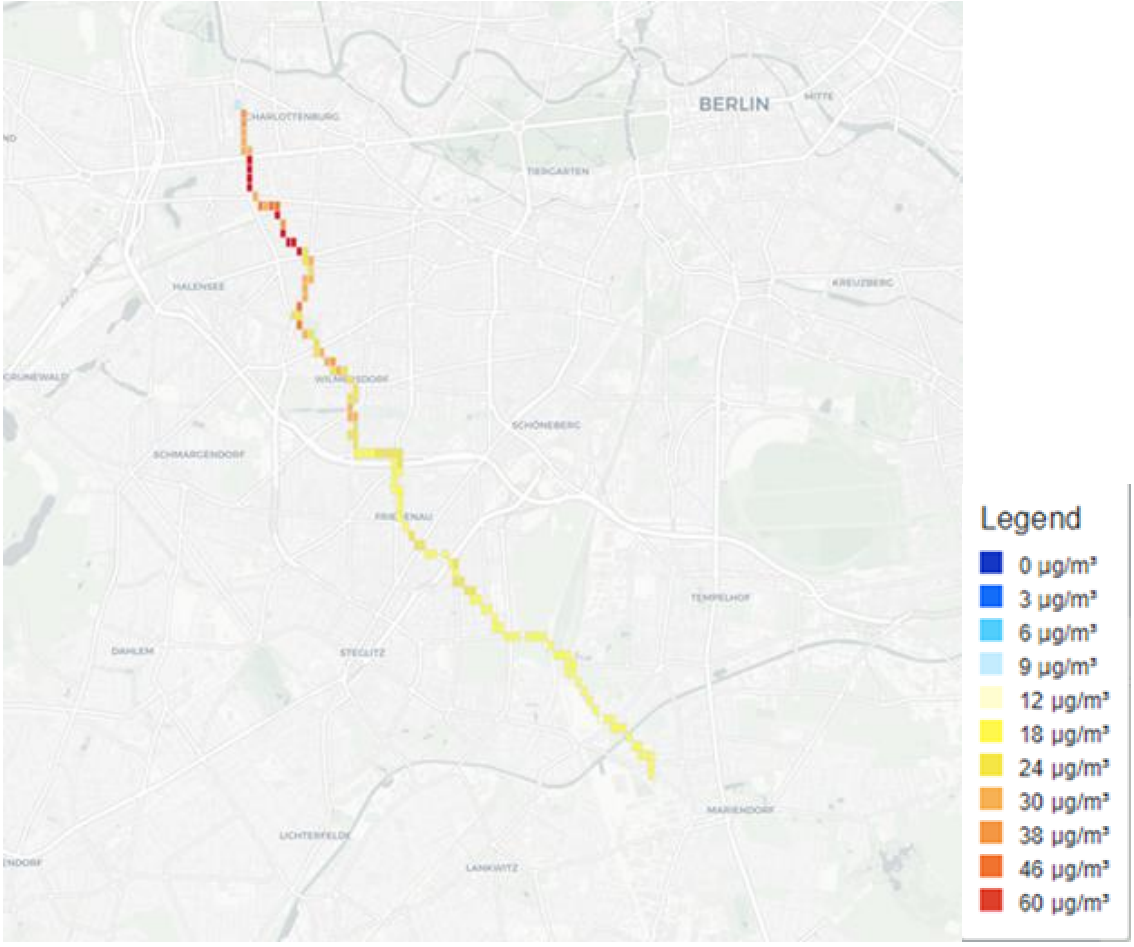


Figure 28: *Example route of the test person with the highest average value of PM 2.5 value in the period 01/02 to 31/05 2024 ; commuting route from 27/02 2024 ; including the legend with the values*

The map comes from the website knowyourair.net and shows an example of how a commute route is recorded graphically. The GPS points can be used to identify the places that have particularly high values. The participant's route led from the west to the south of Berlin and has very high levels of PM 2.5, well above the EU limit.

Use Case 2 - Static measurements in two Berlin districts

The results of the collected data are presented by neighborhood – Bellermannkiez and Donau-/Flughafenkiez.

PM 2.5

Both figures show the average values for PM 2.5 during the entire measurement period (12 February to 31 May) of the participants from both neighborhoods. The colored boxes represent the individual participants - assigned by street and initials. In addition to the average value, the range in which the respective average values are located is also indicated - shown as boxes. Above this, further individual maximum values are recognisable as dots. In addition, as with the mobile measurements, the EU and WHO limit values are shown as red lines. It can be seen that the average values in both neighborhoods are well in line with the official measured values of the BLUME measuring stations and the calibrated SODAQ sensor on Frankfurter Allee and can therefore be regarded as valid. The values for PM 2.5 in the two neighborhoods are also close to each other despite the different traffic situations (neighborhood block vs. through traffic)

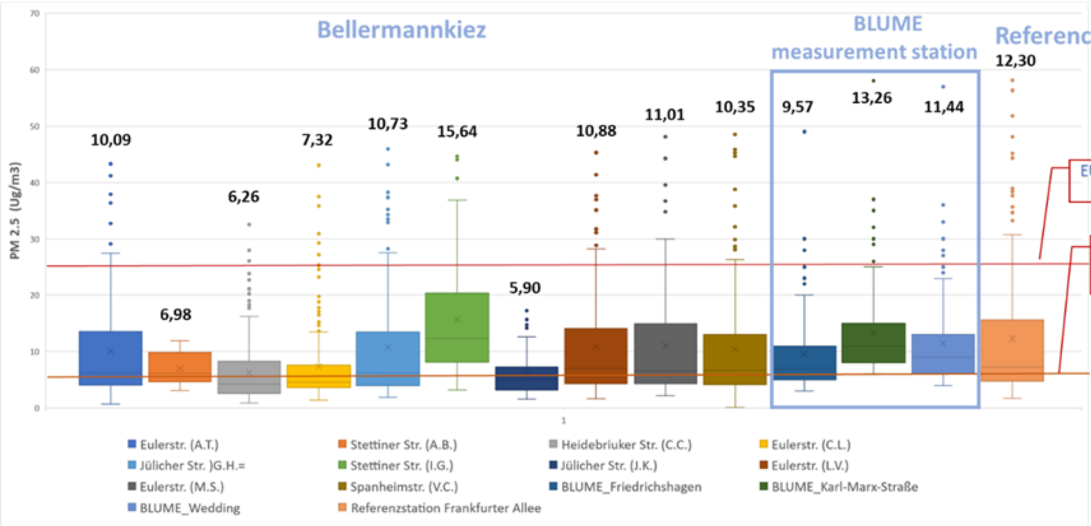


Figure 29: *Amount of PM 2.5 (left axis) and the different participants by street* ***(Bellermannkiez)*** *with their average PM 2.5 (colorful bars) (lower axis) in the period 15/02 to 31/05 2024 ; including the average of PM 2.5 of the three BLUME measurement stations and the reference station at Frankfurter Allee as well as the threshold values for PM of the EU (legally binding) and the WHO (recommended).*

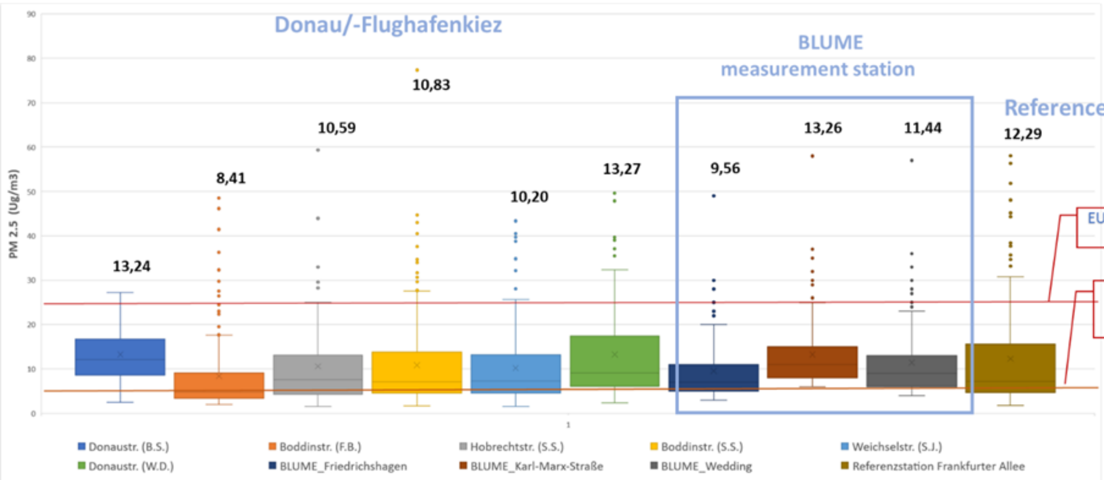


Figure 30: *Amount of PM 2.5 (left axis) and the different participants by street* ***(Donau- and Flughafenkiez)*** *with their average PM 2.5 (colorful bars) (lower axis) in the period 15/02 to 31/05 2024 ; including the average of PM 2.5 of the three BLUME measurement stations and the reference station at Frankfurter Allee as well as the threshold values for PM of the Eu (legally binding) and the WHO (recommended).*

Correlation PM 2.5 and traffic

We were interested in whether there is a connection between the diagonal barriers and the resulting reduction in through traffic in the Bellermann neighbourhood and the concentration of particulate matter. To do this, we looked at the participants who both counted the traffic via Telraam and measured the particulate matter with the SODAQ sensor at the same time. There were two people per neighbourhood. The result is that the average concentration of particulate matter at the two locations in the Bellermannkiez neighbourhood is comparable to that in the Donau-/Flughafenkiez neighbourhood, where there is no traffic calming. This can certainly also be explained by the fact that PM 2.5 is not such a suitable indicator and measured value for measuring the effects of traffic reduction. The measurement of nitrogen dioxide (NO2) would be more suitable here. What we have learned from conversations with residents and the neighbourhood management from the Bellermannkiez, however, is that traffic and noise have been extremely reduced since the introduction of the neighbourhood block, especially in Jülicher Straße. This impression is also reflected in the traffic counts, in which the rate of cars travelling through this section of Jülicher Straße is the lowest compared to the other three streets. It is precisely this section of Jülicher Straße that experiences a significant reduction in traffic in terms of cars and heavy vehicles due to the diversion of the diagonal barrier.

Table 8: *Correlation of PM 2.5 and traffic in two streets of each district with average of PM 2.5 as well as the amount of pedestrians, two-wheelers, cars and heavy vehicles*

Correlation PM 2.5 and traffic in the measurement period 23.02. – 31.05.		
Bellermannkiez		
Eulerstraße[1]	In the measurement period the total amount was: • Pedestrians: 55,825; • Two-wheelers: 25,386; • Cars: 133,071; • Heavy vehicles: 13,993.	On an average day the measurement value on this road was: • 36 pedestrians per hour; • 22 two-wheelers per hour; • 87 cars per hour; • 9 heavy vehicles per hour. The measured value of PM 2.5 is 7.32$\mu g/m^3$.

Jülicher Straße	In the measurement period the total amount was: - Pedestrians: 12,454; - Two-wheelers (bikes): 43,752; - Cars: 42,370; - Heavy vehicles: 4,881.	On an average day the measurement value on this road was: - 8 pedestrians per hour; - 27 two-wheelers per hour; - 25 cars per hour; - 3 heavy vehicles per hour. The measured value of PM 2.5 is 10.73µg/m^3.
Donau-/Flughafenkiez		
Boddinstraße	In the measurement period the total amount was: - Pedestrians: 38,750; - Two-wheelers (bikes): 6,669; - Cars: 58,052; - Heavy vehicles: 2,546.	On an average day the measurement value on this road was: - 26 pedestrians per hour; - 5 two-wheelers per hour; - 41 cars per hour; - 2 heavy vehicles per hour. The measured value of PM 2.5 is 10.83µg/m^3.
Donaustraße	In the measurement period the total amount was: - Pedestrians: 33,048; - Two-wheelers (bikes): 154,900; - Cars: 99,667; - Heavy vehicles: 11,579.	On an average day the measurement value on this road was: - 24 pedestrians per hour; - 105 two-wheelers per hour; - 72 cars per hour; - 8 heavy vehicles per hour. The measured value of PM 2.5 is 13.24µg/m^3.

Black carbon

Until the 1990s, there was a test value for soot in Germany, which was anchored (in the 23rd BImSchV) at 8 µg/m3 annual mean value. After the implementation of better filter systems, the measured values were often well below the test value. With the introduction of the binding, enforceable and EU-wide limit value for PM 10, the test value was abolished and soot measurements were largely discontinued. In the COMPAIR project, the focus was therefore not on the measurement results for soot, but merely served as an assessment and measurement experience. It was much more interesting for us to find out how the participants coped with a rather sophisticated DIY measuring device that was still in the development phase and where there were difficulties with commissioning and maintenance as well as data collection and evaluation. Of the ten BCmeter measuring devices originally distributed, only two ended up measuring. The other devices could not be used due to technical difficulties during commissioning, data recording or because participants dropped out. The two people who were able to collect data with the BCmeters are shown in the following two graphs. It can be seen here that the assumption is confirmed that the data is still well below the previous German test value. One participant measured in the Bellermannstraße (Bellermannkiez) and the other in the Isarstraße (Donau-/Flughafenkiez).

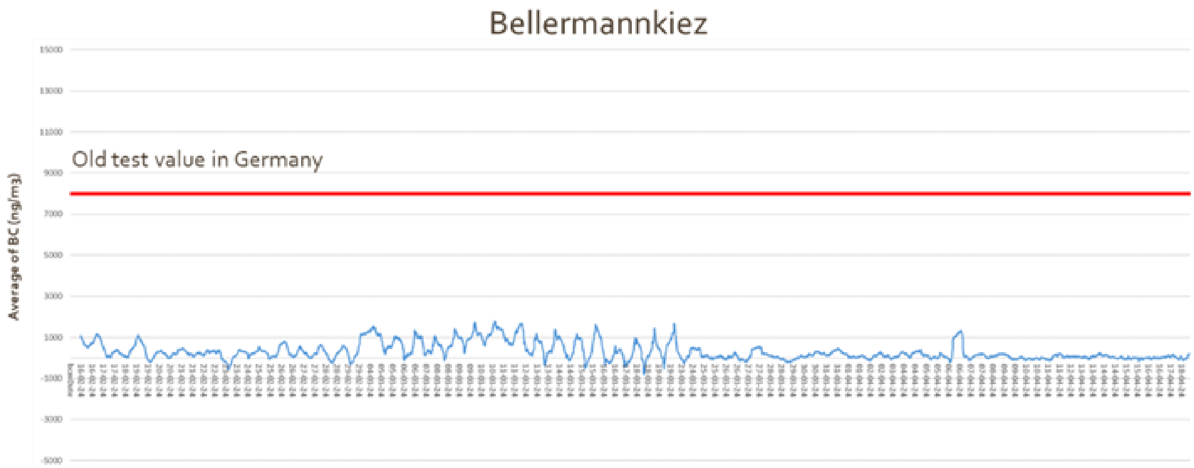


***Figure 31:** Average of BC (left axis) and the measurement period of the participant in (Bellermannkiez) in which the measuring device conducted data shown as a blue line (lower axis); including the old test value in Germany (red line)*

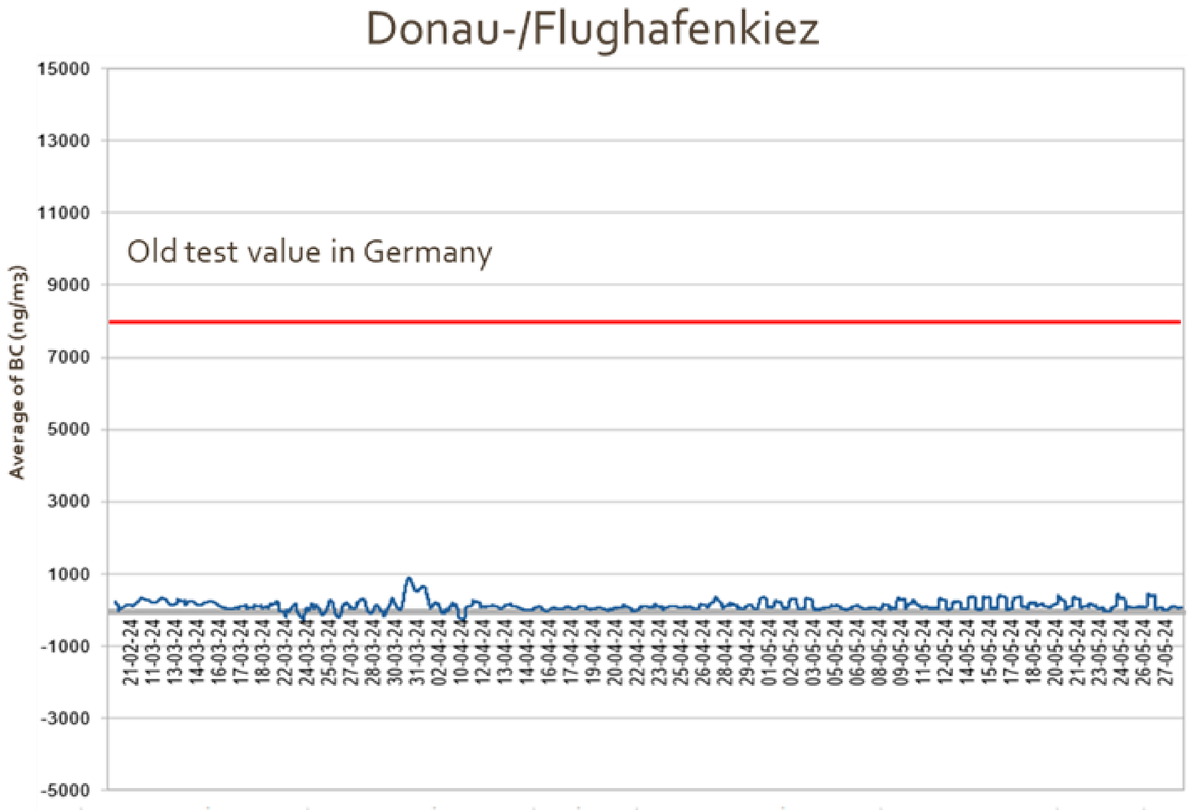


Figure 32: *Average of BC (left axis) and the measurement period of the participant in (Donau-/Flughafenkiez) in which the measuring device conducted data shown as a blue line (lower axis); including the old test value in Germany (red line)*

3.2.3. Lessons learned

The approach of the project was designed around three experimentation rounds (closed, open & public), with each round increasing our outreach towards more citizens. In this setup the public round was the final one, in which we were able to attract significantly more citizens, but at the same time continued to face a number of technical difficulties. As expected, the approach permitted us to learn some valuable lessons.

Use Case 1 - Mobile measurements across Berlin & Use Case 2 - Static measurements in two Berlin districts

Mobilisation of participants:

While the mobilization of citizens for the mobile measurement campaign again went very well, the mobilization for the static measurement campaign proved to be extremely difficult. During the mobile measurement campaign, we were once again able to distribute our information materials and flyers via civil society initiatives and their channels. Within a very short time, we had far more registrations than places (sensors) and were able to select an optimal research design (distribution of participants in Berlin according to their commuting distance in order to fill the data gaps). In the static measurement campaign, we had just enough responses and "had" to select all registered participants without being able to ensure an optimal distribution in the neighborhood. For the static measurement campaign, we distributed flyers in every letterbox in almost every building and used the access to the neighborhood via the neighborhood management. An article was published about our project and we were able to present our project to local initiatives. In retrospect, we would have needed more lead time to regularly present our project in the neighborhood, establish contacts and gain more participants. We would suggest a lead time of three months, in which sufficient capacities and resources are available for this intensive mobilization.

Registration process:

After our learning experience in the open round, we tried to increase the commitment of registrations and participation in the public round by explaining in great detail the upcoming workload and all the dates of upcoming workshops for participants, the added value of Citizen Science and the impact of this project. After receiving this information, the participants were able to decide whether they wanted to sign up for the project. In the public round, significantly fewer people dropped out during the measurements than in the open round, especially in the mobile measurement campaign.

Workshop interim results:

After the response of the participants in the open round to the interim workshop in both measurement campaigns was relatively low, we decided in the public round to organize a workshop for both measurement campaigns together. We also saw the advantage of the participants getting to know the background and results of the other measurement campaigns, even enhancing the learning experiences and an exchange with more perspectives. With 32 participants in the interim workshop (out of a total of 64 participants), we were quite satisfied.

Support of the participants:

As in the open round, we kept in contact with the participants as closely as possible over the four months through the three workshops and targeted inquiries by email as well as the assurance that we would always be available, and the feedback from the participants was also very good in this regard. In the final workshop, we received feedback that tangible references had helped the participants to evaluate the data. For example, in addition to the limit values, they also learned what equivalent the amount of particulate matter now means in terms of years of life lost, in cigarettes or similar easily tangible quantities. We believe that such a "conversion" into tangible units during and at the end of the measurement campaign would have been helpful to support the participants' learning and also to keep motivation high. It would certainly make sense to create a kind of interactive padlet on which the participants could continuously provide their feedback and valuable measurement observations (we collected them by email) and make this information available to all participants in real time.

Technical aspects:

We gained a great learning experience in dealing with technology - measuring devices, dashboards. We gained a great learning experience in dealing with technology - measuring devices, dashboards, apps - because there were a lot of difficulties there. The SODAQ sensor holder is not suitable for many bicycle handlebar sizes, breaks quickly and the magnets are lost. However, the far greater difficulty came with the sophisticated DIY BC measuring devices, which were still in the development phase and of which only two of the eight distributed sensors were in use. The developer and us as contact persons did the best possible troubleshooting, but it still couldn't adequately address the technical problems until the end. The reasons were the lack of time to drive to each of the households and also to locate the error between the measuring device and the dashboard. This of course led to frustration among the participants, so that some of them didn't even take the measure and quit. This would have required even better technical preparation. The same also applies to the dashboards and apps used. The great thing about the app was that the participants' feedback on the first version was implemented directly during the measurement campaign and the app worked much better afterwards.

3.3. Flanders pilots

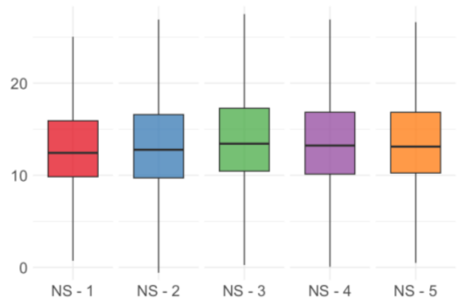
The Public Round originally listed six use cases in Flanders:

- 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

A 4-week project ran in primary school De Krekel in Ghent with an adaptation of the educational package of the INTERREG Joint Air Quality Initiative, built around 2 weeks of lessons on air quality, 2 weeks of experiments and 2 feedback moments with interactions between the schoolchildren, teachers and COMPAIR experts. With the secondary school in Herzele, a 5-week project ran where, after an introductory lesson on air quality, the students themselves drew up a project plan (e.g. cleanest route, wood-burning stove map...). There has also been a 6-week project with students of the HoGeel & KuLeuven master in food sciences where the students took their own measurements with SODAQ sensor.

Due to concerned citizens, both the circulation plan in Ghent and Sint-Niklaas have been postponed to 29 April and 10 of June.

Lastly, since the analysis of the school street trial in Herzele showed that the calibration of the NitroSense NO_2 devices was suboptimal, we elected to perform a co-location trial to further analyse this issue. Five NitroSense devices (labelled here NS - 1 through 5) were co-located with the VMM monitoring station R702 in Ghent from mid-September 2023 until the end of October 2023. The resulting data is shown below.



ID	NS - 1	NS - 2	NS - 3	NS - 4	NS - 5
Mean	12.813	13.118	13.753	13.505	13.441
Median	12.440	12.781	13.436	13.238	13.123
SD	4.291	4.970	4.852	4.879	4.519
Max	27.713	31.408	29.167	33.400	27.208
Min	-5.246	-12.945	-10.663	-8.419	-6.823

Figure 33: *Nitrosense co-location data overview*

To test the performance of the sensors, we compute two benchmarks, based on the standards VMM imposes when writing an official tender for purchase of such devices:

- A between-sensor uncertainty below 7.6 μg/m³ for NO_2
- An R2-value above 0.7 when comparing to the official reference monitor

This between-sensor uncertainty for two sensors S_i and S_j is given by:

$$\mathrm{BSU}_{i,j} = \sqrt{\frac{\mu\left[(S_i - S_j)^2\right]}{2}},$$

where μ denotes the operator computing the mean throughout time. Computing this quantity for each pair, we get the following

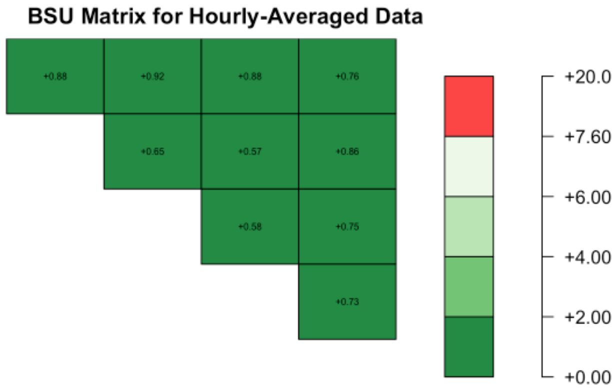


Figure 34: *Nitrosense between sensor uncertainty matrix*

which is clearly well within range. Comparing to the reference monitor then

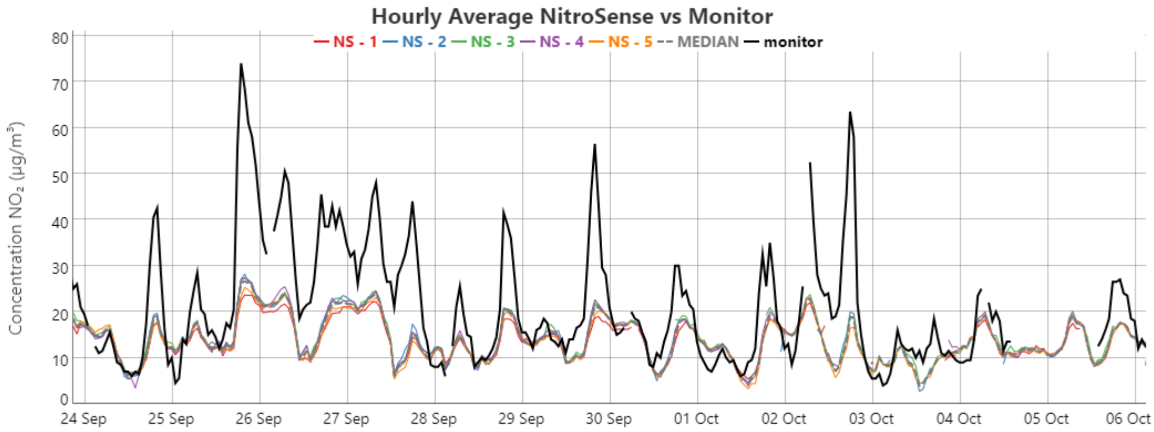


Figure 35: *Hourly average Nitrosense and reference monitor time series*

We note that the range of values measured by the sensors is much more narrow than the values given by the reference monitor. This can be made more evident by a combined distribution plot

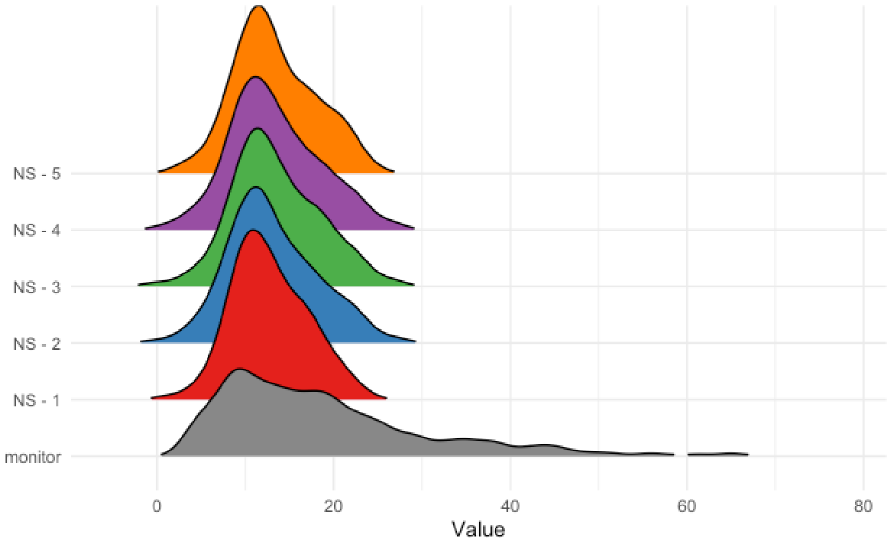
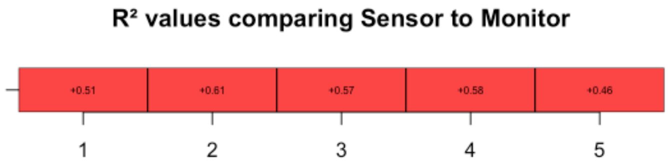


Figure 36: *combined distribution plot of Nitrosense and reference data during co-location*

We test the correspondence between the sensors and the monitor in a more rigorous fashion by computing the R^2-value, given by

$$R^2_{\mathcal{M}\mathcal{S}_i} = (\rho_{\mathcal{M}\mathcal{S}_i})^2 = \left(\frac{\mathrm{cov}(\mathcal{M}, \mathcal{S}_i)}{\sigma_{\mathcal{S}_i}\sigma_{\mathcal{M}}}\right)^2$$

The resulting value for each sensor is shown below



These values do not pass our set benchmarks, confirming the suspicion that the sensors seem to be providing unreliable results. We can perform an orthogonal regression to further understand the relation between sensors and monitor, with the dashed line in the scatter plots shown below being the one-to-one curve and the bold line being the regression curve

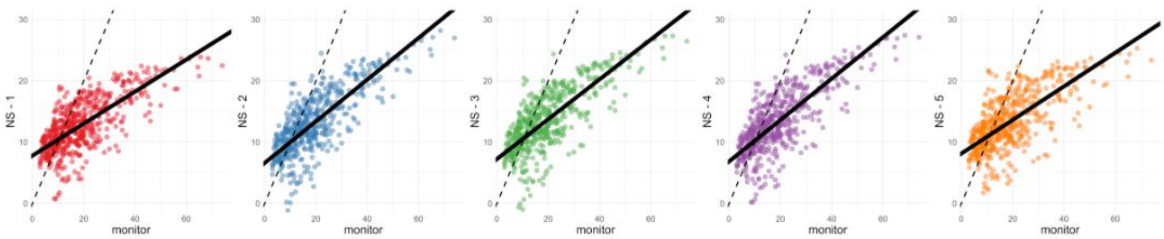


Figure 37: *regression plots for Nitrosense devices vs. reference monitor*

It is clear that this (beyond the poor R2-value) shows a significant slope and intercept, and so that even the form of the less-than-optimal correlation is far from what one would hope. This poor data quality can be attributed to the remote calibration algorithm, which was concluded to be suboptimal in our setting. The team at OnePlanet devised a new calibration procedure which was already applied in the trials in Sint-Niklaas and Ghent, and which showed signs of improvement over the procedure analysed in this section. Thus, this analysis had an immediate impact on future measurements.

3.3.1. Activities

3.3.1.1. Purpose, research questions & hypothesis

Use case 1 - a primary school in Ghent
The Public Round use case in Flanders aims to raise awareness of sources from PM and the consequences of poor air quality on health in a primary school in Ghent. This aim can be refined into 3 principal research questions: do students know more about air quality (1)? Are they more aware of air problems after the project - do they make the link between health and air quality (2)? Was the curriculum accessible to all (3)?
The questions were refined using the methodology set forth in the Open testing methodology and are listed in Table 10. Furthermore any observed effect - or the absence thereof - will give rise to follow-up questions about co-benefits are they willing to modify their behaviour now that they know more about air issues and talk about them with friends, family...

Table 9: *Experimental design for Flanders - use case 1*

Experimental design for Flanders - use case 1	
Purpose	Raising awareness on air quality with kids in secondary school in Herzele
Research question(s)	Questions that must be answered through experiment ● Is students' knowledge of air quality increasing? ● Are they more aware of air issues after the project (link between air quality & health)? ● Is the curriculum accessible to everyone? Questions that can be answered through experiment ● Are they willing to adjust their behaviour for better air quality? ● Do they talk about this with friends, family ...
● **Hypothesis**	● We now expect them to know more about air quality ● We expect them to become more aware about air issues ● We expect curriculum to be accessible to all ● we expect that some will be willing to adjust their behaviour but not others ● We expect students who have a sensor to discuss it at home as well. And so the topic is also offered in the homeroom.

Use case 2 - a secondary school in Herzele

The Public Round use case in Flanders aims to raising awareness of air quality and the different sources in a secondary school in Ghent. This aim can be refined into 4 principal research questions: Do students know more about air quality (1)? Are they more aware of air issues after the project - do they make the link between health and air quality (2)? Was the curriculum accessible to all (3). Can students use the dashboard and DEVA app developed by CompAIR independently (4)?

The questions were refined using the methodology set forth in the Open testing methodology and are listed in Table 10. Furthermore any observed effect - or the absence thereof - will give rise to follow-up questions about co-benefits are they willing to modify their behaviour now that they know more about air issues and talk about them with friends, family...

Table 10: *Experimental design for Flanders - use case 2*

Experimental design for Flanders- use case 2	
• **Purpose**	Demonstrate the impact of a neighbourhood mobility plan on traffic and air quality
• **Research question(s)**	Questions that must be answered through experiment Is students' knowledge of air quality rising? Are they more aware of air issues after the project (link between air quality & health)? Is the curriculum accessible to everyone? Can students independently use the dashboard and app developed by CompAIR (DEV-D & DEVA app) Questions that can be answered through experiment Are they willing to adjust their behaviour for better air quality? Do they talk about this with friends, family ...
• **Hypothesis**	We now expect them to know more about air quality We expect them to become more aware about air issues We expect curriculum to be accessible to all We expect that after an introductory lesson, students will be able to work on this independently We expect that some will be willing to adjust their behaviour but not others We expect that students who have a sensor that they will discuss it at home as well. And so the topic is also offered in the homeroom.

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

The Public Round use case in Flanders aims to raising awareness of air quality with students of the college of Geel & the University of Leuven. This aim can be refined into 4 principal research questions: do students know more about air quality (1)? Are they more aware of air problems after the project - do they make the link between health and air quality (2)? Were the tools from the project accessible to everyone (3).

The questions were refined using the methodology set forth in the Open testing methodology and are listed in Table 10. Furthermore any observed effect - or the absence thereof - will give rise to follow-up questions about co-benefits are they willing to modify their behaviour now that they know more about air issues and talk about them with friends, family...

Table 11: *Experimental design for Flanders - use case 3*

Experimental design for Flanders- use case 3	
• **Purpose**	Demonstrate the impact of a neighbourhood mobility plan on traffic and air quality
• **Research question(s)**	Questions that must be answered through experiment • Is students' knowledge of air quality rising? • Are they more aware of air issues after the project (link between air quality & health)? • Is the curriculum accessible to everyone? • Can students independently use the dashboard and app developed by CompAIR (DEV-D & DEVA app) Questions that can be answered through experiment • Are they willing to adjust their behaviour for better air quality? • Do they talk about this with friends, family ...
• **Hypothesis**	We now expect them to know more about air quality We expect them to become more aware about air issues We expect curriculum to be accessible to all We expect that after an introductory lesson, students will be able to work on this independently We expect that some will be willing to adjust their behaviour but not others We expect students who have a sensor to discuss it at home as well. And so the topic is also offered in the homeroom.

Use case 4 - citizens in Herzele

Citizens in Herzele have already worked with the BC sensor but there were problems with its operation at the time. The BC sensors have been repaired and optimised. With this experiment, we want to evaluate the BC sensor together with them and make adjustments where necessary and see what influence the school street has on BC sensor. This goal can be split into several questions: Are citizens' knowledge of how BC sensor works increasing? (1) Are citizens motivated to search together for solutions to problems that arise (2) Can you use the BC sensor to measure the effect of a school street on air quality? (3) Possibly, the following questions can also be answered. Are the participating citizens willing to adjust their own behaviour now that they are aware of air problems (1). Have citizens learned more about IT and the technical side of how sensors work? (2),

Table 12: *Experimental design for Flanders - use case 4*

Experimental design for Flanders- use case 4	
• Purpose	Demonstrate the impact of a neighbourhood mobility plan on traffic and air quality
• Research question(s)	Questions that must be answered through experiment Are citizens' knowledge of how the BC sensor works increasing? Are citizens motivated to work together to find solutions to emerging problems Can you use the BC sensor to measure the effect of a school street on air quality? Questions that can be answered through experiment Are they willing to modify their own behaviour for better air quality? Did citizens learn more about IT and the technical side of sensor operation?
Hypothesis	We expect their knowledge to increase regarding the operation of the BC sensor We expect them to be motivated to work with us to find solutions We expect that with this BC sensor you can measure the effect of the school street we expect that some will be willing to adjust their behaviour but not others We expect that by finding solutions together/alone, participants will become more familiar with the operation of IT tools (dashboard, DEVA app and operation of BC sensor)

Use case 5 - Environmental council in Hove

The aim of this project is to raise awareness of the wood burning issue among citizens and policy makers. This goal can be broken down into several questions: (1), does the SODAQ sensor detect wood firing, does it increase the knowledge of policy makers on wood firing issues? (2), is the project plan accessible to all (3). With the latter, we mainly want to check whether the BC sensor and the CompAIR dashboard are user-friendly and keep citizens motivated enough to fill in a logbook over a certain period of time. Possibly, the following questions can also be answered. Are the participating decision-makers willing to adjust their own behaviour now that they are aware of the wood burning issue (1). Does objectively measuring wood combustion with a SODAQ sensor increase support for measures concerning wood combustion (2),

Table 13: *Experimental design for Flanders - use case 5*

Experimental design for Flanders - use case 5	
Purpose	Demonstrate the impact of a neighbourhood mobility plan on traffic and air quality
• **Research question(s)**	Questions that must be answered through experiment Increases citizens' knowledge of timber issues Can SODAQ sensors pick up wood fires Is the project plan accessible to all (COmpAIR dashboard, logbook, BC sensor...) Questions that can be answered through experiment Are they willing to modify their own behaviour for better air quality? Will this experiment increase political and public support for measures on wood burning?
Hypothesis	We expect their knowledge of wood burning and air quality to increase We expect SODAQ sensors to pick up wood fires We expect it to be accessible to all we expect that some will be willing to adjust their behaviour but not others We expect them to get participating citizens to talk about this with their communities and that this may be the start of increased support for measures to address the wood burning issue

Use case 6 - circulation plan Ghent

The aim is to find out how the circulation plan will affect air quality and traffic. This goal can be broken down into several questions: does it reduce motorised traffic (1), does it improve air quality (less NO2). Possibly the following questions can also be answered. Does a circulation plan raise awareness among citizens (dialogue about this design, knowledge about air quality)? (1) Does this circulation plan lead to more citizens opting for cycling, walking or public transport? (2).

Table 14: *Experimental design for Flanders - use case 6*

Experimental design for Flanders - use case 6	
• **Purpose**	Demonstrating the impact of a mobility plan on traffic and air quality in Ghent
• **Research question(s)**	Questions that must be answered through experiment Is there less motorised traffic in the Dam Gate neighbourhood? Or does this not reduce but rather displace traffic (TEL sensors)? Does this improve air quality (NO2 sensors) Questions that can be answered through experiment This measure raises awareness of air quality among citizens (all the sensors). Does it create a possible shift (e.g. more trips by bike)
• **Hypothesis**	We expect less motorised traffic in the Dam Gate district We expect an improvement in air quality (less NO2) We expect that by introducing the measure, there will be more dialogue among citizens in the neighbourhood and the benefits (safer & a healthier environment) will outweigh the drawbacks. Provided that this measure ensures less traffic and not just displacement of traffic We expect it to ensure more people choose to cycle, walk or take public transport (TEL sensor)

Use case 7 - circulation plan Sint-Niklaas

The aim is to find out how the circulation plan will affect air quality and traffic. This goal can be broken down into several questions: does it reduce motorised traffic (1), does it improve air quality (less NO2). Possibly the following questions can also be answered. Does a circulation plan raise awareness among citizens (dialogue about this design, knowledge about air quality)? (1) Does this circulation plan lead to more citizens opting for cycling, walking or public transport? (2).

Table 15: *Experimental design for Flanders - use case 7*

Experimental design for Flanders - use case 7	
• **Purpose**	Demonstrating the impact of a mobility plan on traffic and air quality in Ghent
• **Research question(s)**	Questions that must be answered through experiment Is there less motorised traffic in the Dam Gate neighbourhood? Or does this not reduce but rather displace traffic (TEL sensors)? Does this improve air quality (NO2 sensors) Questions that can be answered through experiment This measure raises awareness of air quality among citizens (all the sensors). Does it create a possible shift (e.g. more trips by bike)
• **Hypothesis**	We expect less motorised traffic in the Dam Gate district We expect an improvement in air quality (less NO2) We expect that by introducing the measure, there will be more dialogue among citizens in the neighbourhood and the benefits (safer & healthier environment) will outweigh the drawbacks. Provided that this measure ensures less traffic and not just displacement of traffic We expect it to ensure more people choose to cycle, walk or take public transport (TEL sensor)

Use case 8 - sensor validation Ghent

The aim of this use case was to compare the results of the Telraam traffic counting devices with “industry accepted” technology (tubes) and ground truth (manual counts), executed by a third party (City of Ghent). The objective is to build trust in the Telraam system as a viable alternative for collecting traffic counting data in a citizen science setting.

Table 16: *Experimental design for Flanders - use case 8*

Experimental design for Flanders - use case 8	
• **Purpose**	**Demonstrate useability of a citizen science traffic counting sensor as an affordable alternative for common counting technologies**
• **Research question(s)**	Questions that must be answered through experiment • Can you find engaged citizens to host a sensor for the duration of the test? • Is the accuracy of the data acceptable for transport planners?
• **Hypothesis**	**Given prior experience with Telraam, we expect no problems for the first question. An external validation of the accuracy will confirm earlier internal validation efforts, done by Telraam and will lead to a 90-95% accuracy for car and 80-85% accuracy for bike, which is sufficient for planning purposes**

3.3.1.2. Experimental design

Use case 1 - a primary school in Ghent

In an engaging and educational project, students from three 5th grade classes had the opportunity to interactively explore air quality in their surroundings (11-, 16- and 11-years old). Over a two-week period, they participated in various activities to gain a better understanding of air quality and the factors affecting it.

The project started with an introduction and a survey, in which the students provided information about their daily routine and habits that could affect air quality. We also provided a consent form for the students to ask their parents' permission to take measurements with the sensors. This is because with the GPS present in the sensor, their route is displayed (1).

The teachers then taught about air quality using the educational package created during the European project Joaquin (both information on air quality and experiments) (2).

Then the VMM itself came by om give more information about the SODAQ sensor (operation, test set-up, dashboard where measurements come visible real-time...). After learning about how the sensor works, they were also able to attach it themselves and set it up for use (3).

For a week, students had the opportunity to measure their daily route from home to school. Each morning the results were discussed in class and noted in the logbook. This included identifying any external factors that could have influenced the measurements, such as weather, construction work or the use of fireplaces,... And was also reviewed on SODAQ's dashboard (4). The students were also able to talk about this at Karrewiet (the journal for children in Flanders) which was only beneficial for their motivation.

Logbook:

Datum					
14/11	6,4°	4	3	3	
15/11	6°	3	3	3	
16/11	9°	3	5	2	
17/11					
18/11					
19/11					
20/11	11°	4	5		
21/11	11°	2	0		
22/11	8°	2			
23/11	12°				
24/11					

Figure 38: *example logbook entries*

Together with the students, the VMM also went out for a walk in their city. The students then went out with the SODAQ sensor to discover the air quality in their city. It soon became clear that due to the diversity of sources in a city (wood fires, construction sites, etc.), a great diversity of concentrations was measured. This data was displayed in real time on the KnowYourAir dashboard, which helped students understand the direct impact of their environment on air quality (5).

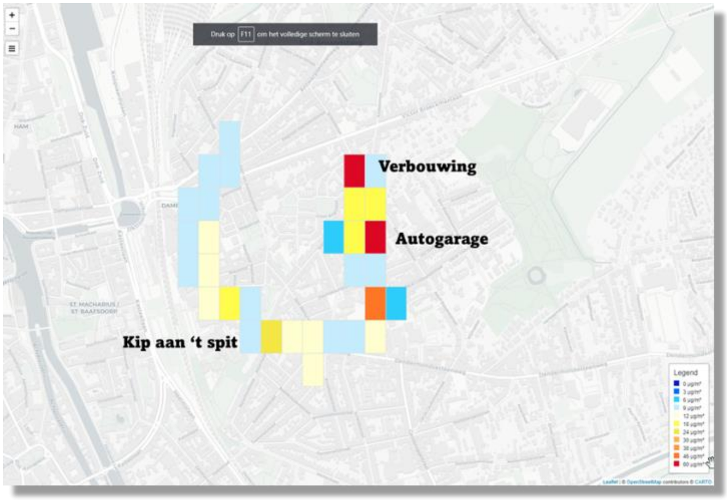


Figure 39: *annotated knowyourair dashboard as used in primary school class*

The project concluded with a workshop, where students had the chance to use their findings from the project to create their own poster. And there is also a concluding survey to (6).
This project not only provided a learning experience for the students, but also contributed to their awareness of how their environment affects air quality. It provided the necessary press coverage and by children clearly also chatting about it with people not involved in the project, it created a "snowball effect". Raising awareness about this topic among outsiders as well.

***Table 17:** Setup for Flanders - use case 1*

Design	**WHAT, WHEN & WHERE:** - 30 SODAQ sensors - Other configuration requirements: - The SODAQ sensor should be attached to a bicycle or backpack for home-school transportation **Practical note:** - Explanation on operation of SODAQ sensors + attachment of the sensors on the bikes is done by the VMM + parental consent regarding GDPR

Use case 2 - a secondary school in Herzele

The measurement project was carried out by two 5th secondary school classes (15 & 19 students), covered a time frame of 8 weeks, with a weekly time commitment of 1 hour. Prior to the project, students completed a questionnaire and obtained permission from their parents to conduct mobile measurements (1).

The project began with a lesson provided by the teacher, based on Compair's presentations (deliver 5.1). During this lesson, a representative from the VMM was present online to offer clarification on any questions the students might have (2).

In the subsequent lesson, the different projects from which students could choose were explained. The SODAQ sensor, the air pipe sensor, the DEVA app and DEV-D were explained in detail by VMM (3).

After this introduction, Jurgen from Digital Flanders came by to explain more about the DEVA app and DEV-D, giving the students a better understanding of the tools they would use for their measurements (4).

The students then worked independently on their projects over several weeks. During this period, someone from VMM was always available online during class hours to take questions from the students and offer support (5).

The project concluded with a presentation by the students on the results of their project, during which they also completed a questionnaire to gather feedback on their experiences (6).

The main findings of this survey were that after the project, students indicated that:

- 20% less would take the car
- 7% more would use bus, train and carpooling
- That they see 75% more opportunities after the project on which they can improve air quality

Based on the students' feedback, the DEVA app was modified.

Table 18: Setup for Flanders - use case 2

Design	**WHAT, WHEN & WHERE:** - 34 SODAQ sensors - 7 sensor.community sensors - Other configuration requirements: - The SODAQ sensor should be attached to the bicycle or backpack for home-school transportation - The sensor.community sensors have to be assembled themselves **Practical note:** - Explanation of operation of SODAQ sensors + fixing the sensors on the bikes is done by the VMM - A manual is provided to students + video material for assembling the air pipe sensors

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. 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. Their reservations and feedback for the app were:

The app:

- After you send the trip, a window will open where you can enter additional information e.g. roadworks, lots of rain... A kind of logbook
- That on the app you can also see how much battery the SODAQ sensor has left

The dashboard:

- You can see on the graph the amount of PM that you have inhaled (your daily dose) but you don't know if that is much/little.... It would be useful for interpretation if somewhere it is mentioned what the average dose of PM you inhale in a day is
- An addition of the EU limit and WHO advisory values on the graph or a mention of them somewhere so that the data can be better interpreted

These issues have been passed on to the technical team.

Table 19: *Setup for Flanders - use case 3*

Design	**WHAT, WHEN & WHERE:** - 6 SODAQ sensors **Other configuration requirements:** - The SODAQ sensor should be attached to a bicycle or backpack for home-school transportation **Practical note:** - Explanation of operation of SODAQ sensors + fixing the sensors on the bikes is done by the VMM

Use case 4 - citizens in Herzele

4 Citizens in Herzele are going to perform measurements with the BC sensor, we started on 25/03/2024. They will perform measurements until 27 May and see what the effect of the school street in Herzele is + test the BC sensor. Possibly also mobile measurements with the DEVA app.

One of the citizens made his own housing for the BC sensor (modular, rain & sun proof).

Figure 40: *Novel 3D printed case for bcMeter*

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 measurements blocks of PM2.5-data (each block is about 100x70m and implies at least one measurement during a single hour). Participants were initially told they were free to measure where and when they wanted. It was also suggested (but not mandatory) to keep a diary to write down events/remark during their measurements.

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.

Table 20: *Setup for Flanders - use case 5*

Design	**WHAT, WHEN & WHERE:** - 8 SODAQ sensors - datasets with results (raw and official files from knowyourair.net) **Other configuration requirements:** in case of bike measurements a dedicated bike mount was used. - The SODAQ sensor should be attached to a bicycle or backpack for mobile measurements. For running the sensor was put in the pocket of a trail running backpack. **Practical note:** - Explanation of operation of SODAQ sensors was done by VMM colleague

Use case 6 - circulation plan Ghent

On April 29th 2024, the district circulation plan went into effect. The TELR sensors have been measuring since February 23rd. There are 23 TELR-sensors, counting on 19 road segments (a few replacements and streets with 2 devices). The 4 NO2-sensors are measuring since the 1st of March 2024.

Figure 41: *TELR-sensors in Ghent*

Figure 42: *Locations NO2 sensors in Ghent (blue spots)*

Table 21: *Setup for Flanders - use case 6*

Design	**WHAT, WHEN & WHERE:** - 4 NO2-sensor boxes in Ghent and one at a reference station from the VMM - 23 TELR-sensors **Practical note:** - The NO2 sensors have a sticker with a QR code that directs to the COMPAIR website where citizens can find more information about the measurement campaign.

Use case 7 - circulation plan Sint-Niklaas

The circulation plan came into effect on 10 of June 2024. The impact of traffic is measured by 10 TELR sensors since February 2024 (see figure below) and air quality by 4 NO2 sensor boxes since 1 of March (see below). The sensors are displayed at 4 locations in Sint-Niklaas and one at the VMM measuring station in Borgerhout for reference.

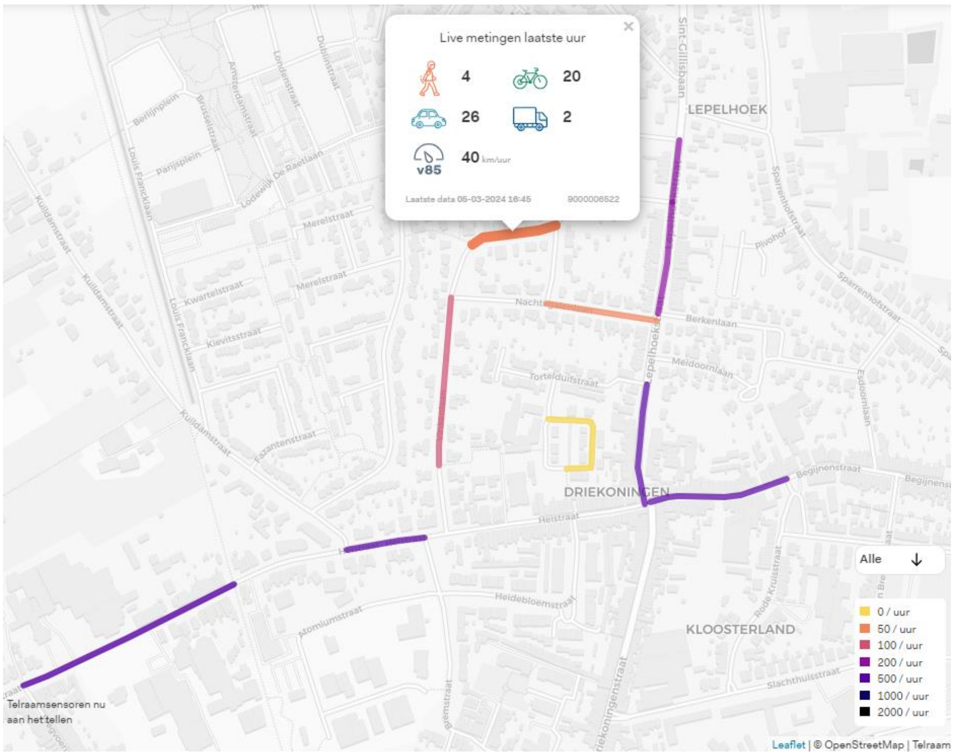


Figure 43: *TELR-sensors in Sint-niklaas*

Figure 44: *NO2-sensor box (left), NO2-sensor box in Sint-Niklaas (middle), locations of the sensor boxes in Sint-Niklaas (right)*

Table 22: *Setup for Flanders - use case 7*

Design	**WHAT, WHEN & WHERE:** - 4 NO2-sensor boxes in Sint-Niklaas and one in an reference station of the VMM - 10 TELR-sensors **Practical note:** The NO2 sensors have a sticker with a QR code that directs to the COMPAIR website where citizens can find more information about the measurement campaign.

Use case 8 - sensor validation Ghent

Table 23: *Setup for Flanders - use case 8*

Design	**WHAT, WHEN & WHERE:** - **Recruiting of 15-25 handpicked volunteers in Gent** - **deployment of tubes over a period of several weeks on a selection of locations (at least 5, max 10), complemented with manual count by the police**

3.3.1.3. Workshops

Telraam Workshop in Ghent

Workshop with schoolchildren by the VMM & DV: *Providing information about air quality & sensors (1), discussing the data (2)*

The krekel:
In the second week of the project The VMM gave a presentation about the operation of the particulate matter sensor (SODAQ AIR sensors) and installed it on their bicycle, scooter or backpack together with the students (1).In the last week, conclusions were drawn and a lively discussion took place about the results. The students worked in workshops to create posters about what they had learned during the project. They also completed a questionnaire about how aware they were of air quality and the environment (2).

Figure 45: *survey after the project (left) and a paster of a student (right)*

Sint-Paulus Institute: The project started with lessons from the teacher about air quality, followed by an informative session by the Flemish Environment Agency (VMM) and Digital

Flanders about the SODAQ, Dynamic Exposure Visualization App (DEVA app) and Dynamic Exposure Visualization Dashboard (DEV-D) (1). After collecting data, the students presented their results to their fellow students, teacher and the VMM.(2)
Students of HoGeel and University of Leuven: he project started with lessons from the teacher about air quality, followed by an informative session by the Flemish Environment Agency (VMM) and Digital Flanders about the SODAQ, Dynamic Exposure Visualization App (DEVA app) and Dynamic Exposure Visualization Dashboard (DEV-D) (1). the data was analyzed and interpreted together in the workshop on the end of the project (2).

Use case 4 - citizens in Herzele with the BC-sensors
There have been two meetings with the citizens of Herzele.
First workshop:

- Sat down with the citizens and explained what has changed in the BC sensor compared to the first measurement campaign
- Together with the citizens, we thought about what can still be measured in the future period, e.g. the effect of the school street, the idling of the cars in the street.

Second workshop:

- Viewed and analysed citizens' data together
- Thought about improving the BC-sensor (in terms of user-friendliness, data supply..), this has also been passed on to the developer of the BC-sensor

Use case 5 - environmental council in Hove
No dedicated workshop was organised in Hove. Participants got their info/guidance when they picked up the sensors at the house of the VMM colleague. Results were discussed as part of the environmental council meeting in Hove (March 27, 2024).

Use case 6 - circulation plan Ghent
Because the circulation plan has been postponed a lot due to protests from local residents and local merchants, the city has not had a workshop with the citizens

Use case 7 - circulation plan Sint-Niklaas
There was an information session organised for the introduction of the circulation plan consisting of the following elements:

- An information session about air pollution, the traffic sensor, the NO2 devices and also how you can take measurements yourself with a (mobile) particulate matter (PM) sensor.
- A data café, where we looked at the data from the traffic sensors together.
- For those who wante: assemble a particulate matter sensor yourself and the option to lend a mobile particulate matter sensor.

Use case 8 - sensor validation Ghent
This use case did not involve any workshops. A call for complementary manual counts was done to the participants, to which some have responded. These manual counts complemented the manual counts executed by the police

3.3.2. Results

3.3.2.1. Analyses

Use case 1 - a primary school in Ghent

Together with the students, two groups made a walk in the neighbourhood (see figure below). The students clearly saw the concentration varying during the walk, e.g. when passing a construction site, a car garage, someone smoking a cigarette, etc. by using the indicator LED on the devices. Afterwards, this was also shown on the COMPAIR dashboard where the students could clearly observe the variation in exposure to air quality (dynamic exposure).

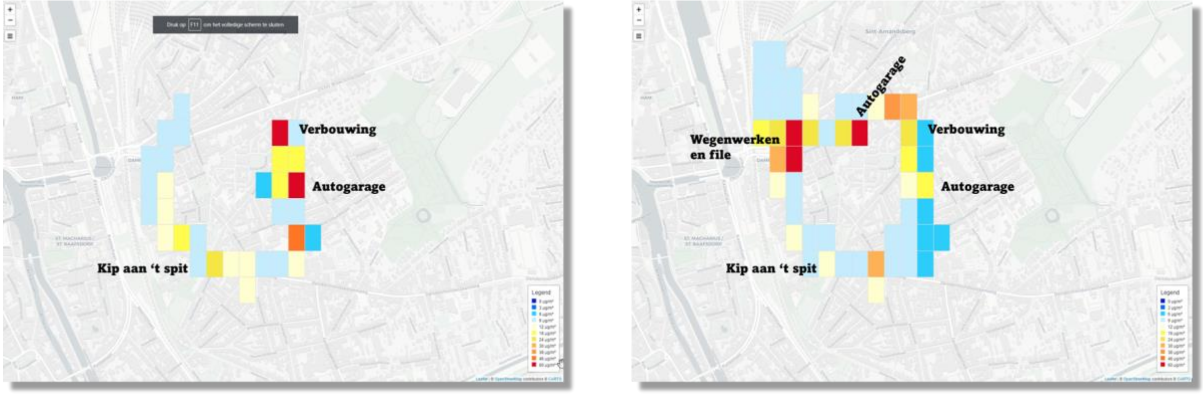


Figure 46: *Walk in the vicinity of the school de Krekel, group 1 (left) and group 2 (right) - indication of sources in Dutch*

Figure: Walk in the vicinity of the school de Krekel, group 1 (left) and group 2 (right) - indication of sources in Dutch

Use case 2 - a secondary school in Herzele

All the students (in groups of 3 to 4 people) presented the results of their measurement project to the other students, the teacher and COMPAIR experts. One of the conclusions of a group of students was that dynamic exposure is indeed very varied and they also saw the effect of the farmer's work on the land on their sensor, namely rising particulate matter concentrations (see figure below the orange concentrations).

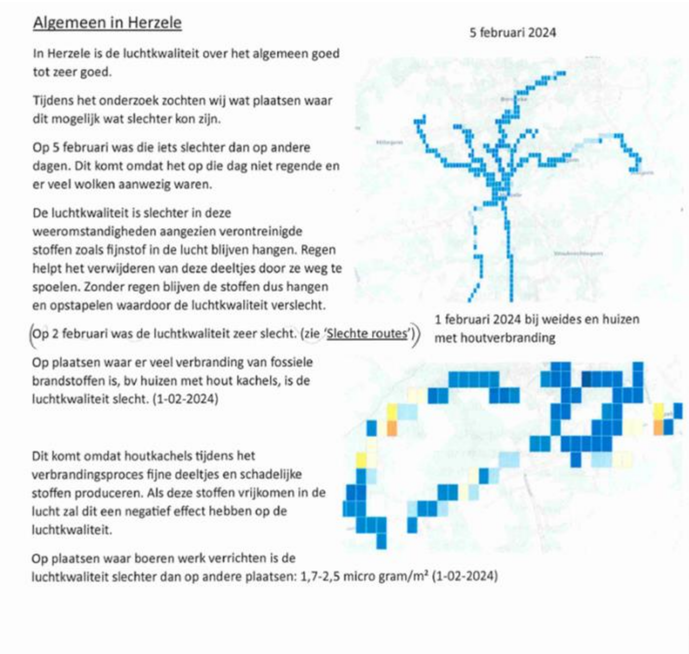


Figure 47: *An example of the result (data, data processing, analysis and interpretation) of a group of students from the Sint-Paulusinstituut.*

Use case 3 - a College of Geel & the University of Leuven
After the measurement campaign, VMM, DV, students and teachers sat together to see what was going well and what could be improved. The points for improvement for the DEVA app and the DEVD dashboard have also been taken into account (e.g. a manual to install the DEVA-app, addition of WHO standards to the dashboard…). Because of this, both tools are more user-friendly for future measurements .

Use case 4 - citizens in Herzele
The trials run by citizens in Herzele highlighted several issues with the bcmeter. Altogether seven devices were installed on site which had all been checked to be technically sound at the VMM office. However, upon installation by the citizens it seems most of the sensors had severe issues connecting to the local wifi network. This issue led to the low data availability which was plotted below.

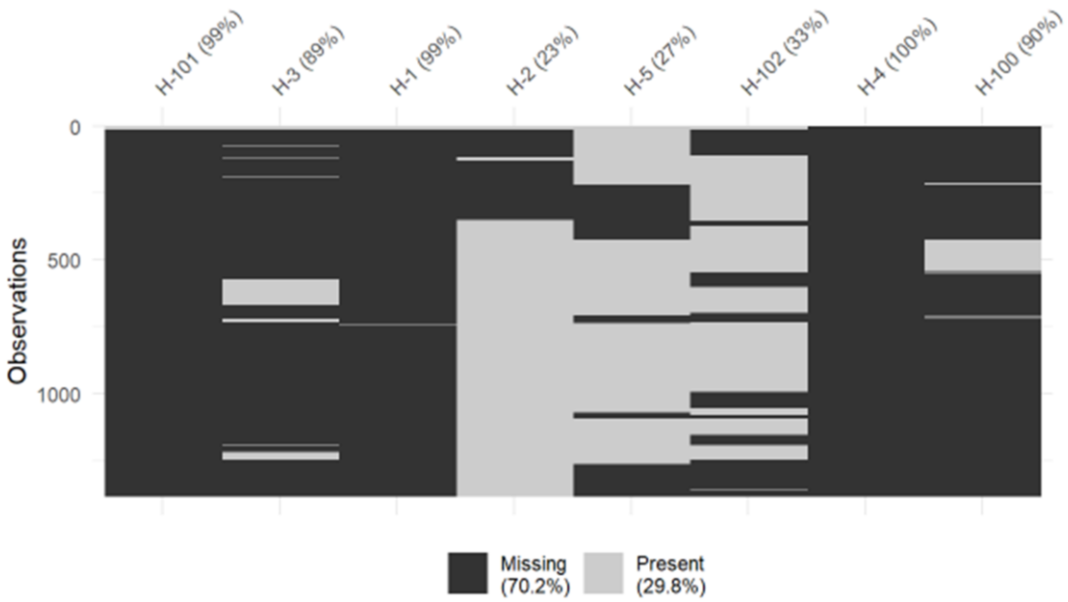


Figure 48: *data availability for each bcMeter during the 2024 campaign*

This graph shows the observations for each sensor (identified by a unique number of the type H - #). In total only 29.8% of the total possible measurements were done successfully, ranging for individual sensors from 0% (devices which were never able to go online) to 77%. The very same devices showed no problems connecting in our tests. This indicates that the network connectivity of the bcmeter is as of now not sufficiently stable or user friendly to be rolled out in a broad citizen science trial.

From the available data, a second observation was taken: though the devices had been tested in a co-location trial and showed no significantly strange behaviour (barring trouble concerning relative biases), the devices measured negative concentrations upon rollout. Even the hourly-averaged output showed such unphysical measurements:

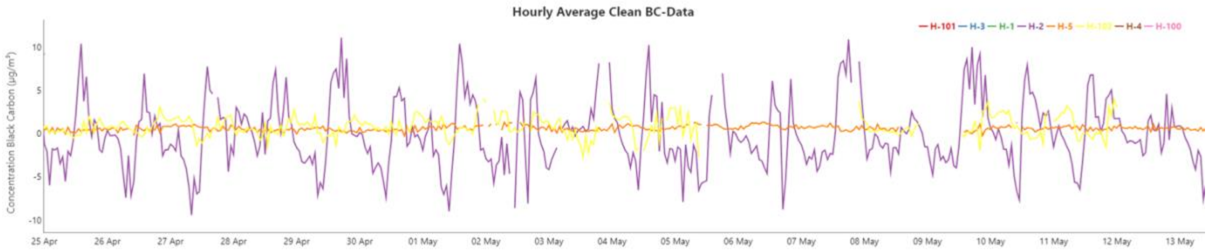


Figure 49: *hourly averaged and cleaned bcMeter data*

These negative concentrations seemed to occur at regular daily intervals:

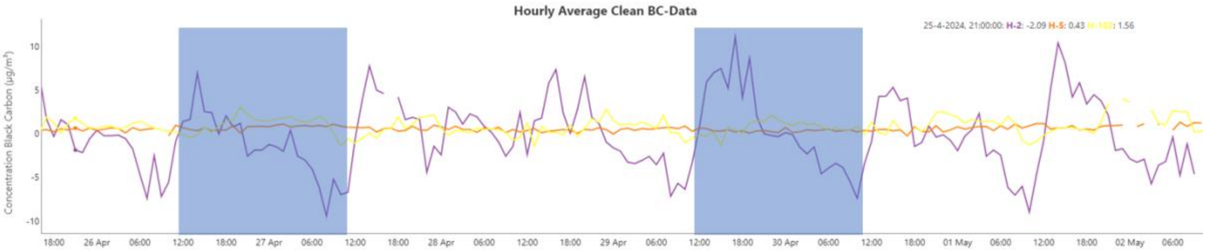


Figure 50: *hourly averaged and cleaned bcMeter data - zoomed in*

At closer inspection, we observed that this erratic behaviour seemed to occur when the internal temperature measurement was raised.

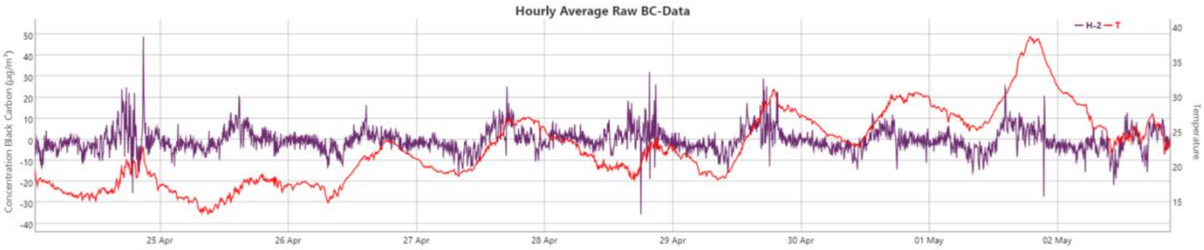


Figure 51: *Hourly averaged raw bcMeter and internal temperature timeseries*

This led us to conclude that the sensor is being affected – either by internal heating or a light leak. A group at VMM has decided to further investigate this issue and propose possible fixes going forward to new trials. This citizen science trial was essential towards finding these issues, which did not pop up in our internal tests.

Use case 5 - environmental council in Hove

Data distribution:

Most measurements were done in the late afternoon or morning. Morning measurements were often related to 'bike to work' trajectories from one or two participants. Virtually no data were collected between 22:00 and 6:00.

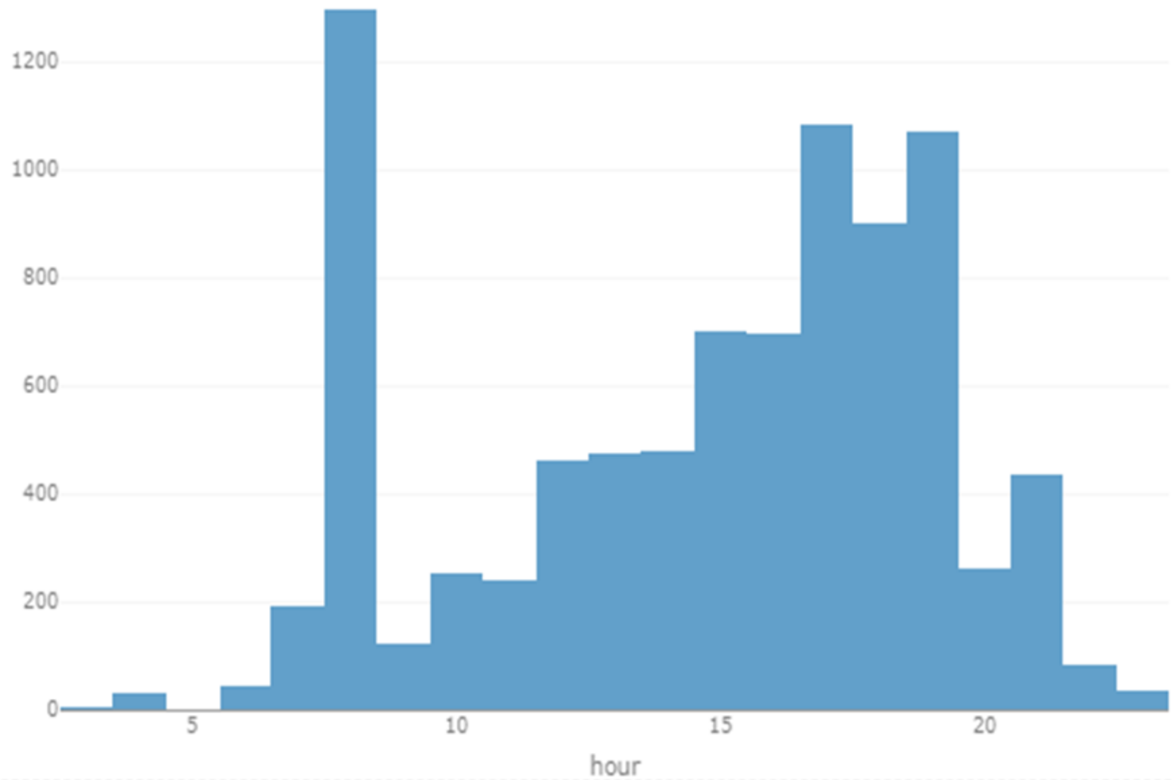


Figure 52: *Distribution of the number of measurement blocks by hour of the day.*

Since people were mostly free to perform measurements when/where they wanted some streets had much more coverage than others, which should be taken into account when interpreting the data.

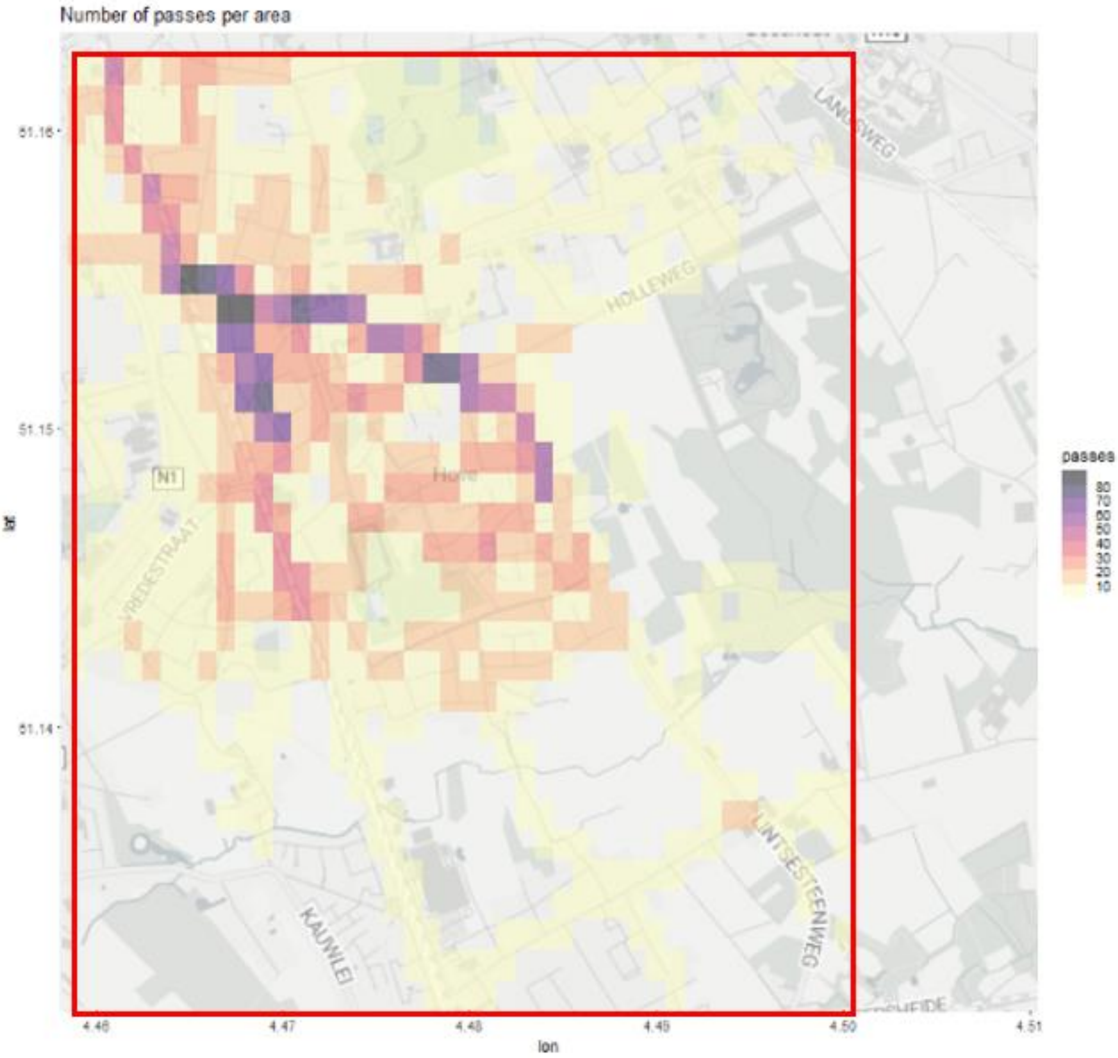


Figure 53: *Visualisation of the number of passes per datablock (one pass=at least one measurement in one single hour).*

<u>Data validation/calculations</u>

The actual data analysis consisted of multiple steps. First a manual validation of PM-measurements was performed. Data with bad gps-info and data that appeared to be measured indoors were removed.

In the next step a correction for the regional PM2.5 background was carried out in order to focus on the local contributions. Due to random noise and variations in the background data were screened for local peaks at different thresholds (e.g. 5-8-10 µg/m³ above the background). On most days 8 or 10 µg/m³ worked best as threshold.

Results were visualised in two different ways: as single trajectories of total PM2.5 and summarised on a map (as net PM2.5, so minus the background).

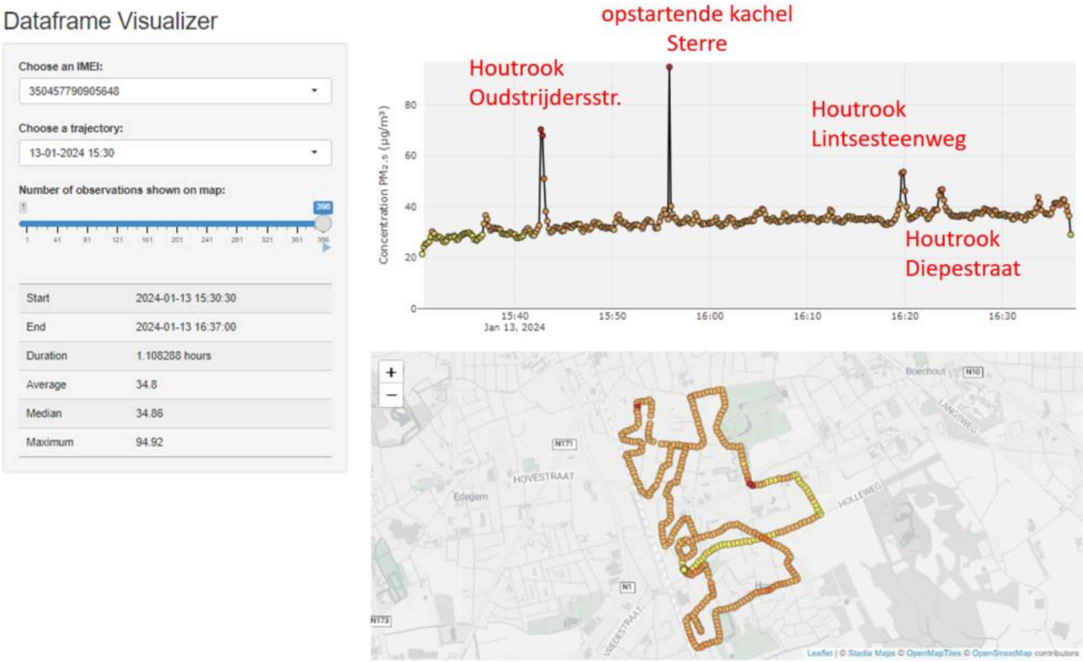


Figure 54: *Single trajectory visualisation including some diary annotations ('houtrook'=wood smoke)*

Figure 55: *Map visualisation of number of measurements above the 10 µg/m³ local threshold. Each flame symbol corresponds to locations where wood smoke was identified as the source of the local peak(s).*

Although the resulting maps are far away from providing a full view of the PM-concentrations at all times/place they already clearly marked two hotspots zone in Hove (marked with red circles on the map).

Results were discussed during an environmental council meeting at the end of March 2024. The general agreements from participants were:

- Contributions from wood smoke were very clearly visualised
- Contributions from road traffic (cars) were much less than expected
- The effect of weather conditions was surprisingly high

The participant with the most datablocks (over 6000) kept a detailed diary describing the nature of observed local peaks. In total a bit more than 100 local peaks were identified, 95% of these could be attributed to wood smoke. Some other sources that were recorded were a cigarette smoking pedestrian, a pick-up accelerating and construction works.

Use case 6 - circulation plan Ghent

To test the effects of a circulation plan in Oud-Dampoort/Gentbrugge in Ghent, four NitroSense devices measuring NO_2 were installed at various locations throughout the neighbourhood, along with one device which was installed at our reference station R701 in the centre of Ghent – functioning as a background measurement.

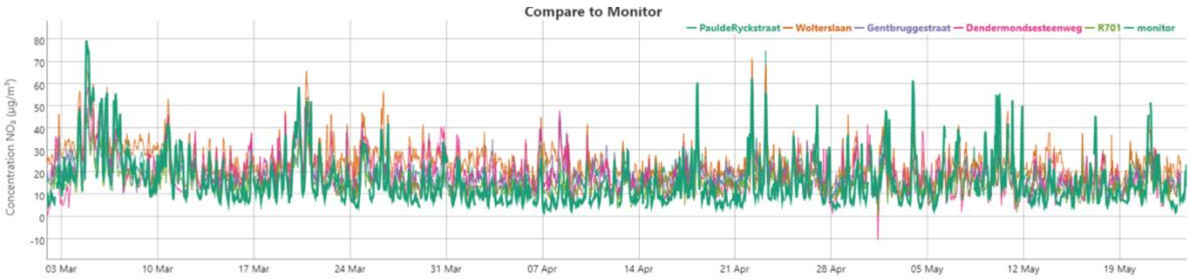


Figure 56: *Nitrosense and reference site timeseries during circulation plan experiment*

The circulation plan went into effect on the 29th of april, so we have about a month's worth of (calibrated) data after the mobility change. A violin plot comparing the distribution of concentrations before and after the mobility change is given below.

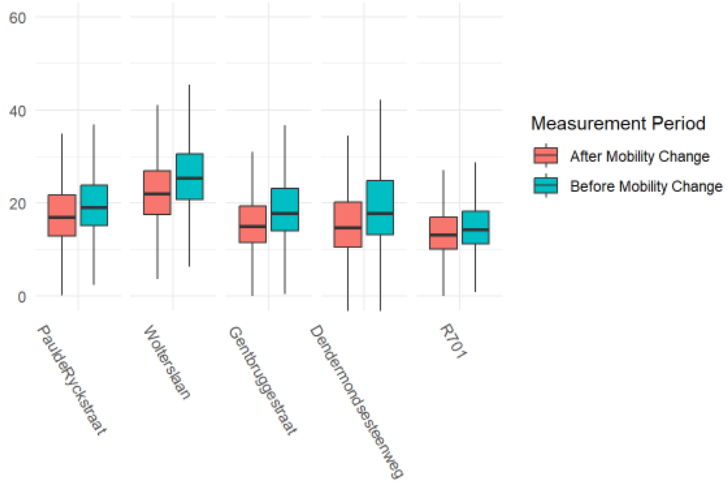


Figure 57: *NO2-concentration boxplots during circulation plan campaign in Ghent*

Note however, that looking at these concentrations without taking into account the background is misleading. For this reason, we will henceforth look at the net concentrations for the four non-background locations by subtracting the result for R701 from all other measurements. (Note that the sensor co-located with the reference station showed an R^2-value of 0.6 when compared to the official reference measurement.) We discard any negative concentrations after performing this subtraction. The result is shown below.

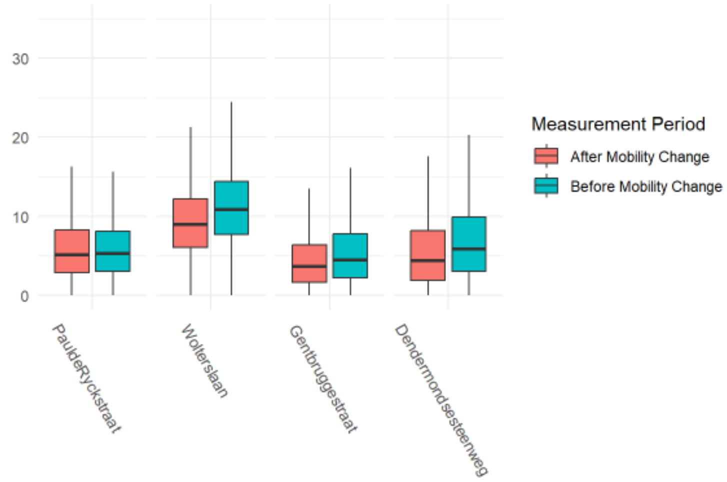


Figure 58: *Net NO2-concentration boxplots during circulation plan campaign in Ghent*

We do see a difference in statistics for all locations except for the Paul de Ryckstraat. This is further illustrated by listing some sensor statistics for the data before the change

ID	PauldeRyckstraat	Wolterslaan	Gentbruggestraat	Dendermondsesteenweg
Mean	5.988	11.265	5.798	7.308
Median	5.370	10.922	4.560	5.922
SD	4.047	5.179	4.982	6.010
Max	40.971	54.502	51.385	92.402
Min	0.007	0.016	0.000	0.001

Figure 59: *sensor statistics before implementation*

and comparing it to the same data after the change:

ID	PauldeRyckstraat	Wolterslaan	Gentbruggestraat	Dendermondsesteenweg
Mean	6.071	9.520	4.602	5.832
Median	5.197	9.006	3.693	4.422
SD	4.372	4.961	3.912	5.352
Max	34.638	43.374	24.171	49.740
Min	0.002	0.001	0.001	0.002

Figure 60: *sensor statistics after implementation*

The differences look altogether rather minute. A more in-depth view can be gleaned from looking at diurnal patterns. Since NO_2 is mostly sourced by combustion engines, we expect an effect of mobility changes to be stronger at times which usually get large amounts of traffic. The following plots show the average concentration of NO_2 for each hour of the day for each sensor individually, comparing the situation before and after the change.

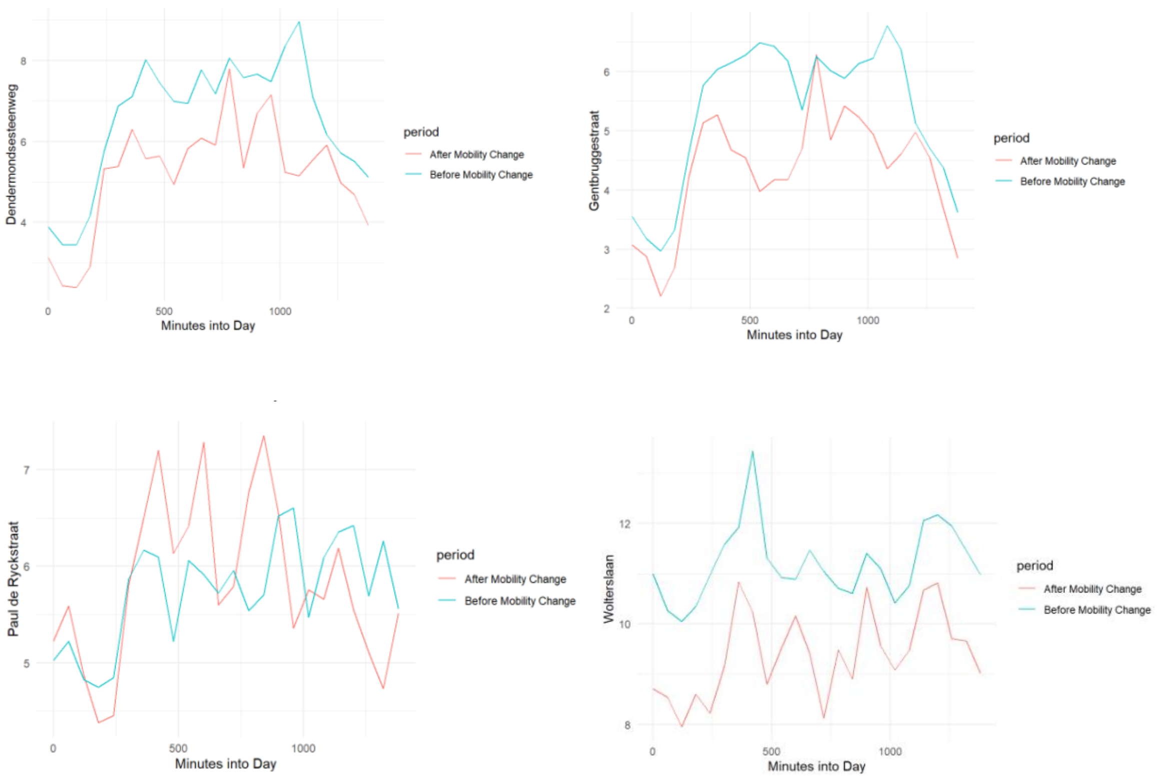


Figure 61: *Diurnal patterns before and after implementation for each site*

In particular the patterns for Dendermondsesteenweg and Gentbruggestraat, which show an altogether similar curve for both situations but with a significant difference in the middle half of the day, suggest that this might be due to a lower amount of traffic. For Wolterslaan, the curve has a similar shape after the change, but is shifted down. For Paul de Ryckstraat, the net zero effect still shows an interesting diurnal pattern: with higher concentrations in the middle half of the day but lower ones at night. We can further confirm these findings by looking at boxplots for each hour of the day for the two situations:

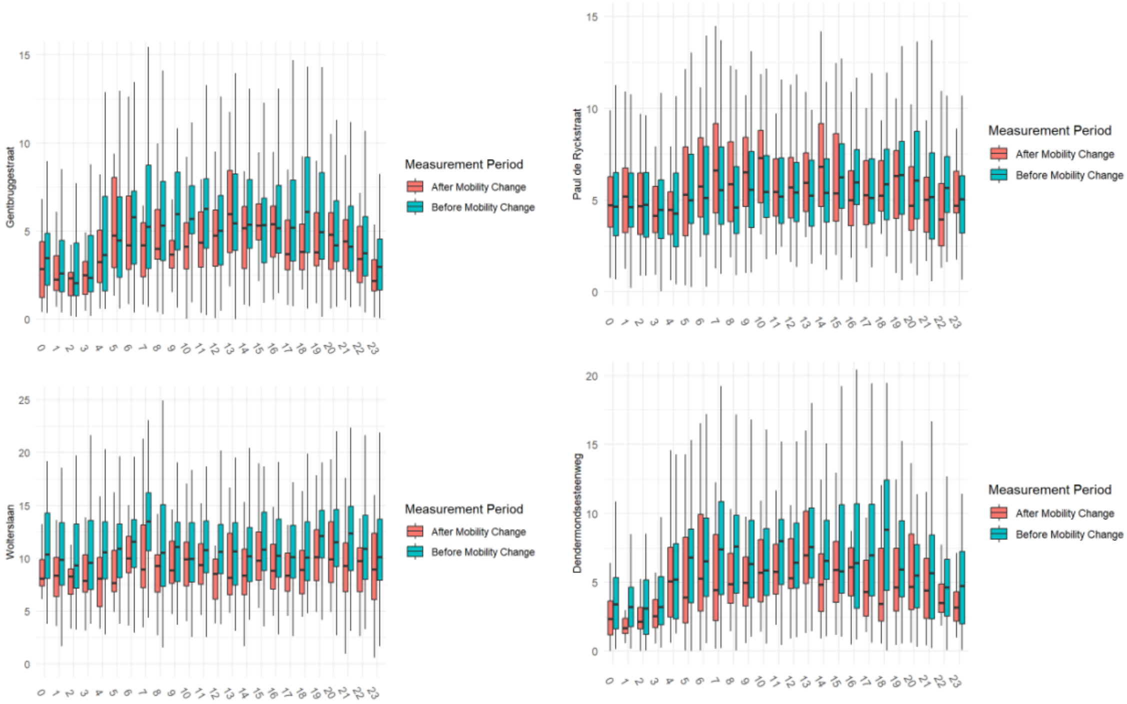


Figure 62: *Boxplots for every hour of the day before and after implementation*

Though this analysis seems to suggest that we can see an effect of the circulation plan, we prefer to delay any definitive statements until more data is available. What's more, since the calibration of the NitroSense devices used in this experiment was newly developed after our feedback from use case 8, we need to run extensive testing to account for sensor bias and drift, for example by performing a co-location after the trial is finished.

Use case 7 - circulation plan Sint-Niklaas

To measure the impact of the circulation plan in Sint-Niklaas, four NitroSense devices were installed on site at the following locations:

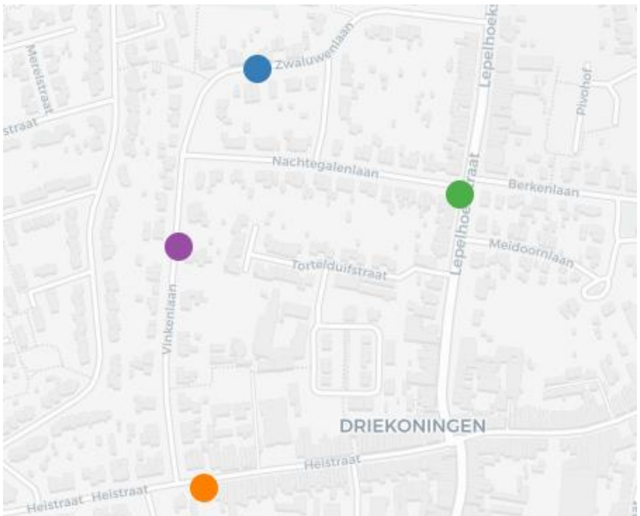
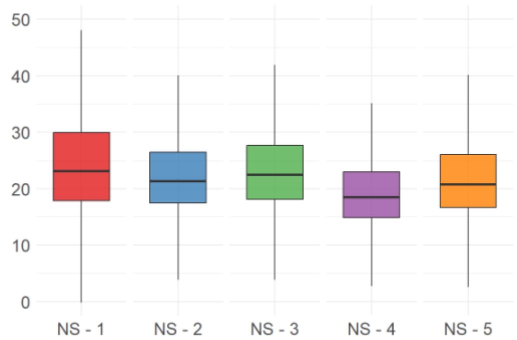


Figure 63: *Nitrosense locations in Sint-Niklaas*

Along with one device (NS - 1) being placed at the reference station R801 in Borgerhout.

Since the circulation plan has barely taken effect at the time of writing, we are unable to make any statements about its effect on air quality as of yet. Rather, we will sketch the situation as it was before the mobility change took place (1/3/24 - 23/5/24).

Looking at the measurements for this period, we see that (ignoring the reference sensor), NS - 3 measures the highest mean concentration of NO_2, with NS - 2 and NS - 5 close behind. The sensor NS - 4 seems to be measuring consistently lower concentrations. Looking at the street plan, our expectation would be that sensors NS - 3 and NS - 5 would measure the highest concentrations, seeing as they are located at large traffic axes. Having NS - 2 be equally high indicates that there could be an unexpectedly large amount of traffic in the Zwaluwenlaan.



ID	NS - 1	NS - 2	NS - 3	NS - 4	NS - 5
Mean	24.981	22.407	23.269	19.541	22.301
Median	23.143	21.320	22.505	18.483	20.770
SD	10.704	8.004	8.491	7.467	8.907
Max	83.024	66.953	68.304	62.364	76.820
Min	-17.505	-15.605	-26.491	-17.524	-13.450

Figure 64: *box plot and basic statistics for the Sint-Niklaas campaign*

Looking at the daily profiles for each location corroborates this vision, as we can see a clear spike on weekdays associated with a morning rush, along with an accompanying spike in the evening.

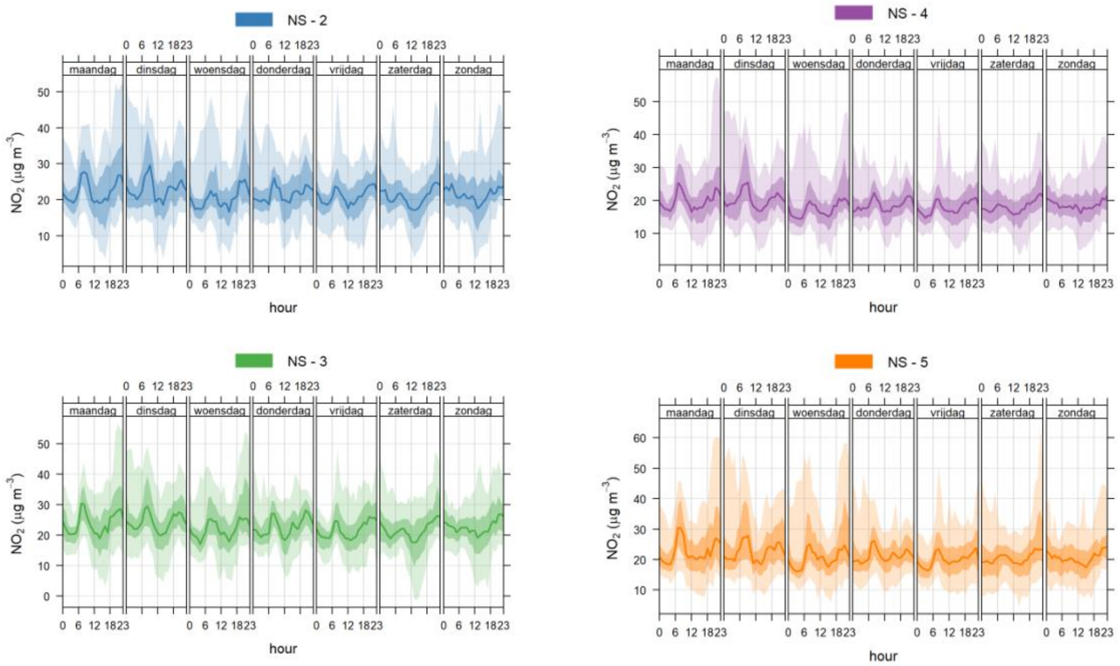


Figure 65: *Daily profiles for each location during the Sint-Niklaas campaign*

It will be interesting to see if/how much this situation changes for the period after which the mobility changes took place.

Use case 8 - sensor validation Ghent

19 users were involved to host a sensor and all users have had their sensor active for the duration of the pilot. A few devices have been replaced because of a manufacturing defect, but this did not impact citizen scientist commitment.

Regarding the accuracy of the devices, the table below summarises the results of the comparison between Telraam and pneumatic tubes.

Table 24: *Comparing bike traffic count from manual counts, Telraam and pneumatic tube (per direction)*

Street	bike - manual	bike - Telraam	bike - tube
Adolf Baeyensstraat	6/13	3/12	N/A
Frederik Burvenichstraat	12/12	11/10	9/7
Oscar Colbrandtstraat	3/2	2/1	N/A
Toekomststraat	12/16	7/16	N/A
Tweekapellenstraat	10/2	9/0	6/2

***Table 25:** Comparing car traffic count from manual counts, Telraam and pneumatic tube (per direction) - The Telraam at Tweekapellenstraat had an incomplete view, so was expected to have lower accuracy.*

Street	car - manual	car - Telraam	car - tube
Adolf Baeyensstraat	33/37	32/36	N/A
Frederik Burvenichstraat	31/32	28/25	30/30
Oscar Colbrandtstraat	1/0	0/0	N/A
Toekomststraat	33/46	30/45	N/A
Tweekapellenstraat	47/0	24/0*	44/1

When comparing daily profiles, from Telraam and tubes, we have the following results

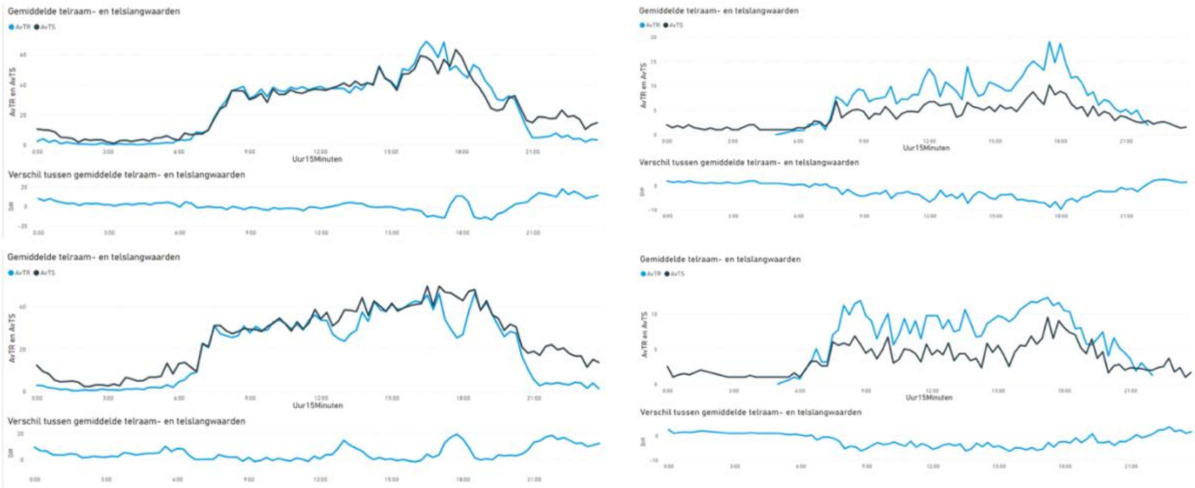
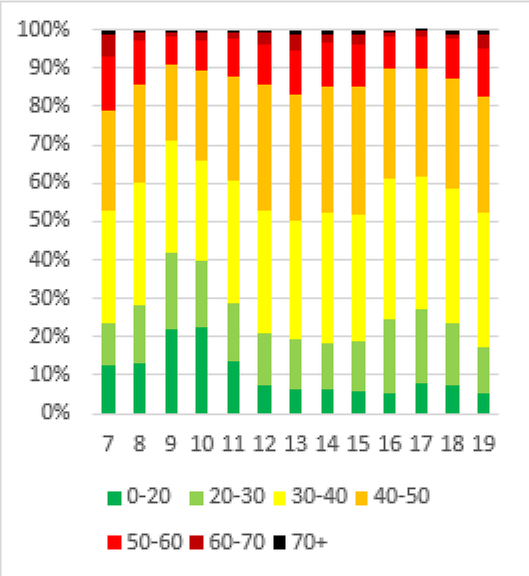


***Figure 66:** comparing daily profile of Telraam with tube count for Frederik Burvenichstraat, for cars (left) and bikes (right) for direction left>right (top) and right>left (bottom)*

Both tubes and Telraam also provide estimates for speeds. For Telraam, this is a secondary output with a lower accuracy, but sufficiently accurate to have an impression of the vehicle speed. Tubes are known to be quite reliable for speed estimates. Table below provides one example (Frederik Burvenichstraat), but results are similar for all streets



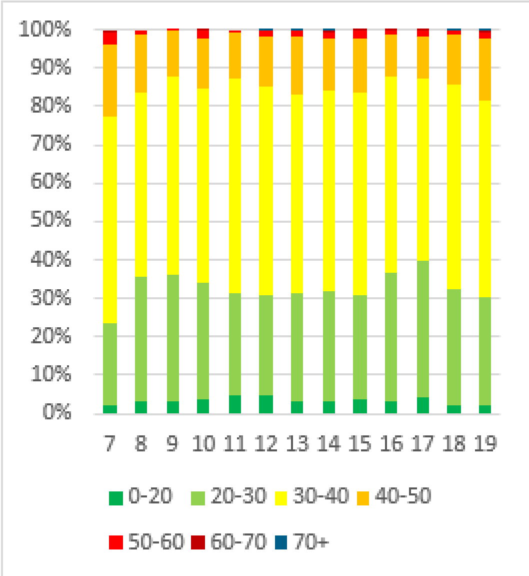


***Figure 67:** comparing car speeds in classes of 10km/h (series), per hour of the day (X-axis) of Telraam (left) with tube count (right) for Frederik Burvenichstraat.*

The comparison between the tubes and Telraam systems reveals a generally strong agreement, demonstrating that both methods are effective for traffic counting. Although the tube tends to underestimate the number of cyclists, particularly in heavy traffic conditions, this finding aligns with expectations and is supported by manual control counts.

This insight underscores the importance of carefully interpreting cyclist data from the tubes. When comparing motorized traffic classes, it is crucial to account for the differing measurement criteria: tubes use axle length while Telraam considers vehicle size.

Despite some challenges, such as Telraam's sensitivity to specific conditions like strong backlighting, the system performs well overall. While there may be slight overestimations in vehicle speeds with Telraam, this does not detract from its overall utility. For accurate and comparable results in before-and-after analyses, it is essential to use the same technique consistently. This consistency is key to ensuring reliable conclusions from the data.

3.3.3. Lessons learned

In this section we'll focus on the non-technical lessons learned during the Public Round implementation in Flanders. Technical learnings are not covered in this deliverable.

During the "Public Round" phase we encountered valuable lessons that have significantly informed our approach and understanding of the air quality and traffic experiments we are conducting. In the Open Round, we engaged with our community of participants, experts, and stakeholders to gather insights and data, ultimately aiming to inform evidence-based decision-making. These insights - together with those of other pilots - will shape our Public Round's success and effectiveness.
In this part of the report, we outline the key lessons learned during this phase, highlighting their significance in shaping the project's direction and impact.

Lesson 1: Recognition of "Local Champions"

- **Technical champions**: citizens who are very strong in the technical side of things and e.g. build their own housing for the BC sensor
- **Functional champions**: people who already have a leadership role and are present in the project anyway. E.g. teachers who get to work on the JOAQUIN project themselves and make it a lesson tailored to their students
- **Internal champions**: people within the organisation who are motivated to take action themselves e.g. colleague who started the measurement project in Hove

Lesson 2: Snowball effect of working around air quality in schools
We find that by working with students you not only raise their awareness about air quality but also their friends, parents, brothers/sisters... So the impact is bigger than just the number of students within a class. And if a project with students is picked up by the media, it ensures that other schools/teachers/students/sympathizers... are motivated to make their own measurements, take action...

Lesson 3: Reaching low SES groups through schools
If you make a call to work with citizens to measure air quality or traffic, you mainly get responses from the good middle class. People from the low SES groups don't have time for this. If you can work with a diverse school, you have a diverse group of students anyway. Which makes it more challenging to get the message across. But on the other hand, you can address a diverse audience through the school than civic projects through a call from the municipality/newsletter.

Lesson 4: Ethical issue
Problems within a city/municipality are often a response to citizens' complaints. We notice that e.g. the circulation plan in Sint-Niklaas comes in a neighbourhood people of the middle or high SES classes. The circulation measures mean less traffic in their neighbourhood but more traffic in the neighbouring connecting roads. The very roads where people live from the low SES classes.

Lesson 5: SODAQ sensor could benefit from several upgrades to help (automatic) data analysis.
Since the SODAQ sensor does not have a dedicated on/off button it's not possible for participants to know when measurements start/stop exactly. This results in indoor measurements than complicate data analysis. Working with a sensor with a dedicated switch would be better.

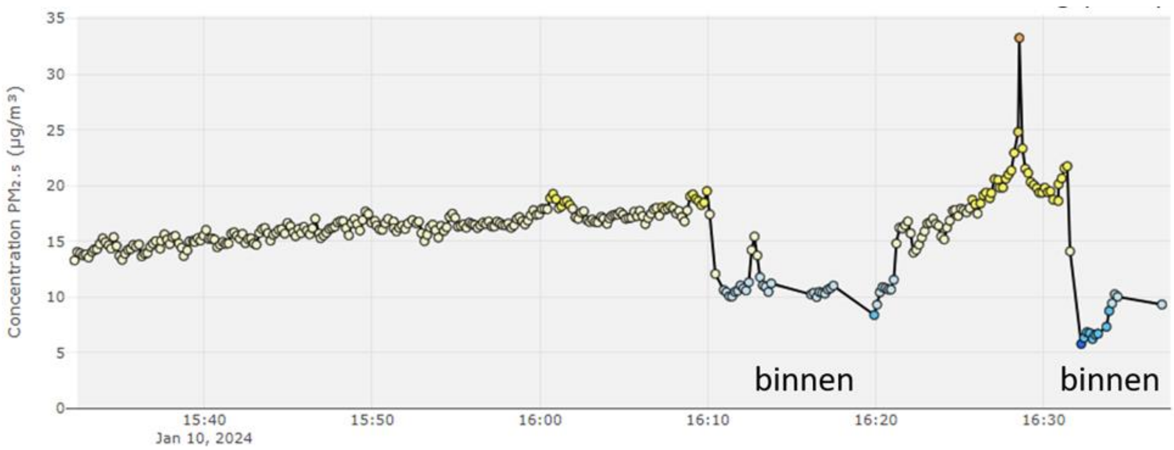


Figure 68: *Indication of the effect of indoor ('binnen') measurements*

Currently the public visualisation at knowyourair.net is not very well suited for citizens to visualise their mobile trajectories. An addition of a linear time vs PM2.5 plot could help users to better understand PM-gradients and to fill in diaries with comments regarding the measurements.

Conclusion

The "Open Round" phase of COMPAIR has been a rich source of valuable insights in Flanders. These lessons learned will significantly inform our future efforts in evaluating policy implementations related to air quality and traffic. Recognizing the role of local champions, fostering interactive engagement through the "Data Café," and maintaining flexibility in the face of challenges are all essential elements for success. Additionally, understanding the impact of political dynamics and the collaboration with schools reinforces the need for adaptability and meticulous planning. These lessons serve as our compass, guiding us towards a more effective and impactful citizen science project in the Public Round that contributes meaningfully to informed decision-making and community engagement.

3.4. Sofia & Plovdiv pilots

3.4.1. Activities

3.4.1.1. Purpose, research questions & hypothesis

As part of the COMPAIR project the Sofia pilot has emphasised on the implementing 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. Following the preset activities and directions performed during the Open Round we extended most of the activities during the Public Round by developing a stronger partnership with citizens, schools and stakeholder communities. The approach is based on the needs of the stakeholders involved. The use cases were also extended to 4, adding the CO2 calculator usage and the raising awareness activities as separate use cases. Considering them as main activities and important policies for improving air quality and changing daily habits with more sustainable ones, we will continue supporting these initiatives and working on these dimensions.

Sofia use case 1 – School bus service

The aim of this use case was to introduce a school bus routes on the outskirts of the LEZ and to create a community building exercise with schools and stakeholders affected by the 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.

During the public round SDA team was able to extend the impact of the introduction of school bus routes, making it more comprehensive and complete service than the previous testing period, as there were school buses available for morning and noon transportation to 3 schools and operating for the whole school year.

The target group was again mainly the students from 1st to 4th grade - the same as during the previous testing period (open round) - as they are considered as the ones driven by their parents with individual cars to school. Thus the areas around schools are more polluted, full of cars in the rush hours and even the safety of children is at risk due to often traffic violations in the vicinity of the schools.

However, during the project phases and the feedback we received directly from parents filling the surveys or calling us on the phone, it turned out that students from 5th to 7th grade might also be interested in using the service and we spread the information also to their parents too.

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 numerous surveys among parents in the 5 schools around and conducted several workshops with students and also with their parents to raise their awareness on the air quality and main pollutants and to get feedback on how the service can be improved and to be 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.

Our expectation was of reduction of car traffic and satisfying feedback and assessment of the municipal service as a reliable alternative of everyday commuting of students to school. This was confirmed by the answers of 382 parents in the last survey we made between April and mid-June 2024.

Table 26: *Purpose, research questions and hypothesis for Sofia use case 1*

Experimental design for SOFIA - use case 1	
Purpose	Providing an alternative transportation mode to students from the 2 biggest schools + 1 smaller in the city of Sofia. Testing a municipal school bus service, designed to serve students living far away from school. Apart from that, educating the students on main air pollutants and how traffic affects air quality to initiate behavioural change.
Research question(s)	Questions that must be answered: A. Are parents switching transportation habits as a result of the provided service? B. Is there an increased understanding of the air pollution and air quality of the students in the participating schools? C. Is there an opportunity to provide / extend this municipal service to other schools in Sofia? Questions that can be answered: D. Is there a difference between morning and afternoon routes in school bus services?
Hypothesis	A, C: Reduction in car traffic to school of 50 vehicles in morning peak only (based on survey)

Sofia use case 2 – Kindergarten

The main goal in this use case was to continue our measurements indoors and to see the correlations first between indoor and outdoor measurements and second - to compare our results with the Canary system. That seemed to be hard to achieve as we could not obtain any data from the Canary system as it turned out the data was not available for the measuring period due to technical issues of the provider of the Canary system. Thus this use case was eventually mainly focused on awareness raising on air pollutants and air quality of preschoolers.

Still, during the public round testing period we had to make sure the sensors were in working order. We found several times that they stopped sending data and needed to be restarted. The first time the reason was in some repairs in the kindergarten, the second time was in changing the internet passwords. That's why we have some missing data from the public round measurements.

As mentioned above, besides the unavailability of data to make comparative analysis, this use case managed to raise awareness among the kids and their parents on the importance of regularly allowing fresh air in the rooms in order to ventilate as when small children play in the rooms a lot of dust is circulating. This was also checked with the SODAQ Air sensors by asking children to jump and play around and looking at how the LED signals change, regardless of the lack of data on the platform due to the IoT connectivity issues.

Sofia use case 3 – CO2 calculator usage

The Sofia pilot recognised the CO2 calculator as a suitable tool for engaging citizens and supporting them toward their climate neutrality and put a priority on this tool. Gathering data on their everyday environmental habits for analysis and decision making helped to motivate and promote the dialogue between citizens and local authorities when developing city policies on one hand, using the Scenario Simulation Dashboard. On the other hand the CO2 Calculator was an awareness raising tool that services citizens to calculate their carbon footprint, compared to households' results with national and European data and respectively receiving some recommendations on how to decrease it.

The SDA team put an effort to polish the features and translation of the tool and also make several workshops and campaigns promoting CO2 Calculator and Dashboard to both citizens and Sofia Municipality with the aim to gather data on citizens' habits and willingness to adopt changes in order to improve the city's sustainability indicators.

Two workshops were conducted in order to promote the CO2 calculator during the public round, the received feedback was reported to the development team in order to make necessary changes. It turned out the tool is interesting for both citizens and policy makers, and more efforts should be put in order to popularise it enough so data could be made available for policy makers to evaluate policies.

Table 27: *Purpose, research questions and hypothesis for Sofia use case 3*

Experimental design for SOFIA - use case 3	
Purpose	Promote the usage of CO2 calculator to raise awareness on individual carbon footprint and also on the ways citizens can take to decrease it.
Research question(s)	Questions that must be answered through experiment: A. What is the willingness of citizens to calculate their carbon footprint? Questions that can be answered through experiment: B. How can policy makers use the tool to assess acceptance level for certain policy measures?
Hypothesis	The CO2 calculator is an effective tool to promote behaviour change and collect data on citizen level in order to assess certain policies.

Sofia use case 4 – Awareness raising campaign

The SDA team is working on the realisation of an awareness raising campaign focusing on positive examples of people living sustainably in general to raise awareness and call to action to change behaviour. The campaign will present in attractive visualisations some of the digital

tools of COMPAIR like CO2 Calculator and other policy measures of Sofia Municipality aiming at promoting sustainable living habits.

The campaign will be a kind of continuation of a SDA campaign performed in 2017 and supported by Sofia Municipality. The main message was "It's cool that you care”. Now we plan to develop further the messages and the visualisations in order to cover different aspects of air quality and sustainable behaviours. Some of the visuals will promote the COMPAIR -provided tools, others will promote pilot projects of 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.

Table 28: *Experimental design for SOFIA - use case 4*

Experimental design for SOFIA - use case 4	
Purpose	Promote sustainable living habits among the general public in Sofia by also raising awareness on COMPAIR digital tools
Research question(s)	Questions that must be answered through experiment: A. How messages of the campaign are perceived - negative vs positive messaging. Questions that can be answered through experiment: B. Is there any willingness from the general public to change behavioural patterns in order to improve air quality?
Hypothesis	People will be more willing to change behaviour if they perceive this as something cool and modern.

Plovdiv use cases

The Plovdiv pilot, in the frame of COMPAIR project, tries to show the connection between traffic intensity and levels of PM and NO2 around the schools and the seasonal variation of PM10.

Due to the connectivity issues, all sensor devices that were based on LTE-M / NB-IoT network technology could not be used in Plovdiv. In order to test the connectivity of the mobile PM sensors of SODAQ (SODAQ AIR), the EAP team performed several tests in different areas of the city. The devices worked, but due to a lack of LTE-M / NB-IoT network they could not transmit data to the dashboards. In an attempt to check the availability of connectivity of the IoT network in Plovdiv, partners from SODAQ provided an additional tracking device to the EAP team in order to check if some connectivity would show up on the map. Unfortunately, a connection could not be established in any part of the city.

Given the same data transmission technique was employed by Telraam in their Version 2 (V2) devices, these Telraam V2 traffic count sensors were also affected by the same problem. Again, the EAP team made many attempts to deploy these sensors in various places to verify their connectivity across a variety of time periods, but a connection could not be established. Despite an agreement signed with Thingstream, the network provider and the largest telecom operator in Bulgaria, A1, back in May 2023, until now there has been no progress made in terms of connectivity.

Due to the connectivity issues, the number of sensor devices used in the Public Round was very limited - 14 Telraam version 1 (V1) sensor (traffic sensor), and 10 DIY PM10 sensors from sensor.community.

Plovdiv use case 1

The goal of use case 1 was to raise awareness of the impact of traffic on air pollution among students and their parents around the primary school Dimitar Talev. After successful implementation of the activities during Open round another school asked for participation and during the Publick round all the activities were implemented in primary school Knqz Alexander I . In order to make difference between both schools the implemented activities in primary school Knqz Alexander I will be described as Use case 3

Table 29: *Experimental design for PLOVDIV - use case 3*

Experimental design for Plovdiv - use case 3	
• **Purpose**	Raising awareness of the impact of traffic on air pollution
• **Research question(s)**	Questions that must be answered: A. Are changes in traffic related to PM concentrations? B. Are changes in traffic related to NO_2 concentrations? C. Is there a difference between morning and afternoon peaks in traffic at the schools? D. What is the effect of school-related traffic?
• **Hypothesis**	Correlation between traffic intensity and NO_2 concentrations No correlation between traffic intensity and PM concentrations

Plovdiv use case 2
The goal of use case 2 was to raise awareness of the impact of traffic on air pollution and seasonal variation of PM10 around the primary school Vasil Levski.

Table 30: *Experimental design for PLOVDIV - use case 2*

Experimental design for Plovdiv - use case 2	
Purpose	Raising awareness of the impact of traffic on air pollution and seasonal variation of PM10
Research question(s)	Questions that must be answered: A. Are changes in traffic related to PM concentrations? B. Are changes in traffic related to NO2 concentrations? C. How much do winter and summer PM concentrations, daily patterns etc. differ?
- **Hypothesis**	Correlation between traffic intensity and NO2 concentrations No correlation between traffic intensity and PM concentrations Distinctly different pollution levels in summer and winter, both can have high pollution episodes. Typical daily profile shows more evening PM in winter (heating)

3.4.1.2. Experimental design

Sofia use case 1 – School bus service
As part of the COMPAIR pilot activities and planning in the public round a third testing period of the school bus initiative was released for the whole school year 2023-2024. This decision was taken by the Sofia City Council on 27 July 2023 and the school buses started operating on 18 September 2023 until 14 June 2024. The service was planned and released in collaboration with the Transport Department of Sofia Municipality and Urban Mobility Center and involved two of the biggest schools not only in Sofia, but in Bulgaria also and some other smaller schools nearby. The school bus route remained the same as there were during the previous testing round but this time they were operating twice a day - one course in the morning and or at noon for the students who are starting school classes in the afternoon.

Measurements around the school area:
We defined one area of interest around school to test the air quality and the effectiveness of the school bus municipal service via 4 DIY *sensor.community* sensors. Two of them were installed in the 18th School William Gladstone and 2 of them were in the 32nd School St. Kliment Ohridski as they were the main school participating in the project and in the school bus service testing.

Devices were installed with the aim of monitoring the air quality around the school area and eventually to detect any seasonal differences and any effects from the implementation of the school bus service. Thus two of the sensors were installed with a streetview to measure the area of the school closest to the street and the other two devices were installed in the courtyards of the two schools in order to make comparisons.

Examining the data from the two devices with a street view (No.15000342 and No.14979977) we can definitely observe the seasonal trends as the air pollution picks are exactly in the winter months starting from November and finishing in March, as in December and January is the highest measured data from both device nevertheless we don't have full measurement period from the 32th School due to Wi-Fi connectivity issues.

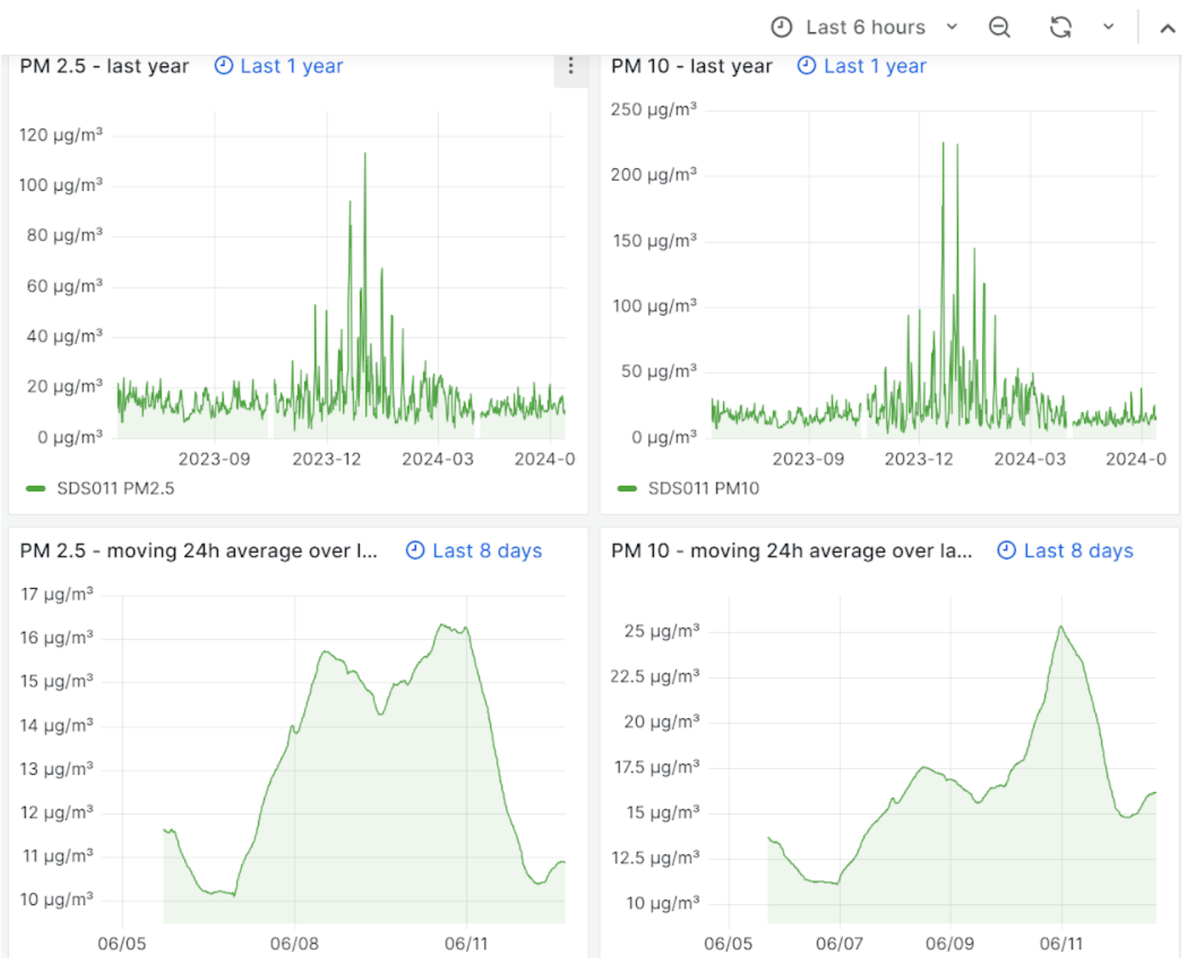


Figure 69: *Data from the Sensor.Community device No. 15000342 installed the 18th School William Gladstone*

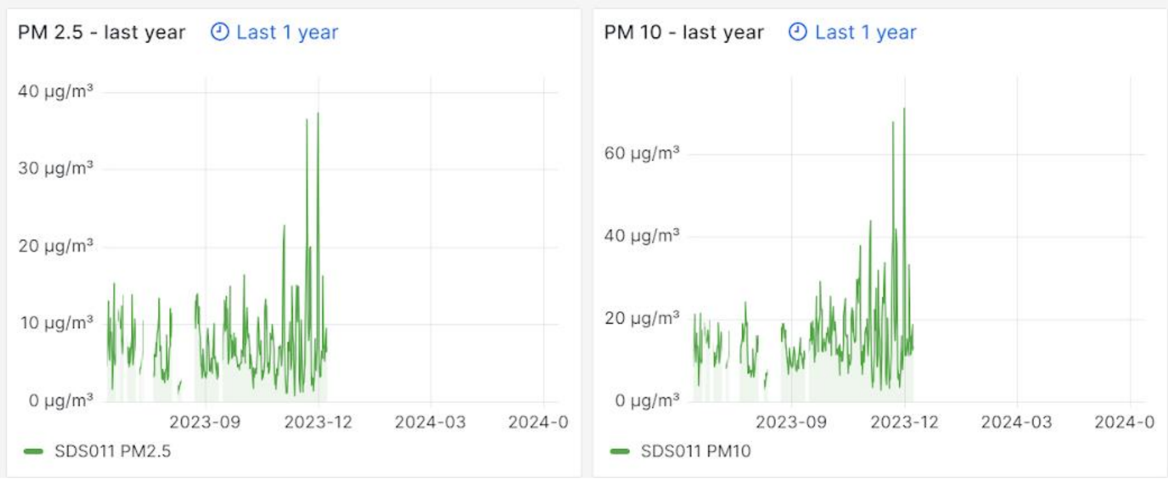


Figure 70: *Data from the Sensor.Community device No. 14979977 installed in the 32nd School St. Kliment Ohridski*

Unfortunately the WiFi connection of the 32nd school was not very stable and we had issues with both devices. In addition the second device also has problems with the power supply. After many attempts to fix the problem, the devices were stopping again a few days later. Thus we have quite fragmentary data and in the end stopped bothering the teachers as from April until the end of the year it's quite a busy period from schools and it was risky to continue insisting on fixing the problem as they get frustrated. During one of these fixes there was a situation of two teachers arguing about the air quality and the conditions children are studying in - it was a suitable situation to raise awareness on the issues with the air around school and in the classroom but also it was a factor for us to stop chasing the teacher-coordinator as we preferred to save our good and long term relationship with the school and took off the sensor device *No. 15021092* for repair. But as we investigated later - the problem was not in the device itself but in the power supply and the connectivity in the whole school area.

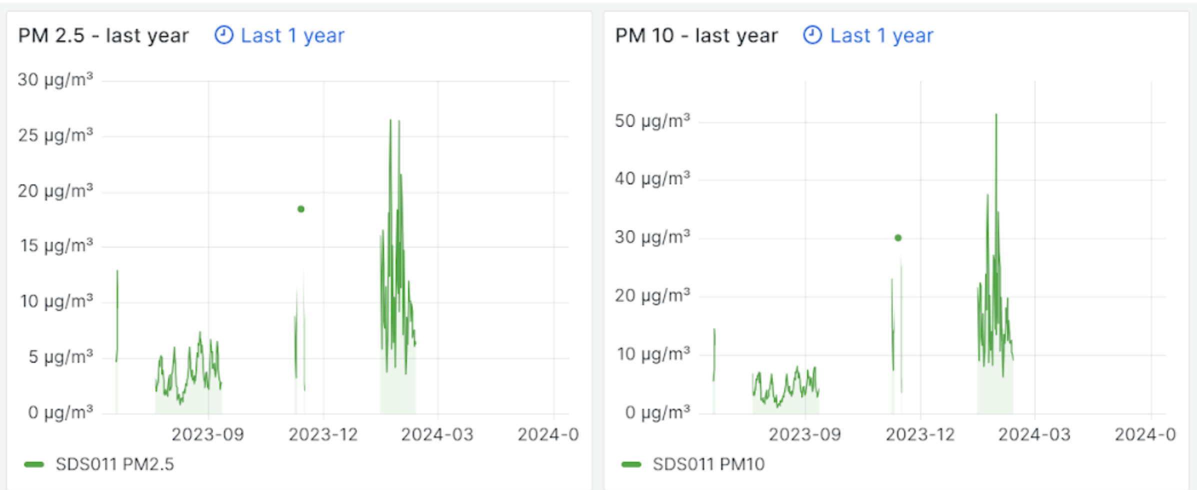


Figure 71: *Data from the Sensor.Community device No. 15021092 installed in the 32nd School St. Kliment Ohridski*

Telraam devices validation:

Our initial plan was to measure also the car traffic around the school but several obstacles occurred - first it was not possible to install Telraam device as there were no suitable windows with power supply nearby that were looking at the street, and second - as it was established during the Open round testing, Telraam devices working with NB-IoT and LTE-M connectivity was not possible to be used in Sofia due to lack of connectivity in most of the city areas.

Nevertheless we tested 5/10 of the newest Telraam devices and only one of them happened to be installed in an area where there was some NB-IoT and LTE-M connectivity and we were able to see how it was working. We talked to the owner of a small grocery store and he gave us his consent to install it and measure. He was also interested in the number of potential clients passing by the show. Unfortunately as the device was installed on the first floor, it was showing quite strange data. As the connection was still not good, it was not able to calibrate it and to set a region of interest (ROI) for the camera manually by the user or network administrator.

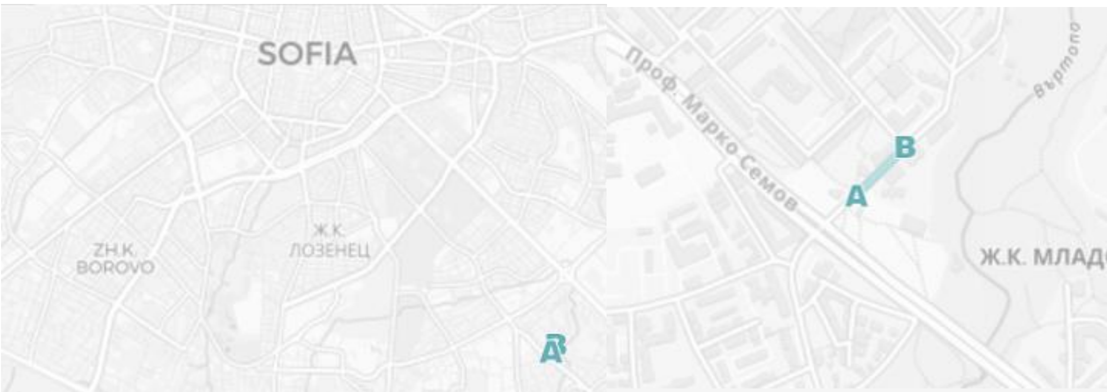


Figure 72 (1&2): *Telraam device No. 3504-5779-0598-336MO - testing area - the street area is defined with A-B line (shown in zoom-in and zoom-out version)*

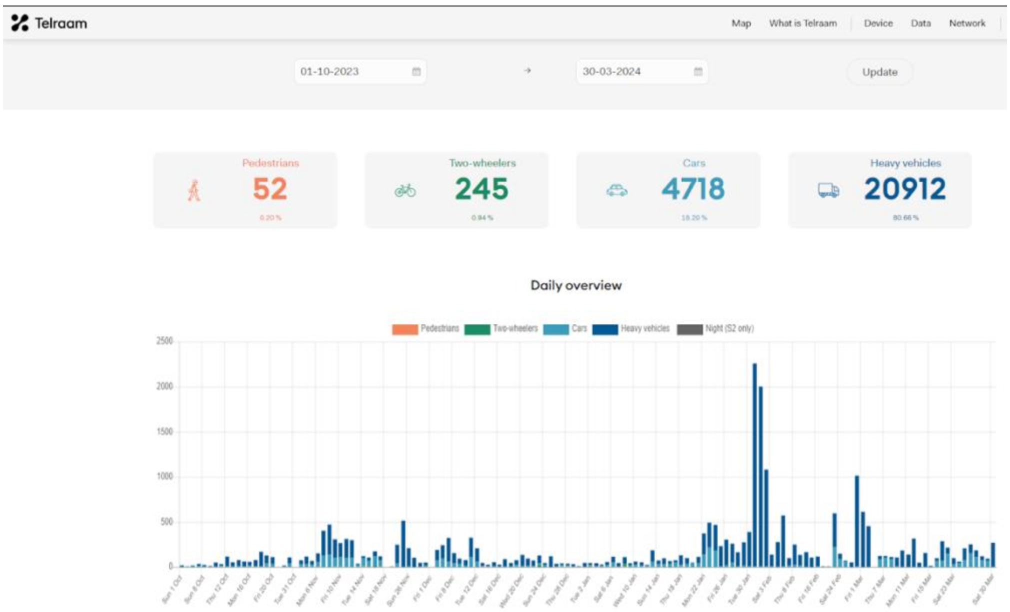


Figure 73: *Telraam device N 3504-5779-0598-336MO testing - data from the dashboard in the period from 1 October until 30 March 2024*

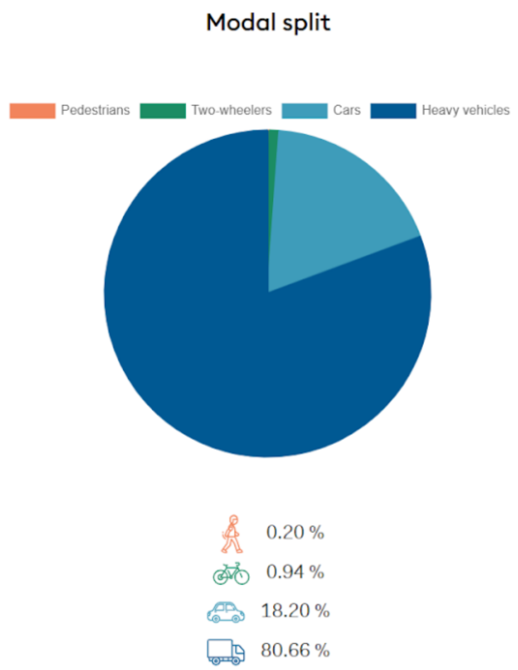


Figure 74: *Telraam device N 3504-5779-0598-336MO testing - data from the dashboard in the period from 1 October until 30 March 2024, modal split*

We can see from the graphs that in the period of the public round over 80% of the traffic is heavy vehicles 18% cars and under 2% are pedestrians and cyclists combined. It was quite strange that the delivered data showed too many heavy vehicles and too little number of pedestrians while the expectations were the opposite as it's a small street in a small residential area where most of the people are pedestrians. As we look at the speed measured - it was between 0 and 10 km/h, we assume that probably most of the pedestrians are counted wrong as heavy vehicles due to the location of the camera - at the shop window, ground first floor that was obviously too close to the street - and due to the NB-IoT and LTE-M that was not very good and it was not possible to calibrate the camera.

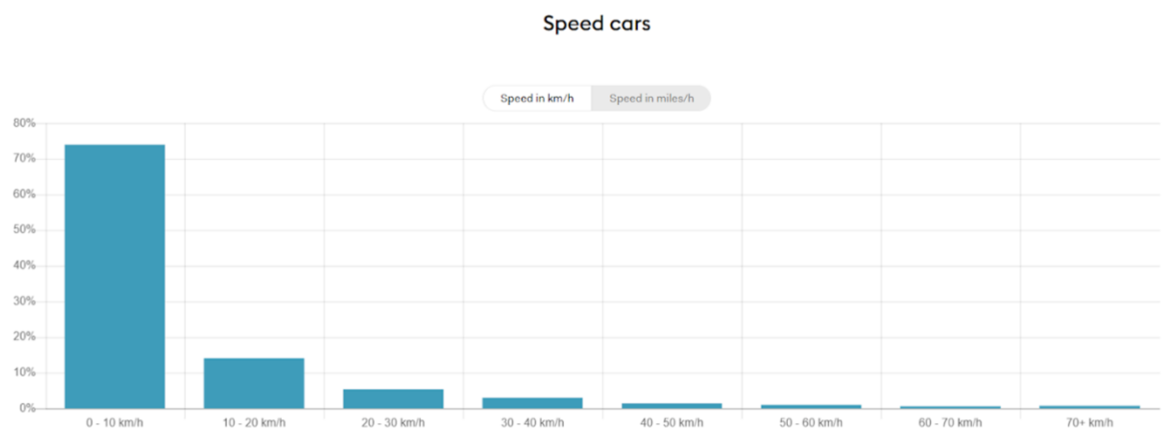


Figure 75: *Telraam device No. 3504-5779-0598-336MO testing - speed cars data from the dashboard in the period from 1 October until 30 March 2024*

The full graphs can be seen at the dashboard here: https://telraam.net/en/location/9000005266

As we continued to experience lack of NB-IoT and LTE-M connectivity as during the Open round, we ordered devices with the previous version of Telraam hardware and software. Using direct communication and the surveys we made, we proposed to parents to be volunteers and to install some devices. Some of them showed an interest but none of them met the conditions for performing the test task - to live in close proximity to the school, to be on first or second floor with windows looking at one of the streets that are with clear view to the street in order to count the pedestrians, cyclists, cars and heavy vehicles passing by. And also as the school bus was already operating when we got the devices - it was too late and also not possible to measure before and after the period of testing.

One of those devices was tested in one of the Urban Mobility Center offices that is working with clients and has WiFi connection. The period of the testing round was from the Car Free Day on 22 September during the EU Mobility Week and continuing until the end of October 2023 in order to raise awareness of the upcoming new measures with the introduction of Low Emission Zone (LEZ).

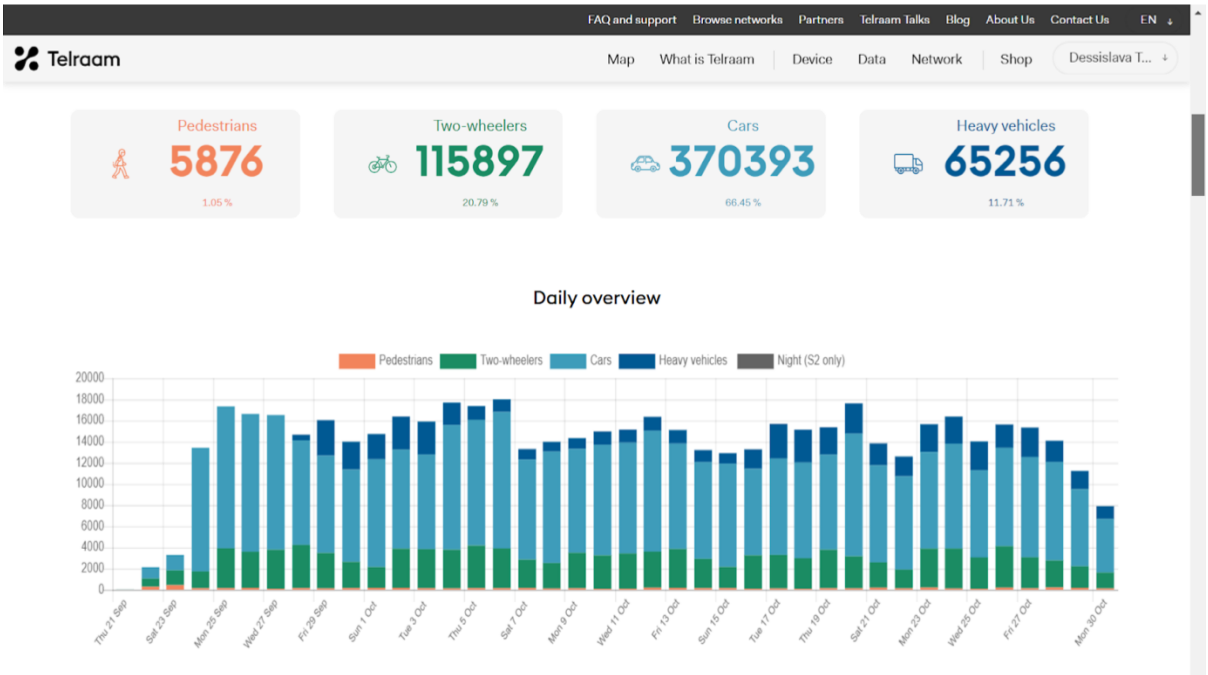


Figure 76: *Telraam device No. 2024-8160-1202-545SN - testing period from 21 September until 30 October 2023, daily overview*

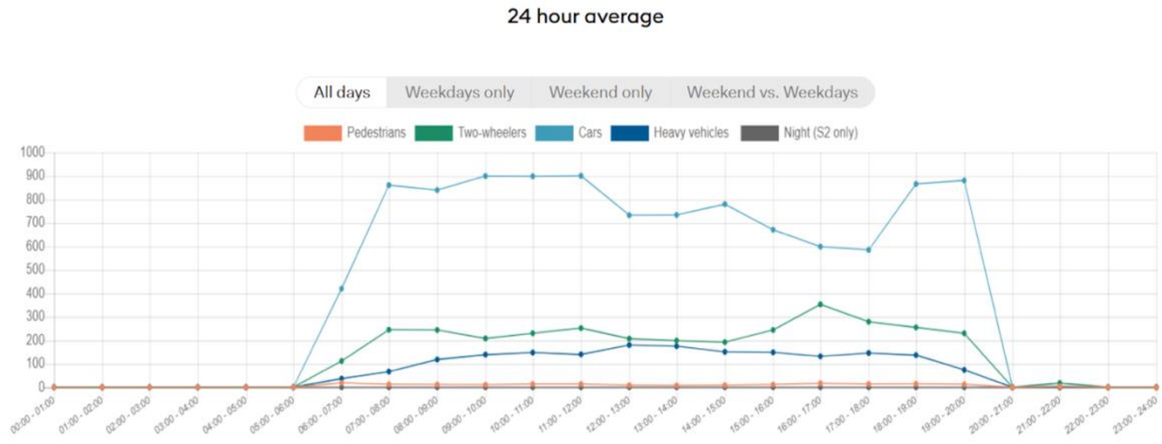


Figure 77: *Telraam device No. 2024-8160-1202-545SN - testing period from 21 September until 30 October 2023, 24 hour average*

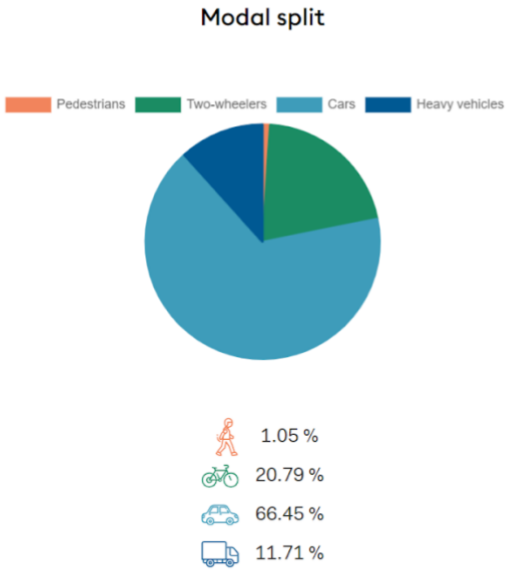


Figure 78: *Telraam device No. 2024-8160-1202-545SN - testing period from 21 September until 30 October 2023, modal split*

Figure 79: *Telraam device No. 2024-8160-1202-545SN - testing period from 21 September until 30 October 2023, location*

This Telraam device was installed at the border of the LEZ zone with the aim to have a picture of the modal split of the traffic in one of the hottest points in the city centre and inside the LEZ itself.
As it's again visible from the graphs, measurements of the heavy vehicles are pretty much inflated at the expense of pedestrians. The measurements again are not very likely and so reliable as there is a bus stop just in front of the office of the Urban Mobility Center and there are a lot of pedestrians that are probably again measured as heavy vehicles due to the very close view of the camera installation. Due to this the Urban Mobility Center officers decided to cancel the measurements.

We continued conversations with the Transport Department and the Urban Mobility Center for starting a new campaign and installing all the devices on different spots inside and outside the LEZ in order to do a cross check of the effectiveness of the measure. As there were mayoral elections and a change in the management of the Department, this conversation is still ongoing and moving slowly.

SODAQ devices testing:

Ten of the SODAQ devices were tested again with the help of the cyclists and public figures during the bike ride dedicated to Car Free Day organised by Sofia Municipality and the Urban Mobility Center (UMC) in collaboration with the Danish Embassy in Sofia. The Danish ambassador, the director of the UMC and representatives of the cyclist society took a bike ride with installed SODAQ devices on their bikes. That was our hope to see at least some of the sensors sending data to the knowyourair.net dashboard.

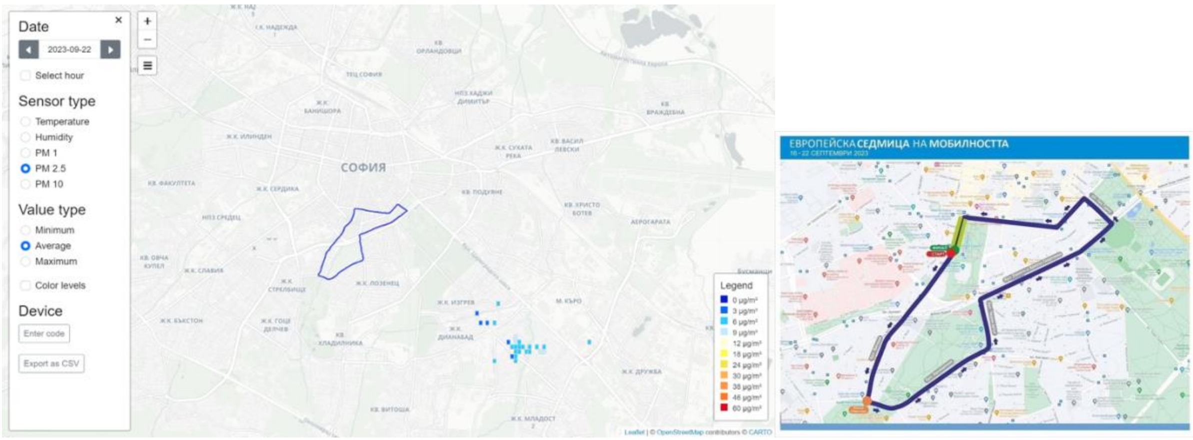


Figure 80 (1&2): *Data from knowyourair.net dashboard on 22 September 2023 and the cycle route drown on the map*

As the bike ride was in the city centre, again the connectivity was lost and we had signal only in one very specific place, where one of the working NB-IoT and LTE-M cells was situated in the city. On the map (Figure 80) the sensors could be seen as blue dots, as the air quality was good on this day, but after they lost connection with the internet network cell, the dots are missing on the other part of the map - especially the area where the bike ride was conducted, none of the sensors is sending data to the server that was one more confirmation that the problem was not in the devices themselves but much more wider concerning the whole NB-IoT and LTE-M network in Sofia city. As we already mentioned, that conclusion was already confirmed with the testing of the latest version of Telraam devices that are also using the NB-IoT and LTE-M network.

Sofia use case 2 – Kindergarten
The measurements in the 76th Kindergarten started again on 27 September 2023 after the mentioned connectivity issues were solved. Although there were other periods of missing data, they were not so long as to compromise the data and we are able to see the trends and to make some analysis.

Looking at the figures from the dashboard of sensor.community (No.14918802 and No.15047529 - figures 81 and 82), we can again conclude that there is a clearly distinguished seasonal trend - the same that we examined in the data from school sensors. Nevertheless we measure the indoor pollution in the kindergarten, we have the same picks in December and January and also some smaller picks in November, February and March. One of the sensors is measuring a higher quantity of air pollution than the other but the trend from both of them is pretty similar.

Also we can see the weekly distribution of air quality as the sensors are indoors and during the weekends the pollution is pretty low - close to 0 micrograms per cubic metre. While examining the school sensor data, where the sensors are outdoors, it's more difficult to define such a trend. There is again a decrease in the values during some days in the weekends but not so clearly expressed.

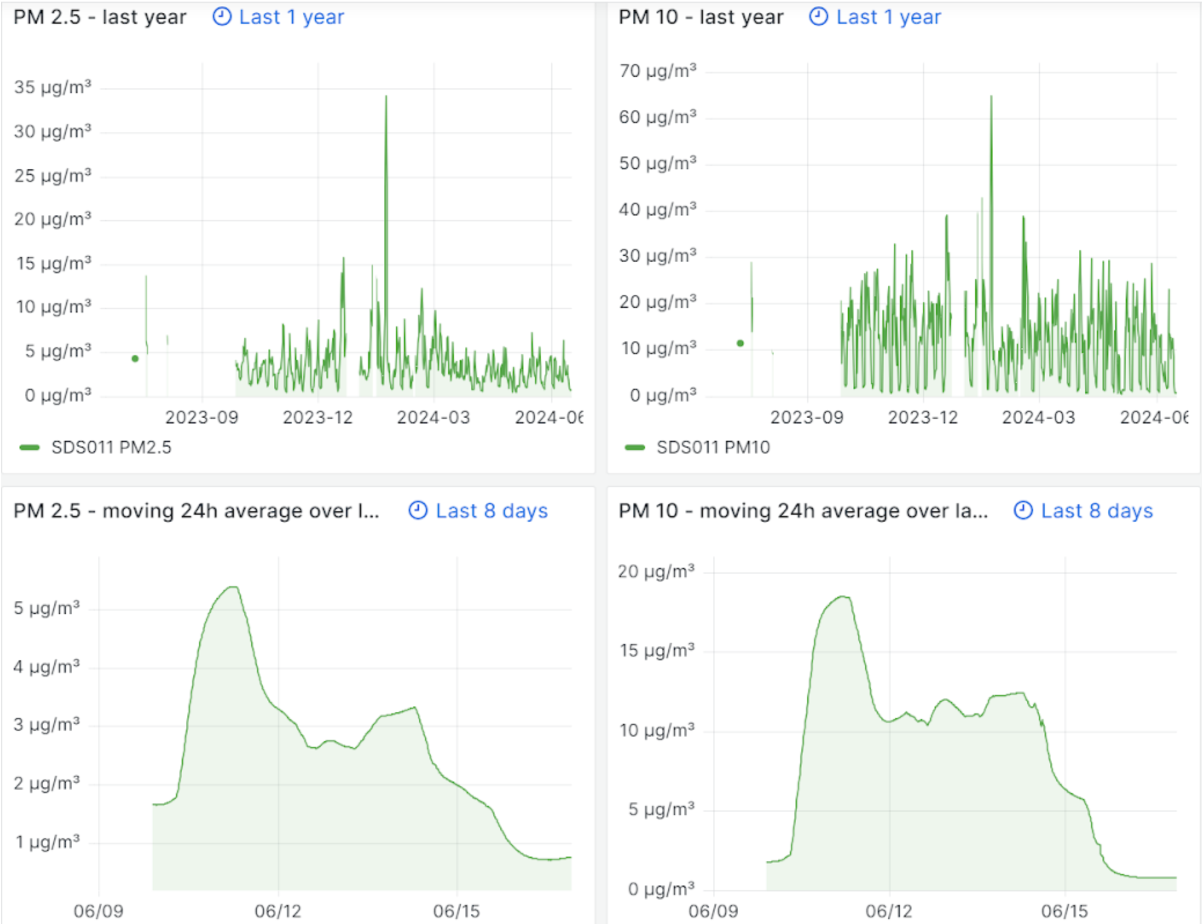


Figure 81: *Data from the Sensor.Community device No. 14918802 installed in the 76th Kindergarten*

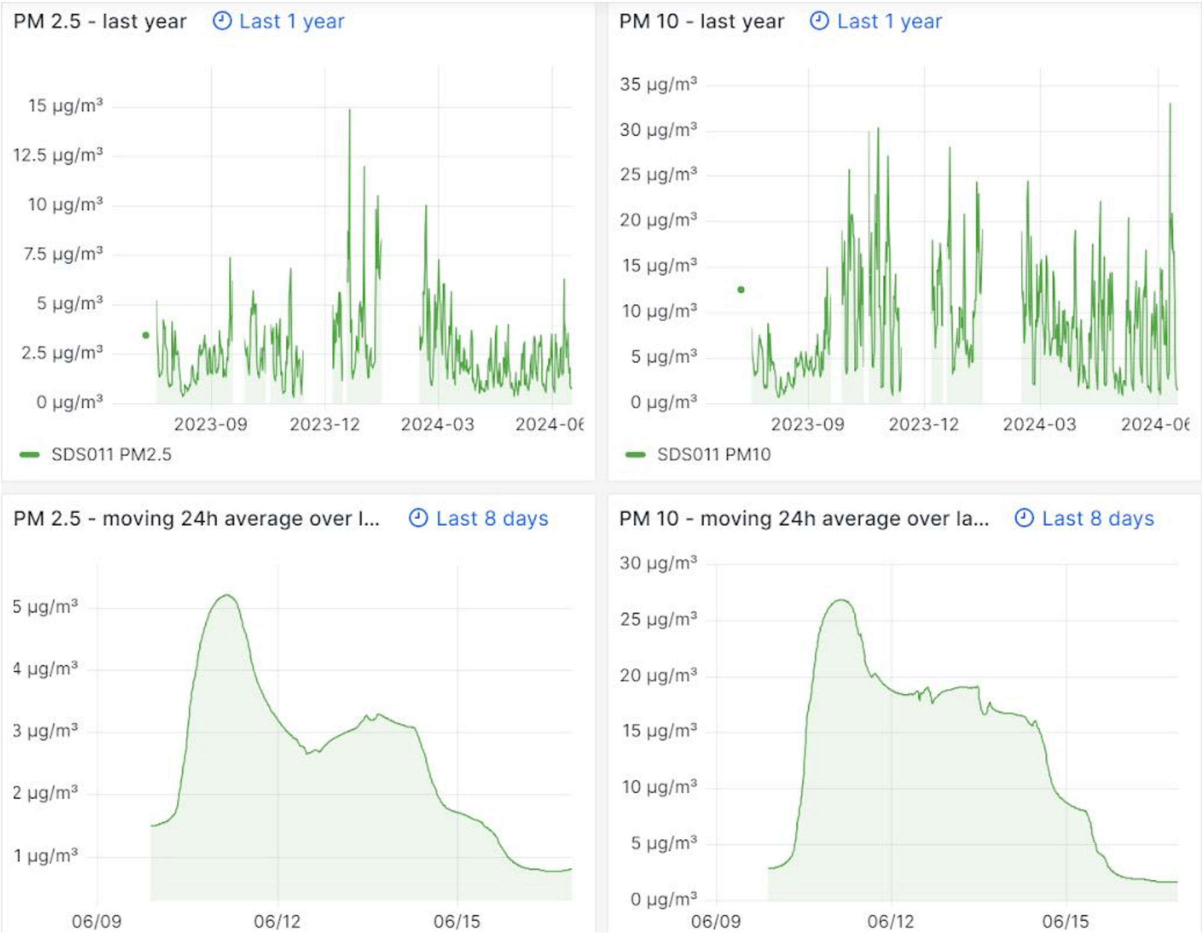


Figure 82: *Data from the Sensor.Community device No. 15047529 installed in the 76th Kindergarten*

On the daily and weekly graphics we can also see the correlation between weekends and measurements during the week. Opening the kindergarten on Monday morning at 8 o'clock gives a very high pick of PM10 and PM2,5 while during the weekend the measurements were close to 0 or 1 micrograms per cubic metre.

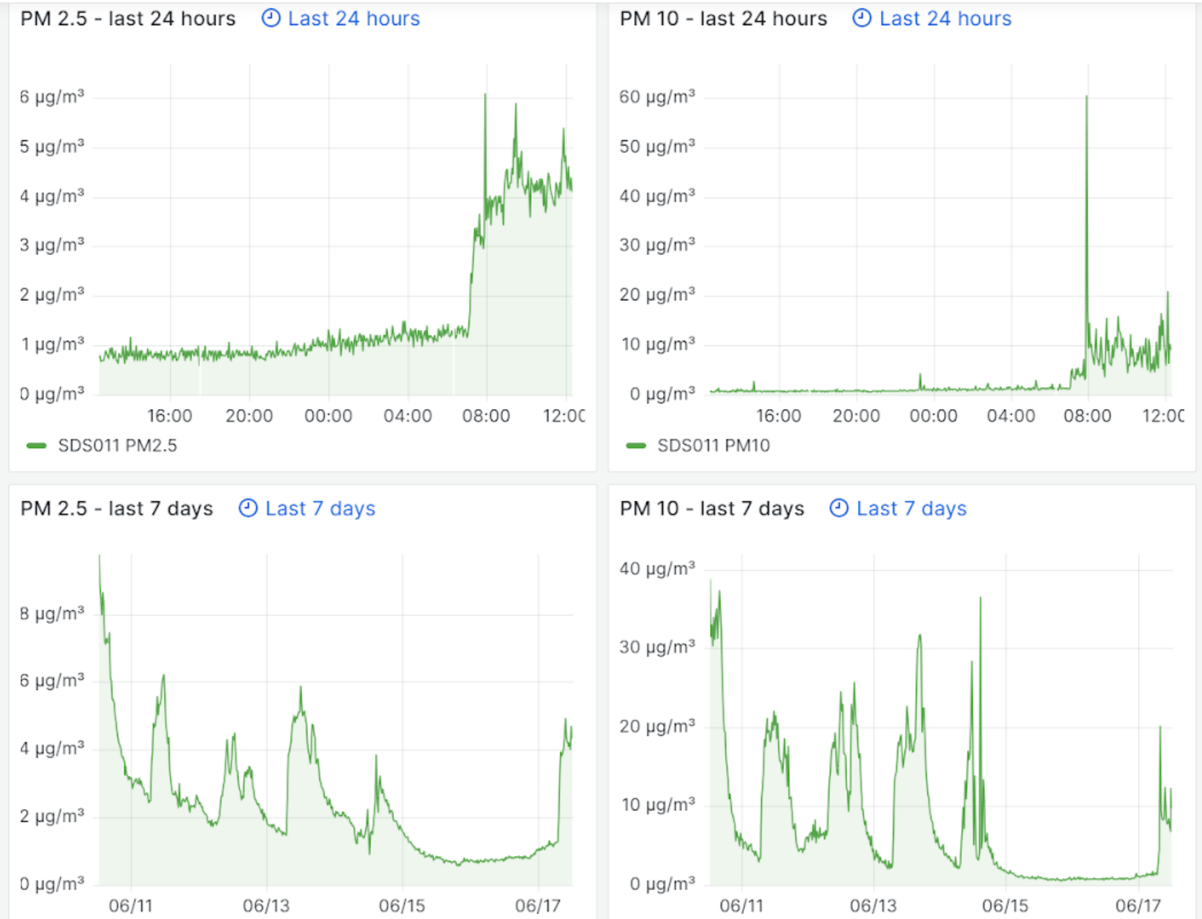


Figure 83: *Data from the Sensor.Community device No. 14918802 installed in the 76th Kindergarten - last 24 hours measurements and last 7 days data.*

We have an absolutely identical scenario with the data from the second sensors from *sensor.community* that can only confirm the trend and need to be addressed as an issue regarding the air quality at the rooms in the kindergarten.

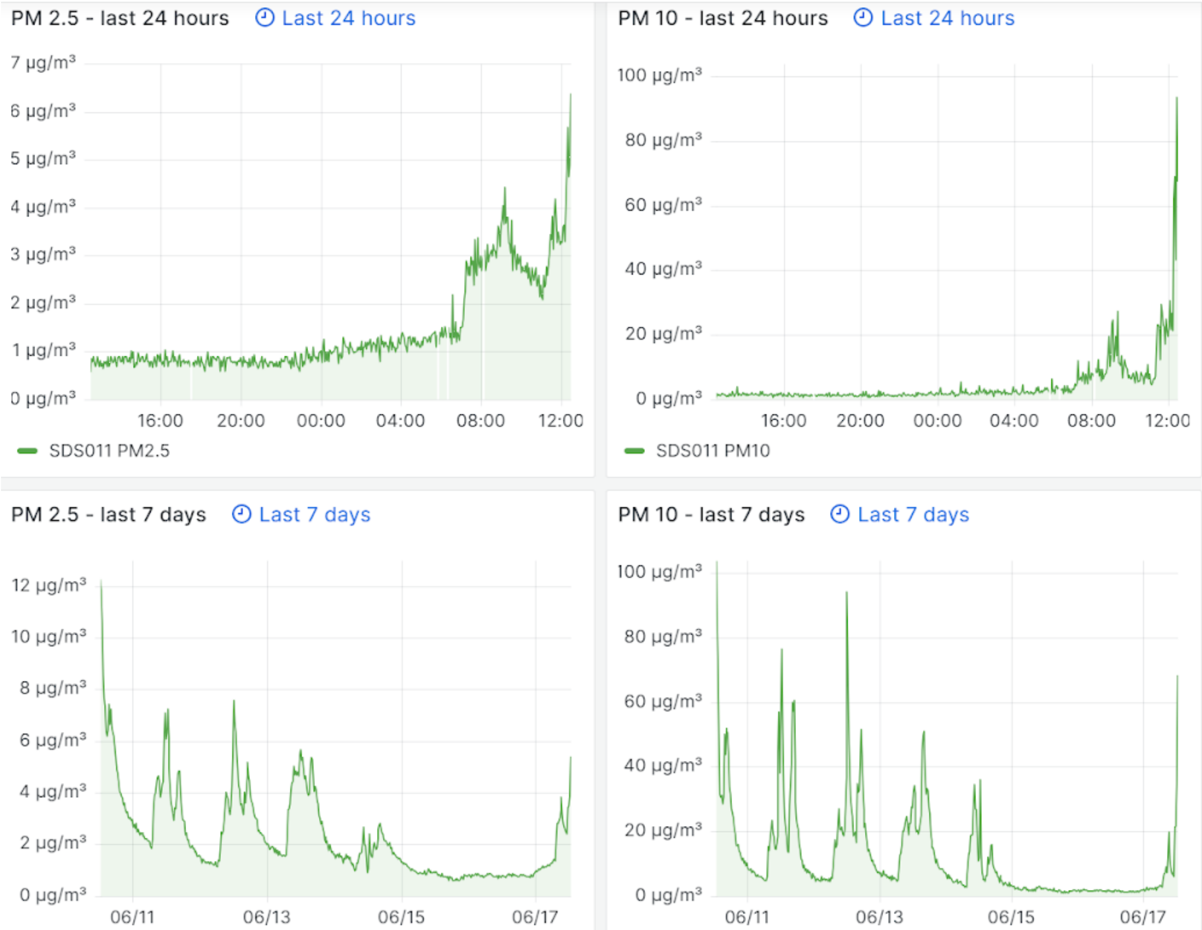
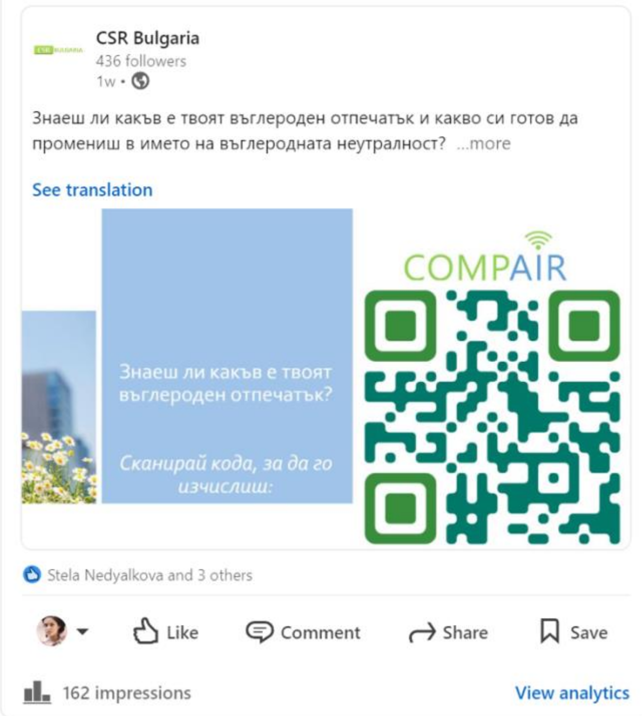


Figure 84: *Data from the Sensor.Community device No. 15047529 installed in the 76th Kindergarten - last 24 hours measurements and last 7 days data:*

Sofia use case 3 – CO2 calculator usage

One of our tasks was first to test the tool and provide feedback to the development team. Thus along with our testing, we involved some people familiar with the tool itself as testers before spreading it to a wider public. After this first round of testing, several attempts to promote the CO2 calculator among the general public were made. The SDA team used its social media channels and also direct emails to attract people to test the tool and provide their feedback. A short survey was also created where users were able to report on their experiences, however it turned out people would rather prefer to report on their experience with the tool via phone calls or emails and were not eager to fill out the short survey that was prepared and distributed.



Moreover, information about the CO_2 calculator was spread among partners' social media channels in order to reach out to people that are not following SDA's media channels. The tool was also spread among young CSR and ESG specialists that are interested in this topic.

Sofia use case 4 – Awareness raising campaign
After the mayoral elections in October 2203 it took time to reach out the newly elected mayor and deputy mayors in order to present to them the COMPAIR project and the planned activities which resulted in some delays in the preparation stage of the campaign. The city council started working several months after the elections due to a political crisis in the country and fragmentation of the elected parties. SDA had its Managing board appointed also with a delay and the Chairman of the management board was chosen on 13 May, even with a bigger delay. That was also a factor for postponing the process and the activities concerning the launch of the information campaign.

Meanwhile the SDA team was working on the planning and the preparation of the campaign such as initial ideas for suitable messages and visualisations that could be later tested and validated with different stakeholders and decision makers. Later on some of them were considered as not so relevant and only half of the prepared ideas passed to a next round of iterations.

Plovdiv use case 2
Due to the connectivity issues and limited number of devices that can be used, the Plovdiv team decided to work with volunteers in this area. We try to work with volunteers from LSES - retired persons or if they received some kind of social aid.

In order to ensure more participants during the Open round we are searching for volunteers from all over the city, not just in this particular area.

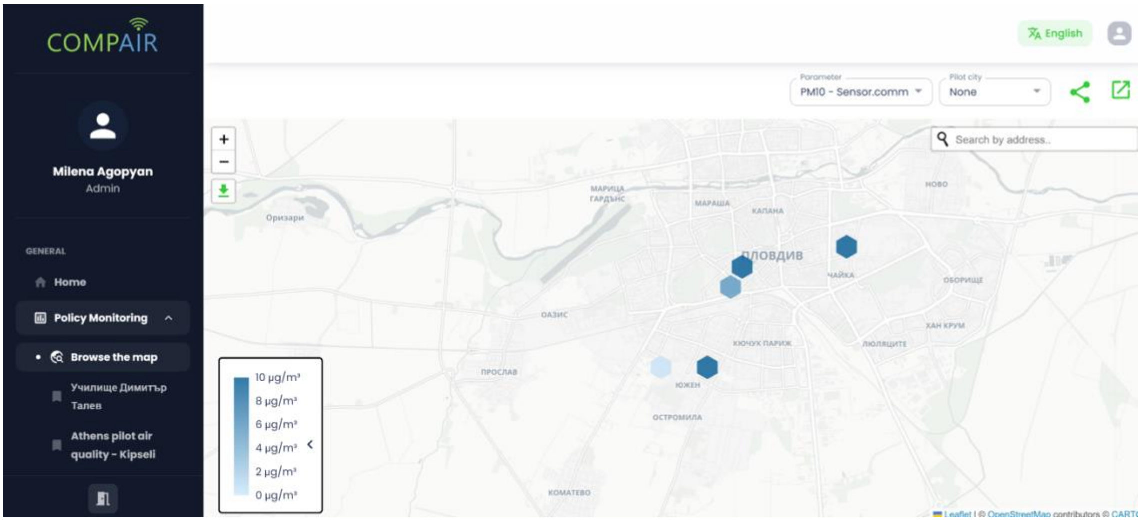


Figure 85: *Distribution of the Sensor.Community devices in Plovdiv*

The measured PM10 values by Sensor.community devices are lower than data from official AQ station. But the trend is the same - higher concentration during winter and heating season:

Figure 86: *Data from the Sensor.community devices in Plovdiv, visualised on the CompAir dashboard*

One of the volunteers lives near to the official AQ station and the values, measured by *Sensor.community device is lower than the official, but with the same trend line:*

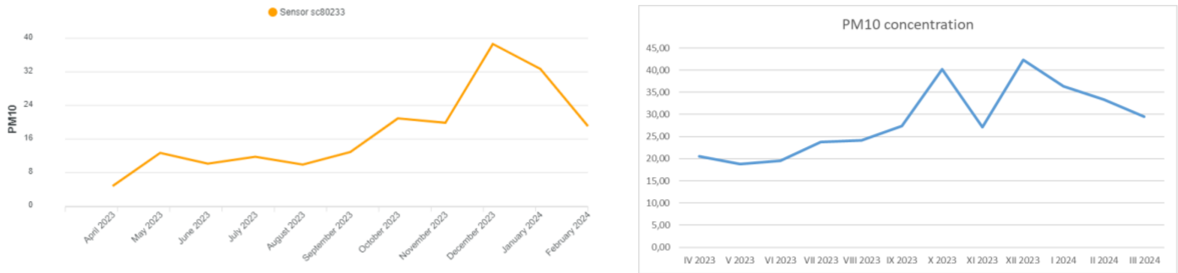


Figure 87: *Data from the Sensor.community devices in Plovdiv (on the left) and data from official AQ station (on the right)*

One of the volunteers reported that sensor, installed in his/ her home is measured very low values:

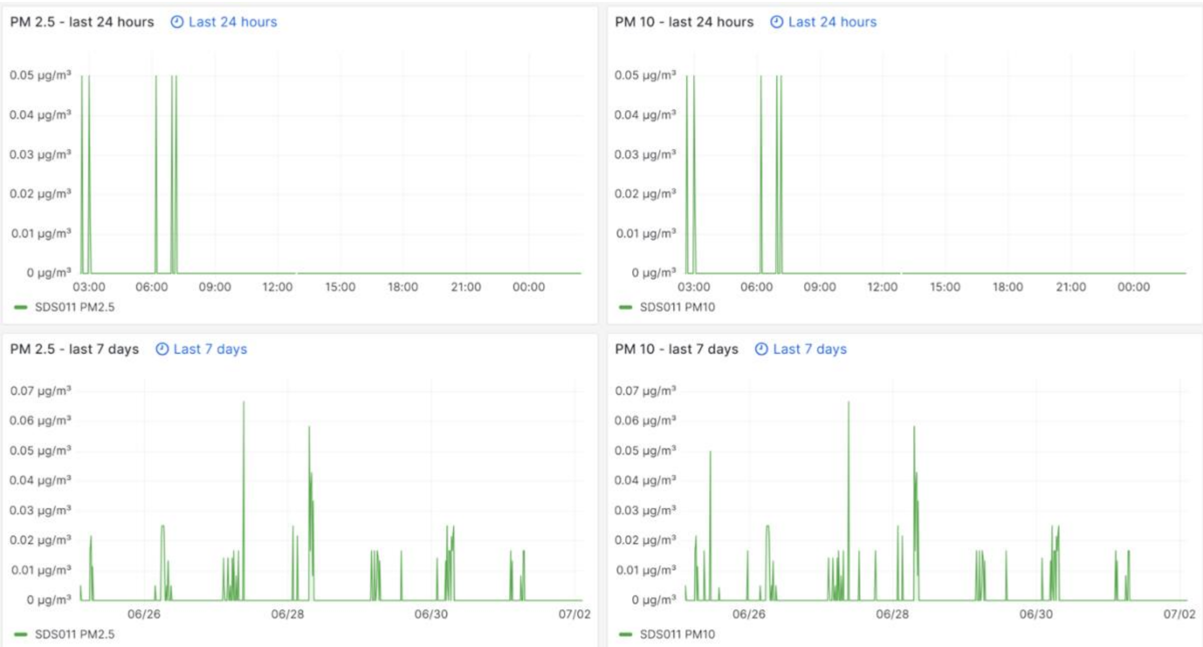


Figure 88: *Data from the Sensor.Community device No. esp8266-10768972 installed in the volunteer home - last 24 hours measurements and last 7 days data:*

Also 10 traffic sensors were distributed to the citizens. For the proper work of the sensors there are requirements for installation and it was hard to find a volunteer in the right place.

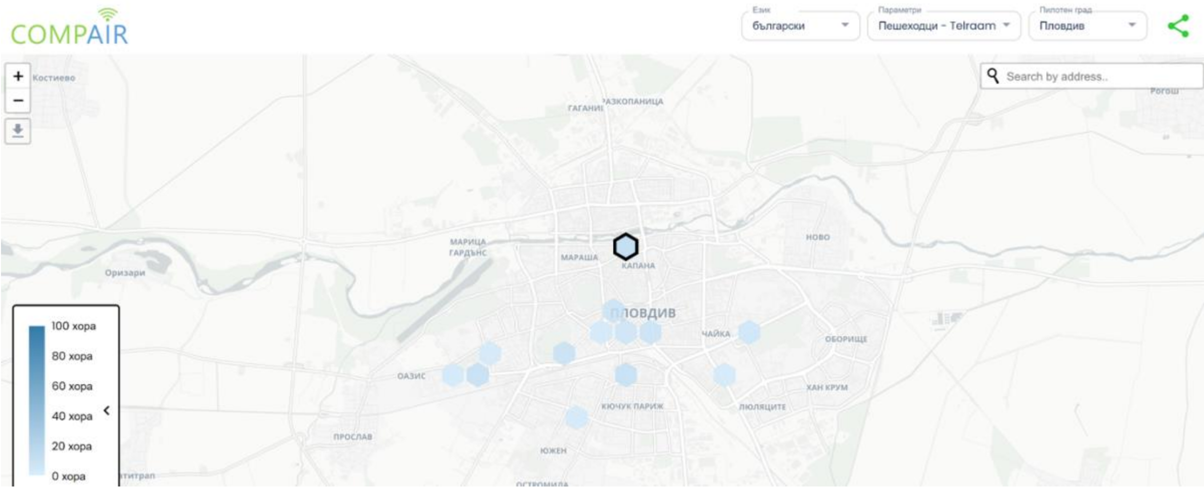
Plovdiv use case 3

More than 1000 students study in the Primary school Knqz Alexander I. The mobile laboratory for measurement of the air quality was situated in the schoolyard (shown in Figure ..).

The mobile laboratory was equipped with:

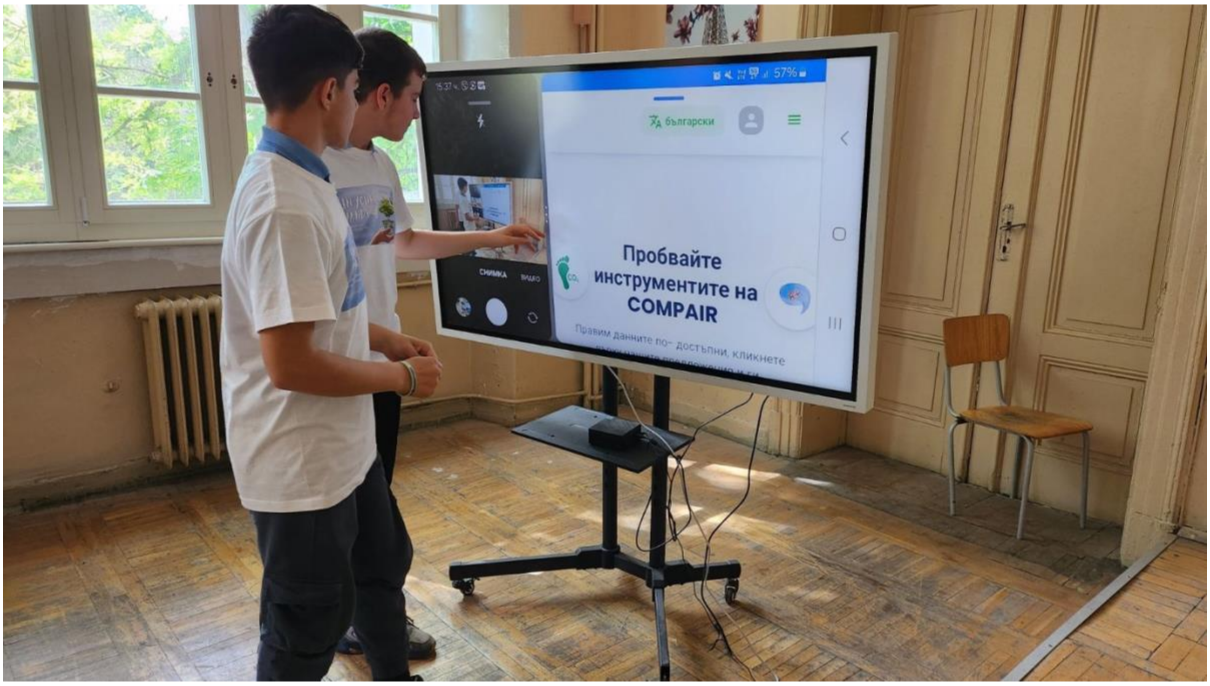
- PM10 dust sampler - PM10 monitor version of OPSIS' SM200
- PM2.5 dust sampler – PM2.5 monitor version of OPSIS' SM200
- Chemiluminescence NO/NO2/NOX Analyzer – Teledyne T200
- Meteorological parameters - wind speed, wind direction, temperature, humidity, atmospheric pressure

The Telraam v1 traffic sensor was installed near to the school by a volunteer.



500 flyers were distributed among students and teachers informed students about the date and time for workshops.

In order 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 director of the school. 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 CompAir CO2 calculator to other students, regular checking of the data on the PMD, to undertake some analysis, etc..



Info and printed materials were distributed to the students - flyers, notebooks,t-shirts, sticky notes and calendars.

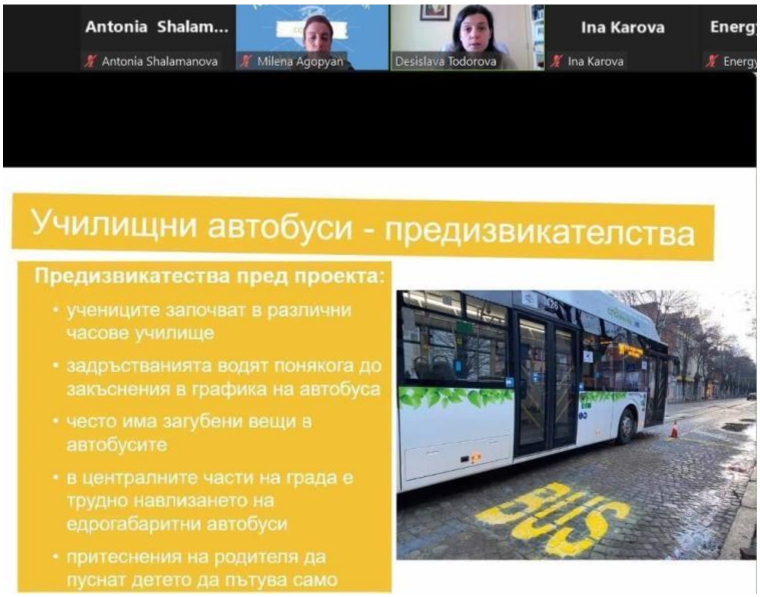
Plovdiv use case 2
Due to the connectivity issues and limited number of devices that can be used the Plovdiv team decided to work with volunteers in this area.

Info and printed materials were distributed to the students - notebooks,t-shirts, sticky notes and calendars.

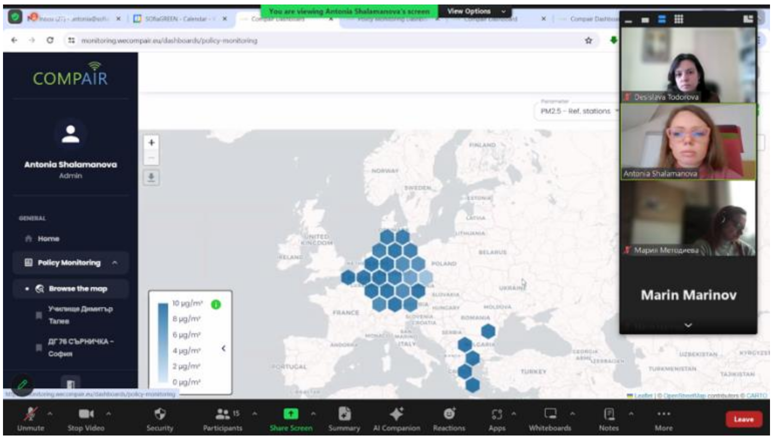
The Plovdiv team prepared an on-line template of Proposal with a list of possible measures for reduction of traffic and improvement of AQ around schools for the municipality of Plovdiv. During the WS, through EAP webpage, facebook page and direct communication the template was presented to citizens with a request to fill in their suggestions. The collected proposals were presented to the municipality.

3.4.1.3. Workshops

Sofia use case 1 – School bus service



We continued collaboration not only with schools but also with different partners outside and inside the project. On 24 January 2024 the school bus service was presented to stakeholders invited by our COMPAIR consortium partner Energy Agency of Plovdiv (EAP). The webinar was dedicated to the impact of transport to air quality. Our team emphasised on the rising issue of increasing air pollution around schools due to too much car traffic and proposed to the discussion the possibility of municipalities to provide an alternative to the parents driving their kids to school. We exposed our methodology of managing and popularising the project with school buses as a good practice and also shared the obstacles and feedback from the parents using the services.



On 2 February 2024 we conducted a COMPAIR stakeholder online workshop with the aim of presenting the tools to representatives of Sofia Municipality and other stakeholders interested in using the tools provided by the COMPAIR project. The webinar was attended by several representatives from the Air Quality Department in Sofia Municipality, the Urban Mobility Center and Trust for Social Achievement (TSA) - a Roma community organisation we are working with and other NGOs working on air quality projects. The discussion was fruitful and one of the outcomes of this meeting was that TSA shared their lack of background data and resources that could be very helpful to them to proceed with their activities in the Roma community and neighbourhoods. In response to the request they stated during the webinar, our team conducted several conversations with them and also provided to them an Air quality educational materials and training materials based on D5.1 Guide to Air Quality Training which were translated and adapted by the SDA team to serve their needs.

The provided manual and materials were used in their work, focused on poor and usually marginalised Roma communities and an information campaign raising awareness on the air quality issues. It turned out quite difficult to work directly with the Roma community as they usually do not trust new people out of fear of being blamed for their habits of burning waste, thus the SDA team worked closely with the TSA Foundation to provide support in their educational activities related to air quality and air pollutants. This turned out to be a very fruitful collaboration and now the TSA team will be purchasing and installing DIY PM sensors that will be installed in the Roma neighbourhood, again with the aim of raising awareness and motivating them to change heating habits.

The next round of workshops was in the form of ideathons in spring 2024 when the SDA team provided several discussion meetings with stakeholders dedicated to the different case studies. On 27 May we conducted a data cafe workshop with representatives of the City Council, the Transport Division, the Marketing Department of the Urban Mobility Center, parents and other stakeholders interested to take part in the further development of the School Bus service.

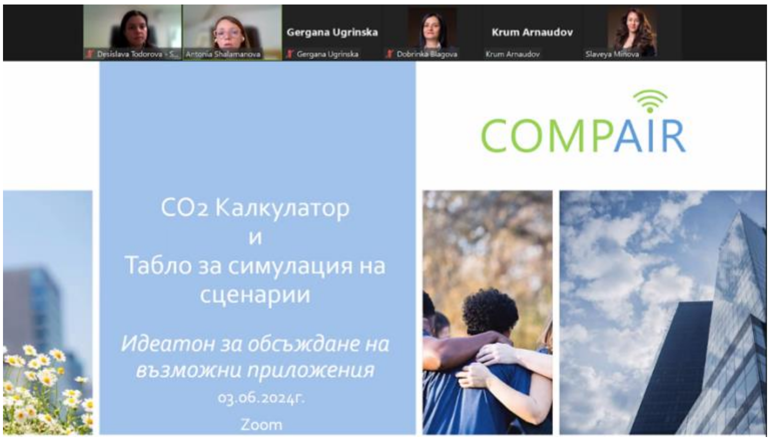
During the discussion we presented the data gathered from the surveys spread among parents and with the help of active citizens and municipal officials, we managed to collect ideas and to draw a vision of the needs and opportunities to make this service stable and a long term measure of Sofia municipality concerning air quality policy. The data from surveys served as a citizen science experiment.

Sofia use case 2 – Kindergarten

Kids in kindergarten was another target group we wanted to involve not only students as they are also a vulnerable group and also often are being driven to the kindergarten every day by their parents.

On 15th December 2023 kids from the 18th Kindergarten in the city centre of Sofia took part in the discussion on the importance of keeping the air clean and the risks we are disposed of when the air is polluted. They got familiar with the COMPAIR-provided sensors we have and how they work. Kids were pretty much engaged with the topic although they were in pre-school age. They realised the importance of taking action and as it was something extraordinary for them to talk on such topics in their daily life, we're sure they told their parents about the interesting talk. That was our goal - to raise awareness also in the families as parents are the one who are taking the decisions but kids are the one that suffer most from the negative effects and are a vulnerable group.

Sofia use case 3 – CO2 calculator usage



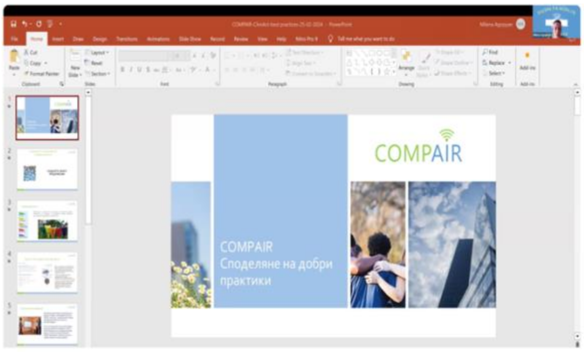
On 3rd June an ideathon dedicated to the CO2 calculator was organised online in order to show live the features of the Carbon Footprint Simulation Dashboard and its admin panel. Representatives of the Digital Department of Sofia Municipality and the Urban Mobility Centre were part of the discussion and they shared useful feedback on how the tool could be further developed. According to them it would be nice to be integrated with some other digital tools of Sofia Municipality on waste management like waste.sofia.bg - an information platform and guide that targets citizens and shows in a user-friendly way how to recycle their waste in an appropriate manner. Now the SDA team is working on including information about the CO2 calculator and to direct citizens towards the tool when they want to calculate their CO2 footprint.

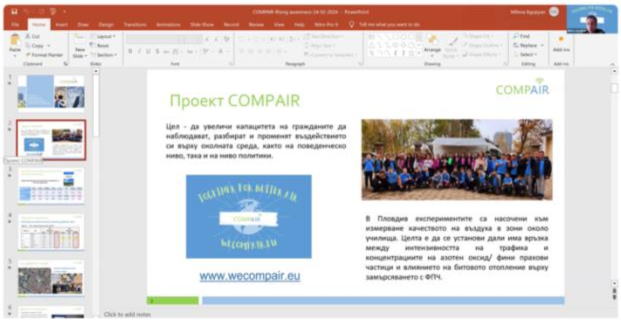
Sofia use case 4 – Awareness raising campaign

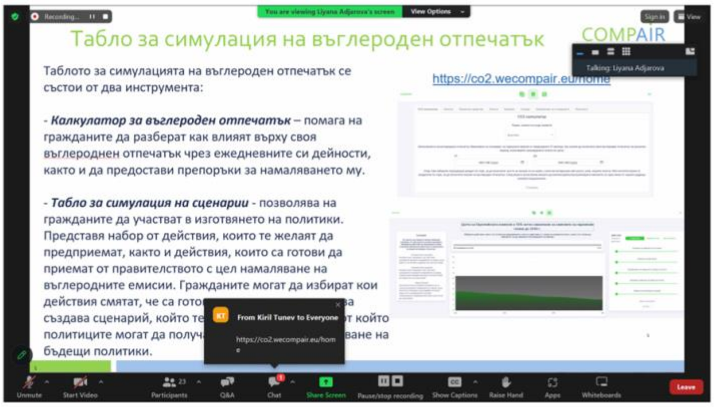
As soon as the SDA team was able to get to know the responsible team of the Deputy Mayor of Environment and the Deputy Mayor herself, the plans for the future campaign were presented and the ideas for the information campaign were received very well. A series of conversations and meetings follow in order to polish the initial idea into visualisations that can be discussed as a next step with a wider range of experts and stakeholders and at a later stage - with a wider audience before they will be published and spread throughout different communication channels. Meetings with stakeholders were some kind of small scale ideathon where messages were agreed upon and coordinated efforts were taken in order to align Municipal plans (e.g. LEZ for domestic heating introduction, Pay as you Throw future introduction, etc.) with the campaign messages / visuals.

Plovdiv use case 2

A series of workshops was organised for the stakeholders and citizens. The WS were dedicated to the introduction of results and digital tools as a part of EAP rising awareness campaign.







Plovdiv use case 3

A series of workshops was organised for the students. The EAP team started by presenting the topic of air quality, the main pollutants and ways to measure them.

The first WS 1st ws introduced why and how we measure the AQ topic with a visit of mobile AQ laboratory.

Photo: Mobile AQ laboratory in the school yard and visit for students

The second WS was dedicated to the introduction of the AQ topic and DIY sensors assembling - students assembled a DIY (sensor. community) devices.

On April 22, 2024 the Earth Day, Primary School Knqz AlexanderI and the Energy Agency - Plovdiv organised an IDEATHON for students in Plovdiv. Students submitted their projects in five categories:

1. Video contest

2. Computer presentation

3. Eco - exhibition – 3D model or drawing

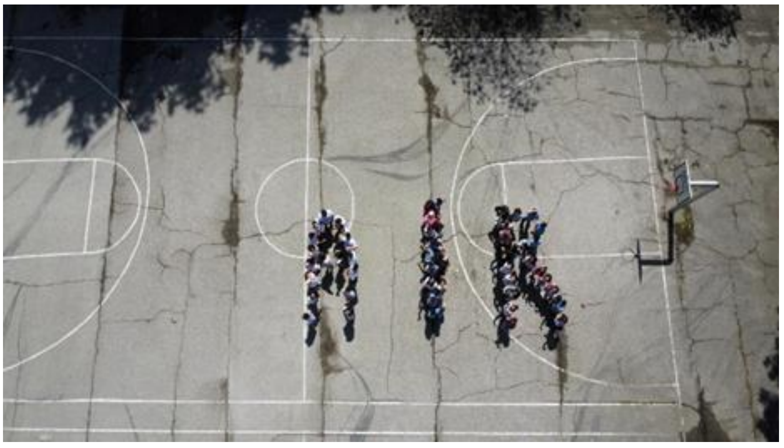
4. "The Earth in my words" - an essay or a poem

5. Advertising campaign – brochures, posters, posts, news, puzzles, crosswords or games;

More than 50 children from the 5th, 6th and 7th grades took part in the Ideathon, who presented projects for environmental protection and air quality improvement.

Especially for the Ideathon, the students prepared a school newspaper. It featured articles on air quality, ideas on how to reduce pollution, a crossword puzzle and other fun tasks related to the topic.

One of the most attractive projects was "Earth from a bird's eye view" - 7th grade students used drones, and 7th and 6th graders wrote the date 22.04 and the words “ЗЕМЯ” ("Earth") and "AIR".



3.4.2. Results

3.4.2.1. Analyses

Sofia use case 1 – School bus service
The school bus project had several testing periods and throughout them the SDA team conducted several surveys and campaigns for gathering feedback, analysing and double checking the results and the efficiency of the project.

One of the contact points was when we were spreading some informational materials, brochures and was able to talk directly with the parents. They shared with us their feedback and their concerns or suggestions. Most of them liked the project pretty much and supported it even though some of them didn’t have the chance to test the service as the bus routes were not close to their home.

The other point of collecting feedback and having analysis for the efficiency of the school bus project was the two surveys we spread among parents. The first one was targeted to get initial feedback mainly from some of the users of the service, that's why it was not spread so widely during the first school term. We got 39 out of 66 answers that “yes, we have used the service” and parents had mentioned which one of the two bus lines their children had used. Regarding the user satisfaction, all of the answers were “yes, we are pretty satisfied with services”, “yes, my kid likes the school bus”, “yes, we prefer the school bus, compare to the public transport”, “yes, we are supporting the project because it leads to reduction of car traffic around school and decreases air pollution”, “yes, I want to be for the whole school year”.

Figure 89: *Answers to the question from the survey: “You have answered that your child is using School bus No. U1. Are you satisfied?”*

Figure 90: *Answers to the question from the survey: “You have answered that your child is using School bus No. U2. Are you satisfied?”*

Most of the parents are sharing that they have used their personal cars to drive their children to school before starting using the school bus service. (Figure 91).

Figure 91: *Answers to the question from the survey: “How did your child get to school before using the U1 or U2 bus line to school?”*

We got 26 answers “We were driving the child to school via our personal car”, 4 answers “using the underground”, 4 answers “using the public ground transport”, 2 of them were walking to school and 3 of them had used a combination between a car and public transport.

Considering the answers of this first survey we can conclude that we have had at least 26-29 cars less around school every morning. This could be confirmed from another question that aimed to see the returning rate of users - 28 out of 39 parents indicated that their child had used the service in the previous testing rounds.

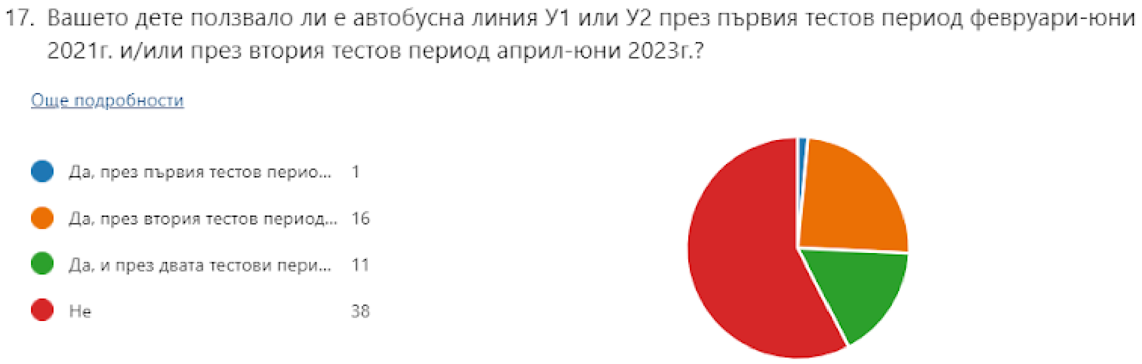


***Figure 92:** Answers to the question from the survey: "Did your child use bus service during the first test period February-June 2021 and/or the second test period April-June 2023?"*

Those who have answered that they haven't used the school bus services are mainly due to the reason that the bus routes were not suitable for them, but they like the initial idea for school buses and if there are new routes passing by close to their home, they will definitely use the service. Only a few of them said that they prefer other types of transportation for their child.

We also wanted to define the main motivators for parents when they choose their type of daily commuting. Of course the main answer is that time is the most important factor.

***Figure 93:** Answers to the question from the survey: "What are the factors that determine how you get to school and how you are commuting in the city?"*

54 out of 66 answers indicate that arriving shortly and in time is the most important for them. Next important factor is the willingness to use environmentally friendly transport to contribute to improving air quality in the city (25 / 66) and 14 of them said that they prefer to walk more in order to be fit and physically active. Others (9 / 66) prefer to use their time for personal development and pleasure like reading a book in the metro. Of course there are people that prefer the comfort of their personal car (14 / 66).

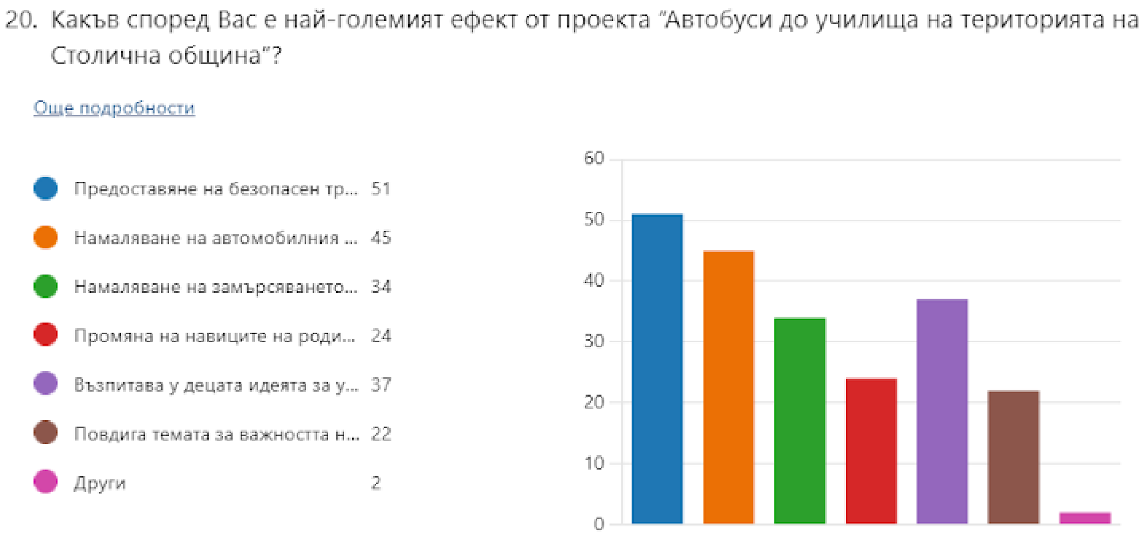


Figure 94: *Answers to the question from the survey: "What do you think is the biggest effect of the School bus project?"*

One of the main important effects of the school bus service is considered to be that it provides safe transportation for children. Then it's assessed as good that it decreases the car traffic around schools and also it educates children in sustainable commuting in the city. Half of the respondents answered that the school bus service leads to reduction of air pollution around the school area and some also think that it raises the importance of air quality as a whole.

Quite similar answers we received in the second survey we conducted in April 2024. This survey aimed not only to gather feedback for the quality and the effectiveness of the school bus service during the whole school year of 2023-2024 but also to draw some ideas and a vision ahead. This time we had 382 respondents and the confirmation of the hypothesis for reduction of the car traffic around school with at least 50 cars was even stronger. More than 40% of the respondents answered that they have used the service - some of them used it for the whole school year, some - only during the morning school term, some during the afternoon school term. That equals 156 out of 382 respondents (the first 4 answers of Figure 95) declaring that they have used the services and probably they were even more as we couldn't get answers from 100% of the parents in the participating schools.

Figure 95: *Answers to the question from the survey: "Please note how your child uses the municipal school bus service of Sofia Municipality:"*

On the next question we can see that 89 parents out of these 156 respondents from the previous question, have declared that their child has used the service every day, 27 said they have used it only on some of the days of the week and 29 - from time to time.

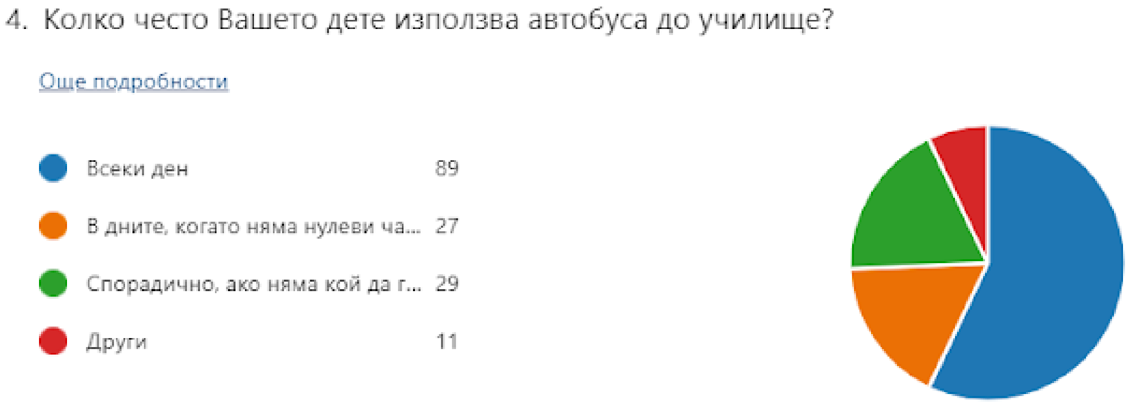


Figure 96: *Answers to the question from the survey: "How often does your child use the bus to school?"*

Sofia use case 2 – Kindergarten

In this case we were working in close collaboration with the Digitalisation Department of Sofia Municipality and the initial planning of this use case was aimed at measuring indoor air quality in the kindergarten, as well as planning to install window meshes in order to prevent PM entering the rooms of children from outside and to validate it both with sensor.community sensors and with Canary system devices. Unfortunately, due to the mayoral elections and the unavailability of budget for window meshes installation, the project was not voted as a priority one for the 2024 budget year and it is currently put on hold, waiting for approval from the Mayoral team.

Again 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 even compare the results from the Canary system with the COMPAIR-provided DIY devices from *sensor.community*.

Nevertheless we had our own measurements and they clearly show 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.

Sofia use case 3 – CO2 calculator usage

Nevertheless people are not very eager to share their experience testing the tool in the survey we prepared, we still managed to gather some fruitful feedback and to make an analysis of what needs to be improved, added or removed as features in order to make the tool more user-friendly and intuitive.

Most of the users said that the tool is useful and interesting. It informs about the main channels of an individual carbon footprint. Some of the users find it more difficult to estimate how much energy their household uses and probably this is a section that needs to be improved and simplified or explained more such as providing typical household electricity consumption data. We are also putting some effort into finding suitable partners and experts that will help us to provide as many links as possible to available sources of information on the individual topics in order to make the tool even more useful and meaningful.

Regarding the Carbon Footprint Simulation Dashboard - it seems from the feedback we gathered that it is very informative and provides a very good tool to understand which policies and behaviour changes would be most effective. One suggestion was to rank the policies by potential as some more effective policies are further down the list and harder to find.

Another suggestion was to integrate the tool in other platforms as there are not so many useful tools like this and it would be nice to be popularised as much as possible which was our goal too. As it was also suggested during the ideathon, dedicated to this COMPAIR tools, SDA's team intention was also to be integrated in one platform of Sofia Municipality - waste.sofia.bg - a platform that is dedicated to the circular economy and guides citizens on how to treat their domestic waste properly. We conducted several conversations on this topic with respective authorities and it is yet to know what their decision will be.

Sofia use case 4 – Awareness raising campaign

Due to some delays resulting from local and national political crises the actual campaign was postponed, however this allowed the SDA team with additional time to test the messages with different stakeholder groups. The actual campaign will be launched in July 2024.

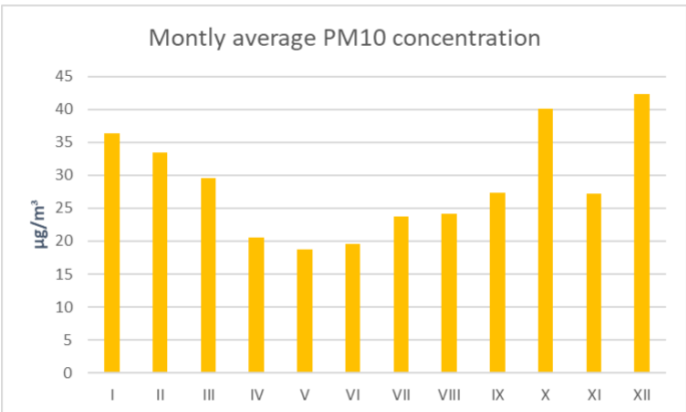
The overall feedback from all the stakeholders meetings was that the visuals and the messages look quite nice and has the potential to attract the attention of citizens and call them to action such as to calculate their CO2 footprint or to play some CO2 scenario or to find how they should treat their domestic waste like old furniture and so on.

Plovdiv use case 2

In this are situated one primary school, one kindergarten, two professional schools, a stadium with several sports halls and a big green area.

The experiments from Open round continue during the Public round to collect more data and see if there is a seasonal variation of PM10 and correlation between traffic intensity and NO2 concentrations.

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 main source of PM10 in Plovdiv is domestic heating with solid fuels. The municipal air quality program shows that the exceedances of the average daily concentration of PM10 are in the winter in the heating season.The heating season in Plovdiv starts in October/ November and ends in March. During the summer months PM10 concentration is almost half of the winter concentration.

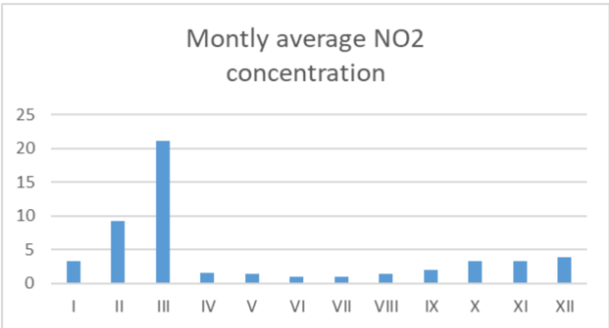
Initially analysis of PM10 concentration was distributed in three categories- average concentration for the period (may 2023 - may 2024), average concentration during the heating season and average concentration out of the heating season. For better understanding the

EAP team made deeper analyses depending on the days of the week - whether they are school days or vacation days, whether they are working days or weekends.

Figure 97 (1&2): PM10 concentration, data from official AQ station Kamenitsa

The main source of PM10 for Plovdiv is domestic heating with solid fuels. The municipal air quality program shows that the exceedances of the average daily concentration of PM10 are in the winter in the heating season.The heating season in Plovdiv starts in October/ November and ends in March. The highest concentration of PM10 were observed during the heating season, on working days during the school year. The lowest concentrations were observed out of the heating season, during the weekends of the school year.

The same approach was used for analysis of NO2 concentrations.



The seasonal variation of NO2 is not so clearly visible as the PM10. The higher concentration February and March are due to reconstruction activities of the nearest boulevard.

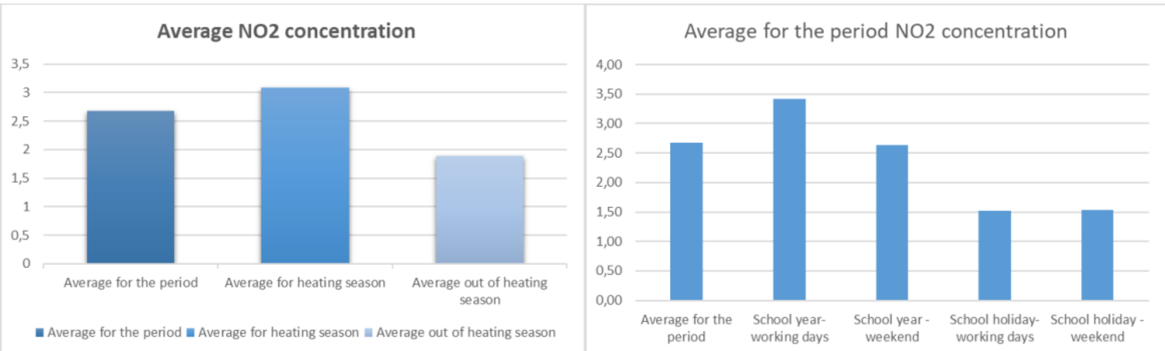


***Figure 98 (1&2):** NO2 concentration, data from official AQ station Kamenitsa*

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 are not going to school and traffic is reduced.

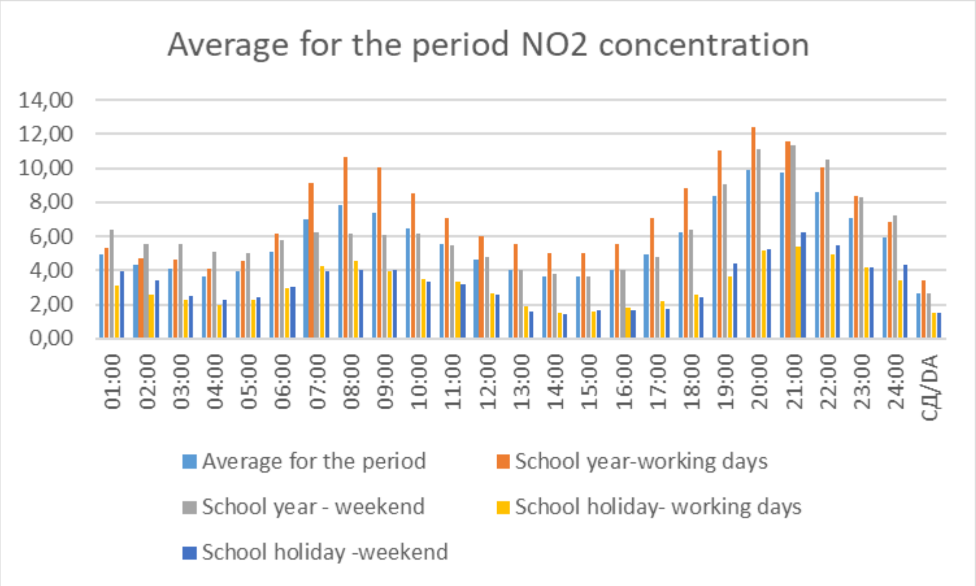


Figure 99: *Distribution of NO2 concentration by hours, data from official AQ station Kamenitsa*

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 of the 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 7pm. In the area is located a large, well-visited city park. There is a football stadium and sports halls nearby. It is likely that the attendance of these facilities contributes to the observed higher concentrations of NO2 in the period from 19:00 to 21:00.

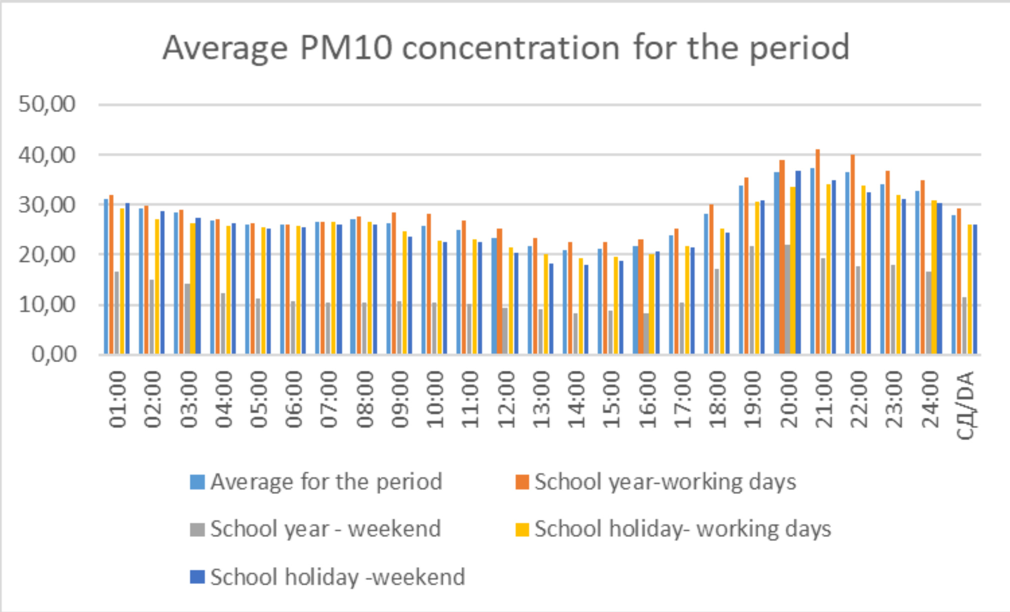


Figure 100: *Distribution of PM10 concentration by hours, data from official AQ station Kamenitsa*

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.

Also 13 Telraam V1 traffic sensors were distributed to the citizens and dara is available on project dashboard:

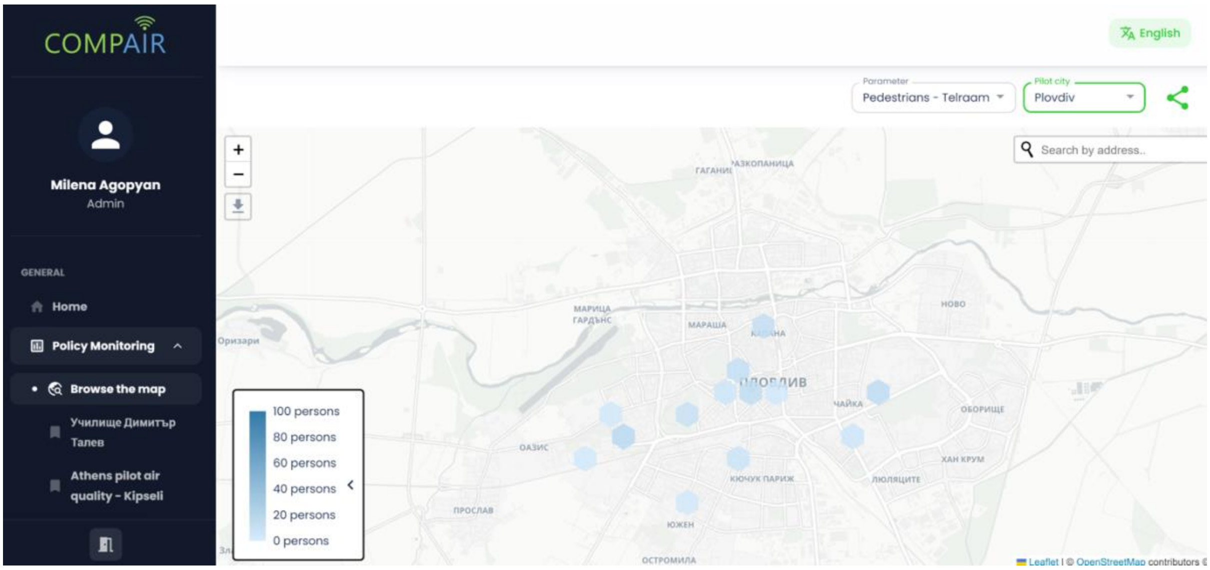
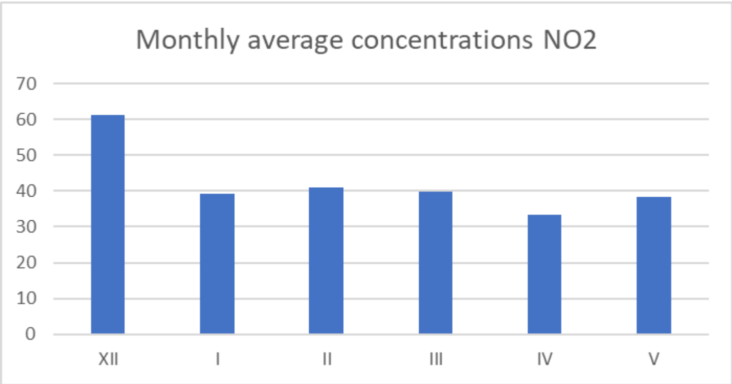


Figure 101: *Distribution of the Telraam V1 traffic sensors in Plovdiv*

For the first time in Plovdiv citizens participated in traffic measurements. Until now, only the cameras of the Center for Urban Mobility reported traffic in the city.

A meeting with district mayors were organised for the introduction of the project results.

Plovdiv use case 3
In this are situated primary and secondary schools and the City Court. 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 where the data is not sufficient to draw a conclusion for the whole year Only in December 2023 there was a significant deviation in NO2 concentrations.

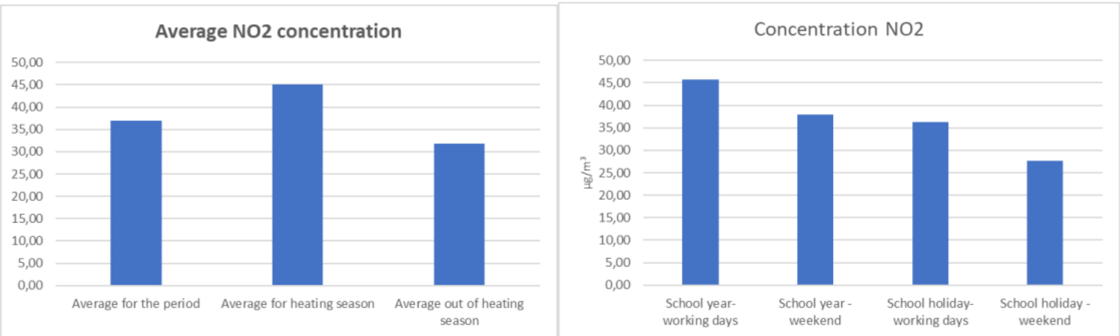


Figure 102 (1&2): *NO2 concentration, data from mobile AQ laboratory*

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 are not going to school and traffic is reduced.

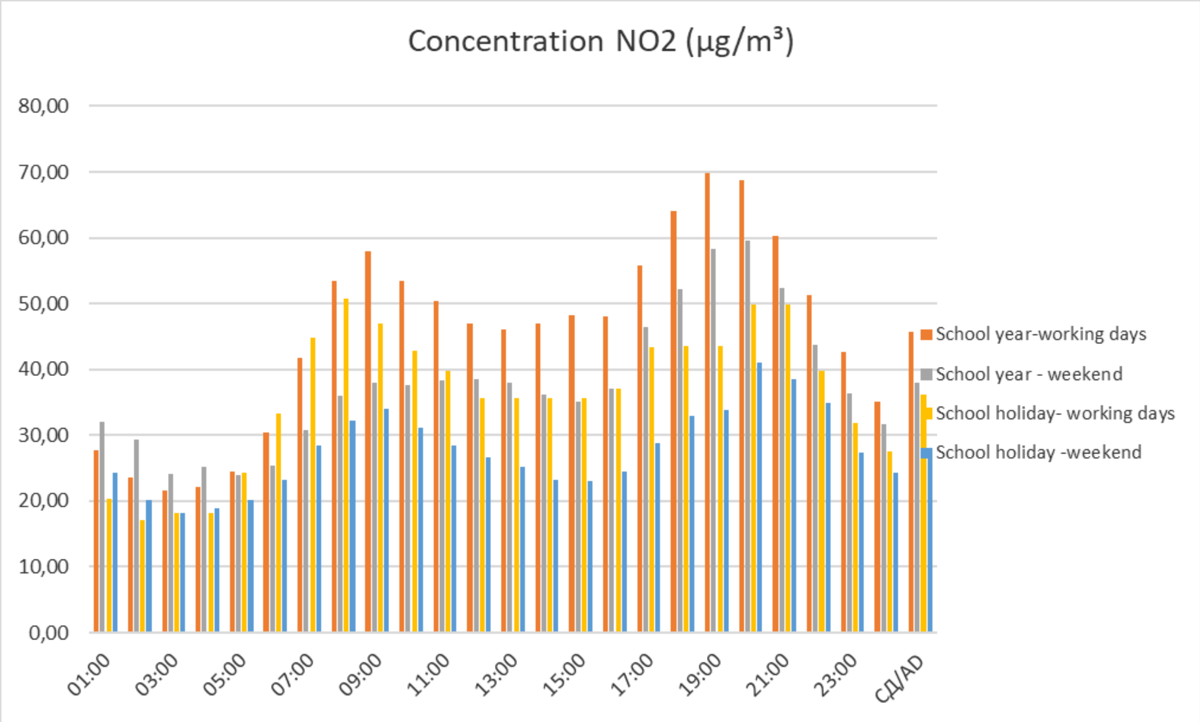


Figure 103: *Distribution of NO2 concentration by hours, data from mobile AQ laboratory*

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 of the 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 7pm. The school is situated near to the city center and probably this is the reason for more intensive traffic, respectively higher concentrations of NO2 in the period from 19:00 to 21:00.

The location in the school yard was not proper for traffic sensor installation. The Telraam sensor was installed by volunteer, near the school. From January to the end of May 2024 data were visualised on the picture below:

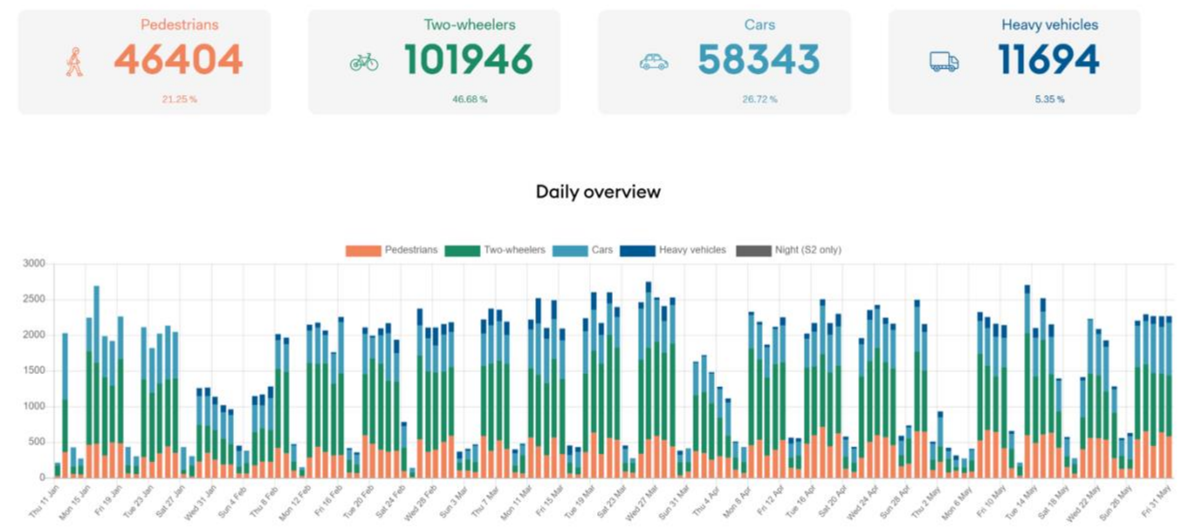


Figure 104: *Data from the Telraam device No.9000006281*

It's easy to see that during the working days traffic is significantly higher than during the weekend. The students were given a task to analyse data for the period from 11/01/2024 to 18/04/2024.

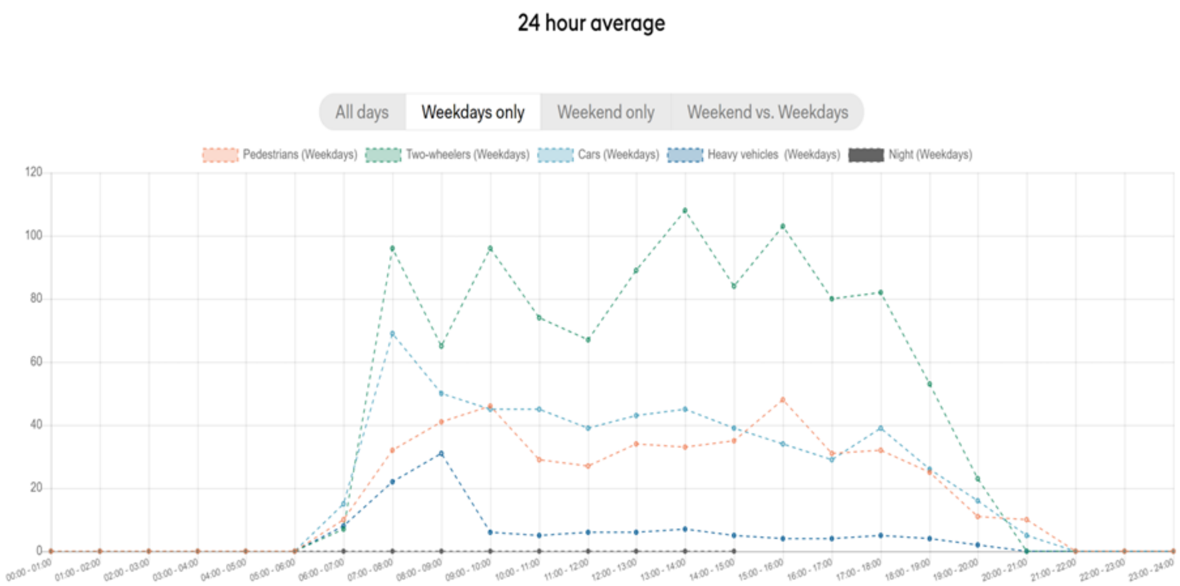


Figure 105: *Data from the Telraam device No.9000006281 or the period from 11/01/2024 to 18/04/2024*

They found that the first peak was when the students came to the school (around 8 am). The second peak was during the morning break (around 10 am), the third peak was when some of the students from the first shift finished classes and left and second shift students came to school (around 1:30 pm). The fourth peak was during afternoon break (around 3:30 pm).

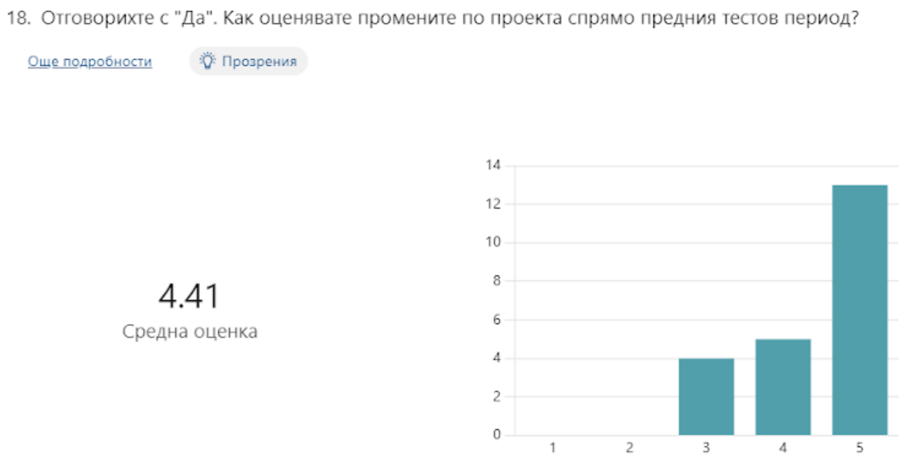
Analysis of data from the mobile air quality laboratory shows that peak values for NO2 - concentrations coincide with the activity hours of schools and City court, while PM 10 levels are relatively constant. Seasonal variations are observed for PM 10, which are higher in winter in the heating season.

3.4.2.2. Results

Sofia use case 1 – School bus service

The overall feedback for the school bus project is positive. We have a solid foundation to build on and the final ideathon dedicated to this project drew a vision by collecting the ideas and the needs of the main users. In order to make this service stable and a long term measure of Sofia municipality concerning air quality policy we need the support of the City Council to prolong the service further. But we can rely on the declared interest by the parents and this positive feedback. The satisfaction of the service is quite good, giving an overall assessment of the quality of 4.41 out of 5 points for changes in the testing period of April - June 2023, when we had 194 respondents to the survey and an assessment of 4.68 out ot 5 points for the changes in the testing period September 2023-June 2024, when we had 66 respondents.

The two figures below show the answers to the question from the survey: "How do you assess the changes in the project compared to the last test period?" The first graph shows the assessment of the service for testing period of April - June 2023 and the second graph is showing the assessment of the service for testing period of September 2023 - June 2024.



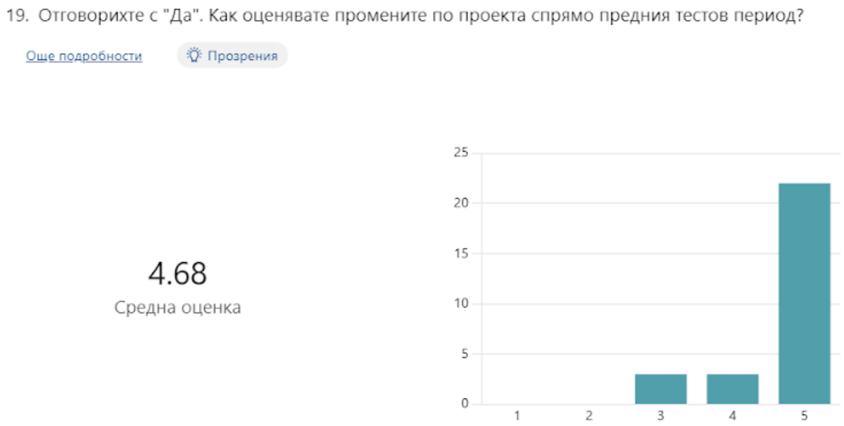


Figure 106: *Answers to the question from the survey: "How do you assess the changes in the project compared to the last test period?"*

In addition only 3 of 382 respondents in the final survey mentioned that the service is not needed and important at all, while 206 consider this service as very important - some of them critical, some not so critical for their daily commuting to school.

Figure 107: *Answers to the question from the survey: "How critical is it for you to have this municipal service?"*

According to some previous surveys our team had conducted in 2017 and 2020 in several schools in Sofia, nearly half of the children are driven to school by their parents using their personal cars, usually on the way to their working places.

Referring to the final survey SDA team conducted with the aim to explore the attitudes for prolonging the project, 210 parents (the first 4 answers from Figure 107) declared to have interest in using the service for the next school year, in the mornings or at noon. That means potentially 200 or even more cars less around the areas of the schools participating in the project. Only 37 parents consider they are not interested or this service is not suitable for their child.

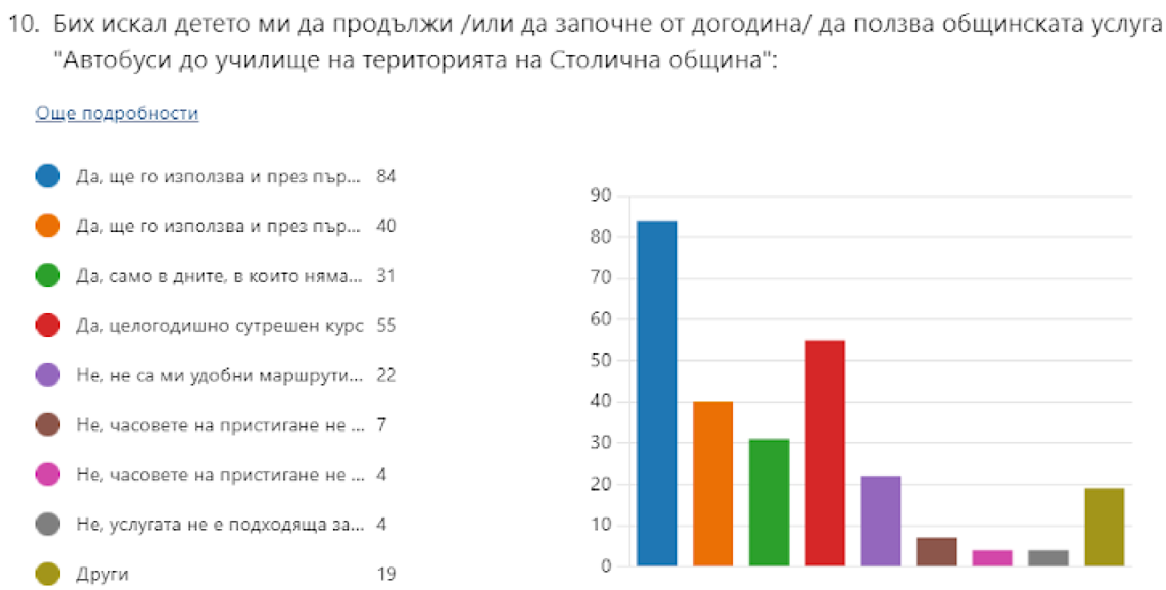


Figure 108: *Answers to the question from the survey: "I would like my child to continue /or start from next year/ to use the municipal School bus service:"*

As we already followed up in this report, the survey shows also an increased interest in sustainable daily commuting and a readiness for changing the behaviour probably due to raising awareness on the importance of clean air but mainly due to providing a qualitative service based on human centric approach that meets the need of the parents and the children itself.

Having these positive feedback and confirmation of the effectiveness of the school bus service and also gathering direct recommendations from the stakeholders for prolonging the duration of the services and even developing it further, we followed up with proposals to the local authorities, including Deputy Mayor of Transport and Director of Transport Division to prolong the service for at least two more years ahead. Additional meetings on policy level are yet to be held to discuss the opportunities.

Sofia use case 2 – Kindergarten
No specific results can be reported for this use case due to lack of data for comparative analysis and postponement of the project idea related to the installation of window meshes to prevent PM entering from outdoors.

Sofia use case 3 – CO2 calculator usage
Main result is that the CO2 Calculator and the Carbon Footprint Simulation Dashboard were presented to citizens and policy makers and feedback on how the tool can be improved and further promoted was gathered in order to finish the development of the tool and to spread it at a wider awareness raising campaign during summer months.

The SDA team mobilised its partnerships and resources to spread the word first at a closer range of stakeholders and after some iterations of improvements - at a wider range of testers and users. This resulted in an increased visit rate from Sofia of the tool having more than 188 visits to the CO2 calculator during the public round.

Figure 109: *Statistics for number of visits and a visitor map of the CO2 Calculator and the Carbon Footprint Simulation Dashboard for Bulgaria, respectively Sofia*

It seems that the tool is interesting for the users and they recognize that there are not many such tools like the COMPAIR CO2 Calculator, especially compared with the Carbon Footprint Simulation Dashboard and it would be valuable for them to know what their footprint is by taking into account the main sources of CO2 emissions individually.

Sofia use case 4 – Awareness raising campaign

When planning the information campaign the focus we had was to give positive examples of people living sustainably in general to raise awareness and call to action to change behaviour. The main message is that "It's cool to live sustainably". It will be represented in different ways and dimensions and relatively with different visualisations - calling for sustainable daily commuting in the city, recycling and teaching your children to take care of the environment and be responsible for the waste, calculating your carbon footprint, planting more trees, growing seeds at your balcony and more. The visualisations are yet to be approved and the campaign to be launched during the summer months.

They will also promote the COMPAIR tools like CO2 Calculator and Carbon Footprint Simulation Dashboard that will help people get to know how each individual is affecting the environment by their actions and to double check where they are on the path to climate neutrality.

Plovdiv use case 2 and **Plovdiv use case 3**

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 also incorporates good practices from the other pilots in the CompAir project - school streets and school buses.

During the work of the Plovdiv team with the schools, it was established that they have maintained green areas, but with seasonal vegetation. They have the largest leaf mass in spring and summer. In autumn, the leaves fall off. In winter, when the highest levels of pollutants in the air are found and the conditions for their dispersion are the worst, the natural green wall is gone. The report to the municipality also includes a measure for appropriate year-round landscaping.

The Plovdiv team conducted a survey on the satisfaction of students, stakeholders and citizens with their participation in the project. To the question "How satisfied are you with your participation in the project" 62% of citizens and stakeholders and 54% of the students answered "very satisfied".
To the question “Did you learn something new, were the project activities interesting to you?” around 49% of citizens and students answered “The activities were interesting to me”; around 42% of citizens and 37 % students answered “I learned new things and the activities were interesting for me”.

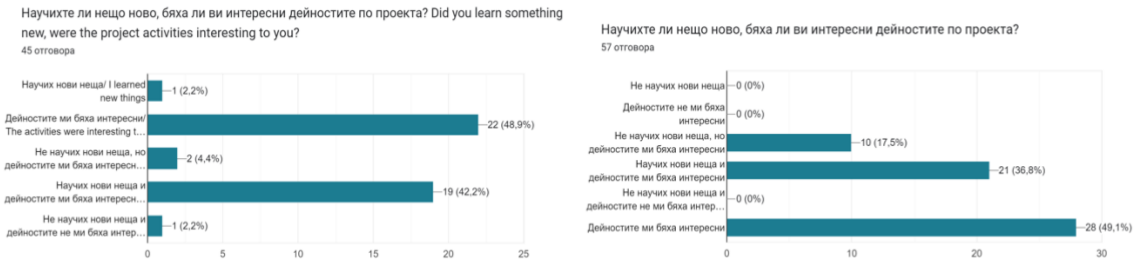


Figure 111 (1&2): *Answers to the question “Did you learn something new, were the project activities interesting to you?” - on the left - citizens and stakeholders, on the right - students*

This shows that the participants are interested in doing something specific, participating in the creation of something new and seeing their contribution.

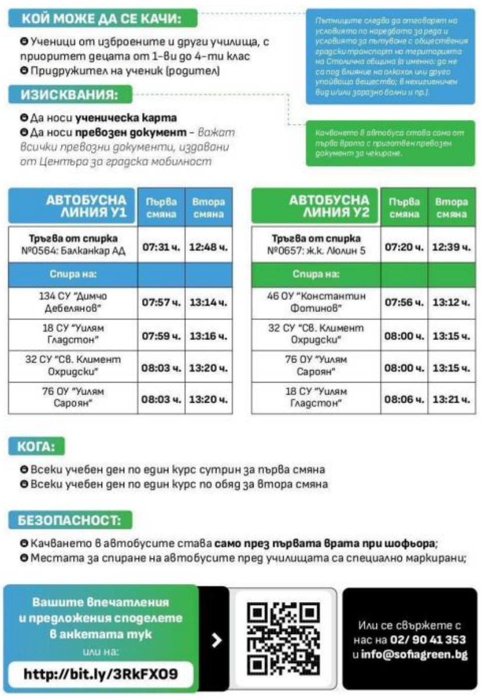
3.4.3. Lessons learned

Sofia use cases
Sofia use case 1 – School bus service
Engagement
Continuation of the activities and the main focus from the Open round to engage as much as possible the different stakeholders, during the public round testing we put a stress on the engagement of parents as they are the decision makers regarding their kids’ commuting to school. That’s why we involved parents as much as possible in filling the surveys and also participating in workshops and direct conversations during the whole school year. What we realised is that there should be a balance in sending them messages and asking them to fill in the questionnaires as there is a risk of annoying the parents or the teachers as they are very busy during most of the time. So if we wanted to receive their feedback and engagement we should precise the rhythm and frequency of asking them to assist. What we noticed was that the newly informed parents were far more responsive and eager to answer the questions

in the survey, also the parents that were highly appreciating the service and used it every day. The first ones are interested in something new and innovative for which they hear for the first time, the second ones are engaged as they want the service to be prolonged for the next school year and have a direct benefit of taking part in the project activities. So building a community of people that are directly affected by the results leads to a good collaboration and positive outcomes.

Communication

Communication has always been a very important part of building a community and creating sustainable and long term relationships with different groups of stakeholders. Having direct conversations with parents kept them feeling assured that everything was fine. There were several childrens' belongings left in the buses and we needed to coordinate returning them to the parents. This attitude and the fast response of our team to every issue that occured made parents thankful judging from the surveys' responses and they gave the service a high quality assessment.



Our team put extra efforts to maintain a high level of open and honest conversation as we did during the Open Round Testings. Starting from the beginning of the school year with participating in the European Mobility Week, we spread a press release and articles with information about the start of the school bus service that were published also on our website and the schools' websites. We continued spreading brochures among parents in front of the school yards and used direct communication via phone calls when questions occurred. We spread the first survey from the very beginning of the school year. That probably was not the right moment and we should have waited for some time and to focus only on this topic as we didn’t get so many responses to this questionnaire.

Before the beginning of the second term when students are switching their timetables from mornings to afternoons and vice versa, we made another massive campaign to inform and to remind the parents about the school bus service as some of them might not know that there is a school bus also at noon for the afternoon classes.

Then in April we spread the second survey and this time we didn’t make the mistake to overload with too much information and focus only on this message. Also as we already had some feedback from the first survey, we decided to involve a wider range of parents - not only parents from 1st to 4th garage but also from 5th to 6-7th grade as we realised that they are also an important target group and are interested in the service as much as the other parents.

As a final milestone was the ideathon in the end of May with parents and stakeholders from Sofia Municipality which was another opportunity to talk to parents directly and gather some useful feedback no matter whether some of them were not able to take part in the meeting itself.

What we had as a conclusion regarding the communication is that we should grab any chance of direct and open communication and in every conversation there might be something important and positive as an outcome for the project. Everytime we spoke with any of the stakeholders was an opportunity to remind them about the project and to get some dividends or feedback that could be essential for the future of the project itself and for its development if we have managed to win this person as an ambassador for the school bus project and clean air cause.

Data availability/gathering and analysis

Similar lessons we learned also while we were trying to gather some citizen science data. We realised that at first people are more motivated and eager to assist installing the sensors but later when we had some issues with Wifi or LTE-M networks and they should have to put some effort into reinstalling the device and or to assist us for doing some technical support, they started losing motivation and it was even annoying for them. When they are not directly operating with the sensor they are not interested even in the statistics. If we had the mobile SODAQ Air devices working in our city area we are sure we could engage the participants much more as at the first conversations they were really interested in the devices and the ability to check their air pollution exposure. But as we couldn’t rely on these devices and the tools related with air quality exposure monitoring, we put as much more effort into engaging stakeholders in activities more directly related with school bus service.

Sofia use case 2 – Kindergarten

The outcomes and lessons learned from use case #2 are pretty similar as the ones from the school bus as the SDA team was working with the same main groups of stakeholders, engaging teachers, parents and kids, in this case smaller, but still all of them were interested to be involved in the activities and informed about the importance of the air quality topic and mitigation of negative effects of air pollution when being aware of their personal exposure to polluting agents.

Sofia use case 3 – CO2 calculator usage

Engagement

The main goal concerning this instrument was to first to make a close testing round with partners and friends and after implementing their feedback to improve the features of the instrument, to make the next iteration showing the digital tool and admin panel to the policy makers. That was our strategy and it worked well as with every iteration we received the next level of understanding and further improvements. Now we are planning a wider population of the tool, including it in the Awareness raising campaign during the summer, where there will be a larger number of users. Using this agile approach was a key to make sure that everything is working fine before publishing it to the wider public.

Communication

In this case communication was made on several different dimensions - first with testers and then technical team and secondly with the final users and policy makers to get feedback how this tool meets their expectations and needs. It's again a question of balance between all the different stakeholders' opinions and user requirements and a matter of efficient communication and holistic approach.

Data availability/gathering and analysis

When you offer a tool that looks easy to use, innovative and meets the requirements of the stakeholders, it seems that it's quite interesting for the users, taking into consideration the statistics of the users of the tool and number of impressions. We are still in the process of finding out whether we have done our job well as the promotion of the tool is still ongoing and will continue until the end of the project COMPAIR with a larger scale awareness raising campaign that will allow us to make a broader data analysis.

Sofia use case 4 – Awareness raising campaign

Engagement

During the process of planning the awareness raising campaign, achieving a synergy between different departments of Sofia Municipality was very important as we would like to promote not only COMPAIR tools and SDA's pilot activities but also different programs, projects and incentives Sofia Municipality is providing in order to improve air quality and sustainable living, sustainable daily commuting, etc.. The SDA team's role was to set the vision and to coordinate the process and continued to involve as many key stakeholders as needed in taking the decisions and sharing feedback. It is important first to split the responsibility but more importantly to get the maximum benefit of such a campaign and to scale up the resources and the capacity we use.

Communication

The more stakeholders you involve the more difficult to balance between different opinions and requests there is but also the more resources you get and opportunities occur. So effective communication again is the key. The goal of the use case itself is to reach as large an audience as possible and this could be done by using all kinds of different communication channels available in the municipality itself. Honest and open communication builds trust and longer relationships beyond the scale of one campaign.

Data availability/gathering and analysis

Up to now the feedback of the strategy of the campaign is very positive and every stakeholder we involved was eager to share their feedback and to make their own research and analysis of the possibilities, risks and opportunities to contribute and to get benefits of the awareness raising campaign. As we are still in a planning phase, and in process of developing the final visuals and PR strategy, the SDA team would be able to share any specific data and analysis after the campaign is finished.

Plovdiv use cases

The children participated with great enthusiasm in the project activities. The conduct of the training and the setting of tasks were aligned with their curriculum. For example, for the students of the 5th grade (11-12 years old) in Environmental Sciences, when they came to the topic of air quality, we organised a workshop where we used the training materials developed under the project, we organised a visit to the mobile laboratory to familiarise the children with the equipment and measurement principles, had the opportunity to assemble sensors themselves. When in Mathematics they were on the topic of tables and graphs, they were presented with the results of the measurements and an opportunity to analyse them.

Older students (12-14 years old) were given personal tasks, for example, to present the CO2 calculator to their classmates, to find out what the peaks and measured concentrations of pollutants are due to, etc. Since we aimed to include as many children as possible from families with low socio-economic status, but without putting them in an uncomfortable position in front of their classmates, we turned to the school director for assistance and asked for information - families with 3 or more children, children of single parents, orphans, with some disabilities , etc. Such children were assigned personal tasks. The children did very well, made good guesses and proved their theses. This can also be used in other schools, and a significant contribution to the analysis and interpretation of data could be made by students from vocational high schools in mathematics.

Our experience shows that children are motivated to participate in science experiments and seek a stage to perform. This can be used and developed in the future. Also, they share with their parents and friends and it is a way to change for a more sustainable behavior. It also widens the pool of volunteers involved in future citizen science projects.

While working with the schools we noticed that they have good landscaping, but it is only from spring to fall. In winter, when the levels of pollutants in the air are the highest and the conditions for their dispersion are the most severe, the green wall is missing.

A comparison of data from the official air quality station and DIY sensors showed that the trend was the same. The measured concentrations with the low-cost sensors are lower, but they can be used in areas not covered by official measuring stations and for indicative measurements. If any deviations are noticed and the local authority needs more reliable data to take measures, it can take the appropriate actions.

We shared the experience of other pilot areas with local authorities and stakeholders. The results show that peaks in measured NO2 concentrations coincide with peaks in traffic intensity in areas around schools. A possible solution to this problem is school street (Flanders pilot) and the introduction of school buses (Sofia pilot).

The results of the project will remain long after its completion and can be used in the development of plans for urban mobility and improving air quality.

4. Recommendations for disseminating the results

4.1. Policy impact

It is helpful to seek cooperation with policy makers and the administration right from the start of the project. This is the best way to ensure that the results are ultimately usable and useful to the administrations and policy makers. Sufficient and continuous time should therefore be planned for this outreach cooperation process. Places and events (e.g. policy forums, conferences) where policy makers are present are ideal for building networks with administrations and communicating your own project results as well as clear recommendations for action and reports in order to put yourself on the radar of policy makers and have worked for the COMPAIR project. These networks can amplify the reach and impact of the project findings. It is also a good idea to initiate events and opportunities yourself to which policy makers are specifically invited. Involving citizens in such events and processes, by strengthening the dialog between them and the administrations, also supports the policy impact. In Citizen Science projects, it is also important to devote time to reflect back to participants that their involvement and co-research can, in the best case, contribute to policy impact.

4.2. Scientific results

Through journals, publications and the open-source sharing of project results in general, as well as participating in conferences and organizing webinars, we can disseminate the scientific results. This creates new networks and potential collaborations for follow-up projects and research that take up our project results. COMPAIR's technical focus has led to the creation of a number of open-source dashboards and apps. It would be a good idea to motivate other researchers to also use these tools so that they can be used in further studies.

4.3. Community and citizen engagement

Workshops with citizens are a central way to introduce them on topics of citizen science, air quality and climate, educate and raise awareness as well as present findings to local communities. In COMPAIR each pilot organised several of such workshops in order to reach and interact with the local community. When communicating with citizens, it is important to pay attention to the type of communication. Continuous, respectful contact at eye level, regular feedback, updates and transparency regarding changes in the course of the project are crucial to gain the trust of citizens. Such respectful and friendly interaction with one another can help to establish a community in which the participants regularly interact - this boosts motivation and increases the sense of responsibility for the outcome. In order to reach hard-to-reach target groups, it can also be useful to work with intermediaries who build a bridge between the research project and the local community. It should be kept in mind that such a process takes time, patience and trust. In the Sofia pilot, this approach proved to be very successful. To involve as many citizens as possible and to use and consolidate the project results in the long term, it is always important to establish partnerships and relationships with other projects and local initiatives with similar focus and activities to enhance the impact and dissemination of the project results. Working with the local communities automatically involves administrations. It should be ensured that any necessary permits are obtained at an early stage in order to ensure successful citizen engagement.

5. Conclusion

This section provides a brief overview of COMPAIR's accomplishments during the Public Round of its pilot experiments & co-innovation work package. We managed to start experimenting and involving citizens in all pilot regions. Every pilot actually worked on at least two experiments during the Open Round, in part also to reduce the impact of delays or failures with any of the technological components. The table below outlines the experiments in each pilot.

Table 31: *Overview of the five pilots and its experiments content*

Pilot	Experiments
Athens	• Engaging senior citizens in Neos Kosmos area through Friendship Clubs • Replicating the Neos Kosmos approach in Kipseli area • Raise awareness on the impact of daily activities through the carbon footprint tool (CO2 dashboard)
Berlin	• Determine cyclist exposure to air pollution while filling gaps in official monitoring data • Evaluating the impact of traffic calming measures in a so called "Kiezblock" in the Bellermann neighbourhood as well as detect the air quality and traffic flow in the Donau-/Flughafenkiez neighbourhood
Flanders	• Demonstrate the impact of a school street in Herzele and Ghent on both traffic and air quality • Demonstrate the impact of wood burning in Herzele and Hove • Evaluating a mobility plan in Ghent and Sint-Niklaas
Sofia	• Assess the impact of the introduction of new school bus routes on behavioural choices and air quality • Investigate the indoor/outdoor air quality relationship in a Kindergarten (could not be realised due to technical problems) • Promote the usage of CO2 calculator to raise awareness on individual carbon footprint and also on the ways citizens can take to decrease it • Awareness raising campaign focusing on positive examples of people living sustainably in general to raise awareness and call to action to change behaviour
Plovdiv	• Investigate the relationship between traffic and air pollution in 2 school

	areas to raise awareness ● Raising awareness of the impact of traffic on air pollution and seasonal variation of PM10

In spite of the learning experiences in the Open round all pilots faced significant challenges during the Public Round mainly due to delays in sensor delivery, the bankruptcy of SODAQ and technical issues with the devices or dashboards. In close cooperation with COMPAIR's technical teams, we managed to identify most issues and work on them to have improved products at hand during the Public round. Recruiting choices and workshops seemed to be rather effective, a greater participation and more attention to involve participants even with a lower socio-economic status worked better in the Public round than in the Open round. Through a series of meticulously designed pilot projects in Athens, Berlin, Flanders, Sofia, and Plovdiv, the project has not only generated valuable data but also engaged communities in meaningful environmental action which are presented in the following conclusion.

As a result the COMPAIR pilots managed to organise around 25 **workshops** as well as local recruitment campaigns, school lessons, ideathons and other engagement events. Through these efforts we managed to **directly** reach about 600 citizens with at least an additional 3,000 through **indirect** forms of engagement. Based on available statistics and proxies we estimate the share of participants with a **lower socio-economic status** to be around 20% in total, the proportion varies greatly between the five pilots from 5% to around 95%.

The **Athens** pilot successfully engaged citizens, especially elderly participants as a SES group, through the existing Friendship Clubs network. Volunteers monitored air quality and the pilot demonstrated the power of community involvement in environmental initiatives. Through collaboration with local NGOs, schools, the city of Athens and municipal bodies, the project effectively raised awareness about air pollution, its health impacts as well as the measurements provided information about the linkage of behavioural choices because of air pollution. The use of various communication channels, including the Synathina platform, ensured broad participation and visibility in workshops and discussions groups. The analysis of PM measurements in specific neighborhoods such as Neos Kosmos and Kipseli area provided valuable data for future urban planning, pollution control efforts. In parallel campaigns for the collection of data on the CO2 footprint of citizens in Athens are ongoing, however they have provided valuable first outputs and results.

The **Berlin** pilot effectively utilized both mobile and static air quality measurements to engage citizens in understanding and addressing air pollution. The mobile measurements with 45 cyclists highlighted the exposure to particulate matter during daily commutes, while the static measurements in different neighborhoods provided with 19 participants insights into the impact of traffic calming measures by conducting data at a Kiezblock, for instance. The six workshops and hands-on training sessions empowered participants with the knowledge and tools to monitor air quality and traffic flow, fostering a community of informed and proactive citizens who who are more aware of their environmental choices. The data collected not only filled gaps in the official monitoring network of Berlin with validated data but has also helped to put the issue more firmly on Berlin's political agenda by engaging in targeted dialogue with initiatives and the administration.

In **Flanders** the pilot team focused on the school street cases in Herzele and Ghent monitoring air and traffic quality. The educational initiatives in primary and secondary schools successfully increased students' knowledge and awareness, leading to behavioral changes and greater community involvement.The traffic data collected by the citizen scientists clearly showed the positive effect of the school street, whilst the air quality picture is less clear. Further use cases focused on demonstrating the impact of wood burning in Herzele and Hove while other use cases evaluated a mobility plan in Ghent and Sint-Niklaas. The collaboration with local councils and environmental groups amplified the project's reach and impact and was very special and effective in the Flanders pilot. The experiments demonstrated the effectiveness of educational campaigns and the importance of involving young people in environmental stewardship. It has received positive responses from participants indicating a strong foundation for ongoing and future initiatives to improve air quality in the region due to its high proportion of stabilisation.

The pilots in **Sofia and Plovdiv** demonstrated innovative approaches to engaging citizens in air quality monitoring and environmental action. Still, unfortunately both pilots were still hampered in their execution in the Public round because of the lack of LTE-M coverage for sensor data communication; the SODAQ devices couldn´t be used. As a result, in **Sofia** the focus was on the CO2 Calculator and Carbon Footprint Simulation Dashboard which attracted significant interest, providing valuable feedback for tool improvement and wider dissemination. To assess the impact of new school bus routes on behavioural choices and air quality the pilot worked with pupils and also conducted playful experiments and measurements with children from the kindergarten. The awareness-raising campaign promoted sustainable living practices, further enhancing community engagement. In **Plovdiv**, the focus was on investigating the relationship between traffic and air pollution and raising awareness by working with two schools and seasonal variation of PM 10. The collection of citizen proposals for air quality measures and the integration of good practices from other pilots into municipal plans highlighted the effectiveness of participatory approaches. The positive feedback from pupils and stakeholders underscored the importance of hands-on, community-driven projects in fostering environmental awareness and action.

Pilot activities in the Public round also allowed us to learn valuable lessons across the pilot cities. In Athens, the engagement of senior citizens in air pollution measurement was a success and their enthusiasm was noteworthy. Although working with the elderly presents specific issues in troubleshooting device errors and deployment issues. In Berlin, the challenges of the non-functioning bcMeter and growing frustration and drop-out rate among the static measurement participants highlighted the importance of smooth technology. The approach of working together with administrations from the very beginning to obtain usable data and generate findings that can be truly utilised, as in Flanders, is a central building block for both citizen science projects in general and for the field of air quality and mobility measures. Focusing on structural issues that block behavioural change (like improved cycling infrastructure) can unlock individual behaviour change in cases where citizens have little leverage over their behavioural options.

This closing section of the Public Round report provides a summary overview of the lessons learned in the Athens, Berlin, Flanders, Sofia, and Plovdiv pilots during the Public Round. These lessons cover various aspects of the project, including engagement, communication, and data availability/gathering and analysis. Here's a concise summary of the key lessons from each pilot:

Athens

- Continuous collection of data and hence quality of collected data is challenging since it requires major field works, on-site visits and regular recurrent workshops and thus sufficient resources such as personnel
- Technical problems with the measuring devices can lead to participants dropping out and should be resolved as quickly as possible
- To make the data as usable as possible at the policy level, in future projects DAEM aims to test another approach of citizen science, namely to collect data from municipal points of interest (e.g. school buildings, administration etc.)
- In order to support the continuous collection of data, additional material (e.g plugs, large cords etc.) might be necessary, since participants sometimes forget to charge their devices
- When interpreting the data, it is important to note that measurements of air pollution at street level reflect on the external weather and other conditions of the city

Berlin

- The recruitment of participants, especially in the static measurement campaign, requires sufficient time as well as building trust and presence in the neighbourhood
- The registration process should be detailed and transparent and, for example, show participants the workload for the various tasks to the minute and hour
- Combining the workshops of the stationary and mobile measurement campaigns has the advantage that there is more exchange and even more learning experiences between the groups
- Very good accessibility to the participants is extremely important in order to maintain the motivation of the citizen scientists and to provide direct assistance in the event of problems
- It is important that the technical measuring devices, apps and dashboards are easy to use and work well so as not to lose participants

Flanders

- It is important to recognize “Local Champions” because they can be the drivers of a project
- Snowball effect of working around air quality in schools is helpful to reach many people because the group you work with (e.g. awareness raising) also influences its environment
- In order to reach low SES groups, it makes sense to go to various schools because there is a heterogeneous group there
- The project has also presented us with ethical challenges for which we do not yet have a solution: Traffic calming leads to less traffic in neighbourhoods with high SES classes, which is then diverted to the surrounding main roads, where lower SES classes live
- the SODAQ sensor could benefit from several upgrades to help (automatic) data analysis, e.g. an on/off button

Sofia & Plovdiv

- Communication is key; in order to best serve different stakeholders' interests it is helpful using different communication channels
- Honesty and clear communication need to be maintained at all times during the experiment
- Always be prepared with a plan B if something does not work out as expected
- Allow enough time to establish and manage partnerships
- Quality of results and scaling up largely depends on properly identifying user needs

The COMPAIR project and especially the Public round have demonstrated the feasibility and effectiveness of involving citizens in monitoring air quality and influencing policy decisions. Key findings from the pilots indicate that citizen engagement can lead to measurable behavioural changes and contribute to validated and localized air quality data. These insights are crucial for shaping future urban policies aimed at reducing pollution and enhancing public health.

The project's success hinges on the robust experimental designs, the innovative use of technology such as low-cost air devices and dashboards, and the strategic partnerships with local authorities and stakeholders. The lessons learned from the public testing highlight the importance of tailored engagement strategies, continuous support for participants, and the integration of citizen-generated data into municipal decision-making processes as early as possible.