COMPAIR

DELIVERABLE

D5.4 Open Round report

Project Acronym:	**COMPAIR**
Project title:	Community Observation Measurement & Participation in AIR Science
Grant Agreement No.	101036563
Website:	www.wecompair.eu
Version:	1.0
Date:	31 October 2023
Responsible Partner:	VMM
Contributing Partners:	DAEM, INTER3, EAP, SDA
Reviewers:	Internal: all pilots and technical partners External: Gitte Kragh - Aarhus University (DK) Andrew Stott - Independent (UK) Otakar Čerba - UWB (CZ) Karel Jedlička - UWB (CZ) Martine Van Poppel - VITO (BE) Karen Van Campenhout - Flemish government (BE)
Dissemination Level:	Public — X Confidential, only for members of the consortium (including the Commission Services)

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

Revision History

Version	Date	Author	Organization	Description
0.1	05/06/2022	Evelyne Elst	VMM	Initial structure
0.2	29/09/2023	Christophe Stroobants, Vlatko Vilovic, Antonia Shalamanova, Desislava Todorova	VMM, INTER3, SDA	Methodology, Berlin description, Sofia description
0.3	9/10/2023	Ilia Christantoni, Dimitra Tsakanika, Christophe Stroobants, Milena Agopyan, Antonia Shalamanova, Desislava Todorova, Tom Callens	DAEM, VMM, EAP, SDA, DV	Final input on all pilots
0.4	13/10/2023	Christophe Stroobants	VMM	Version for review
0.5a	27/10/2023	Pilot & tech teams		Internally reviewed version
0.5b	27/10/2023	External reviewers		Externally reviewed version
1.0	31/10/2023	Christophe Stroobants	VMM	Final version

Table of Contents

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

List of Tables

List of Figures

Executive Summary

This report summarises the activities, results and lessons learned during the Open Round of the COMPAIR project In the Open Round COMPAIR organised experiments in Athens, Berlin, Flanders, Sofia & Plovdiv in which we provided technology to citizen scientists with the aim of affecting local policy decisions and citizen behaviour. The Open Round ran from November 1st 2022 to 31st of October 2023 (extended from original June 30th end date due to sensor delivery issues).

The Open Round follows COMPAIR's Closed Round in which only project partners were involved in product development and testing, a.o. the closed round performed a benchmark of the available sensor devices. The Open Round built on this by involving citizens closely related to participating organisations involving them in data collection, analysis and visualisation while still developing the various products. It will be followed by a Public Round which will feature wider citizen involvement, also involve them in the data jams, policy hackathons and work on sustained behavioural change using matured products.

All pilots used a common approach to setting up their experimental design. This approach is based on work in European projects such as Interreg Zuivere Lucht[1] and LIFE VAQUUMS[2], which was simplified and transformed into a semi-structured interview approach that is now tried and tested for further use. This approach sets up the experimental design based on (1) a defined research question and key stakeholder expectations, (2) a crisp description of the experiment (what, when, how) and (3) a set of practical checks and balances (e.g. alignment with citizen engagement plan, analysis strategy, etc).

The Open Round featured experiments in all of COMPAIR's pilot regions.

- In Athens the pilot focused on engaging citizens in behavioural changes to reduce their carbon footprint and improve air quality. To this end the Aegean University and pilot team developed and tested a Carbon Footprint Simulation Dashboard and distributed air quality sensors. Three experiments were conducted:
    - Engaging with senior citizens in the Neos Kosmos area
    - Replicating this engagement in the Kipseli area (Public Round, preparations during Open Round)
    - Using carbon footprint calculations to raise awareness on the impact of daily activities and increase the support base through the related policy tool (Public Round, preparations during Open Round)
- In Berlin the pilot organised 2 experiments: mobile measurements to determine cyclist exposure stimulating behavioural change and the evaluation of a new parking scheme at the neighbourhood level. The first experiment aimed to assess people's perception of air quality, their commuting habits, and their views on sustainability-related public policies, while filling in gaps in the official high-end air quality monitoring network as a side-benefit. In the second experiment changes were made to parking spaces to promote communal and sustainable uses, and COMPAIR aimed to assess their impact

[1] https://www.projectzuiverelucht.eu/
[2] https://www.vaquums.eu/

on traffic and air quality through traffic, particulate matter and black carbon measurements using sensors.
- In Flanders the pilot planned for 2 experiments: demonstrating the impact of a school street in Herzele and evaluating a local mobility plan in Ghent both through citizen science. The second case however was hampered by legal action against the introduction of the mobility plan, the current outlook is to have it implemented in late December 2023 and take it up as part of the Public Round.
- In Plovdiv the pilot aimed to investigate the relationship between traffic intensity and levels of particulate matter (PM) and nitrogen dioxide (NO_2) around school areas in the city. The key objectives were to raise awareness of air quality around schools and identify areas for improvement to both traffic intensity and air quality.
- In Sofia the pilot project comprised two distinct use cases addressing air quality challenges in the city. One use case focused on the introduction of a school bus service to alleviate traffic congestion and reduce air pollution in the vicinity of schools. The pilot aimed to measure the impact of the school bus service on outdoor air quality near the school and transport modes used by school children and raise awareness on air quality among students. The other use case focused on indoor air quality in a kindergarten. The pilot aimed to compare the existing indoor air quality monitoring system (Canary) with other sensors and test the effectiveness of window meshes in reducing air pollution indoors.

Given the varying goals and context of each pilot, their approach was tailored and all of them featured one or more workshops to engage and/or recruit citizen scientists. All pilots faced significant challenges during the Open Round mainly due to delays in sensor delivery and technical issues with the devices or dashboards. In close cooperation with COMPAIR's technical teams, the pilots managed to identify most issues and worked on them, to have improved products in place for the Public Round. Despite the challenges, the pilots managed to get to some interesting conclusions during the Open Round.

- In Athens the main result is the successful involvement of senior citizens through the "Friendship Clubs" concept. In total, 21 sensors for particulate matter were distributed among participants in Neos Kosmos. The 21 participants - 16 of whom were senior citizens - collected data on particulate matter, humidity and temperature, while also filling out logbooks on activities that might correlate with the pollution levels. During the workshops and training as part of the "Friendship Clubs" concept, discussions were held on environmental issues with participants. Initial data analysis showed differences in pollution levels were attributable to local topography (e.g. lower pollution levels in elevated areas). Once measurements are up and running in the Kipseli area, further data analysis will be initiated as part of the Public Round and comparison of both regions, highlighting key differences and initiation of discussions with participants on logbook observations and activities influencing air quality, will be undertaken.
- In Berlin 14 citizens, primarily from areas with fewer official measurement stations, participated in the mobile measurement campaign. Over eight weeks they performed mobile air quality measurements and engaged on the topic through workshops. During those workshops they received expert advice and were able to perform self-assessments on pollution exposures. At key points during the campaign the pilot evaluated behavioural changes through surveys. Regarding the parking ban, the pilot launched a local engagement campaign on the new parking scheme. Eleven citizens

became closely involved, 2 of whom lived in streets where the parking changes were implemented, while the rest served as a control group. The measurement campaign is still ongoing. It started mid-June and will continue until the end of October with parking changes introduced in July. An introductory workshop on the parking scheme, sensor assembly and air quality took place, followed by a workshop over summer looking at intermediate results. A final workshop is being planned to assess the parking scheme's effects on traffic and air quality, with a focus on black carbon.

- In Flanders the pilot deployed 37 traffic sensors in both locations (Herzele & Ghent) and 7 bcMeters and 3 NitroSense devices in Herzele. Additionally, 2 NitroSense devices were deployed at a reference site in Ghent for calibration and performance monitoring. Due to legal action against the mobility plan in Ghent, this use case is not reported on further in the report. In Herzele the pilot directly involved 1255 students (both primary and secondary school) through an educational package on traffic (primary) and an expert talk on the AI recognition system in Telraam (secondary). 29 inhabitants of Herzele were directly involved in data collection and analysis. They received training and information in 2 workshops (traffic & air quality). Based on statistics available at the local level the pilot concluded that 28% or 348 participants represented a lower socio-economic demographic. Additionally, the traffic data collected by the citizen scientists clearly showed the positive effect of the school street. A great decrease in the number of vehicles in the school street was observed with only a minor increase in neighbouring streets. Two streets were identified as suffering a greater increase in traffic count with even illegal traffic moving in the opposite direction on a one-way street. COMPAIR and the local authorities are investigating flanking measures to mitigate this. Based on these results, the local authority decided to (1) extend the school street implementation and (2) expand it to another school in their territory. The air quality picture is much less clear, mainly due to data loss from poor connectivity. A potential, very indicative effect can be elucidated on a handful of days with good data at key locations. It seems that on average, pollutant concentrations during school street activation are 19% lower in comparison to other times during the day and compared to other locations.
- Both the Plovdiv and Sofia use cases were severely hampered in their execution because of the lack of LTE-M network coverage for sensor data communication.
    - In Plovdiv, only Telraam devices (older Wi-Fi version), 2 bcMeters and 10 *sensor.community* PM sensors were deployed. The local team cooperated with the Deputy of Mayors for Ecology and Education to recruit primary schools, resulting in 2 schools participating. At one school the team focused on awareness on traffic and air pollution by setting up a mobile reference station, Telraam device and PM-sensor. At the other school the focus was on seasonal variations in PM levels. This school was located fairly close to a reference monitoring site, allowing the pilot to use that reference data as well. Preliminary data analysis for the school with the mobile station shows coinciding increases in traffic and NO_2 corresponding to the school opening and closing hours. Non-school days showed lower overall NO_2 concentrations. For particulate matter this relation was not clearly observed, however the influence of nearby roadworks was discernible.
    - In Sofia the local team deployed 10 *sensor.community* devices at two schools participating in the school bus project. Due to connectivity issues no other pollutants were monitored at this time. A survey that was conducted by the

team showed that 33% of respondents (students) used the bus service, which was also evidenced in passenger counts. Based on these results, the service was extended for the entire school year of ‘23-’24. Due to budget constraints, the installation of the window meshes at the kindergarten was delayed. The local team managed to deploy PM sensors, which showed correlations between outdoor PM levels and indoor PM levels measured by the Canary. The pilot hopes to demonstrate the effectiveness of the window meshes upon installation in the Public Round.

The activities in the Open Round allowed pilots 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 overall device deployment plans. In Berlin, the challenges of participant registration and commitment highlighted the importance of clear communication. The "Data Café" approach - in which citizens can freely walk in and out to have in-depth discussions on the experiments, data and policy - was effective for knowledge sharing, while continuous support was crucial for maintaining participants over prolonged periods. 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.

In Flanders, local champions played a pivotal role. Adaptive planning was necessary to address unforeseen challenges. The "Data Café" approach also enhanced engagement, but extended data collection periods are essential for a more robust assessment. The Sofia and Plovdiv activities emphasised the importance of close cooperation with teachers for student engagement, along with transparent communication with parents about device functionality. Connectivity issues posed challenges in both Sofia and Plovdiv, providing a clear working point in light of a more connected European Union. In Plovdiv, trust-building with local stakeholders, addressing electricity grid limitations, and planning for more Wi-Fi-connected devices were other important take-aways.

These lessons will shape the Public Round of the COMPAIR project due to start November 1st 2023 and end June 30th 2024, enhancing our engagement, data collection, and communication with participants and stakeholders.

1. Introduction

In this report, we delve into the multifaceted pilot projects conducted during the Open Round, offering a detailed exploration of the activities, results, and valuable lessons learned throughout the pilot experiments. The Open Round represented a pivotal phase in the COMPAIR initiative, where innovative approaches to air quality & traffic monitoring, policy options and community engagement were put into practice.

The Open Round follows COMPAIR's Closed Round in which only project partners were involved in product development and testing, a.o. the closed round performed a benchmark of the available sensor devices. The Open Round built on this by involving citizens closely related to participating organisations involving them in data collection, analysis and visualisation while still developing the various products. It will be followed by a Public Round which will feature wider citizen involvement, also involve them in the data jams, policy hackathons and work on sustained behavioural change using matured products.

The Horizon2020 project COMPAIR is 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 Open Round related to air quality and mobility in urban environments. The Open 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 Open Round, summarising their key objectives, methodologies, findings, and the valuable insights gained. 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 mission: 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 aim 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. Open Round testing methodology

A critical factor in achieving both a sustainable environmental impact and behavioural change through our pilot experiments, is proper experimental design. VMM, WP6 and Open 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] was developed as part of COMPAIR's WP6 and applied in pilot discussions.

The Open Round experimental designs were based on pilot interviews conducted by VMM (experimental design expertise) and IMEC (technical development expertise). The pilot lead teams were interviewed twice and were able to contribute to the resulting experimental design document. VMM and IMEC summarised the results of these interviews in a draft experimental design table which was reviewed and approved by all partners. Upon start of the Open Round experiments, the experimental design document was maintained as a living document and updated with changes to timing and scope given the actual situation on sensor production, recruitment, policy implementation, etc.

The Open Round experimental design summary provides a backbone to the Open 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 Open Round, lessons will be learned on this process and a new iteration will be performed in preparation for the Public Round. We have provided the May '23 snapshot of this living document as an example in **Annex 1 – Experimental design document May '23 example of living document**.

2.1. Adaptation of LIFE VAQUUMS air quality sensor roadmap and INTERREG Zuivere Lucht's guidelines

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 points of this methodology. Please note that the summary of each method uses the method's terminology (e.g. 'sensor networks is to be interpreted very broadly encompassing also personal, mobile measurements etc.)

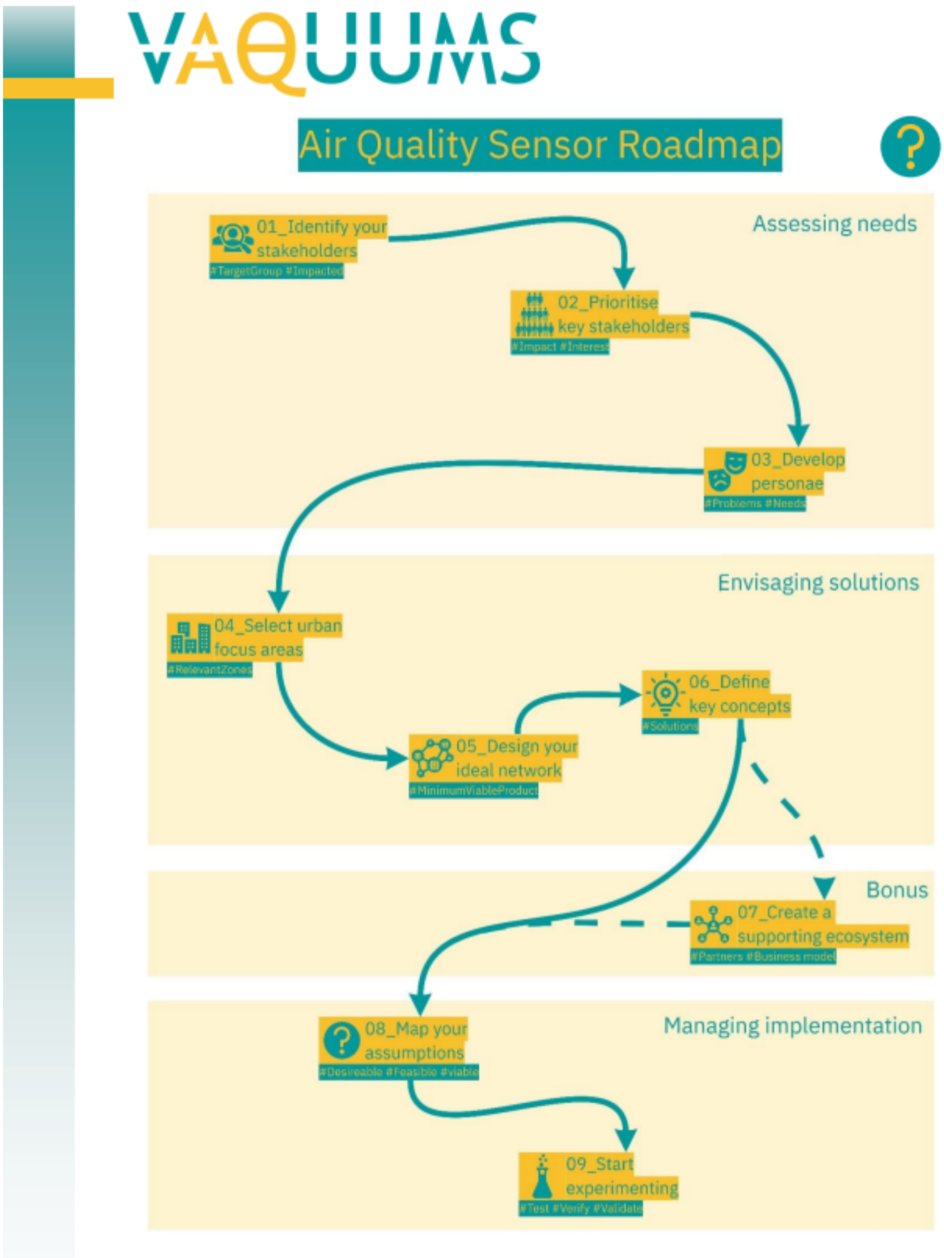
The **standard LIFE VAQUUMS roadmap** consists of three journeys (steps or phases), each encompassing three elaborately described steps.

- The first journey is on assessing needs, by developing personae (fictional characters representing different user or stakeholder types[3]). It describes how to empathise with

[3] https://www.interaction-design.org/literature/article/personas-why-and-how-you-should-use-them

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 the sensor network.
- The second journey starts 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 trialled or prototyped in the ensuing experiments. At this stage, use cases linked to stakeholder challenges and technical parameters are developed.
- In the final journey, assumptions are mapped and experiments are defined that allow for validation of those assumptions to start building the sensor network through experimentation. Typical assumption categories used are desirability, feasibility and viability. At the end of this journey, experiments are prioritised, put on a timeline and eventually developed into a project plan.

Figure 1: *Schematic representation of LIFE VAQUUMS air quality sensor roadmap*



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 - or in COMPAIR's implementation: citizen science initiator - should ask before starting their own experiment (the questions marked with a double asterisk ** were copied as a starting point for our interview guide):

- 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, 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. These interviews were undertaken with the pilot teams initiating the citizen science projects and conducted by the Open Round task lead (VMM) and technical team representative (imec). Questions, other than the ones marked with a double asterisk, 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 (first journey)**: 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 (project partners initiating the citizen science projects), citizens and local policy makers were considered in the interview and no other stakeholder identification or prioritisation was undertaken.

- **Envisaging solutions (second journey)**: as COMPAIR's implementations are already centred 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 use 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 (third journey)**: 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 design document.

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

1. Use case definition (combination of research question and stakeholder expectations)
    a. Context:
        i. What challenges does your pilot face in light of air quality and traffic?
        ii. Is there a policy change related to this challenge 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, once the type of sensors was clarified in the first iteration of the interview.
   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 and dashboard releases?
   d. How are you handling citizen engagement and lower socio-economic status (LSES) 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 externally).

Final note: in COMPAIR quality control of sensors was covered at a different stage and centralised level (across all pilots). Hence, guidelines on quality control and assurance were not included in this list. COMPAIR will provide a generalised version of this approach on its website.

2.2. Structuring and key elements of experimental design

Based on the above, COMPAIR elucidated an experimental design summary (**Table 1**) focussed on the 3 main topics of the semi-structured interview:

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

Table 1: *Experimental design table template*

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 Open Round testing outcome

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 bringing about behavioural change towards reducing their carbon footprint and improving air quality. These two dimensions are going to be achieved through the development of a Carbon Footprint Simulation Dashboard and the distribution of air quality sensors. In this section, a detailed description of senior citizens' engagement and sensor distribution activities undertaken in Open Round testing are included. The main objective of the Open Round in Athens is to raise awareness on air quality among citizens targeting elderly inhabitants in the area of Neos Kosmos, selected after internal discussions with the Municipality of Athens. The Public Round will feature two use cases which are also summarised here as the preparations for these experiments have already commenced during the Open Round.

Athens use case 1 – Neos Kosmos

Table 2: *Purpose, research questions and hypothesis for Athens use case 1*

Experimental design for Athens - use case 1	
Purpose	Creating awareness on air quality among elderly habitants of Neos Kosmos
Research question(s)	Focus on awareness
Hypothesis	Collect variations in PM, humidity and temperature across Neos Kosmos of varying temporal frequencies such as daily, monthly, seasonal, etc

The activities carried out in the Open Round were initiated by internal meetings with the Municipality of Athens and specifically the Agency of Social Affair and Solidarity that is responsible for the operation of the Friendship Clubs. Then, meetings with the administration of the Neos Kosmos Friendship Club were held in order to engage them with the scope of the Athens pilot. Additionally, workshops were organised for mobilisation of the target group, as mentioned in the section below.
In collaboration with the administration, volunteers were identified that met the criteria for the participation in the pilot and were also provided with sensors. They were members of the Club living in the area (shown in **Figure 2**) with a house that had an outdoor area for placing the sensor.
In terms of measurements of sensors and hypothesis, it was aimed at collecting variations in PM, humidity, temperature across Neos Kosmos at varying temporal frequencies such as daily, monthly, seasonal, etc. Also, the end-users gained insight on behaviours that affect air quality, by observing local activities such as extreme weather conditions, severe traffic,

roadworks, etc. and correlated these with measurements. As a final step in the forthcoming period, it is aimed to allow for discussions with the elderly in order to elaborate on the visualisations and the collected data and to generate insight in their own behaviour affecting air quality.

In total, during the Open Round DAEM had the availability of:

- 11 sensors from *sensor.community*
- 26 SODAQ AIR devices for the Open Round

And distributed to participants:

- 6 sensors from *sensor.community*
- 15 SODAQ AIR devices

In total the participants of the Open Round were 21, among them:

- 16 were from the LSES group of senior citizens (over 65 years old, majority retired)
- 5 were adults (less than 65 years old)

Figure 2: *Athens pilot area #1 - Neos Kosmos*

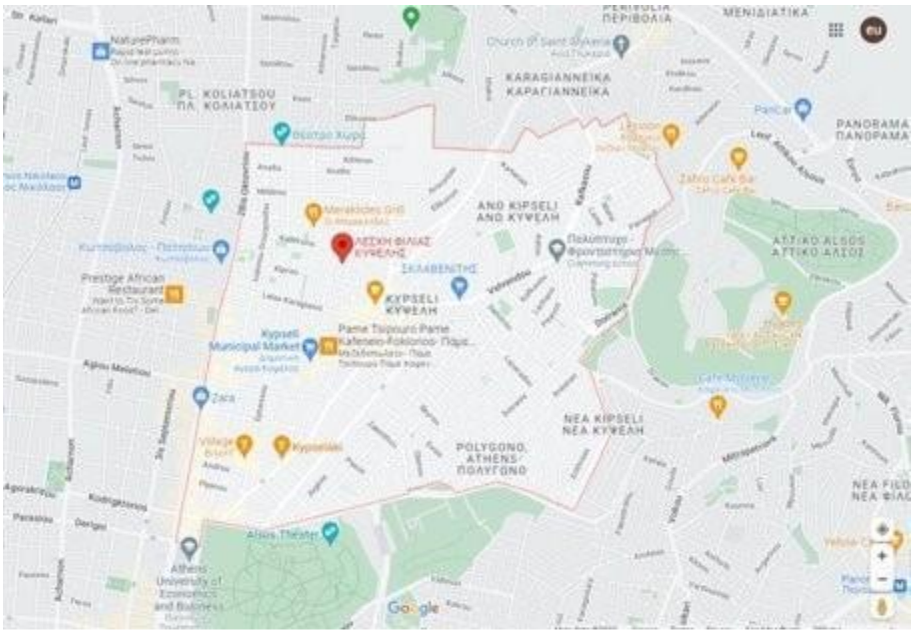
Athens use case 2 – Kipseli (future Public Round case)

Table 3: *Purpose, research questions and hypothesis for Athens use case 2*

Experimental design for Athens - use case 2	
Purpose	Creating awareness on air quality among elderly habitants of Kipseli
Research question(s)	Focus on awareness
Hypothesis	Collect variations in PM, humidity and temperature across Kipseli of varying temporal frequencies such as daily, monthly, seasonal, etc. Comparison of variations among Neos Kosmos and Kipseli

The second use case that is planned for the Public Round will actually be a replica of the Use case 1 applied in the area of Neos Kosmos to the 2nd area of interest for the Athens pilot, Kipseli as shown in **Figure 3**.
The experiment will follow the same approach as use case 1. The first step will be to inform and receive official agreement by the Municipality of Athens for the engagement of senior citizens in the Friendship Club of Kipseli. This action has already been completed.
Then workshops will be organised for the mobilisation of volunteer end users. The same approach of logbook completion will also be followed as in the Open Round, aiming to support seniors in understanding the effect of various events in the air-quality and in interpreting the measured data and comparing those to their air quality.
Also, in use case 2 it is planned to deploy bcMeter and NitroSense devices to measure black carbon (BC) and nitrogen dioxide (NO_2) in the 2 areas in buildings that are under the administration of the Municipality of Athens. The purpose of this advancement in the Public Round will be to discover BC and NO_2 concentrations at these locations.
The COMPAIR Athens pilot team will ensure sufficient monitoring of the measuring devices using the COMPAIR tools and dashboards.

Figure 3: *Athens pilot area #2 - Kipseli*



At a later stage of the Athens pilot measurements made in use case 1 and 2, will be integrated in the Athens Digital Twin for policy making support.

Athens use case 3 – carbon footprint (future Public Round case)

Table 4: *Purpose, research questions and hypothesis for Athens use case 3*

Experimental design for Athens - use case 3	
Purpose	Calculating carbon footprint using dashboard
Research question(s)	Focus on raising awareness on daily activities and on the carbon footprint that is produced at a household level
Hypothesis	Citizens can contribute to reduction of CO2 if they familiarize with their carbon footprint

The third use case, also planned for the Public Round, includes the engagement of citizens of Athens to calculate their carbon footprint using the Carbon Footprint Simulation Dashboard. The goal is to raise awareness on citizens' daily activities and on their carbon footprint that is produced at a household level and it is based on the vision that citizens can contribute to the reduction of CO2 if they familiarise themselves with their carbon footprint. The answers in the CO2 calculator and the adoption of improved daily habits will showcase the behavioural change, as well as the intention of end-users to adopt policies proposed in the policy planning feature. Finally, the policy planning feature of the tool will be utilised for citizens' participation in decision support.
The target audience will be engaged through planned online activities and campaigns and also in person for senior citizens that are not tech savvy and will need support in providing the necessary inputs into the Carbon Footprint Simulation Dashboard.

3.1.1.2. Experimental design

Focusing on the use case 1 that was launched in the Open Round, the sensors that were distributed for the citizen science activity were SODAQ AIR and *sensor.community*[4] sensors. The measurements include $PM_{2,5}$ and PM_{10}, as well as temperature and humidity.

The Open Round of the Athens pilot was deployed in the neighbourhood of Neos Kosmos within the district on the balcony of individual residences (apartments preferably on lower floors) of elderly participants.

Senior citizens for the Athens pilot are the main LSES group targeted, hence end-users in this group are elderly citizens and the majority of them are retired. The Municipality has provided the age threshold of 65 years old for the definition of seniors. Seniors engaged in this use case, take part in the socialising centre of Neos Kosmos called "Friendship Club" that is operated by the City of Athens. A minor percentage of end-users engaged in this use case were not in the group of seniors but adults who were contacted through the contacts of DAEM for the Open Round.

The *sensor.community* devices were preconfigured and assembled by DAEM and at the distribution meeting the Wi-Fi credentials of the volunteers were updated. Then DAEM

[4] https://sensor.community/en/

updated the settings in the *sensor.community* relevant page by inserting the new Wi-Fi details and the new location information for the sensors. Volunteers were requested to confirm that they have space in an outside part of their houses to set up the devices (as shown in **Figure 4**) and also were asked to bring the Wi-Fi credentials during the distribution meeting, so that the DAEM team could perform the necessary configurations. However, this was the major obstacle for the *sensor.community* devices, since it was noticed after the engagement phase that a vast majority of senior citizens had not provided DAEM with correct credentials. It was found that it is naturally difficult for the older population to note down or find the correct Wi-Fi name and password. However this experiment did expose the technical challenges that the Athens pilot wishes to overcome as part of COMPAIR.

Figure 4: *Sensor installed on the windowsill - Neos Kosmos*

A similar procedure was followed for the SODAQ AIR sensors. The devices were pre-charged for the convenience of the end-users.

All volunteers received a copy of the logbook. The methodology of keeping a logbook was proposed by VMM as a format where elderly citizens keep track of outdoor activities that could help correlate to sensor data. It was agreed jointly among VMM and DAEM to provide printed logbooks to the seniors participating.

The initial planning of the pilot foresaw the monitoring of measurements by end-users and DAEM through the project's platforms and to proceed to discussions on them. However, it coincided with the summer period when Friendship Clubs are closed. It is planned to reconvene with this action point in the forthcoming months.

The duration of the use case 1 is planned to be active for 1 year and also be enhanced with more end-users. Hence, during the next months of the Public Round more volunteers will be engaged from the area of Neos Kosmos. Also due to the fact that the *sensor.community* devices were not usable enough for the audience of the Athens pilot, it is planned to replace them with SODAQ AIR devices for the initial end-users, since SODAQ AIR devices are plug-and-play and more devices will be delivered for the Public Round.

3.1.1.3. Workshops

For the engagement and sensor distribution to seniors of the Friendship Club of Neos Kosmos a series of meetings and workshops were organised. At the first stage, a discussion with the Deputy Mayor of Social Affairs and Solidarity was held along with the Head of Seniors Citizens Department. Then, DAEM team and the administration of Friendship Club of Neos Kosmos discussed bilaterally, in order to present pilot activities scope and objectives as well as the process of volunteers' engagement. In total 4 workshops, starting from 18/5/2023, were organised and the first one had the following structure:

- Presentation of COMPAIR objectives
- Presentation of the Athens pilot scope and activities
- Demonstration of diverse types of sensors
- Clarifications
- Bilateral discussions with seniors when they confirmed their participation in the pilot
- Logbook distributed for observations

In the follow-up workshops (as shown in **Figure 5**), troubleshooting actions continued, including tasks that are mentioned in the previous sections (i.e Wi-Fi configuration, plugging issues, etc). In addition, interesting discussions were held on environmental issues, on quality of life, and even on technology matters. The importance of these workshops as well as their outputs and feedback are described in the next sections.

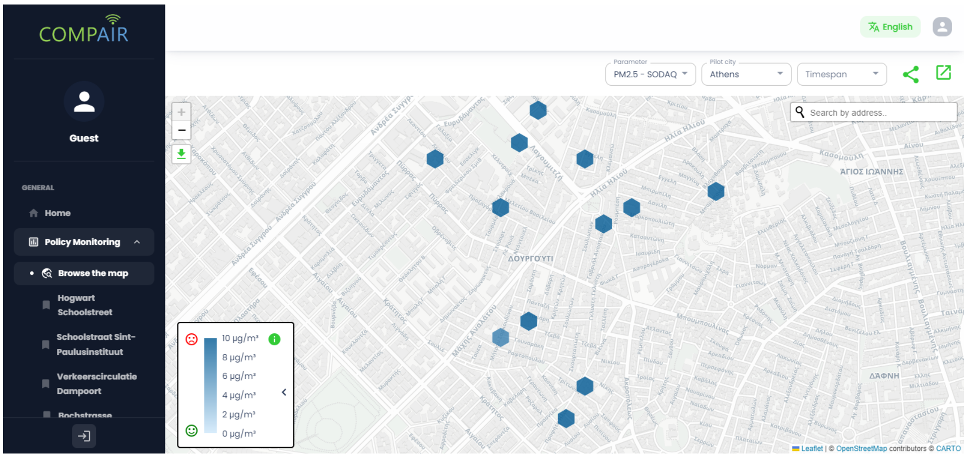
Figure 5: *Neos Kosmos Friendship Club venue*

3.1.2. Results

3.1.2.1. Analyses

The planned analysis for the Athens pilot is mainly focused on comparing the data from the 2 areas of Kipseli and Neos Kosmos, hence the core part of the data interpretation will be done during the Public Round of the pilot. Nonetheless, it was also foreseen to analyse data at various aggregation levels within each area (monthly, seasonal etc).
Taking into account the targeted audience of seniors, the analyses are planned to be communicated at a higher level to them, omitting difficult to understand terms and details.
The analysis will also correlate the data from the Neos Kosmos area with the logbooks' observations. This is a task that will take place during the Public Round, since Friendship Clubs pause their activities for the whole summer period.
During the COMPAIR general assembly in September a series of data interpretation and data processing workshops were hosted, so that pilot teams can familiarise with the data analyses. This is an ongoing task and its implementation is also envisioned for the Public Round for the Athens pilot use cases.

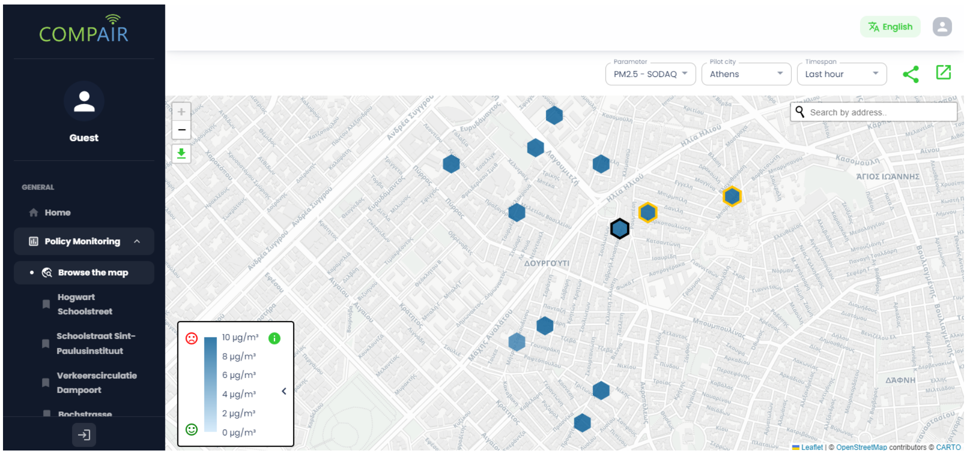
Figure 6: *PMD print screen - Neos Kosmos*



3.1.2.2. Results

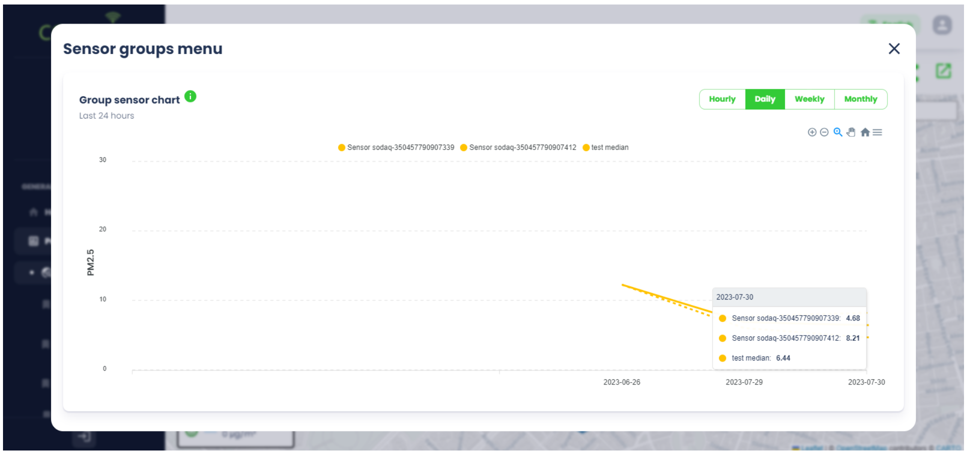
Figure 6 is evidence to show that the SODAQ devices were successfully measuring data upon deployment. In addition to this, when two sensors are grouped in the PMD, it is found to be indicated in a yellow highlight as seen in **Figure 7**.

Figure 7: *Indicative analysis of Neos Kosmos data*



To elaborate on these observations, as seen in **Figure 8**, the sensor ending in 412 measured double $PM_{2.5}$ concentration for a specific day than the sensor ending in 339 - 8.2 μg/m^3 and 4.6 μg/m^3, respectively. This was expected, since the second sensor (339) is located on a hill with better air quality, while the first sensor (412) (though located only a few blocks away) is surrounded by streets with more traffic.

Figure 8: *Indicative analysis of Neos Kosmos data*



3.1.3. Lessons learned

Positive general feedback

After the completion of the workshops and sensor distribution, the general feedback is very positive, since the interest from the seniors and volunteers in learning more is high. They were also motivated and enthusiastic to contribute to measuring pollution. Although the targeted group for this pilot is senior citizens, thus people over 65 years old, their interest in activities referring to more technical tasks, is indeed very remarkable. Elderly people are a citizen community eager to learn day by day and sensitive to environmental issues. Hence, their engagement succeeded.

Engagement process

Lessons learned from the engagement of people of the Friendship Club of the first selected area are described below in detail. These lessons have been helpful and useful to DAEM in planning the engagement of seniors from the Friendship Club of the second area as well as volunteers that expressed their interest through the COMPAIR 's website.

Unfortunately, the citizens that expressed interest in the experiments through the COMPAIR website were not located in Neos Kosmos or Kipseli. For that reason DAEM plans to update the relevant page information and to add in the website dedicated web pages with more specific information regarding criteria for volunteer selection.

PM sensors

In terms of the types of sensors that were handed over, specific feedback was collected and important lessons learnt have been derived.

Firstly, for the *sensor.community* devices, they were promoted as a research product and were very preferable by end-users. Also the cable was easy to use in case an outside plug is not available. Constraints were noted on their pre-configuration. Despite the pre-configuration, elderly citizens did not manage to transmit data effectively, Wi-Fi details are necessary and seniors gave them wrongly. Troubleshooting therefore wasn't easy in combination with the fact that some plugs were not functioning.

Regarding the SODAQ AIR sensors, they were easy to use and the dashboard developed by SODAQ for monitoring was also very useful for the Open Round. The negative points are that there is no indication when the battery is low and the charging of the devices is not convenient. For these problems to be solved, the plan is to give to the end users of the Public Round plugs for continuous charging.

The DAEM pilot team received many concerns on the power that is necessary for the charging and transmission of data for both the *sensor.community* and the SODAQ AIR devices which were later addressed during the Open Round testing.

bcMeter

Additionally, two bcMeters are also distributed to DAEM and they aren't yet handed over to end users, they are at the company's premises for testing purposes and the measurements are represented in the bcmeter.local webpage. The result from the testing process is that they are not easy to use by non-technical people, hence if they will be distributed, a focused onsite troubleshooting will be required. Measurements are expected to be integrated in the COMPAIR PMD, as soon as the devices are troubleshooted.

NitroSense

Two NitroSense devices received by DAEM (that are not intended to be handed over to citizens) are also being tested at the company's premises in order to be able to measure NO_2 in the Public Round. The NitroSense devices do not have a monitoring dashboard yet but measurements are expected to be integrated in the COMPAIR dashboard PMD.

All bcMeters and NitroSense devices will be installed in municipal buildings in the two areas of interest.

A final take away from the Athens pilot is the difficulty to collect effective and continuous measurements in a citizen science (CS) project, if a lot of technical work is required of seniors. Even the Wi-Fi credentials can be a problem or the reminder to charge the devices, since seniors - and others with busy schedules - tend to forget easily. Generally, a citizen-science project requires vast effort in field work and interventions with each volunteer individually which limits the number of end-users that can be supported.

3.2. Berlin pilots

3.2.1. Activities

3.2.1.1. Purpose, research questions & hypothesis

In Berlin, INTER3 organised 2 experiments: mobile measurements to fill in gaps in the official high-end air quality monitoring network and the evaluation of a new parking scheme at the neighbourhood level.

The goal of the mobile measurements was to ascertain the exposure of cyclists and school children on their way to school/work, evaluating both spontaneous and “helped" behavioural change. Spontaneous behavioural change refers to citizens changing their behaviour based on their access to the most basic data on PM pollution along their commute routes. “Helped” change, on the other hand, is more informative and provides, along with information on individual and cumulative exposures, a set of recommendations to adopt more healthy behavioural patterns. The overarching aim is to carry this experience to other cyclists and schools across Berlin.

The goal of the second measurement campaign was to demonstrate the positive effect of a local parking ban on liveability in the affected neighbourhood. Apart from understanding the impact on air quality and traffic, the campaign also aimed at involving residents from the neighbourhood and building support for this specific measure through monitoring and data workshops.

Use Case 1 – mobile measurements across Berlin

Table 5: *Purpose, research questions and hypothesis for Berlin use case 1*

Overview of Berlin’s experiment - use case 1	
Purpose	The goal of the mobile measurements was to ascertain the exposure of cyclists on their way to work, evaluating “helped” behavioural change. “Helped” change is informative and provides, along with information on individual and cumulative exposures, a set of recommendations to adopt more healthy behavioural patterns. The overarching aim is to push this experience to other cyclists across Berlin.
Research question(s)	The following questions will be addressed through experiments: A. What is the cumulative exposure across a cyclist’s route? What are hotspots along the route? B. How does an individual participant’s exposure relate to his/her peers? C. How does individual behaviour change based on the data presented?
Hypothesis	- A: Cyclists will encounter PM hotspots along their individual routes - B: Cumulative exposure at the group level follows a normal/Gaussian distribution - C: Participants will be triggered to varying extents of behavioural change when examining their own data

Use Case 2 – reconfiguration of parking spaces

Table 6: *Purpose, research questions and hypothesis for Berlin use case 2*

Overview of Berlin's experiment - use case 2	
Purpose	The goal of the second measurement campaign was to demonstrate the positive effect of a local parking ban on liveability in the affected neighbourhood. Apart from understanding the impact on air quality and traffic, the campaign also aimed at involving residents from the neighbourhood and building support for this specific measure through monitoring and data workshops.
Research question(s)	The following questions will be answered through the experiment: A. Can "looking for parking" traffic be distinguished in Telraam data? (i.e. time of day etc.) ○ Because of the parking ban, has incoming traffic at key moments reduced? B. What is the effect on $PM_{2.5}$ concentrations before and after implementation? C. What is the effect on BC concentrations before and after implementation?
Hypothesis	- A: Clear reduction in traffic intensities at times when non-inhabitant traffic is largest (should be close to 0, but might be difficult to distinguish) - B: There will be no effect on PM levels - C: There will be an effect on BC concentration at specific time of day, either on absolute level or in the ratio to the background location - D: Over time, the occurrence of certain elevated levels (e.g. PM) could be explained by things like e.g. wood burning…

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 high-end measurement stations 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 to other areas in the city with similar characteristics.

Despite the 17 high-end air quality stations in Berlin, 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[5], 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 on the meta level pertaining to citizen behaviour, and another prioritising data collection on particulate matter (PM).

Table 7: *Experimental outline for Berlin use case 1*

<table>
<tr><th colspan="2">Experimental design for Berlin - use case 1</th></tr>
<tr><td>Type of experiment</td><td>Comparative
Descriptive
Threshold testing</td></tr>
<tr><td>Design</td><td>What
➔ Mobile $PM_{2.5}$, PM_{10} measurements
➔ 15 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
➔ Before “helped” behavioural change: late July until early September
➔ After “helped” behavioural change: early September until late October
How
➔ Devices provided to participants and assembled at workshops
➔ Device(s) monitoring:
◆ By both pilot staff and citizens via SODAQ’s knowyourair platform
➔ Pilot lead will host an interim workshop with participants to discuss ongoing results, observations and to get feedback on measurement campaigns as well as to induce helped behavioural change. See campaign breakdown below.</td></tr>
</table>

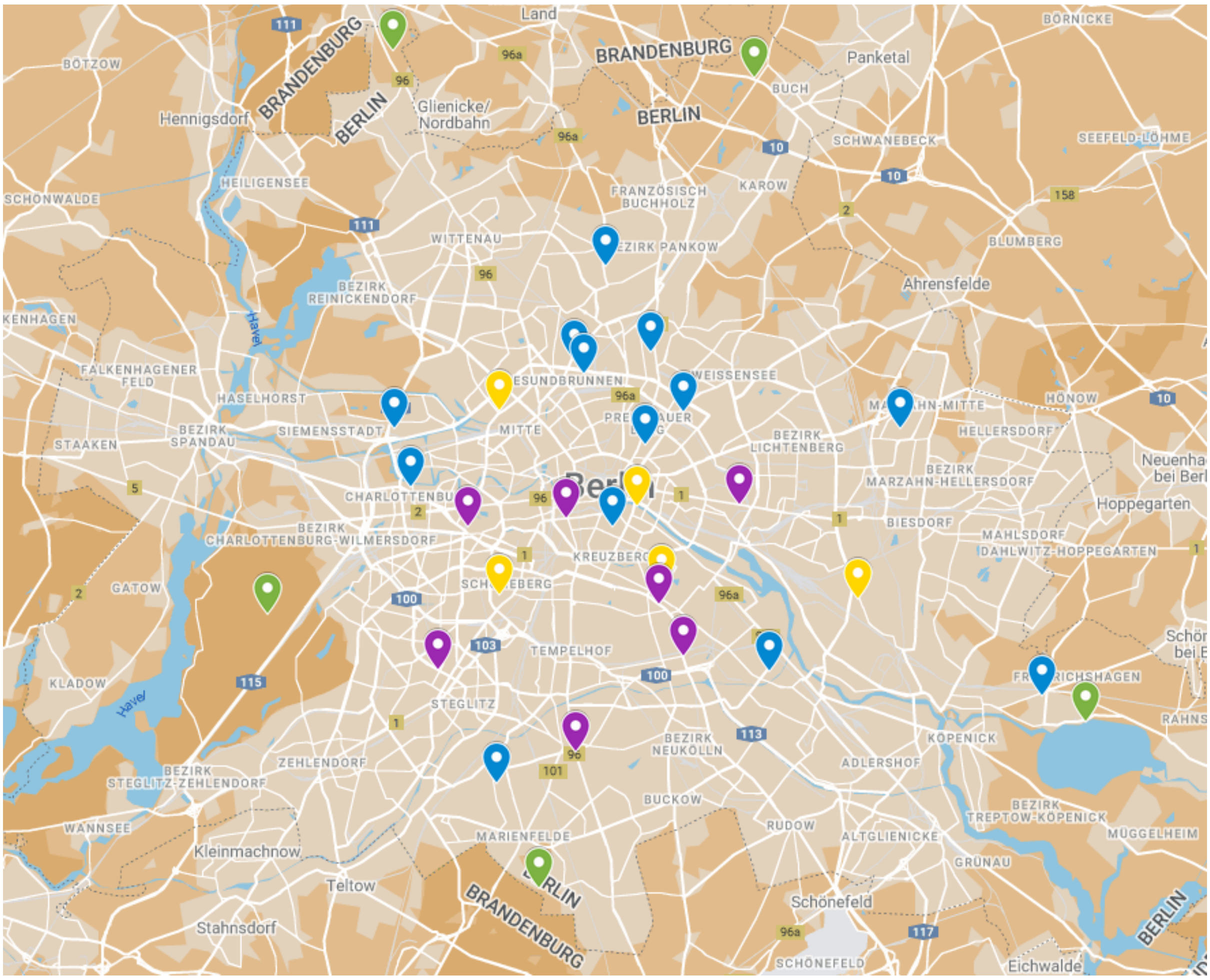
[5] https://www.eea.europa.eu/themes/air/urban-air-quality/european-city-air-quality-viewer

The first goal of the campaign was to assess how citizens perceive air quality, what means of transport they usually use for their commute, how often they commute along their regular routes and how they rank different public policies related to sustainability. The idea was for citizens to measure and engage with air quality over the course of 8 weeks and gain more insights into the topic. Apart from their self-assessment of pollution exposure, expert advice was provided during the measurement campaign detailing individual and group exposures to participants. The aim was to further strengthen the perceived importance of air pollution and its adverse health effects in order to push participants into more sustainable behavioural patterns. To assess the behavioural effect of the campaign and the expert advice, a second survey was conducted at the end of the campaign.

In the context of the data collection network of official measurement stations, the second aspect of the campaign was 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 14 citizens participating in the mobile measurement campaign in Berlin during the Open Round. Most of the citizens came from areas of the city, primarily city outskirts, where official measurement stations are scarce. The distribution of the residences where participants live can be seen in the map below.

Figure 9: *Map outline - BLUE: Residence locations of participating citizens; PURPLE: Official stations along high traffic roads; YELLOW: Official stations in urban background locations; GREEN: Official stations 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 the knowyourair.com platform. Participants collected data between August and October 2023, 3 - 5 days a week for at least 2-3 weeks along their regular commuting routes. They were told to regularly consult the map 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 September 6 to provide a more fine-grained picture on individual and cumulative exposure patterns. Berlin's COMPAIR team recommended potential new routes and nudged the participants to adopt more sustainable behaviours, or at least reframe their thinking patterns. After the workshop, the citizens set out to measure air quality for another 2-3 weeks potentially taking the newly recommended routes. A final workshop on October 25th engaged the citizens in a more interactive way, providing more insights into the collected data and encouraged citizens to discuss their (changed) perceptions on air quality, traffic and public policy measures supportive of sustainable mobility and air quality improvements.

Table 8: *Breakdown of the mobile measurements campaign in Berlin*

Breakdown of the mobile measurement campaign
1. First questionnaire assessing baseline behaviour
2. Baseline exposure measurement 4-5 weeks
3. Workshop collecting self-reported behavioural change and insights. Expert analysis and advice (e.g. histogram, route advice, maps of collated data, etc) and follow-up information by email
4. 4-5 weeks helped exposure evaluation
5. Workshop reflecting on helped behavioural change, expert advice, useful metrics, etc.
6. Final questionnaire reflecting on helped behavioural change, expert advice, useful metrics, etc.

August 2023

October 2023

Use Case 2 – reconfiguration of parking spaces

Table 9: *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 ➔ 8 *sensor.community* devices ➔ 5 bcMeters ➔ 2 Telraam devices **Where** ➔ Background location ◆ residential area with sufficient distance from traffic roads: ◆ 1 *sensor.community* device ◆ 1 bcMeter ➔ Graefekiez ◆ mixed zone area of small stores/coffee shops/restaurants on the lower floor and residences in the upper floors ◆ 6 *sensor.community* devices ◆ 4 BCmeters ◆ 2 Telraam ➔ Unaffected street location outside Graefekiez ◆ 1 *sensor.community* device **Who** ➔ Device(s) assembly: ◆ *sensor.community*, Telraam and bcMeter: Participants, initially helped by pilot staff ➔ Device(s) installation: ◆ *sensor.community*, Telraam and bcMeter: Participants by following translated instruction manuals **When** ➔ The "before" or "baseline" measurements start in June before the ban has been implemented ➔ The "after" or "policy" measurements start on July 17 **How** ➔ Devices provided to participants and assembled at workshops ➔ Device(s) monitoring: ◆ *sensor.community*: Pilots staff via *sensor.community* dashboard and admin page/Grafana ◆ bcMeter: regular check-ups via email, asking citizens to send .csv files ◆ Traffic: Telraam dashboard and PMD ➔ Pilot lead will host data café 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 Berlin's Graefekiez, a set of measures aimed at reconfiguring parking spaces towards more communal and sustainable uses was introduced on July 17 2023. Apart from enabling a platform to engage residents and get them together as a community, the mobility measure aimed primarily at understanding how banning parking would affect traffic flows. COMPAIR became part of the project in the early days of 2023, aiming at involving local residents to not only assess the effect of the mobility measure on traffic but also on air quality.

The engagement campaign started in April 2023 and successfully involved 11 citizens by the beginning of the measurement campaign in June. Scattered around the neighbourhood, two of the citizens lived on the two street sections where the park space ban was implemented, while the rest were distributed around other similar streets, serving as a control group. Finally, a background location was selected to serve as a benchmark during the assessment of the final effect of the mobility measure. Citizens measured the flow of traffic with Telraam devices and two types of pollutants - black carbon with bcMeter, an experimental sensor, and particulate matter with *sensor.community* devices, shown in **Figure 10**. Measuring black carbon was particularly interesting because there is generally little data on this pollutant in Berlin, least of all on the local neighbourhood level.

Figure 10: *Map showing the measurement location and type of sensors placed in Graefekiez, Berlin*

The measurement campaign began mid-June and ended in October 2023. During that time period, the parking ban measure (in the two street sections marked with a red line) was implemented on July 17. The measurements were conducted during the entire period to assess whether the mobility measure had an effect on traffic, black carbon and particulate matter, taking into account citizen data from the two action streets, surrounding streets and the background location.

Figure 11: *Engagement flyer*

3.2.1.3. Workshops

Use Case 1 – mobile measurements across Berlin

There were a total of 4 workshops that took place during the mobile measurement campaign. The first two workshops, organised on July 26 and August 9, were attended by 14 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 third workshop, which took place online, 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 in groups, sharing what they learned until then and presenting their thoughts to the other participants. Each citizen was provided with a set of recommendations per email after the workshop, including alternate bike routes and ideas on how to adapt behaviour in order to decrease exposure to air pollution.

The final workshop was a data analysis workshop during which all the collected data was analysed. The citizen scientists contributed to a very fruitful discussion on what the issue of air quality means to them after the measurement campaign and how the new insights will and won't change their behaviour.

Use Case 2 – reconfiguration of parking spaces

The second measurement campaign began with a workshop on June 13 near Berlin's Graefekiez. 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 Graefekiez case. The next session focused on explaining the study design to assess the effect of the parking ban, integrating additional feedback from the citizens. In the final, interactive session, citizens learned how to assemble and use the two air quality devices - bcMeter (black carbon) and the *sensor.community* devices (PM). After the workshop, citizens were given additional information on sensor usage, management and data retrieval.

A second event, a data café, took place on August 8 and presented a first overview of the data collected by citizens. Although by that time the effect of the parking ban was not yet assessed, it was still interesting to see what data was collected during the 6-week period and how it compared to official measurements.

A final data workshop will take place on November 16. There, citizens will analyse their own data and assess the final effect of the parking ban on air quality and traffic in the neighbourhood. Special focus will be placed on black carbon, as the biggest changes are expected with this pollutant.

3.2.2. Results

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 together with precipitation data in order for citizens to understand the relationship between these two variables and to contextualise the fluctuating PM values. 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.

Use Case 2 – reconfiguration of parking spaces

The main purpose of the second use case was to test the effect of a parking ban on local air quality and traffic flows. A network of traffic, PM and black carbon sensors was placed around the neighbourhood so that citizens were measuring in action streets (with parking ban) and surrounding streets (without parking ban). This was done in order to control for other potential variables that could potentially contribute to changes in air quality and traffic flows other than the parking ban. Local residents started measuring air quality and traffic flows in their respective streets in June before the parking ban (started on July 17) and continued collecting data until the end of October. Apart from the before-after analysis, a correlation analysis was conducted to compare car traffic with pollutant concentration levels.

3.2.2.2. Results

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 average PM exposure over the course of ten weeks. The beginning and end of August, as well as late July, were relatively humid, with a dry period marking the middle part of the measurement campaign mid-August. Moreover, citizens were provided with information on precipitation and temperature levels during that time period in order to get a better understanding of the fluctuation of PM values. As can be seen, PM values tended to be generally lower around the time with some precipitation and higher during the period with no rainfall. The upward trend in PM levels near the end of September could also be explained by lower temperatures leading to higher heating rates across the city.

Measuring concentration levels during certain times of the day also gives a better insight into how exposed participants were during morning and evening rush hours. As the graph below shows, highest pollution levels were recorded between 7am and 8am. A rising tendency can also be observed towards the end of the workday. Most measurements were taken during that period as well, lending credence to the idea that morning and evening rush hours truly do contribute to higher concentration levels during those periods of the day.

Figure 12: *Average PM2.5 values (left axis) and precipitation rate (right axis) in the period 26/7 to 17/10. Red line represents WHO threshold value, green line is $PM_{2.5}$ (µg/m³) and blue line is precipitation (mm).*

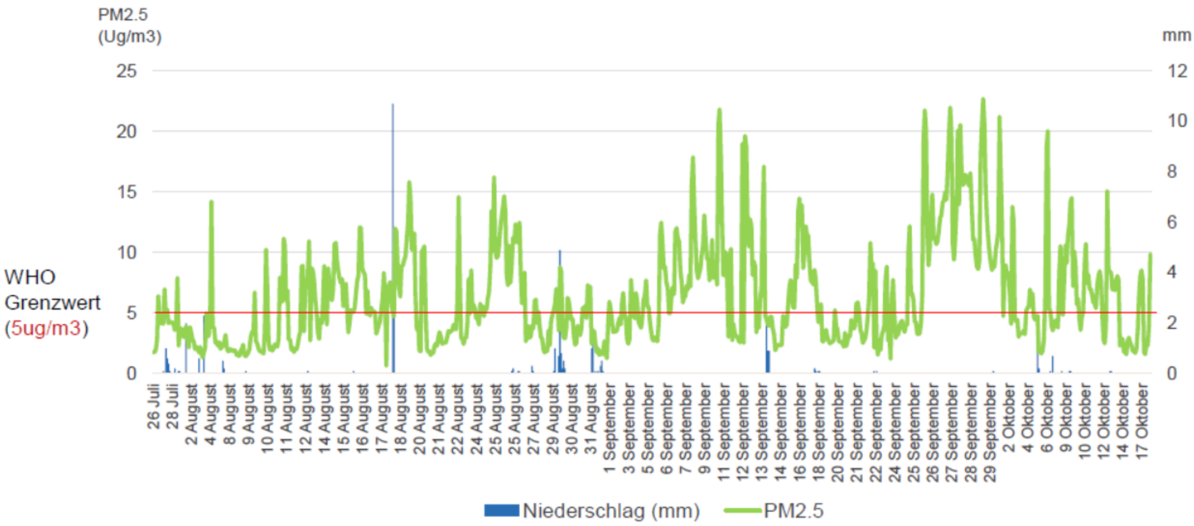


Figure 13: *Average PM2.5 values (left axis) and temperature (right axis) in the period 26/7 to 17/10. Red line represents WHO threshold value, green line is $PM_{2.5}$ (µg/m³) and yellow line is temperature (°C).*

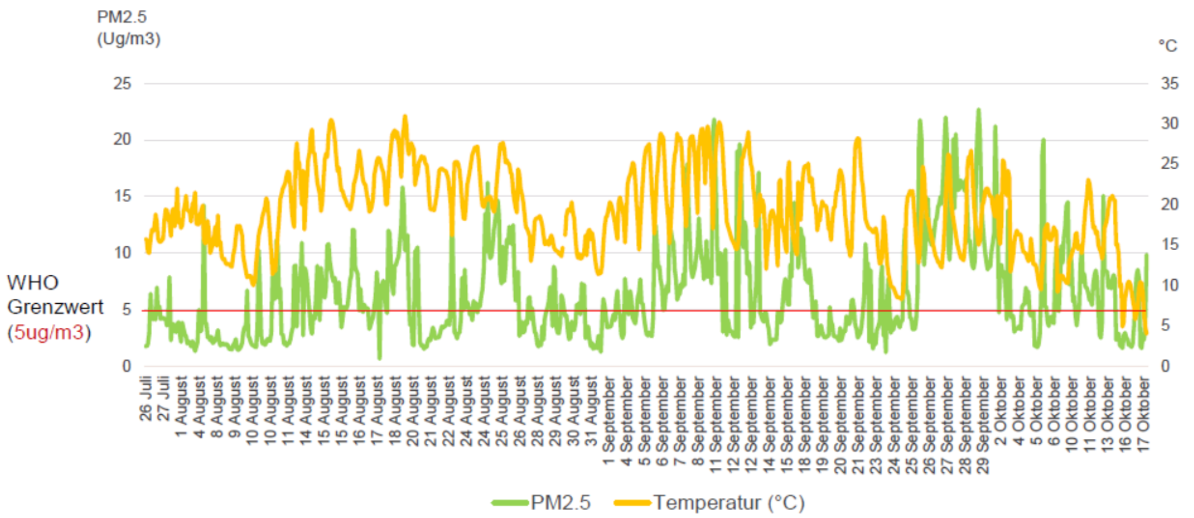
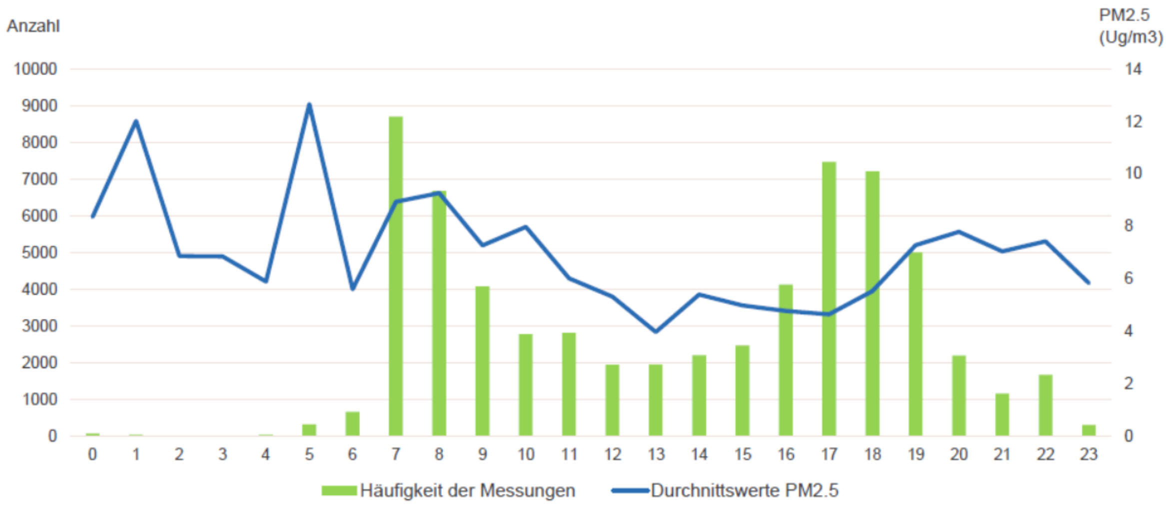


Figure 14: *$PM_{2.5}$ values (right axis, blue line) and number of measurements (left axis, green bars) averaged for every hour of the day in the period 26/7 to 17/10.*



Individual exposure profiles were created to contrast participants' own commuting routes to the average exposure. Since most participants commuted to/from areas with few or no official reference stations all across Berlin, the average concentration levels serve as a quasi-reference to individual exposure levels. For example, one participant's exposure profile can be observed in the graph below. Although they did not measure at all times, it is still possible to compare their exposure levels to average values to get a sense of whether they are at a higher or lower exposure risk during their regular commute. Likewise, individual participants' exposure during the 24 hour period was juxtaposed against average values.

Figure 15: *Average (green) and individual (blue) $PM_{2.5}$ values in the period 9/8 to 17/10. Red line is WHO guideline for $PM_{2.5}$.*

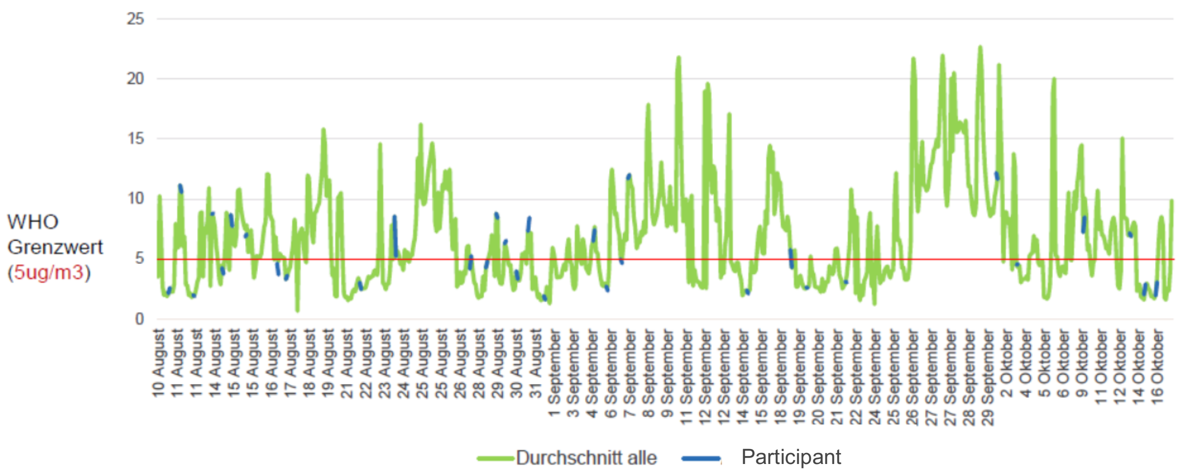
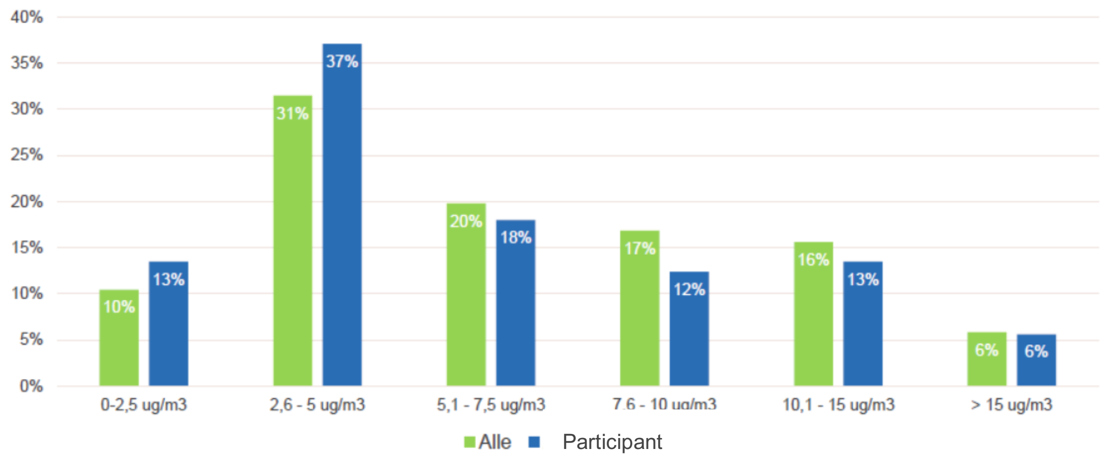


Figure 16: *Average (green) and individual (blue) $PM_{2.5}$ values averaged for every hour of the day in the period 9/8 to 17/10.*

.

Finally, individual values were clustered into different categories to create a quasi-histogram comparing the rate at which different pollution levels were measured between individuals and average values measured by all participants.

Figure 17: *Clustered measurement frequencies of different concentration levels of $PM_{2.5}$ for the period 9/8 to 17/10. Average (green) and individual (blue).*



Use Case 2 – reconfiguration of parking spaces

Since the final workshop will take place in November 2023, preliminary results exist only for traffic and PM measurements at this point in time. More specifically, due to a lack of air quality data in the policy monitoring dashboard (PMD), the before-after effect could only be analysed manually (using Excel) and only after the submission of this report. On the other hand, the effect on car traffic can be clearly seen in the PMD and will be shown below. As for PM, preliminary results from the first phase of the measurement campaign will be presented.

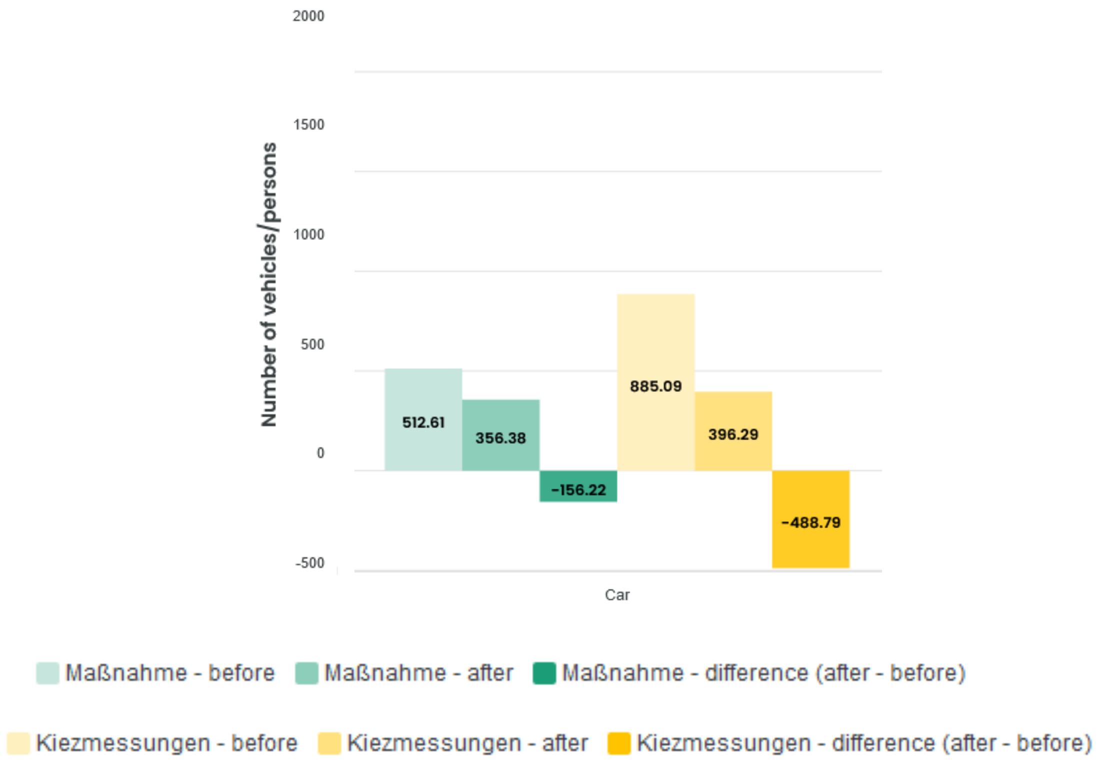
Two Telraam devices were measuring traffic flows in two different street segments - one where the parking ban took place (action street) and one in a neighbouring street where there was no parking ban. It is important to mention that the Telraam device in the action street was partially obstructed by a tree, so that additional tests were done to determine the validity of the measurements. It was confirmed that car measurements were counted correctly by the Telraam device, so the before-after effect only pertains to cars.

The green bars in the graph below present car traffic flows before (June 13 - July 16) and after the parking ban (July 18 - August 20) as well as the total reduction in the action street, while the yellow bars show the same for the neighbouring street. It is visible that there was a reduction in car traffic flows in both street segments during that time period, although more traffic was reduced, on average, in the neighbouring street than in the action street. The reason for this might simply be measurement error - as was mentioned, a tree obstructed a clear view in the action street so the number of cars may have been mismeasured. However, another reason is more likely, namely construction works in the neighbouring street during the summer period, which greatly reduced traffic. Furthermore, it is difficult to assess whether the parking ban contributed significantly to reduced traffic in the action street and to which degree the summer break played a role. Nonetheless, a clear effect is observable in both street segments and the parking ban may well have contributed to that.

Figure 18: *Unpaving of parking spaces in Graefekiez*

In terms of PM pollution, an initial comparison with official measurement stations was carried out in order to affirm the validity of the measurements made by the residents. Over a period of five weeks (June 23 - August 2), the data collected by the participants shows somewhat lower values than those measured by official reference stations (see boxplot below). A closer inspection into daily values still shows a similar trend, but less so. Over the course of five weeks, official reference stations tended to measure lower values than the *sensor.community* devices in Graefekiez. This trend disappears, however, at the beginning of the measuring period, where all devices picked up very high concentration levels. These higher levels were caused by wildfires in the United States, peaking in Europe in mid- to late June. Moreover, the difference between official and citizens' measurement was also lower towards the end of July.

Figure 19: *number of vehicles before, after and the difference for the affected area (green) and the neighbourhood (yellow).*



Although not shown in the graph (but apparent in graphs from Use Case 1 above), this period was marked by rainfall and higher humidity, which washed away the fine dust and hence stabilised the pollution levels.

Figure 20: *Comparison of median $PM_{2.5}$ values. Left: Values from selected participants from Graefekiez. Right: Values from official measurement stations*

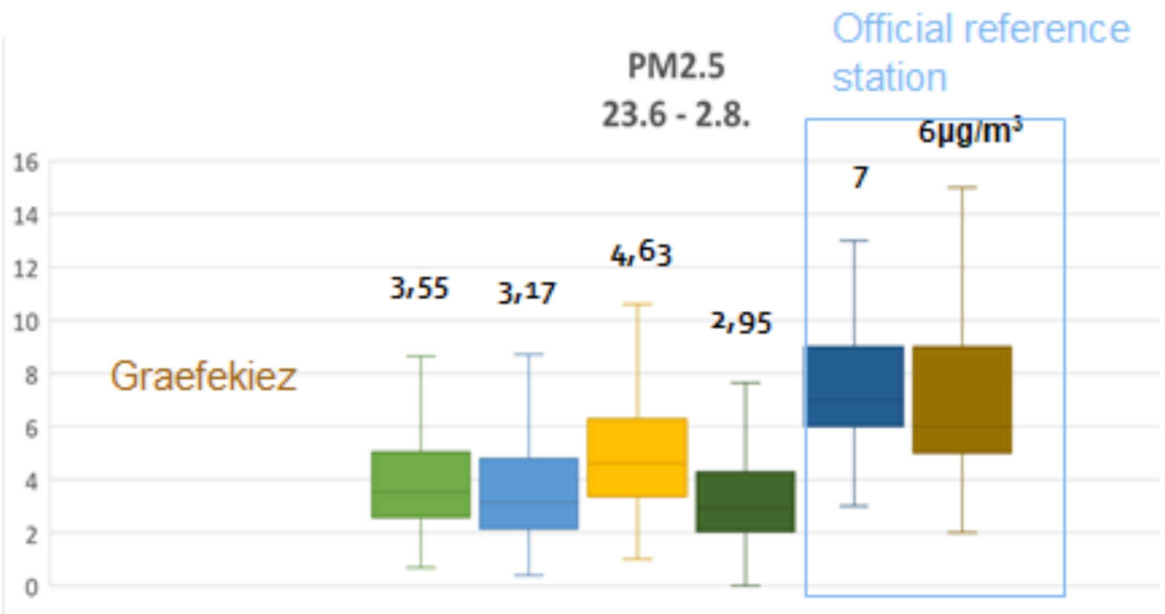
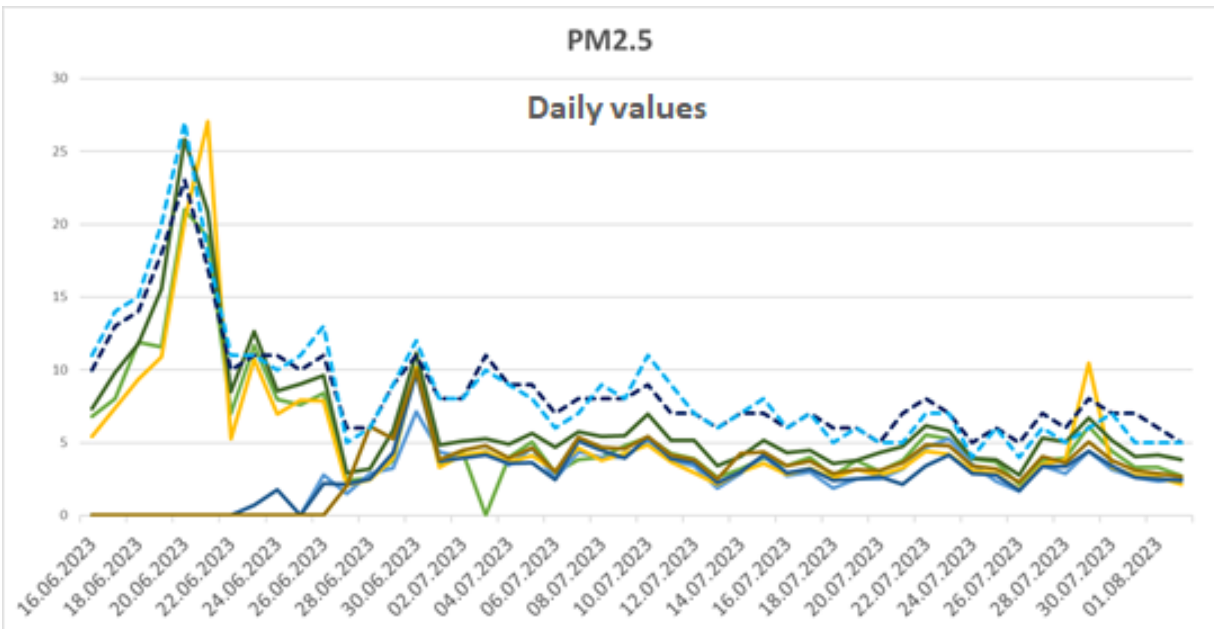
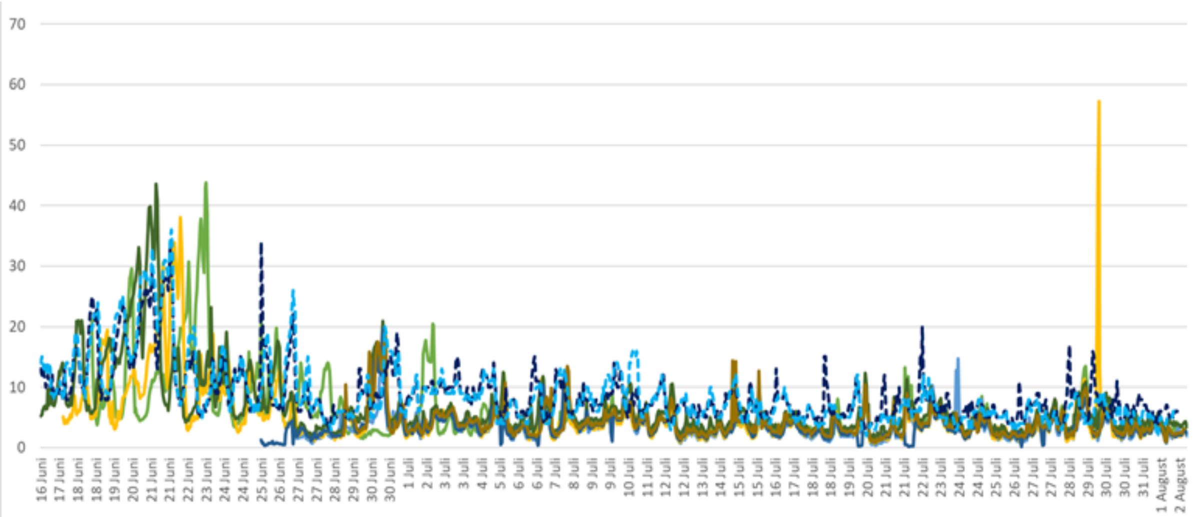


Figure 21: *Daily $PM_{2.5}$ values. Solid line: Graefekiez measurements; Dashed line: Official reference stations*



The hourly values show an even more nuanced story. Except for a brief period in early July, there are almost no differences between official and citizens' $PM_{2.5}$ data, lending further credibility to citizen-collected data. It is very interesting to observe the peak of the yellow line (one of the participants in Graefekiez) on July 29. Based on first-hand information, this extreme jump in concentration levels occurred due to a nearby barbecue party organised in the neighbours' backyard.

***Figure 22:** Hourly $PM_{2.5}$ values. Solid line: Graefekiez measurements; Dashed line: Official reference stations*



Looking at individual data in Graefekiez, some interesting results are noticeable. Similar to the Flemish pilot, the background location was chosen as a baseline against which all the other measurements are compared. It served as a benchmark with very little to no traffic and other influences impacting concentration levels. What is apparent from the image below is that the background device measured relatively high concentration levels compared to the sensors in Graefekiez. A possible explanation for this is the location of the devices. The background device was constantly exposed to sunlight and heat (as seen in the graph depicting temperature levels below), potentially leading to higher PM values. The lower values measured in the central and northern part of the Graefekiez neighbourhood may be explained by the following: generally lower traffic volumes, buildings blocking air pollution from being transmitted from the main road (eastern border) into the neighbourhood and trees filtering fine dust and providing enough shade to cool the devices. Because there are no barriers between the main road and the device in the southern part of the area, fine dust from the street could easily enter the neighbourhood and cause higher concentration levels. The data bears this out.

Figure 23: *location and average $PM_{2.5}$ and PM_{10} concentration of sensor.community devices in Berlin*

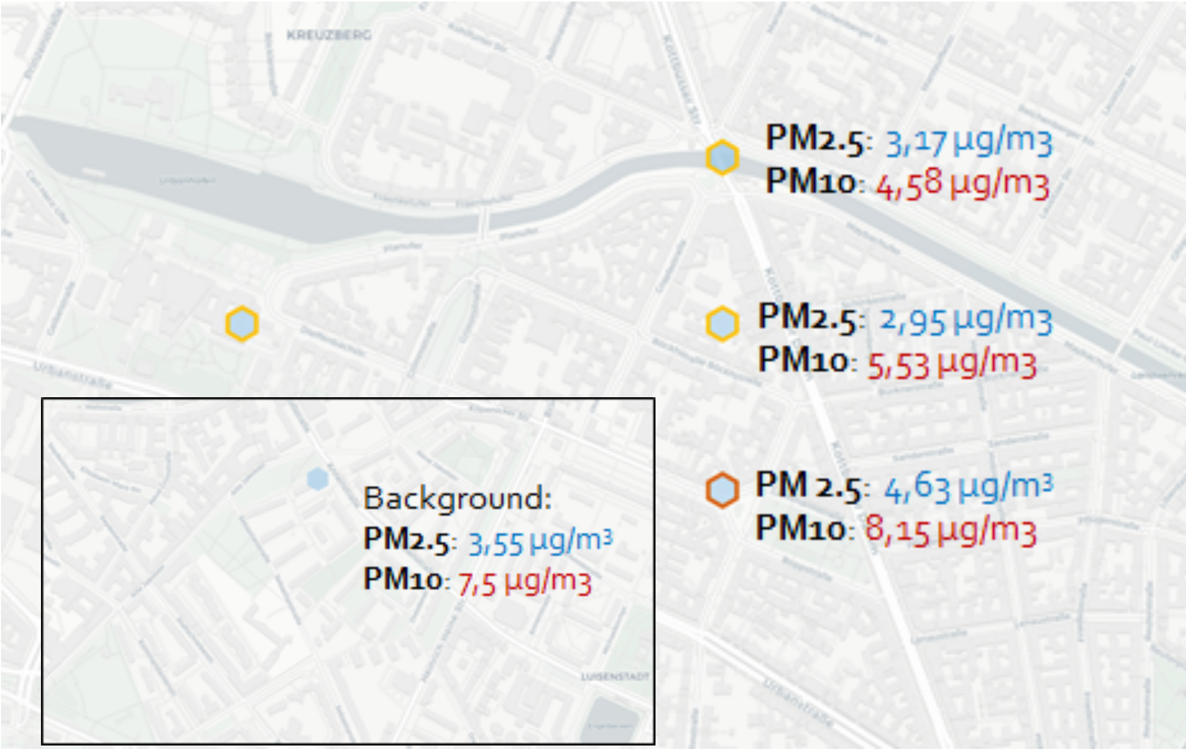
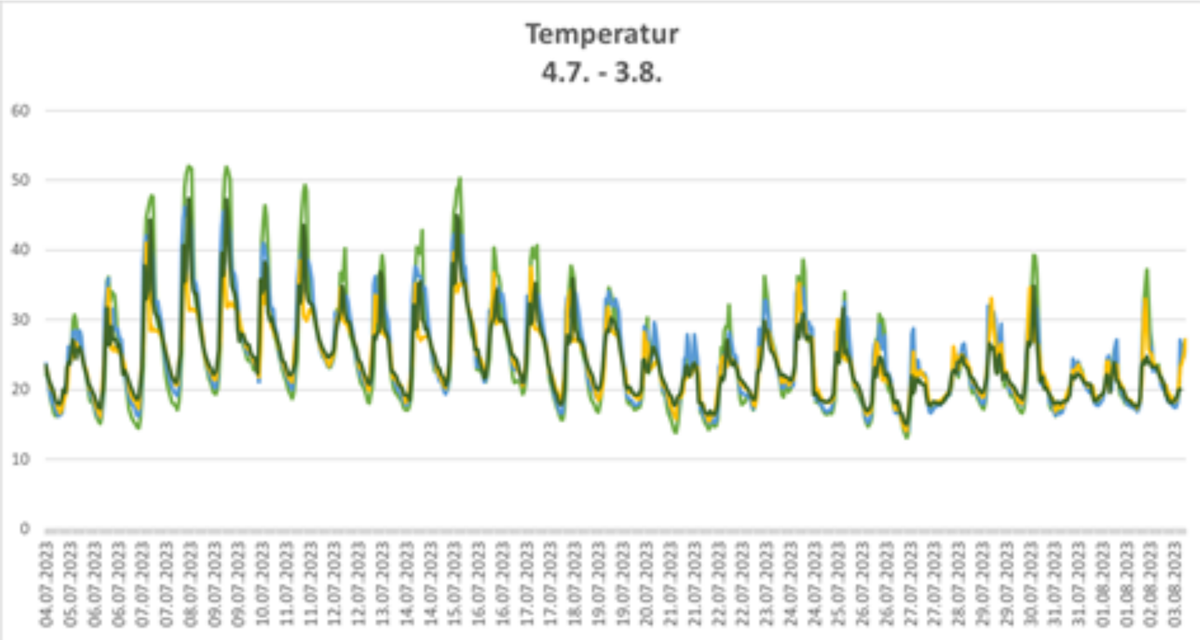


Figure 24: *Temperature as measured by the participants. Bright green: background location*



3.2.3. Lessons learned

Use Case 1 – mobile measurements across Berlin

The approach of the project was designed around 3 experimentation rounds (closed, open & public), with each round increasing our outreach towards more citizens. In this setup the open round still allowed for some technology issues as participants were informed of this during recruitment and the numbers of participants were not particularly high. The approach permitted us to learn some valuable lessons, as expected.

Registration process:
For the mobile measurement campaign, the Berlin pilot had an extremely good response with 70 registrations. However, of the 70 people, only 20 people committed to participate in the measurement campaign. Of these, only 13 people have reported back. More people should have been asked to sign up right from the start in order to plan for a buffer, because there is always attrition in the course of participation.

We also did not ask for all important data in the registration form or provide participants with all important information right from the start. Here we would have had to ask directly for the following data in order to be able to filter the participants effectively: place of residence and place of work, so that we can see where their commute takes them and we can decide whether we need a person for areas not covered by official measuring stations. It would also have been important that we clearly communicated all follow-up appointments (introductory workshop, interim workshop and final workshop) and showed exactly how much effort participants needed to invest in participating in the campaign. Finally, it would have been important for mandatory participation to be incentivised in the registration form in order to increase the chance of commitment. In the public round, we want to ask about motivation and educational attainment in the registration form in order to have more data about the participants and to be able to make an appropriate selection of participants, particularly those coming from disparaged communities.

Introduction workshop:
After the introductory workshop, we realised that it would have made sense to introduce the topic step by step by first saying what our research institute inter 3 does, then what the goals of the COMPAIR project are, and then explaining what citizen science is so that everyone is on the same page and has a clear idea. We should also have made it clearer in the introductory workshop what the added value of participating in COMPAIR is.

Workshop interim results:
The Berlin team planned 60 minutes for this workshop because it shouldn't overtax the participants' time. However, it turned out that the participants would have liked to have had 90 minutes because there was a lot of need for exchange. Namely, participants were very eager to share issues they encountered while using the SODAQ devices and thereby shifted the focus from a results-based discussion to a more issue-oriented dialogue. This lesson was incorporated in the final workshop, which lasted 90 minutes and gave the citizens more time to both engage in a dialogue and feedback and analyse the results with the Berlin team.

Support for participants:
Because our measurement phases lasted many weeks or months, there was very close cooperation and regular support of the participants. Follow-up emails, regular checks and feedback was given throughout the entirety of the campaign. Participants were very receptive to that and were more engaged as a result.

Change of environmental behaviour:
One of the goals was to capture the potential change of environmental behaviour of the participants by showing them the amount of air pollution they are facing by cycling this specific daily route. To analyse this potential change a questionnaire is used. It became clear, however, that this method is not very effective. At the end of the data café for mobile measurements, we showed participants tips on how participants can reduce their particulate matter pollution (e.g. use more side streets, avoid standing at intersections, drive more slowly, etc.). However, that didn't help much for several reasons. For example, participants pointed out that if there are paving stones on side streets or they have to stand at traffic lights, there is no meaningful way to change cyclists' behaviour and improve their exposure to air pollution. The discussion from the final workshop has, for instance, shed light on the fact that individual participants actually did not experience a large impulse to make major changes to their behaviour - whether this is choosing new routes or taking air quality into account in that context. Instead, the leverage lies in the structural issues of transport infrastructure, which is where the focus lies, according to the participants. We hence do not believe that encouraging individual behaviour in the Public Round is productive given the infrastructural mismatch in the area of interest.

Use Case 2 – reconfiguration of parking spaces

Mobilisation of participants:
Getting participants in the Graefekiez was much more difficult than with the mobile measurement campaign. An effective approach that was taken was to link up with existing actors in the Graefekiez who have good networks and access to the neighbourhood and its residents. This made it easier to establish contact with willing participants. Distributing flyers in the mailboxes, in local establishments and putting up posters around the neighbourhood greatly contributed to the effort to engage the residents. The mobilisation campaign could have, however, started earlier to find more participants.

Introduction workshop:
The same insights and lessons learned as in use case 1.

Workshop interim results:
Unfortunately, only two of eleven participants participated, even though we communicated the date well in advance. In the next phase, the Berlin team will use different incentives in the registration form to point out that participation in the workshops is highly encouraged in order to increase participation.

Support for participants:
The same insights and lessons learned as in use case 1.

3.3. Flanders pilots

The Open Round originally listed four use cases in Flanders:

- Demonstrating the impact of a school street on traffic and air quality in Herzele
- Demonstrating the impact of a mobility plan on traffic and air quality in Ghent
- Raising awareness on traffic and air quality with kids in secondary school in Herzele
- Raising awareness on traffic and air quality with kids in a primary school in Ghent

The last two use cases intended to rely on mobile devices for air quality measurements. During the Open Round only one mobile monitoring solution was available, SODAQ AIR. Delivery of the SODAQ AIR devices in a sufficient amount for classroom activities (i.e. 25) shifted to mid-May due to supply issues for the hardware components. As a result, both schools agreed to postpone the participatory experiments with kids to after summer. Due to practical considerations - the first two months of a school year (September and October) are focused on getting back to school, first field trips, building a foundation, etc - the schools suggested implementing experiments of the last two use cases only during the Public Round. The current outlook for the Public Round, features a 3 week project in the primary school in Ghent with an adaptation of the INTERREG Joint Air Quality Initiative's educational package built around 2 weeks of experimenting and 2 feedback moments with interactions between the school kids, teachers and COMPAIR experts. Planning with the secondary school in Herzele is an ongoing process at the moment.

Due to legal action by inhabitants, the introduction of a mobility plan in Ghent was postponed. The current, most positive outlook is introduction of the mobility plan in December 2023 depending on a judicial decision at the end of October. As distribution of traffic counting devices for data collection in the months leading up to the implementation of the plan was already under way, we were able to pick up on the validation of the Telraam devices with traffic counting systems and the local mobility model of the City of Ghent. The need for this validation came from discussions with city administrators uncovering a low level of trust in these measurements. As it is one of COMPAIR's goals to increase this level of trust, we consider this a principal aspect of the use case in Ghent (cf. further).

Hence the Open Round focused on the first Herzele use case, allowing the COMPAIR partners to put more effort into participant interaction. As a result we decided to also experiment using the more experimental bcMeter device for black carbon measurements and organise an intermediate data workshop called a "schoolstraten café". Both are discussed - among all other relevant results - in more detail in the following sections.

What is a school street?

A school street offers a solution to the traffic congestion and thus breaks the vicious circle. You close the street for half an hour at the beginning and end of the school day. Typically local volunteers and/or school staff help accomplish this using removable signs and fences. The environment around the school gate is becoming calmer and more pleasant. The space taken up by cars is freed up for pedestrians, cyclists, greenery and meeting places.

What rules apply?

While the school street is active, the road is reserved for pedestrians and (e)cyclists
Certain types of vehicles do have access:
- Priority vehicles (e.g. emergency services) when needed in light of their task
- Vehicles with a permit (e.g. inhabitants)

More information

3.3.1. Activities

3.3.1.1. Purpose, research questions & hypothesis

Use case 1 – school street Herzele
The Open Round use case in Flanders aims to demonstrate the impact of a school street on traffic and air quality. This aim can be refined into 2 principal research questions: is there an effect on traffic around the school and does this effect lead to a discernible change in air quality? Both 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 like awareness raising on vehicle use and a broadened support base for permanent implementation. We consider these questions as non-essential in light of our main purpose in the Open Round, but relevant enough to keep an eye on them. Lastly, a third type of question came up in the interviews focussing on an opportunistic look at the data gathered for the school street evaluation, e.g. can we detect other phenomena (e.g. pollution sources) than the school street effect in the available dataset (e.g. distinctly different behaviour between BC and NO_2 levels)?

In order to formulate a proper experimental design, the expected outcome was also discussed as this provides more precise information on the experimental design, e.g. sensor network configuration. The principal questions for instance lead to the hypotheses:
- Traffic volume is reduced in the school street when the measure is active. The effect might start before activation and last slightly longer. Overall traffic will reduce, however some traffic flows will redistribute over neighbouring streets.
- The local contribution to pollution levels in the school street is reduced during school street activation in comparison to the local contribution at comparable sites (similar amount of traffic, type (e.g. urban street canyon, country road, etc)) and if possible configuration (parallel orientation, air flow/ventilation etc.).

Hypotheses related to the non-essential research questions (for the Open Round) are not discussed, but included in the experimental design table.

Table 10: *Purpose, research questions and hypothesis for Flanders use case 1*

Experimental design for FLANDERS- use case #1	
Purpose	Demonstrate the impact of a school street on traffic and air quality.
Research question(s)	Questions that **must** be answered through experiment A. Is there less motorised traffic because of the measure in the neighbourhood of the school? Or does this not result in a reduction in traffic, but rather in a traffic displacement (TELR sensors)? B. Is the air quality better because of the measure (NO2/BC sensors)? Questions that **can** be answered through experiment C. Does a school street create awareness about air quality by the citizens (all the sensors)? A possible modal shift (e.g. replacing cars by bicycles)? D. Does a temporary implementation of a school street provide more support to the permanent implementation of this measure in the future? E. Can you pinpoint the source of air pollution? E.g. increase in $PM_{2.5}$ but no increase in BC start-up wood fire e.g. BBQ
Hypothesis	A. Less traffic after introduction of a school street B. Better air quality (less NO2/BC pollution) after introduction of a school street C. A school street creates awareness with the citizens (creates dialogue about this topic, knowledge about air quality). This may lead to more citizens opting for cycling, walking or public transport. Whether this is also influenced by the weather can only be verified if the measure is introduced for a whole year. D. The advantages of a school street (safety, health) will outweigh the disadvantages (inconvenience) provided that it does not merely displace traffic flow but rather reduces it E. This is possible if the citizen also logs possible incidents

Use case 2 – sensor validation Ghent

As discussed before, we had to severely reduce the scope of the Open Round in Ghent due to a shortage in electronic components, leading to delays in sensor delivery, and legal action postponing the introduction of the new policy. However in preparatory discussions with the city administration, it became apparent that a lack of trust in crowdsourced, sensor based data exists. As we considered policy makers as one of three essential stakeholders in our hands-on methodology this challenge, that surfaced during the interviews, was translated into a principal research question to address: Does a city administration validate the new Telraam 2.0 results when compared to other formal validation counts done by the city administration as well as manual counting by participants? Additionally do NitroSense devices match at least the indicative quality label as applied by the Flanders Environment Agency? (the quality label is one that is trusted by the city administration).

Table 11: *Purpose, research questions and hypothesis 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 A. Do the new TELR2.0 get validated when comparing them with other formal validation counts done by the city administration as well as manual counts by the volunteers? B. Do the NitroSense devices obtain at least the 'indicative' quality label as applied by VMM when compared to a reference site in Ghent?
Hypothesis	A. TELR2.0 works as expected from the lab test[6] B. NitroSense meets the quality criteria (expanded uncertainty and between sensor uncertainty) of the 'indicative' level in VMM's quality label[7].

Due to delays in obtaining validation data from the local authority, this use case will not be discussed further at this time. Conclusions drawn as compared to the hypothesis laid out, are expected to be reported under the Public Round report.

3.3.1.2. Experimental design

Use case 1 – school street Herzele

School streets have been evaluated in Flanders before, this is however the first case where a citizen science approach is applied. Focussing on the principal research questions, the most minimalistic design would mimic earlier research such as VITO's school street evaluation in Kampenhout as part of the City of Things-project led by VMM. This design in essence:

- Focusses on local contributions
- Monitors air quality at 3 locations: background, school street, unaffected location comparable to the school street location
- Consists of before and after campaigns of 3 months each (preferably)
- Implements traffic counting in at least 2 locations + every locations with a risk of negative side effects

The major assumptions in this design are: uncertainties of the measurement techniques are well known and a well informed choice of the 3 sites.

COMPAIR's approach does not allow for this well informed site selection for the background and unaffected location, as we are reliant on the home addresses of participants and limited knowledge on local pollutant concentration levels and traffic intensities. By increasing the number of sites and a broad recruitment across Herzele, we ensured some selectivity up front and degrees of freedom in the analysis for identifying a suitable background and unaffected location. Furthermore the bcMeter performance has only been demonstrated in a brief campaign during the closed round. Hence monitoring across a range of sites in Herzele during the Open Round allowed us to validate bcMeter output, by comparison to reference sites in Flanders according to the 'Determining precision & accuracy' chapter of our DIY Citizen Science Lab deliverable (D5.3).

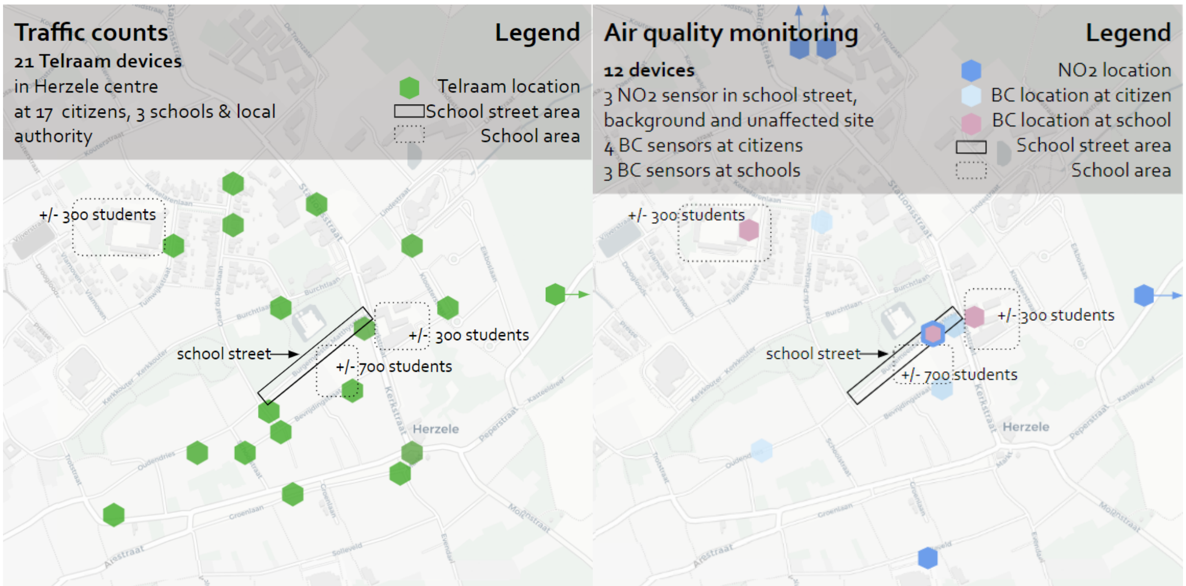
Finally, our principal research questions inherently link air quality and traffic. Hence, we want to maximise co-location of air quality and traffic measurements. This led to the network configuration summarised in **Table 12** and illustrated on **Figure 25**.

[6] https://telraam.net/en/blog/precision-accuracy-and-validations-of-the-original-telraam-sensor
[7] https://doi.org/10.1016/j.apr.2021.101246 (Table 1 describes VMM's quality label)

Table 12: *Experimental outline for Flanders use case 1*

Design	**WHAT, WHEN & WHERE:**
	- **3 NO_2 sensor boxes (NitroSense):** 4/5/2023-30/6/2023
	    - 1 sensor box at the school Sint-Paulus Institute (school street)
	    - 1 sensor box on a street similar to the school street (traffic configuration), but unaffected by it
	    - 1 sensor box at a background location (local library, Wattenfabriek)
	- **7 BC sensors (bcMeter):** approx. 25/4/2023-4/7/2023
	    - 3 at the schools close to the school street location, 1 of which was co-located with NO_2 (NitroSense) and traffic (Telraam) devices at the unaffected location
	    - 4 at citizens residences, all co-located with traffic devices close to the background location
	- **21 traffic sensors (Telraam):** 20/3/2023-31/12/2023
	    - 1 device at the school in the school street, all other devices with citizens at their residences, 2 other schools and 1 town hall
	- **Existing reference network in Flanders**
	    - For context and accuracy evaluation
	
	Other configuration requirements:
	- School street implementation is
	    - Mo to Fr: 8h00-8h45
	    - Mo, Tu, Th, Fr: 15h20-15h50
	    - We: 12h00-12h30
	- Given these time slots at least 15’ resolution is required
	- NO_2 data is preferably calibrated to compensate for temperature and relative humidity
	- BC data should be sufficiently well based on closed round benchmark
	- Traffic data is ready to use after +/- 2w learning period
	
	Practical note:
	- NO_2 devices will be installed by VMM on posts in the public domain (e.g. streetlight)
	- bcMeters at citizens residences will be installed by citizens on windowsills or balconies facing the street
	- bcMeters at schools will be installed by VMM in lockable enclosure with separate power supply at a street side location close to the building facade
	- Telraam devices will be installed by citizens and school staff on windows facing the street
	- Air quality sensor monitoring will be done by VMM and IMEC to follow up on technical difficulties
	- Traffic sensor monitoring will be done by TELR

***Figure 25:** Map of traffic and air pollution monitoring in Herzele*[8].



LSES/vulnerable groups

The main vulnerable group in the case of Herzele are pupils with lower socio-economic status characteristics.

Three schools are located in the perimeter in which measurements are taken:

- Sint-Paulusinstituut (+/- 700 pupils of secondary education)
- Gemeentelijke basisschool De Kersentuin (+/- 300 pupils of primary education)
- Vrije Basisschool Herzele (+/- 300 pupils of primary education)

By implementing the school street in front of Sint-Paulus Instituut, the impact of the COMPAIR initiative could be assessed for +/- 700 pupils. All pupils from this school would benefit from the traffic safety measure and presumed improved air quality in front of the school[9]. Existing LSES indicators for Equal Opportunity Education that are made public by the Flemish government, at school level[10] were used to make this assessment.

The two other schools' pupils were involved in the various workshops or experiments (Traffic and Air quality measurements, education about Traffic and Air Quality, using Policy Monitoring Dashboard) that were conducted.

Finally citizen scientists were recruited, next to a digital campaign, with an offline campaign:

---

[8] Some Telraam devices are very close to each other and grouped in a single hexagon, hence the number of hexagons does not match the number of Telraam devices. The two "blue" hexagons with the arrows are collocated at the reference station in Ghent. The "pink" hexagon with blue edges represent the location of both bcMeter and NitroSense devices deployed at the school.

[9] We assume that indirectly some pupils from other schools, going by bike or by foot to school, will also benefit, but we are unable to count them

[10] https://onderwijs.vlaanderen.be/nl/onderwijsstatistieken/themas-onderwijsstatistieken/leerlingenkenmerken

- the municipality sent 1000 personal letters to citizens to announce the initiative and to invite them to an information session;
- the municipality hosted a physical information session about COMPAIR
- the municipality sent 1000 personal letters to recruit citizen scientists
- 100 posters (shown in **Figure 26**) and 1000 flyers were distributed through schools, pharmacies and municipality buildings

Figure 26: *Poster used as part of inclusive communication*

We assumed that the citizen scientists were representative of the LSES groups. We calculated the number of citizen scientists with an increased compensation for insured persons in health insurance as one of the indicators used in Flanders for weaker socio-economic position, from publicly available statistics on neighbourhood level.

Use case 2 – sensor validation Ghent

Not discussed at this time.

3.3.1.3. Workshops

Telraam workshop
In February 2023 an interactive workshop in Herzele was held with 21 Telraam participants to see how the Telraam device works and to prepare them for installation. Please note that a similar workshop was also conducted in Ghent, but we do not report further on this use case in the Open Round report.

bcMeter workshop
In May an interactive workshop was held about air quality and the use and installation of bcMeter demonstrated in **Figure 27**. Participants received information on the state of air pollution in Flanders, the associated health effects and importance of further action and the current air quality outlook in Herzele. In the second part of the workshop they were introduced to the bcMeter device, the onboarding and configuration process and we had a hands on product tour and discussion. Already during this discussion the eagerness of participants to assist in product improvement surfaced. COMPAIR partners stressed that any kind of feedback was appreciated throughout the experiment.

Figure 27: *Enthusiastic participants learning about the DIY bcMeter*

Primary Schools in Herzele Commit To Sustainable Mobility and Climate
In an exemplary effort to promote sustainability and climate awareness, primary schools in the municipality of Herzele (including the schools participating in this use case, namely Gemeentelijke basisschool De Kersentuin and Vrije Basisschool Herzele) have committed to the educational programme "Schools Count![11]". Schools Count! is a ready-made teaching

[11] https://telraam.net/nl/network/school-op-de-teller

package to work with pupils (seen in **Figure 28** and **Figure 29**) in the 5th, and 6th grade on safe and child-friendly school environments.

Figure 28: *5th and 6th grade pupils of Kersentuin*

On 1 June 2023, the 5th and 6th grades of Kersentuin dived into Schools Count!, and on 6 June, the 6th grade of VSBH did the same. An introductory lesson placed mobility in the broad context of global warming and environmental pollution. Children gained insight into the big impact small changes can have, in behaviour. Next, pupils took a critical look at mobility around the school and in their neighbourhood using Telraam data. They were asked to think about the routes people take and discussed the impact of traffic on their school environment.

Figure 29: *6th grade pupils of VSBH*

Children are intensely engaged with the topic of global warming and sustainability. They are also good at naming the consequences of a lot of car traffic on themselves, the environment, and the climate. There is also a general gut feeling among the children that there is too much car traffic, in certain streets in Herzele, and that this poses a danger to themselves and other active road users. Diving into the Telraam data also objectified this gut feeling for them and prompted them to also look at the data from the other Telraam devices in Herzele.

Secondary class invites Telraam expert to learn about the AI
A fifth grade class from a STEM programme asked their teacher if somebody from COMPAIR could come and explain how the Telraam counter can distinguish the different traffic modes. We were pleased to give such a lecture and answer all the interesting questions from the pupils.

Data Café
Mid-June citizens were invited to a School street café (shown in **Figure 30**). They could walk in and out freely, engaging in conversations with experts about experiment results. This interactive approach led to more profound discussions, better comprehension of project objectives, and a heightened sense of ownership among participants. The "Data Café" was an effective means of fostering collaboration and knowledge sharing.

Figure 30: *School street café in Herzele*

LSES/vulnerable groups

From each school we used the indicator School allowance as a good representation of Lower Socio-economic status.

Table 13: *Pupils with school allowance in Herzele (school year '21-'22)*

School name	Number of pupils with school allowance	Number of pupils	Percentage
Sint-Paulusinstituut	154	644	23%
GBS De Kersentuin	93	287	32%
VSBH	97	324	30%
Total	**344**	**1255**	27%

We assume that of the pupils we reached, almost 30% belong to the LSES-group given the overall school statistics available.

Amongst the persons within the municipality centre neighbourhood we targeted with our recruitment campaign, we see that that 14,9% has (in 2022) an increase compensation for insured persons in the health insurance[12] (hence they are considered in the LSES group). When this percentage is applied to the number of citizen science participants (29 persons), we assume that at least 4 persons have a lower socio-economic status.

3.3.2. Results

3.3.2.1. Analyses

Use case 1 – school street Herzele

As mentioned in the introduction to the Flemish Open Round pilot, we have suffered delays in producing and delivering air quality sensor devices. Given the closed round outcome we also stopped the mobile NO_2 sensor development and re-oriented to the static black carbon sensors as a good (and more DIY) alternative. This resulted in devices becoming available at a stage too late to perform 'before' air quality measurements in Herzele, which had to be taken into account when planning the required analyses.

After data cleaning (cf. D5.3), we see 3 main categories of analyses that should be performed:

- Data exploration:
    - Time series at various temporal aggregation levels
    - Box plots of air quality measurements to assess the distribution of measured values
- Evaluation:

12 https://provincies.incijfers.be/databank/report/?id=rapport_bgz&input_geo=gemeente_41027

- Identifying representative periods (i.e. days, weeks with no exceptional events, similar weather, etc)
- Before/after analysis on traffic monitoring locations for all transport modes
- Daily profiles for NO_2/BC in school street vs. other sites to identify different pollution profiles when school street is active
- Box plots of the ratio of concentrations when the school street is in effect to other time frames for all sites to identify indications of school street effect
- The above but for local contribution only

- Comparison
  - Correlation plots of NO_2 vs BC at various temporal aggregation levels, colour coded for week & weekend days
  - Correlation plots of small vehicles vs. NO_2 and small vehicles vs. BC

Table 14: *Analysis breakdown for Flanders use case 1*

Planned analysis	**Analysis**	**PMD**	**DEV-D**	**Ext.**	**Int.**
	• Time series at various temporal aggregation levels	X			X
	• Box plots to assess the distribution of measured values				X
	• Identifying representative periods (i.e. days, weeks with no exceptional events, similar weather)	X			X
	• Before/after analysis on traffic monitoring locations for all transport modes	X			X
	• Daily profiles for NO2/BC in school street vs. other sites to identify different pollution profiles when school street is active				X
	• Box plots of the ratio of concentrations when the school street is in effect to other time frames for all sites to identify indications of school street effect				X
	• The above but for local contribution only				X
	• Correlation plots of NO2 vs BC at various temporal aggregation levels, colour coded for weekdays & weekend days				X
	• Correlation plots of small vehicles vs. NO2 and small vehicles vs. BC				

Use case 2 – sensor validation Ghent

Not discussed at this time.

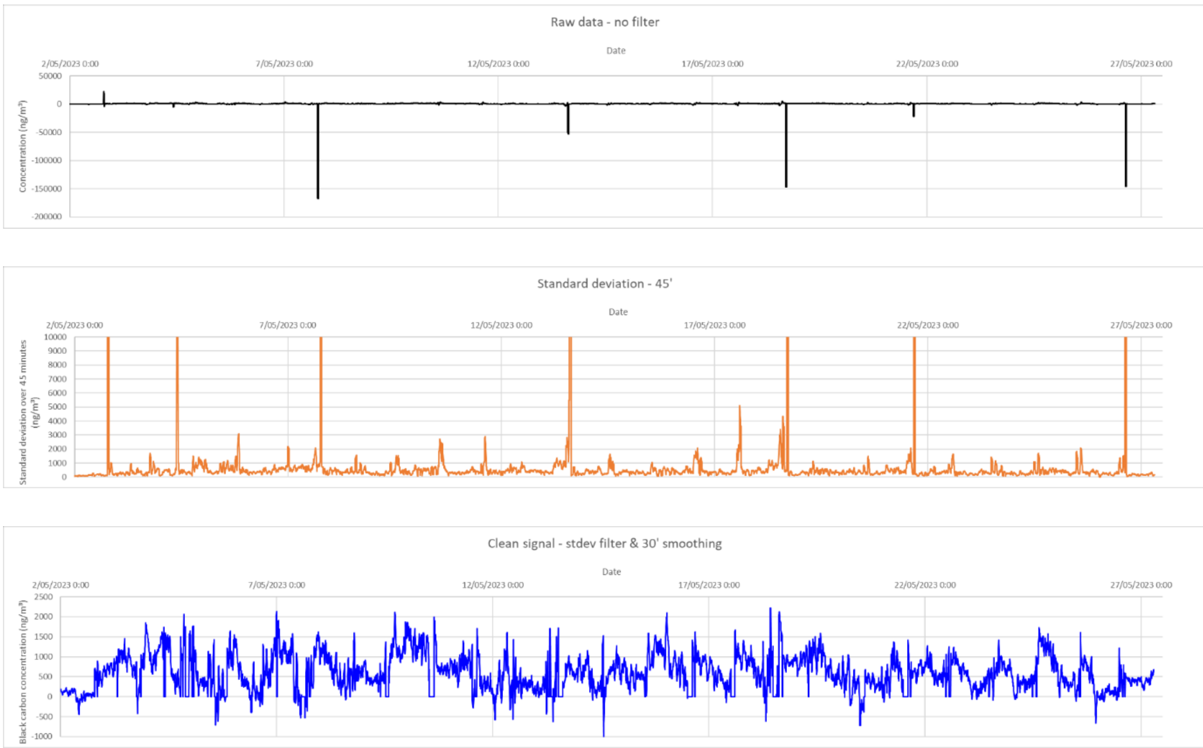
3.3.2.2. Results

Use case 1 – school street Herzele

In Herzele one of our participants stood up as a local champion, having actually followed a recent course in traffic management. He made the primary assessment of traffic impact using the COMPAIR tools. For air quality the analysis was performed by VMM data scientists as (1) COMPAIR tools mostly rely on a before and after period, (2) data availability in the COMPAIR tools was very low due to technical issues and (3) the data in the COMPAIR tools required additional cleaning and is inherently harder to interpret. However, VMM performed an intermediate data analysis of black carbon measurements during the data café which was simple enough to be performed in Excel with the idea of providing this as a template to play with by citizens and to provide a basis for a new xlsx download feature in the COMPAIR tools. The final analysis was performed in R using more complex data cleaning, scripting and visualisation techniques, the full analysis is available in R markdown (in HTML so download and open again). In the Public Round we will try to move towards citizen driven interpretation on air quality as well, building on the intermediate data analysis by VMM.

Data cleaning
Initial data analysis of black carbon shows some very clear outliers resulting in an extremely "spiked" time series. A closer look during the intermediate analysis showed these spikes to coincide with direct sunlight hitting the sensor setup, causing temperatures to spike. These sharp changes in temperature resulted in erroneous measurements and in a single worst case event, the device completely failed due to cracking of the plastic around mounting bolts that are used to hold the filter paper in place. The observed behaviour was clearly linked to rapid changes in the device output and a sliding 45-minute standard deviation metric seemed most suitable to automatically remove the outliers. Using standard deviation allowed us to maintain a certain level of understanding among citizen scientists. The graphs in **Figure 31** illustrate the raw signal, sliding standard deviation metric and clean signal, smoothed further by a running half hour average.

Figure 31: *Data cleaning methodology*



In the final data analysis for the Open Round, VMM applied the Hampel filter, a filtering technique based on the median absolute deviation (MAD) in a rolling window. This was deemed the most suitable filter as it is often applied in relation to air quality sensors.

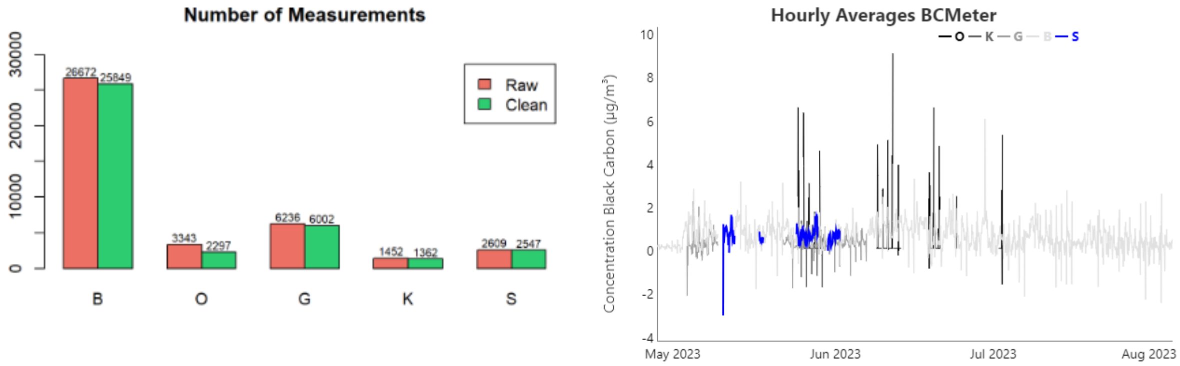
$$\mathrm{MAD}_t = m\left(\{|R_t - m\left(\{R_{t_w}|t_w \in w\}\right)|\}\right)$$

In this calculation, Rt is a raw reading at time t, m represents the median operator and w represents a rolling window centred on t. A datapoint is considered an outlier if

$$R_t \notin \left[m(\{R_{t_w}|t_w \in w\}) - \kappa\,\mathrm{MAD}_t, m(\{R_{t_w}|t_w \in w\}) + \kappa\,\mathrm{MAD}_t\right]$$

where κ is a threshold factor which determines the sensitivity of the filter along the length of the rolling window w. In the case of measurements obtained from the bcMeter every 5 minutes, we chose a threshold factor of κ=3 and a rolling window of three hours, corresponding to 36 measurements. The amount of data points discarded (**Figure 32**) is <10% for most sites (except 'Oudendries', which turned out not to produce usable data), which is comparable to the standard deviation based method. As you can see in **Figure 32**(a), data availability was fairly limited in all but one site (B: Bevrijdingsstraat). Detailed explanation on data availability is provided in the following section. Applying the Hampel filter to the sensor data resulted in the time series shown in **Figure 32**(b).

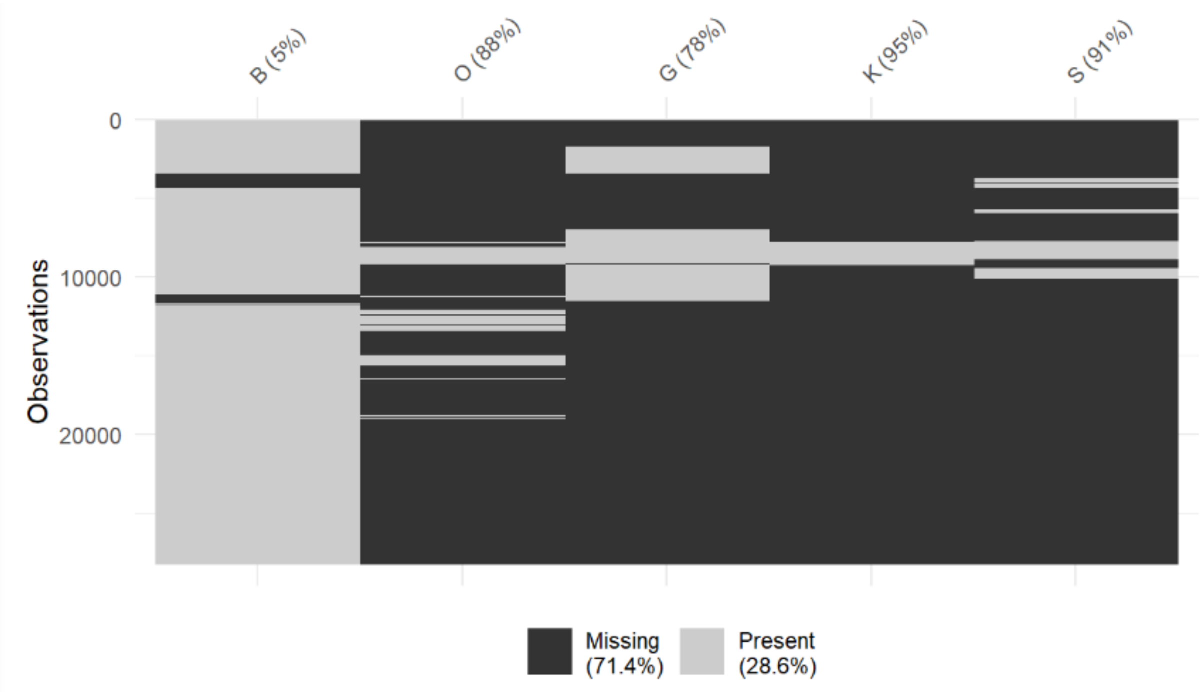
Figure 32: *(a) shows the number of bcMeter measurements taken at five sites namely B: Bevrijdingsstraat, O: Oudendries, G: Graaf du Parclaan, K: Kerkstraat and S: Sint-Paulusinstituut (b) shows hourly averaged bcMeter values*



The same data cleaning method was applied to the NitroSense-NO_2 data but is not discussed in detail here as a lot less cleaning was required.

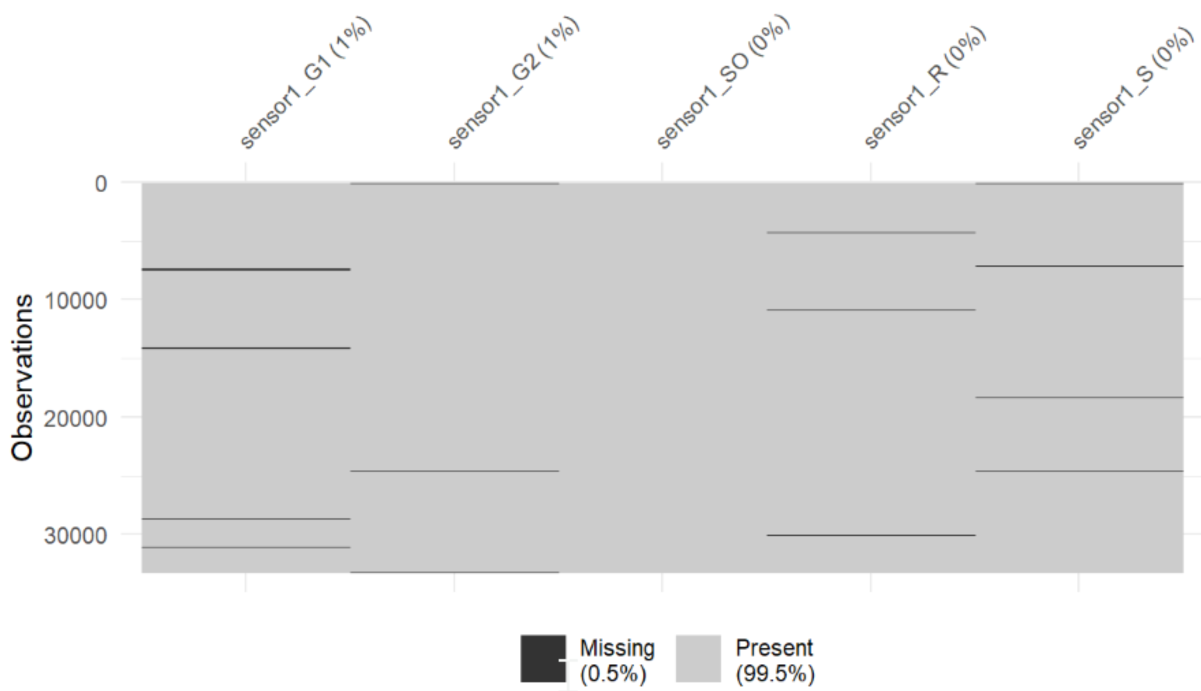
Data exploration
As shown above (**Figure 32**), data availability for black carbon devices was fairly low for all but one site (B: Bevrijdingsstraat). The main causes identified were: technical issues in data communication between device and data manager due to a last minute change to COMPAIR's backend, connectivity issues due to Wi-Fi strength (schools mainly), unknown connectivity issues with private Wi-Fi networks, unknown bug in local backup and untimely startup of devices by participants due to technological barriers. The technical issues are targeted to be addressed over Fall (November 2023 onwards) through bcMeter development sprints. Other issues were amended to the best of our abilities, by at least weekly on site visits. A more rigorous analysis of data availability (**Figure 33**) showed data being available only 28,6% of the time with about 1 week of data coinciding across all sites. Unfortunately, only one location at the rear side of the school (B=Bevrijdingsstraat) was up and running for almost the entire time (95%). The school street (S: Sint-Paulusinstituut) had only 8% data availability (+/- 13 days), mainly due Wi-Fi connectivity issues and backup failure, severely hampering any significant conclusions on the effects of the school street in black carbon measurements.

Figure 33: Detailed data availability metrics of the bcMeter BC measurements



The NitroSense data availability however was much higher at 99,5% during the entire experimentation period (**Figure 34**). The very limited interruptions in data availability remain to be investigated in depth and are planned to be conducted in the Public Round.

Figure 34: Detailed data availability metrics of the NitroSense-NO2 measurements at G1: Ghent reference station, G2: Ghent reference station, SO: Solleveld, R: Ressegemstraat and S: Sint-Paulusinstituut



It is important to note that the NitroSense device provides 2 NO_2-channels as - in the COMPAIR configuration - it has 2 NO_2 sensors within a single device. Furthermore, due to the prioritisation given to the calibration of SODAQ AIR PM devices data (not used within this use case at Flanders), the NitroSense output was not calibrated by COMPAIR's calibration pipeline The data obtained from the devices were in raw nA, which have been converted to ppb using the factory provided calibration coefficients to prepare the figures and tables within this report.

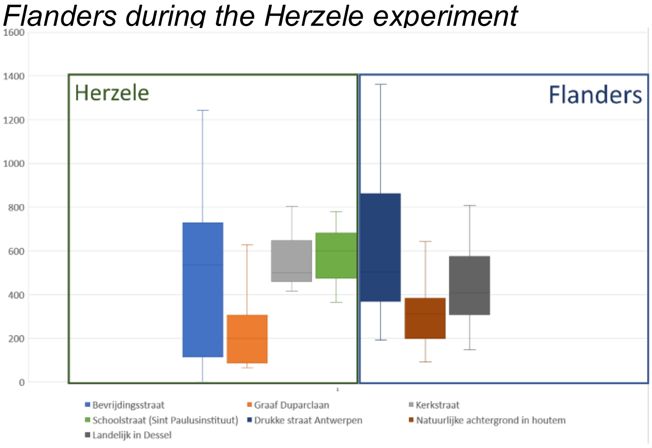
The following descriptive statistics for black carbon and nitrogen dioxide measurements was performed for each location site.

Table 15: *Descriptive statistics for black carbon and nitrogen dioxide in Herzele*

Location	Black carbon (µg/m³)					Nitrogen dioxide (ppb)				
	Mean	Median	SD	Max	Min	Mean	Median	SD	Max	Min
Bevrijdingstraat	0,55	0,56	0,95	14,46	-14,62					
Oudendries	0,14	0	0,98	9,67	-1,96					
Graaf du Parclaan	0,21	0,18	0,71	5,38	-7,31					
Kerkstraat	0,52	0,59	0,94	5,52	-8,55					
Sint-Paulusinstituut	0,61	0,57	0,42	6,97	-5,16	6 32	8 34	11 12	73 115	-67 -55
Solleveld						17 32	17 35	10 17	78 96	-38 -132
Ressegemstraat						9 24	10 26	11 15	73 120	-52 -69

When talking to citizens at the data café the first question we wanted to answer was "are the black carbon data you collected usable?". In order to assess this, we provided the citizens with a colour coded time series of daily averages and a box plot comparison to 3 reference sites in Flanders: an urban location in Antwerp, a more rural site in Dessel and a background site in Houtem. The period chosen was based on the days when data from the bcMeter devices were available, which were placed in the school street.

Figure 35: *Boxplot comparing bcMeter sites in Herzele to reference black carbon sites in Flanders during the Herzele experiment*

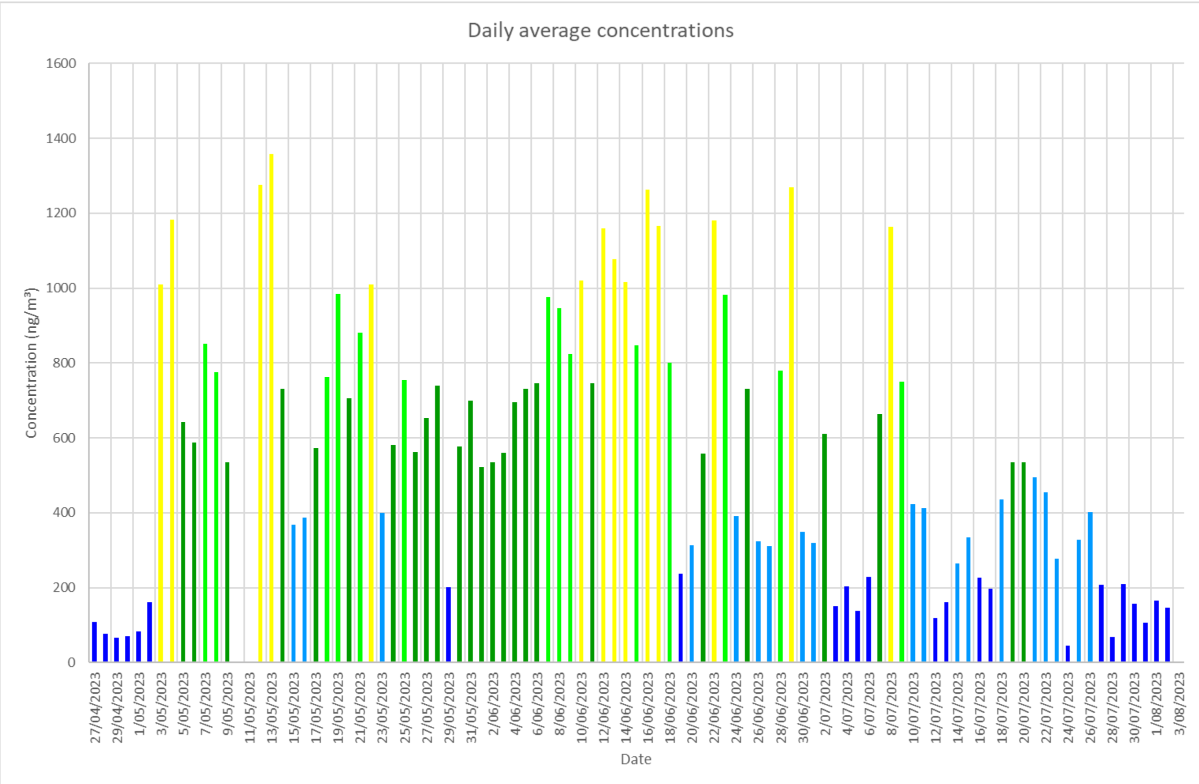


The comparison to reference sites in Flanders (**Figure 35**) delivers a number of valuable observations:

- The observed concentration ranges are very similar. After data cleaning they do not yield unrealistically high values. At the lower end of the concentration range, the sensor measurements in Herzele do appear to be lower. This is in line with observations of quite some negative values in the data set. More stringent cleaning on this lower end might be required, although it may also be indicative of a measurement bias at times.
- One of the citizen owned locations in Herzele appears to be usable as a local background location. This can be used to calculate the local contribution at the other sites later on.
- Average concentrations and range are similar in sites close to the main road and the school (Kerkstraat & Sint-Paulusinstituut). Concentration ranges are highest in the Bevrijdingstraat location, which is a street canyon.
- Overall the difference between the 3 reference sites is much more limited than what is usually observed throughout a year. The time frame under consideration was one of high wind speeds coming from a north-eastern direction which typically reduces the local variation in concentrations. This last observation is particularly unfortunate as it will also reduce the observable school street effect in an already very limited dataset.

Finally **Figure 36** illustrates a typical daily averaged time series for one of the devices located in Herzele (B: Bevrijdingstraat). Some clear day to day variation can be seen, as well as overall lower concentrations on weekends (May 6&7, 13&14, 20&21, 27&28). Additionally concentrations were clearly lower at the end of May as wind speeds were increasing at that time.

Figure 36: *plot of the daily averaged concentrations for bcMeter located in the Bevrijdingstraat*



Evaluation

For traffic measurements, our local champion identified two relevant periods ranging from March 20th to March 31st before the school street implementation and the weeks of April 17th and May 8th after the implementation. Weather conditions during these school weeks in April and May were normal: not too sunny, not too rainy. **Figure 37** shows the typical end of school situation with the school street implemented. Sensors were located just outside the right hand side of the figure near the school entrance.

Figure 37: *typical end of school situation with the school street implemented, sensors are located just outside the right hand side at the school entrance.*

To have a global view of the impact of the policy measure on traffic we used the COMPAIR Policy Monitoring Dashboard (**Figure 38**).

Figure 38: *Differences in traffic numbers in the neighbourhood and the school street*

When we compared (Figure 22) the average of the traffic in the school street (green) with the traffic in neighbourhood (orange) during the school weeks of 20th of March and 8th of May, we see a significant decrease (-230,00) in the number of cars from 378,60 to 148,60, but not much change in the number of heavy duty vehicles in the school street. We also see a significant increase in the number of bikes (+ 113,80) from 65,00 to 178,80 and a significant increase in the number of pedestrians (+ 95,80) from 83,40 to 179,20. These results are what we expected: much less cars and much more bikes and pedestrians.

***Figure 39:** Traffic numbers in the neighbourhood and in the school street, before and during the policy measure*

The positive effect of the school street on the amount of traffic near the school street is clear from Figure 22 and 23. Figure 23 also shows the effect of the school street on the amount of traffic in the neighbourhood. While the intention was to result in reducing traffic near schools, we wanted to avoid generating cut-through traffic on roads not intended for this, within the neighbourhood.

At first glance, we see a slight decrease in the number of cars (-15,61) in the neighbourhood. Some citizen scientists and other inhabitants reported or complained about a significant increase in car traffic in adjacent streets. To investigate this more closely, we created separate views on the PMD, where we compared the traffic in each street with that on the school street.

On one street (Graaf du Parclaan, Figure 24), perpendicular to the school street, we clearly see an increase (+50,00) in the number of cars (from 579,00 to 629,80). That is about 9% and apparently a nuisance for those inhabitants, maybe because it is concentrated during a very “visible” time window (e.g. when they leave for work). During the Public Round we will make observations on the ground and suggest supporting measures to the municipality.

On another street (Burchtlaan, Figure 25), parallel to the school street, we see an increase in the number of cars by 100% (+90,00) (from 89,20 to 181,20). That was very unexpected, because the street is intended for local traffic only. Furthermore it turned out that this one way street was being used in both directions to drop off kids closer to school. The local police suggested to the municipality to take measures to avoid allowing cut-through traffic at all costs, to also ensure the high heritage value of such streets is not compromised.

Figure 40: *Increase of car traffic in Graaf du Parclaan*

Figure 41: *Increase of car traffic in Burchtlaan*

As mentioned before, air quality analysis was hampered by the lack of before measurements due to sensor production delays and low data availability of black carbon measurements for various reasons (cf. data exploration). Our aim therefore, was to find a potential indication of the school street effect in different pollutant "behaviour" in the school street compared to other sites. In the next sections we only consider measurements during the "representative period" when data was available in the school street.

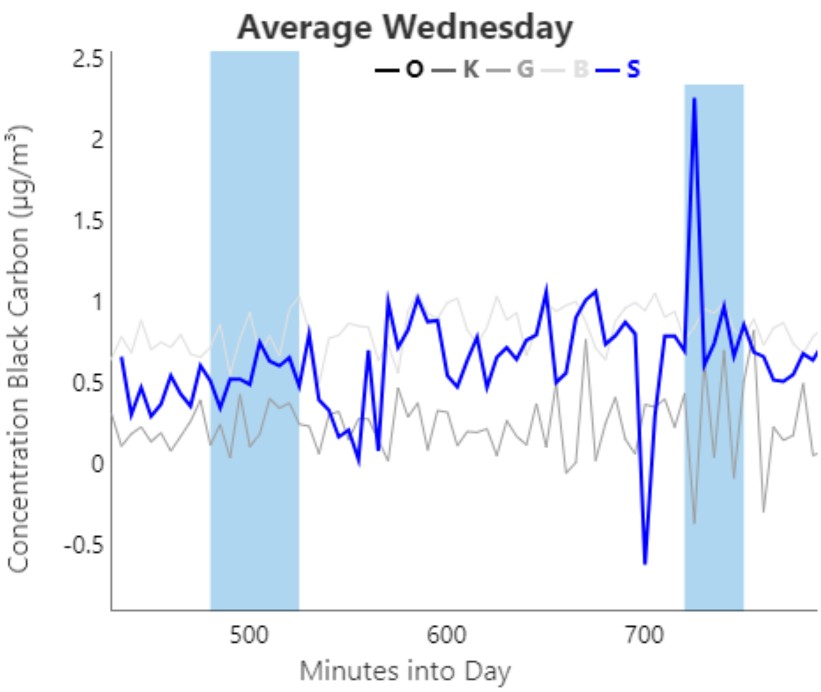
As a reminder, we reiterate the school street timing here (blue bands in Figure 26 below).

Table 16: *School street timing in Herzele*

Monday, Tuesday, Thursday, Friday	Wednesday
8h15 - 8h45	8h15 - 8h45
15h15 - 15h45	11h45 - 12h15

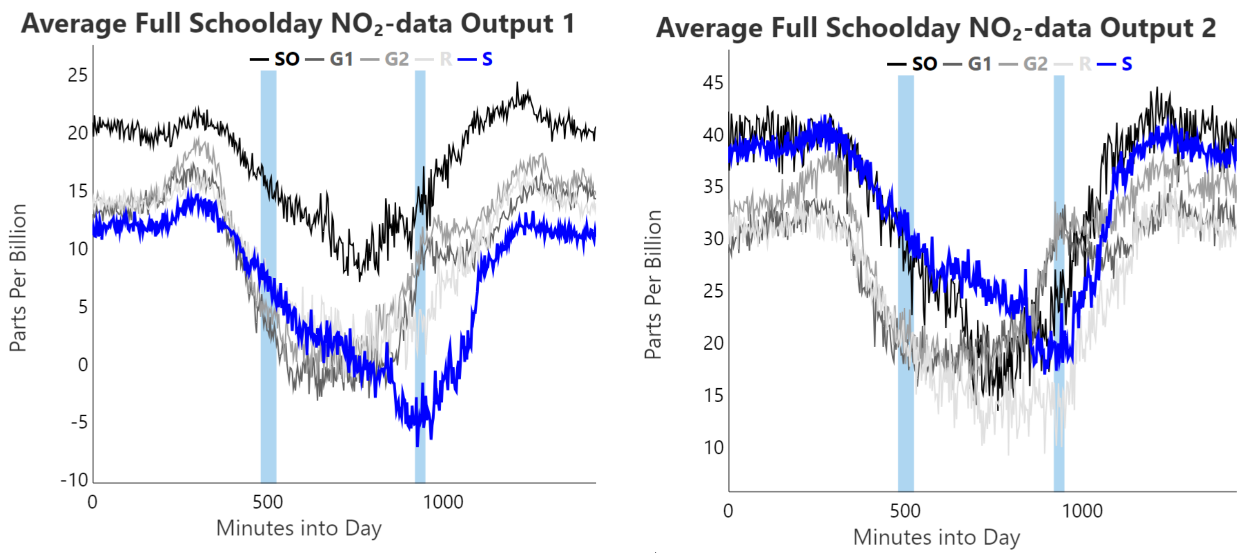
For black carbon we first looked at the daily profiles for schooldays and Wednesday by performing an analysis internally at VMM. In the average school day profiles, no relevant observation could be made. On Wednesdays (Figure 26) the relevant sites were: Graaf du Parclaan (G) - background, Bevrijdingsstraat (B) - street behind school and the school street (S) itself. One observation is that the school street measurements are closer to the background values during the morning activation of the school street than the time window in between both activations. The same effect is not observed in the noon activation though.

Figure 42: *Daily profile for black carbon concentrations on Wednesday (only sites with sufficient data included), blue bands indicate school street timing*



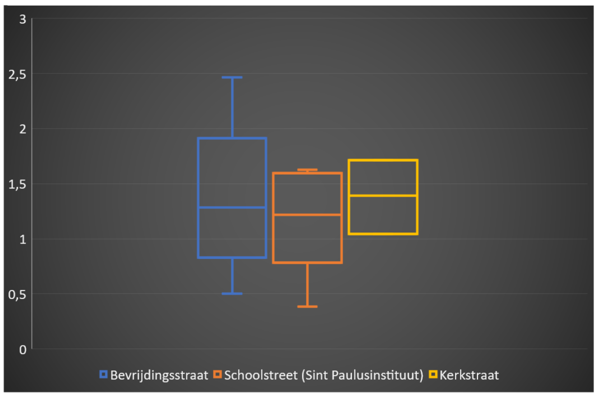
For NO_2 we have a decent amount of raw data available, but unfortunately not yet a well calibrated dataset. The figures (Figure 27 and Figure 28) below illustrate the school day profiles for NO_2 using the factory calibration for both NO_2 channels on each device (output 1 and output 2). The relevant sites here are: Ressegemstraat (R) - the unaffected location similar to the school street, the school street (S) itself and Solleveld (SO) which is considered the local background near the library. The most prominent observation that can be made at this time is the delay in the afternoon rise of concentration at the school street. This could be an indication of the school street effect but could also be due to local temperature effects. This will be taken into account for data coming out of COMPAIR's calibration pipeline, which should shed more light on this.

***Figure 43** a and b: Daily profile for NO2 concentrations on schooldays for channel 1 (a) and channel 2 (b) of NitroSense devices.*



These daily plots and tentative observations are very difficult to convey to citizens. Our intermediate data analysis for the data café therefore focused on local contributions during the school street morning activation and their relation to local contributions during the rest of the day. We captured this as a ratio (local contributions during the school street morning activation to local contributions during the rest of the day) for every day in the representative period and plotted the ratio for 3 sites in a box plot (**Figure 44**).. It is obvious that the differences are not statistically significant. The ratio is on average - and also in the "extremes" - lower for the school street than both other sites. On average the ratio for the school street site was 19% lower than the ratio in Bevrijdingsstraat (rear end of the school) (except during 1 school day when the ratio in Bevrijdingsstraat was higher). The relative difference during the afternoon activation was smaller. A similar comparison of the school street with the Kerkstraat site was not possible because that site was a lot more affected by direct sunlight distorting the measurements.

***Figure 44:** Boxplot of morning to rest of day ratio in local black carbon contribution*



These observations are to be considered as very indicative only and would not stand under thorough scientific scrutiny. A similar analysis will be conducted on the much larger NO_2

dataset once fully calibrated data is available. This might yield more robust scientific results that will be reported in the Public Round report.

Comparison
The outlined comparative analyses between black carbon, nitrogen dioxide and traffic measurements have not yet been performed as they require a calibrated NO_2 dataset. These too will be performed and reported in the Public Round report.

Conclusion & recommendations
On the Open Round in Flanders we can make the following conclusions:

- Our engagement strategies so far, worked well as we were able to recruit the desired number of participants
- Involving pupils, through schools and traffic related policy measures, not only had benefits regarding creating awareness through education, but offered equal opportunities for participation in citizen science experiments. And because we have LSES indicators publicly available at school level in Flanders we could calculate their involvement not only in a GDPR-proof way but also without asking delicate and sensitive questions
- Telraam devices operated as they should “out of the box” and were easy to set up by participants
- NitroSense devices were not intended for public use, but they provided reliable data once deployed in the field
- bcMeter devices were too unreliable for large scale deployment among citizens. Development sprints have been planned in the final quarter of 2023 to make amends to the device. The data produced however seemed to be of sufficient quality and were comparable to reference monitoring sites. Technical adaptations are needed to make devices more robust and user-friendly
- We were able to achieve our goal to use citizen science data to demonstrate the impact of a school street on local traffic in the area
- We were unable to achieve our goal to use citizen science data to demonstrate the impact of a school street on local air quality in the area
- Preliminary conclusions on traffic impact sufficed to convince the local authority to extend the pilot experiment and even start a new school street at a different location

In light of these conclusions the following recommendations were made:
- Further develop the bcMeter prototype in 4 key areas

Table 17: *bcMeter key development areas*

User friendliness	Reliability
❑ Display and/or status-LEDs ❑ E-mail notifications ❑ Actual buttons/switches ❑ Toolless filter replacement ❑ Flat and long USB cable	❑ Fixing components ❑ Waterproof housing solution ❑ Proper data backup, handling network loss and communication to data manager (incl. onboarding)
Technique	**Applicability**
❑ Temperature correction ❑ Airflow and humidity sensor	❑ GPS ❑ Battery and/or solar panel

- Some side effects of the school street were observed in a number of streets. The local authority was advised to consider flanking measures to avoid cut-through traffic in non-transecting roads. Additionally we recommended no longer opening up the rear entrance to the school, to which the school agreed.
- Build on the base of engaged citizens and work with them to (1) test whether COMPAIR tools can be used by citizens to get to valid conclusions and (2) set up a novel winter experiment designed by citizens themselves

Use case 2 – sensor validation Ghent

Not discussed at this time.

3.3.3. Lessons learned

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

During the "Open 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: Recognizing Local Champions

One of the standout discoveries from the "Open Round" was the pivotal role played by local champions. These community members exhibited a remarkable ability to activate and inspire fellow participants. They acted as effective organisers, rallying support and driving engagement. Recognizing these champions and empowering them to take leadership roles proved to be a winning strategy. Importantly, we found that champions are often willing to step up when asked for assistance or recognition. Thus, actively soliciting their involvement can foster a more vibrant and committed community.

Lesson 2: The Power of the "Data Café"

Traditional lecture-style presentations followed by Q&A sessions have their merits, but we found that a "Data Café" format yielded superior results during the "Open Round." Citizens were invited to walk in and out freely, engaging in conversations with experts about experiment results. This interactive approach led to more profound discussions, better comprehension of project objectives, and a heightened sense of ownership among participants. The "Data Café" was an effective means of fostering collaboration and knowledge sharing.

Lesson 3: Adaptive Planning for Innovation

Our experience reinforced the importance of adaptive planning in an innovation project. Unforeseen challenges, such as supply shortages for sensors and equipment, are not uncommon. Maintaining flexibility and a willingness to adapt to these challenges is vital for project continuity. Our approach - with a living experimental design document and jointly owned timeline with technical teams - enabled us to address setbacks promptly and keep the project on course, ensuring that our objectives are met despite unexpected obstacles.

Lesson 4: Need for Sufficient Data

Drawing meaningful conclusions about air quality and traffic demands an adequate data collection period. Our initial findings emphasised that three weeks of data, especially when impacted by supply issues, may not provide a robust basis for assessment. Similarly, a mere two weeks of measurements before policy implementation may not yield solid ground for drawing traffic-related conclusions. Extending data collection periods enhances the credibility and accuracy of our findings, reinforcing the importance of patience and thoroughness in our research approach.

Lesson 5: Political Dependencies

When performing policy evaluations, we must acknowledge our dependence on the political landscape. Legal actions taken against the policies being assessed can significantly affect project timelines and scope. To navigate this challenge effectively, we must remain agile and adaptable in the face of political hurdles. Flexibility in project planning and execution allows us to maintain the integrity of our research while accommodating political dynamics. This lesson is more relevant in very local studies and probably less for broad scale, regional policy studies. The latter has not been tested in COMPAIR though.

Lesson 6: Engaging with Schools

Working with school children to perform experiments is a rewarding endeavour. However, it requires strong buy-in from teachers, which makes us dependent on school agendas and the preparation cycles of educators. Ensuring a seamless partnership with schools demands careful planning and alignment with their academic schedules. By integrating our project into the educational framework effectively, we can maximise its impact on both students and the broader community.

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 toward 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

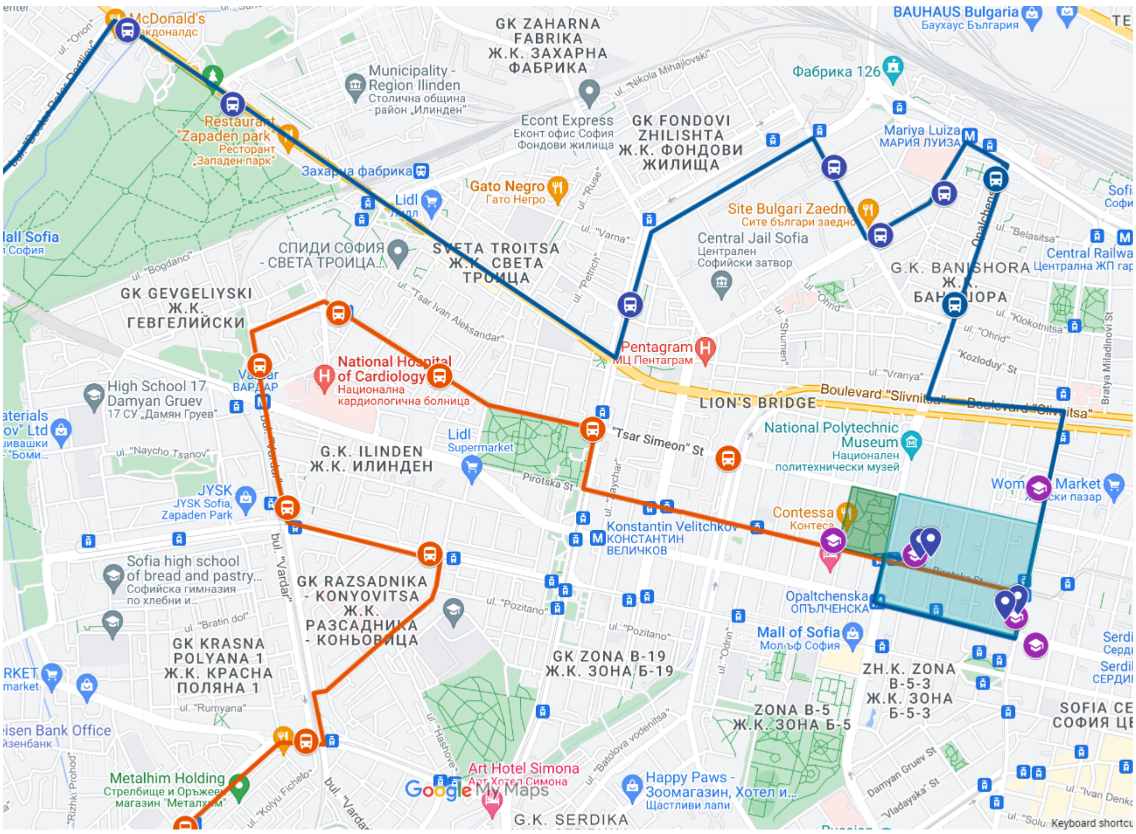
3.4.1.1. Purpose, research questions & hypothesis

Sofia pilot

Sofia use case 1 – School bus service

Sofia is a city that is experiencing problems with air quality and the Municipality is constantly trying to introduce different measures aiming at reducing traffic and solid fuel domestic heating, in order to improve air quality. As part of the COMPAIR pilot activities and planning, a second testing period of the school bus initiative was voted by the Sofia City Council and the bus routes started operating in mid-April 2023, serving the two biggest schools in the city of Sofia and several smaller ones (shown in Figure 32). In order to assess the effectiveness of this measure, the SDA team planned to install a number of COMPAIR-provided sensor devices around the two schools and also conduct workshops with students to raise their awareness on the air quality and main pollutants.

Figure 45: *SDA installed two static sensors of sensor.community in each of the two schools participating in the School bus project.*



In the planning phase of the COMPAIR Open Round testing and drafting the experimental design of the testing, the SDA team envisaged a number of measurements of traffic, PM and

BC around the two schools that are served by the recently introduced school bus policy measure by the Sofia Municipality. However, due to connectivity issues in Sofia, most of the sensor devices could not be used during the Open Round testing period and the SDA team had to adapt the activities in accordance with the available technologies and sensors. In order to test the connectivity of the mobile PM sensors of SODAQ (SODAQ AIR), the SDA team performed several tests along the school bus routes and in the area around the schools equipped with 4 sensor devices (SODAQ AIR) in order to see if data on PM levels will be transmitted to the dashboards. While connectivity was established in some places shown in Figure 33, these were neither around the schools, nor along the two bus routes. In an attempt to check the availability of connectivity of the IoT network, partners from SODAQ provided an additional tracking device to the Sofia team in order to check if some connectivity will show up on the map. Unfortunately these attempts to find connectivity, also did not turn out to be successful. The same issue applied to the Telraam V2 sensors for traffic count, as they are using the same data transmitting technology as the SODAQ AIR devices. Again, the SDA team performed several attempts to install the sensors in different locations to test their connectivity over different periods of time but connection was not found. Telraam partners even reached out to the main IoT network provider to see if they have a local partner in Bulgaria that can help solve the issue but to present date no progress has been made in regards to establishing connectivity, even though an agreement was signed between the Thingstream network provider and the biggest telecom operator in Bulgaria A1 back in May 2023.

***Figure 46:** The yellow points show where SDA managed to find some connectivity of sensors using the IoT network in the city but despite many attempts no connectivity was found around schools or along the school bus routes.*

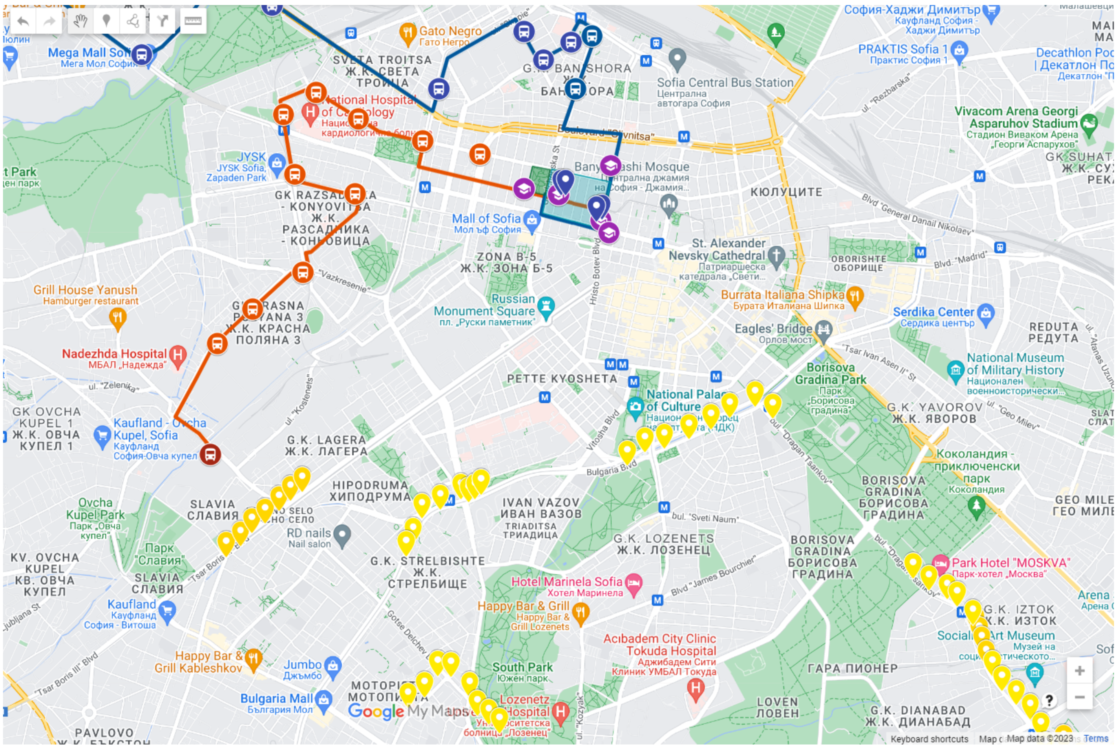
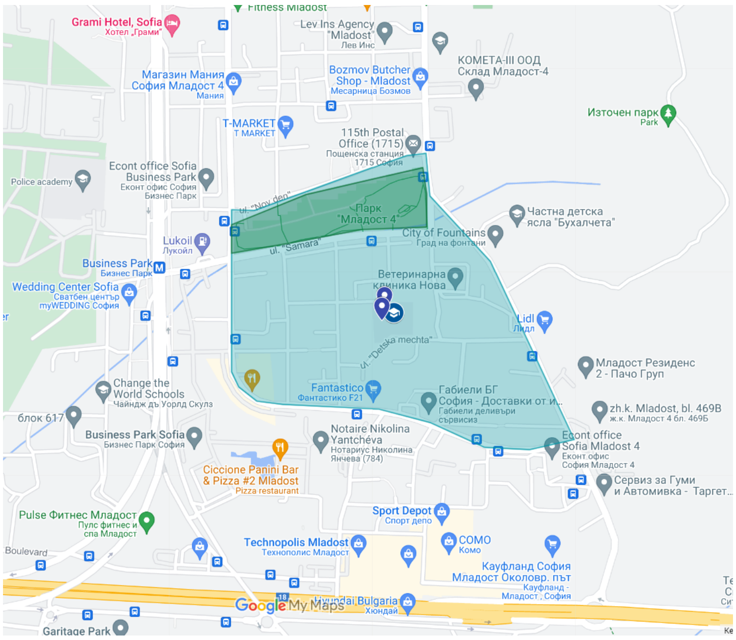


***Table 18:** Purpose, research questions and hypothesis for Sofia use case 1*

Experimental design for SOFIA - use case 1	
Purpose	Determining the impact of the introduction of school bus routes for morning and noon transport to school through a community building exercise with 2 schools on the outskirts of the future LEZ.
Research question(s)	Questions that must be answered: A. Is the amount of traffic reduced due to the school bus scheme at the schools? B. Is there a difference between morning and afternoon peaks in traffic at the schools? C. Is there a difference between morning and afternoon peaks in air pollutant concentrations at the schools? Questions that can be answered: D. Summer/winter difference based on outside PM devices (requires continuation into public round)
Hypothesis	A, C: Reduction in car traffic to school of 50 vehicles in morning peak only (based on questionnaire) B, D: No effect on $PM_{2.5}$

Sofia use case 2 - Kindergarten

***Figure 47:** Kindergarten location*



The SDA team got in touch with the 76th Kindergarten in Sofia as shown in **Figure 47**, for its 2nd use case. This kindergarten has been using for more than 2 years already a system called the Canary for indoor air quality measurements. When the indoor air quality is not optimal, the system rings an alarm which alerts the children and their teachers of the need for some air ventilation. Classrooms in the kindergarten have been fitted with this Canary system which is equipped with a sensor that starts singing like a bird when it detects increased levels of carbon dioxide and fine particulate matter (PM_{10}/$PM_{2.5}$) in the indoor space. In addition to this, the Sofia Municipality planned to install air meshes on windows which have the ability to absorb PM and other pollutants preventing them from entering the classrooms. The Municipality wishes to test the effectiveness of this innovative product in preventing PM and other pollutants entering the classrooms from the outdoors, when windows are opened for ventilation indicated by the alarm of the Canary system.

Table 19: *Purpose, research questions and hypothesis for Sofia use case 2*

Experimental design for SOFIA - use case 2	
Purpose	Evaluate the efficiency of window meshes at reducing indoor PM levels at a kindergarten school - due to delay in contracting the air meshes installation the use case #2 during the open testing round will monitor how the *sensor.community* sensors measure against the already installed Canary system. Indoor measurements are planned only. Measurements started on 18th July and 2 sensors were installed in each of the two buildings of the kindergarten.
Research question(s)	Questions that must be answered through experiment: A. What is the efficiency of the window mesh at reducing the indoor to outdoor ratio of PM under varying ventilation regimes (including current everyday use)? Questions that can be answered through experiment: B. How do the current canary sensor devices and their alert thresholds compare to *sensor.community* devices for indoor measurements?
Hypothesis	A: Efficiency <<< 92,5% (reported $PM_{2.5}$ efficiency by manufacturer) B: Hypothesis on canary devices to be formulated when we have more information on that system (might e.g. also or only take CO_2 into account).

Plovdiv pilot

The Plovdiv pilot, in the frame of COMPAIR project, tries to show the connection between traffic intensity and levels of PM and NO_2 around the schools. Exposure to air pollution is a significant risk to children's health. The students and volunteers were involved in air quality and traffic measurements. The main goal of the Open Round in Plovdiv was to raise awareness of air quality around schools and to find a way for improvements.

In the city of Plovdiv, there are still problems with air quality, which are mainly due to domestic heating with solid fuels and transport activities. To improve air quality, the municipality takes a number of measures. For example, replacing old inefficient polluting devices using solid fuel for heating with new ones that meet the requirements of the Ecodesign requirements (EU 2015/1185 and EU 2015/1189). Regarding transport, the municipality makes efforts to stimulate citizens to use alternative and ecological ways of commuting, including the introduction of school streets.

The EAP team conducted several meetings with two deputy mayors - of Ecology and of Education. They signed an invitation to have two primary schools participate in the COMPAIR project activities. The initial plans included measurements of traffic, PM, and BC around the pilot schools.

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 with 7 SODAQ AIRs given to students and volunteers. 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 Open Round was very limited - 1 Telraam version 1 (V1) sensor (traffic sensor), 2 bcMeters, and 10 DIY PM_{10} sensors from *sensor.community*. This led to a change in the testing performed in the Open Round, compared to what was originally planned.

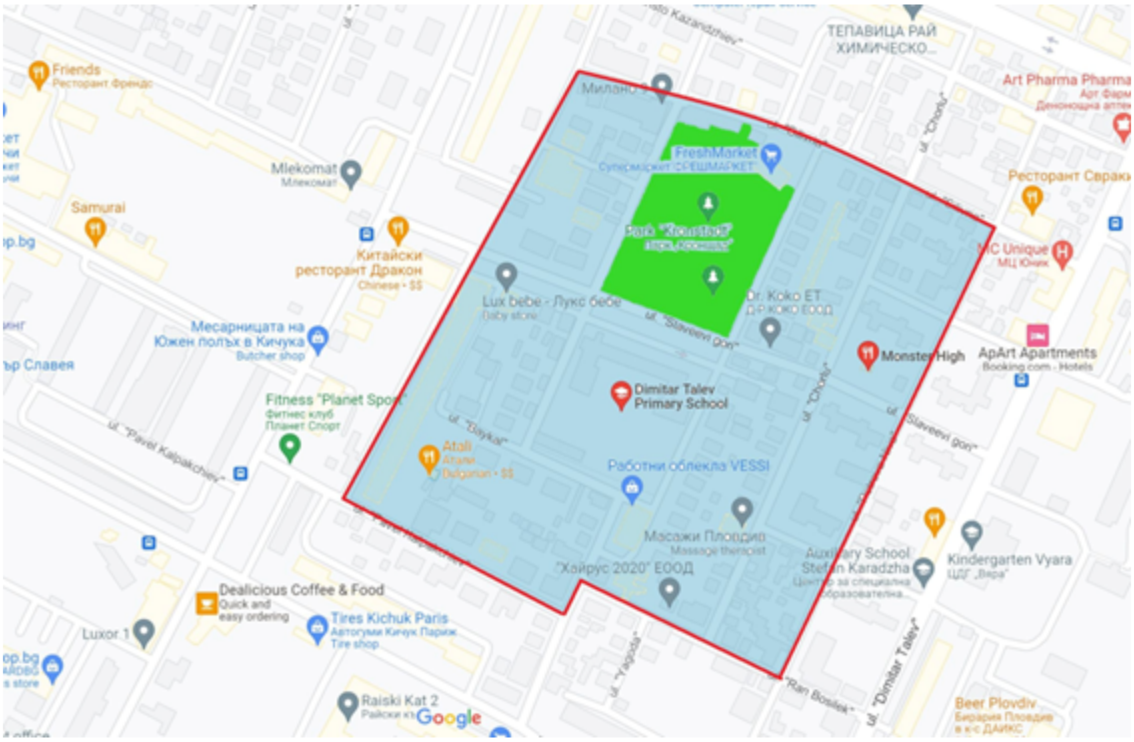
Plovdiv use case 1 – Primary school Dimitar Talev

Table 20: *Purpose, research questions and hypothesis for Plovdiv use case 1*

Experimental design for PLOVDIV - use case 1	
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 NO2 concentrations? C. Is there a difference between morning and afternoon peaks in traffic at the schools?
Hypothesis	Correlation between traffic intensity and NO2 concentrations No correlation between traffic intensity and PM concentrations

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, shown in Figure 30. Due to unavailable network connectivity to use SODAQ AIR devices to measure PM (as well as some delays experienced in device delivery) and Telraam V2 devices to measure traffic, this goal was achieved using 1 mobile laboratory that was calibrated in a certified laboratory to measure PM, NO_2 and meteorological parameters, 1 Telraam V1 traffic sensor to measure traffic, 3 *sensor.community* sensors to measure PM and 1 bcMeter to measure black carbon.

***Figure 48**: Map of region covered by sensor devices around primary school Dimitar Talev*



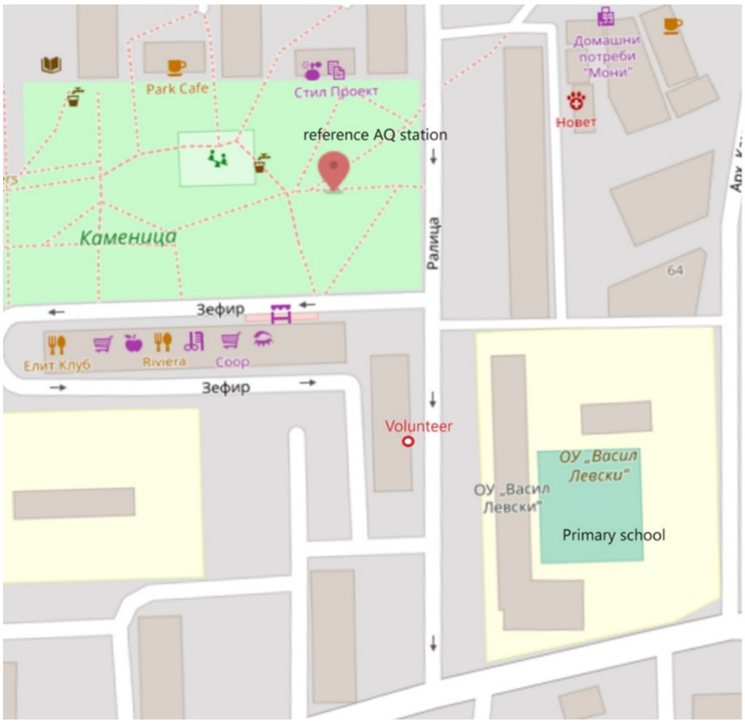
Plovdiv use case 2 - Primary school Vasil Levski

***Table 21:** Purpose, research questions and hypothesis 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 PM_{10}
Research question(s)	Questions that must be answered: A. Are changes in traffic related to PM concentrations? B. Are changes in traffic related to BC and NO_2 concentrations? C. How much do winter and summer PM concentrations, daily patterns etc. differ?
Hypothesis	Correlation between traffic intensity and BC and NO_2 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)

The goal of use case 2 was to raise awareness of the impact of traffic on air pollution and seasonal variation of PM_{10} around the primary school Vasil Levski, shown in Figure 31. The heating in the area is partially connected to the central heating supply and partially to the gas supply, while the remaining households use old inefficient stoves for heating during the winter season. The school is situated near a reference air quality (AQ) measurement station (around 100m distance away). The reference AQ station measures PM_{10}, O_3, NO, NO_2, SO_2, CO, benzene and meteorological parameters. This reference station gave us access to air quality data and filled the gap that was created due to the planned COMPAIR sensor devices not being able to send data.

__Figure 49:__ Map of region covered by sensor devices around primary school Vasil Levski



In addition to the AQ reference station, this goal was achieved using 7 *sensor.community* sensors to measure PM and 1 bcMeter to measure black carbon.

3.4.1.2. Experimental design

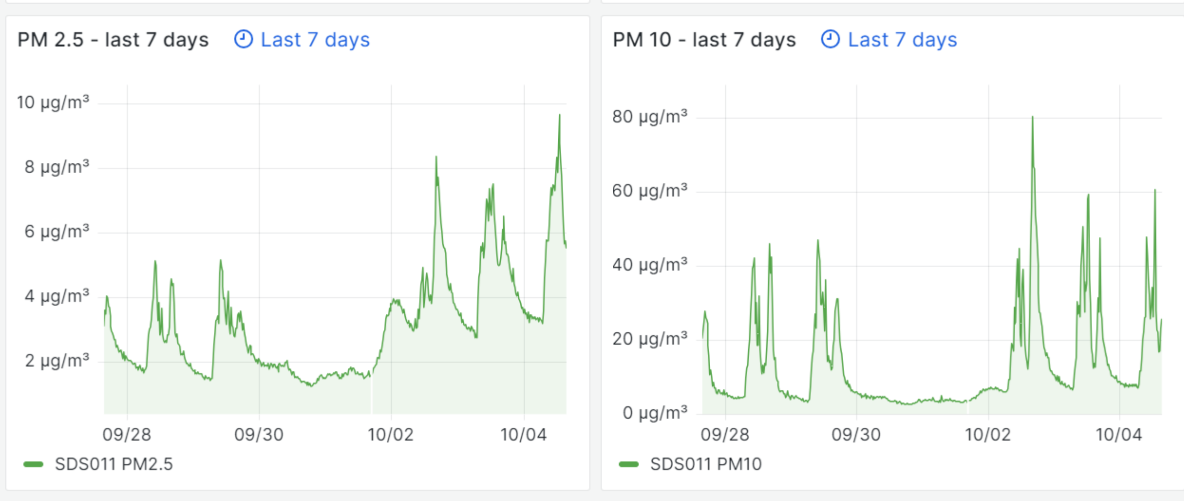
Sofia use case 1 – School bus service

What was done in the Open Round was mainly dedicated to awareness-raising activities and communication with the school students and their teachers while also indirectly spreading the information about the project to their parents with the help of the teachers. A limited amount of data was collected as only 8 *sensor.community* sensors, 1 bcMeter and 1 Telraam v1 device (from the Closed Round) were installed in the two schools that have transmitted data during the Open Round testing period. Apart from that, volunteering students were provided with an opportunity to test SODAQ AIR devices on their way to and from school. A total of 11 sensors were provided to students from the 2 schools but unfortunately no data was collected due to the already mentioned lack of NB-IoT and LTE-M connectivity in Sofia.

Sofia use case 2 - Kindergarten

Due to significant delays in adopting the municipal budget for 2023, the installation of the air meshes was postponed, but still the SDA team managed to install 2 *sensor.community* devices in two of the classrooms of the kindergarten in order to compare data and see if there is a difference in the levels of PM detected by the two different types of sensors (*sensor.community* and the Canary system).

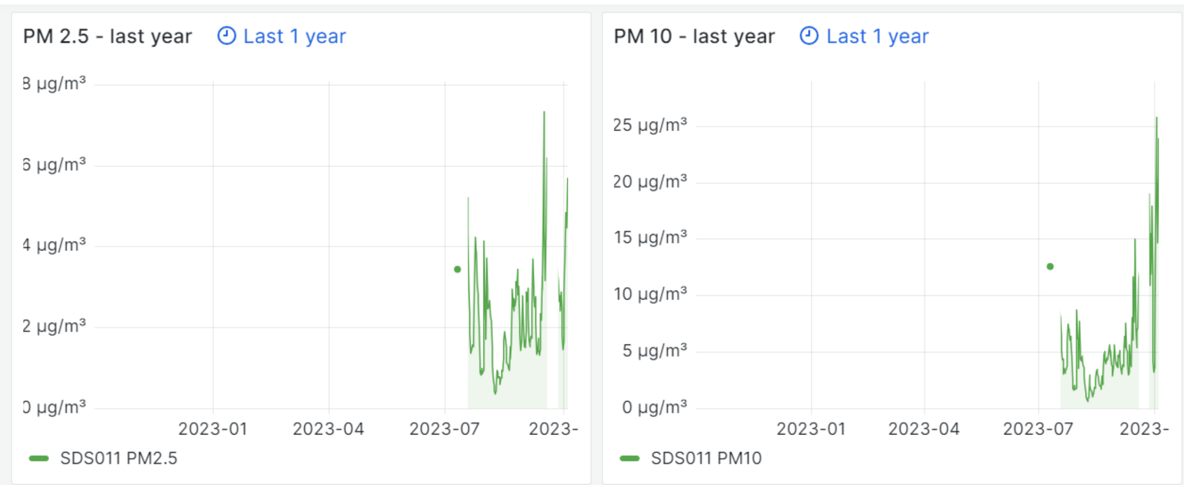
Figure 50: *Data from the sensor.community sensors installed in the kindergarten.*



COMPAIR *sensor.community* sensors were installed during the summer period when the Canary system was undergoing maintenance and not in use but still with the first data obtained, a clear correlation between personal experience of the amount of dust and PM levels when children were outside and when they were inside the room playing or sleeping was seen. Showing that when there was no activities in the room PM levels were dropping while when there were children in the room there was an increase in the PM levels. We can also see in **Figure 50** that during working days (28/09-29/09 & 02/10-04/10) when there were kids in the classroom PM levels were higher than during the weekends (e.g. 30/09 - 01/10).

From **Figure 51** we can also see that during the summer period there is a decrease in $PM_{2.5}$ and PM_{10} (dustiness indicators) levels, and as soon as the school year starts on 15/09 we can clearly see an increase in $PM_{2,5}$ and PM_{10} measurements.

Figure 51: *$PM_{2.5}$ (left) and PM_{10} (right) measurements over summer*



Measurements in this use case will continue during the Public Round

Plovdiv use case 1 – Primary school Dimitar Talev

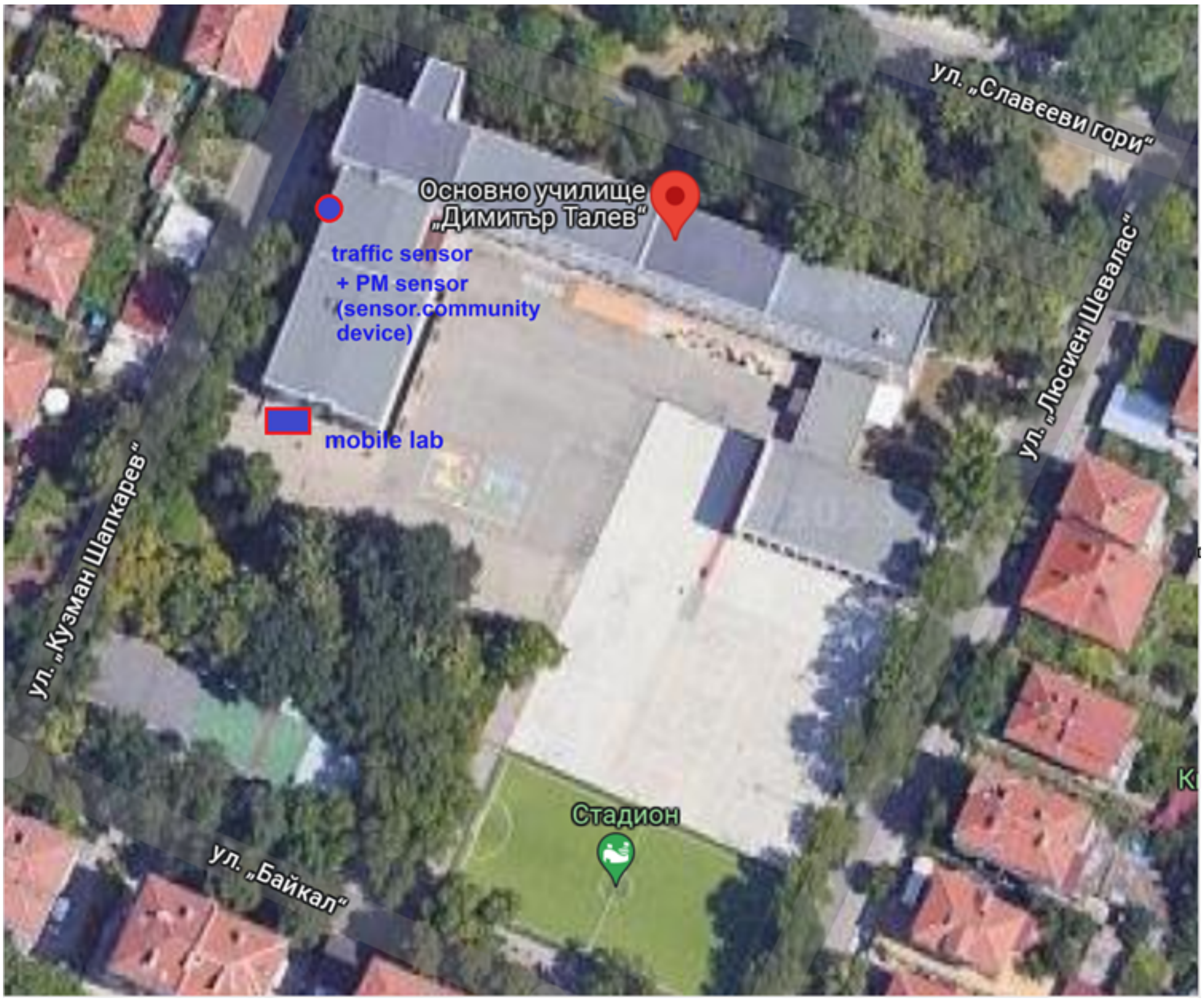
The experiments started at the beginning of April and finished on 15th June 2023 with the end of the school year. The mobile laboratory for measurement of the air quality was situated in the schoolyard (shown in **Figure 52**). The mobile laboratory was equipped with:

- PM_{10} dust sampler - PM_{10} monitor version of OPSIS' SM200
- $PM_{2.5}$ dust sampler – $PM_{2.5}$ monitor version of OPSIS' SM200
- Chemiluminescence $NO/NO_2/NO_X$ Analyzer – Teledyne T200
- Meteorological parameters - wind speed, wind direction, temperature, humidity, atmospheric pressure

The list of IoT devices that were placed, as well as their location is described below and in **Figure 52**:

- 1 Telraam v1 traffic sensor installed in a classroom
- 1 DIY (sensor.community) sensor was installed in the same classroom as the Telraam V1 traffic sensor and 2 DIY (sensor.community) sensors were given to students living in the area to install at their homes.
- 1 bcMeter was installed in the same classroom as the Telraam V1 traffic sensor.

Figure 52: *Map showing the location of the mobile station and IoT devices deployed*



More than 800 students study in the school. They were all given the opportunity to visit the mobile laboratory.

The classroom where the 1 Telraam V1 traffic sensor, 1 PM *sensor.community* and 1 bcMeter devices were installed specialises in teaching environmental science, physics, and chemistry and is attended by over 180 students during school hours. As an introduction to COMAIR, the EAP team along with one of the teachers gave a brief introduction of the project's aims, AQ topics, and how the mobile laboratory works. The teacher even familiarised the children with the sensors deployed in their classroom, what they measure, and where they can see the results. The school's principal and 2 other teachers ensured their full support during the Open Round testing period.

The biggest newspaper for south Bulgaria published several articles, dedicated to the activities in the school, including COMPAIR.

The measurements carried out by the mobile laboratory, one Telraam v1 device and three *sensor.community* sensors during this period were usable, as they were continuously running till the end of the Open Round testing, however the bcMeter overheated within a few days of deployment.

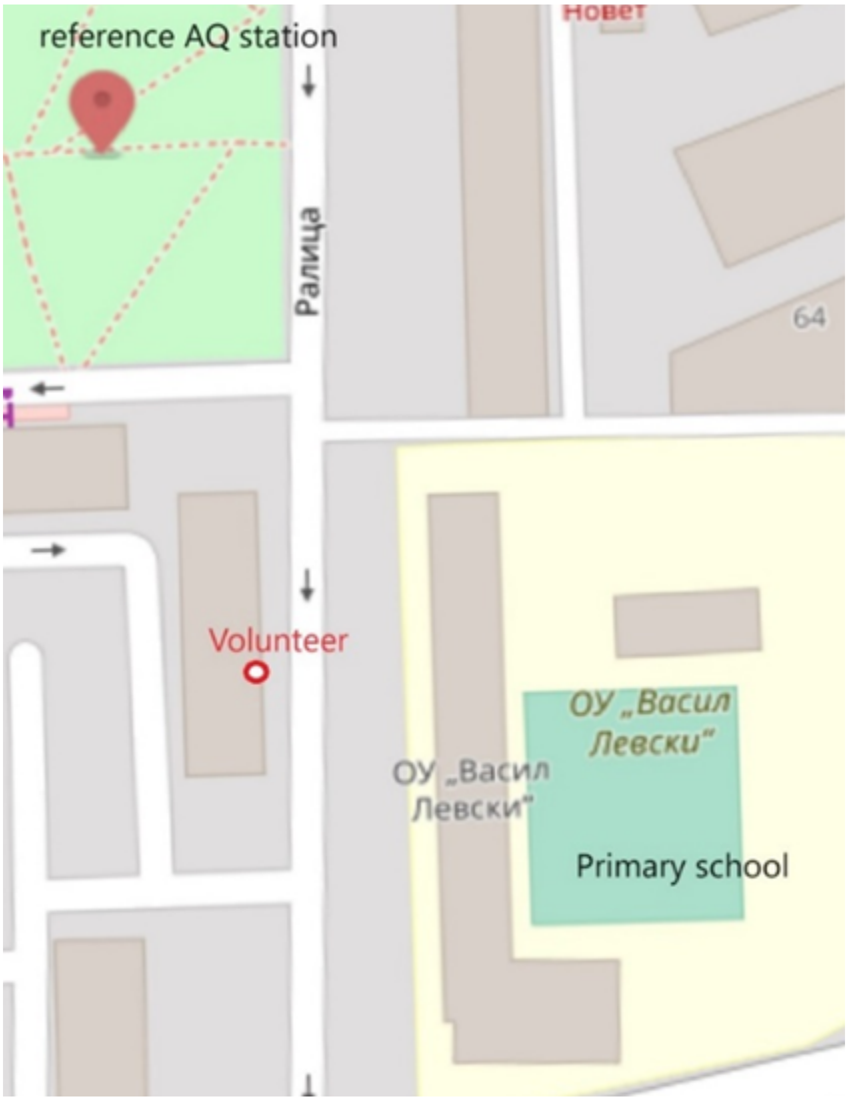
Plovdiv use case 2 – Primary school Vasil Levski

The measurements started in the second half of April. From the reference station (shown on **Figure 53**), PM_{10}, NO_2 and meteorological measurements were collected.

The list of IoT devices that were placed near the school, are described below and in **Figure 53**:

- 1 bcMeter was installed, but without a Telraam v1 traffic sensor (during the Open Round, the 1 Telraam v1 device available at Plovdiv from the Close testing Round was used for use case 1; another Telraam v1 device was made available to EAP during the GA meeting in Sofia and this was installed on October 15, 2023) at the location indicated with a red dot on **Figure 53**.
- 7 PM_{10} DIY *sensor.community* sensors were distributed to volunteers living in the area of the school to deploy at their homes.
- Two SODAQ AIR devices were given to the volunteers and teachers to test the network connection.

Figure 53: *Map showing the location of the AQ reference station and 1 bcMeter deployed*



Based on data from the reference AQ station, the seasonal variation of PM_{10} will be analysed (comparison of the PM concentration during the heating season (winter) and during the summer) and reported in the Public Round report. The heating/ winter season in Plovdiv starts in October/ November and ends in March. This will therefore be measured as part of the Public Round. The Open Round covered the summer period from March to October. The goal of use case 2 to raise awareness of the impact of traffic on air pollution was hampered due to lack of a traffic sensor and therefore this is also planned to be undertaken in the Public Round.

3.4.1.3. Workshops

Sofia use case 1 – School bus service

Figure 54: *school kids working on sensor.community device*

Even though data availability was limited during the Open testing Round to make analysis of air pollution before and after the introduction of the school bus service, the SDA team managed to organise workshops where air quality training was provided to students from 3rd and 4th grade in both of the schools that are served by the school bus. Apart from introduction of the air quality topic and introduction of main sources of pollution and ways to limit air pollution in the city of Sofia, students were able to take part in *sensor.community* sensors' assembly and were also presented with the other sensors COMPAIR is using, together with the dashboards presenting the data collected by the sensors. Moreover, students were answering questions related to main pollutants and had the opportunity to propose ideas for limiting air pollution in cities.

Sofia use case 2 - Kindergarten

Workshop in the kindergarten was held only with the teachers that are working with the children in the classrooms where the two *sensor.community* sensors and the Canary system were installed. After initial conversation with the teachers it was suggested that in order to be presented to children, the air quality training materials needed to be adapted for children in preschool age. During the workshop, the teachers were able to see how *sensor.community* sensors are assembled and also received information about the other COMPAIR sensors that will be used. It was agreed that during the Public Round testing a meeting with the parents of the children needs to be organised in order to present to them COMPAIR sensors and dashboards and engage them in activities related to improving the air quality and possibly a change in behaviour when commuting (e.g. bringing their kids with public transport, bike or by foot to the kindergarten).

Plovdiv use case 1 – Primary school Dimitar Talev

For the students 3 workshops were organised:

- 1st workshop, shown in **Figure 55** - The workshop was held on 7th April 2023. In the schoolyard yard was installed mobile laboratory for air quality measurement. The students were introduced to the way the mobile laboratory works and the parameters it measures. The main goals of the CompAIR project were presented and students assembled DIY (*sensor.community*) devices.

Figure 55: *1st workshop conducted on 7th April 2023*

- 2nd workshop, shown in **Figure 56** - The workshop was held on 7th April 2023. During the working meeting, the children got acquainted with the topic of air quality, the different measurement methods, the different types of sensors, including those that will be used within the project. The dashboards for monitoring the measurement data were presented.

Figure 56: *2nd workshop conducted on 27th April 2023*

- 3rd workshop - The workshop was held on 9th June 2023. The results from measurements and ideas for Public Round were presented.

Plovdiv use case 2 – Primary school Vasil Levski

Due to the connectivity issues and limited number of devices that can be used ass of the beginning of April Plovdiv team decided to work with volunteers in this area. The first volunteers were a family of pensioners. They were acquainted in detail with COMPAIR project. The bcMeter and DIY sensor (*sensor.community*) were presented to them and were installed on their terrace. They were trained on how to use the sensors and how to monitor the measurement data.

A meeting and training with active citizens (volunteers) was organised. They were well acquainted with the COMPAIR objectives that more nuanced local actions and measures are needed to tackle the issue of poor air quality and climate change and that if poor air quality is caused by human activity, then human behaviours must be changed. The different types of sensors were presented them and also their working way. After the held workshop they installed the sensors in their homes and were learnt how to monitor the measurement data. In this way COMPAIR approaches behaviour change from a capacity building standpoint, giving people the digital tool model to understand and better analyse the air quality and then for diverting their everyday habits for its improvement. The meeting is shown in **Figure 57**.

Figure 57: *Volunteers meeting and training in Plovdiv*

3.4.2. Results

Sofia use case 1 – School bus service

The school bus service was in operation from 18th April 2023 till 30th June 2023. The two routes that served the schools were operating both in the morning and at noon as in Bulgaria students are studying in two different schedules - morning and afternoon. This was a major improvement and makes the service more complete allowing also students who go to school in the afternoon to benefit from the school bus service.

The bus routes have been prepared and adapted based on the feedback collected from parents of pupils who have used the service in its first testing period in 2021. After the feedback on the preferred routes and bus stops of parents of students from 1st to 4th grade of the 18th school William Gladstone and 32nd school St. Kliment Ohridski, extended routes were adopted allowing parents from over 11 neighbourhoods in the capital to use the service.
A survey was conducted to gather information and feedback from parents on their perception of the service and also measure its effectiveness. Results from the survey showed that 33% of respondents had used the bus service to school, which is a significantly higher percentage compared to the previous test period (February-June 2021) when only around 20% of parents who completed the survey had actually used the service. This was an indication that the extended routes and improved communication with students and school administration, together with the prepared materials to promote the service as part of the COMPAIR project have proven effective.
Apart from the survey distribution, an active passenger counting was performed during the active period of the operation of the service. Passenger counts showed that 1136 passengers used the school bus over the test period of about 2 and a half months. On active school days an average of around 50-55 passengers were carried on the two buses combined.
The two routes were almost equally preferred and users indicated satisfaction with the service. Many parents indicated that they would like to see even more extension of the bus routes. 62% of children who used the service had previously been driven to school by car, which equals to 37 less cars entering the perimeter of schools.
The ultimate aim of the measure is to significantly release the traffic in the central urban area during peak hours, especially in the morning, reduce air pollution and the levels of PM, as well as to ensure greater safety in the areas around schools.
Based on the positive feedback gathered during the Open testing Round from the bus service, the Sofia City Council voted in favour of prolonging the service for the whole upcoming school year (September 2023 - June 2024), while opportunities for further improvement of the measure are also under consideration.

Sofia use case 2 - Kindergarten

As the policy measure that was planned in the initial planning of the experimental design of the Open testing Round was not implemented during the timeframe of the Open testing Round activities it is difficult to report on its results in this deliverable. The SDA team will continue its efforts to support the measure implementation in the coming months to ensure that proper analysis will be carried out and reported in the Public Round report.

Plovdiv use case 1 – Primary school Dimitar Talev

This area of the district is not covered by a reference AQ station.

A large part of the schoolyard is occupied by green areas and sports fields. Because of this, the mobile laboratory could be placed only in limited places. Where positioning was possible, there appeared to be a problem with the power grid. The power grid is designed for low power consumption - for example, lighting, computers, and multimedia. When the equipment of the mobile laboratory was switched on, the power consumption increased sharply, the installation was overloaded and the equipment would switch off (the automatic protection of the equipment gets activated). This resulted in data gaps.

The measurements of NO_2 and PM_{10} (shown on **Figure 58**) taken by the mobile laboratory were on an hourly basis. It is clear from this figure that on non-school days, observed NO_2 concentrations were lower than on school days. However such a huge difference was not visible for PM_{10} even though they were lower on non-school days than on school days, in comparison. This behaviour in NO_2 was compared to traffic patterns to find a correlation.

Figure 58: *Measurements of NO2 and PM10 taken by the mobile laboratory.*

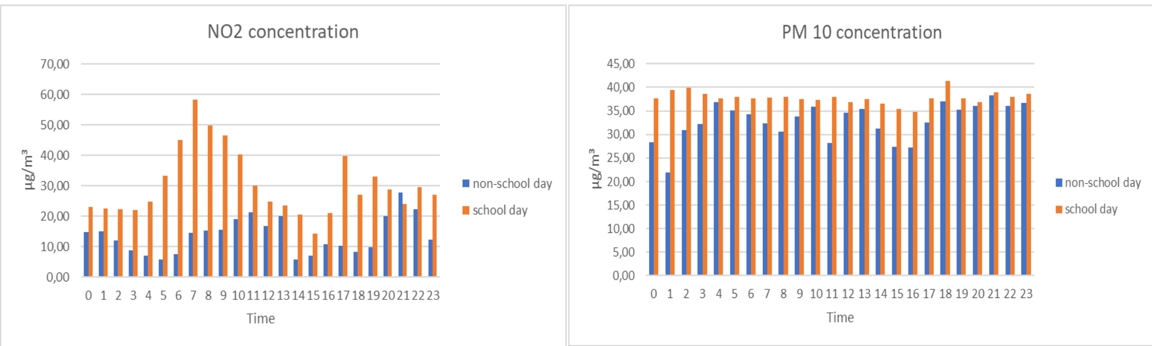
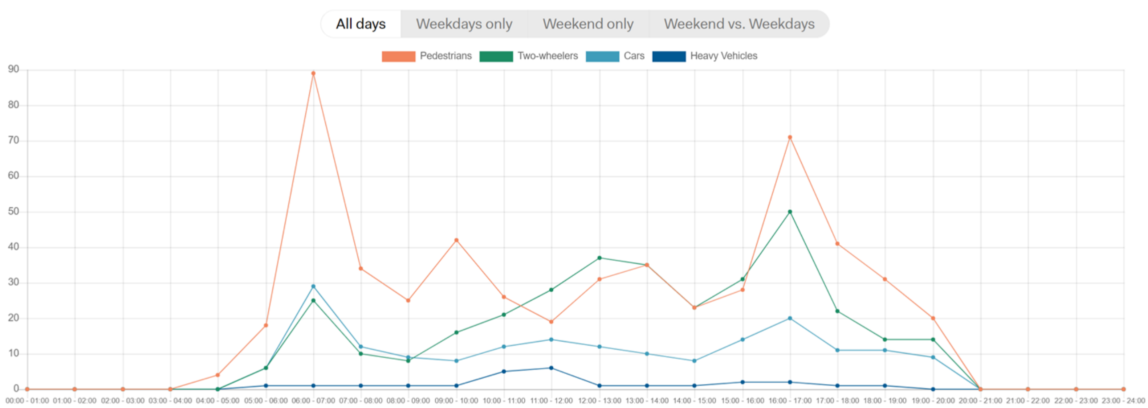


Figure 59: *Traffic counts on an hourly basis on school days*

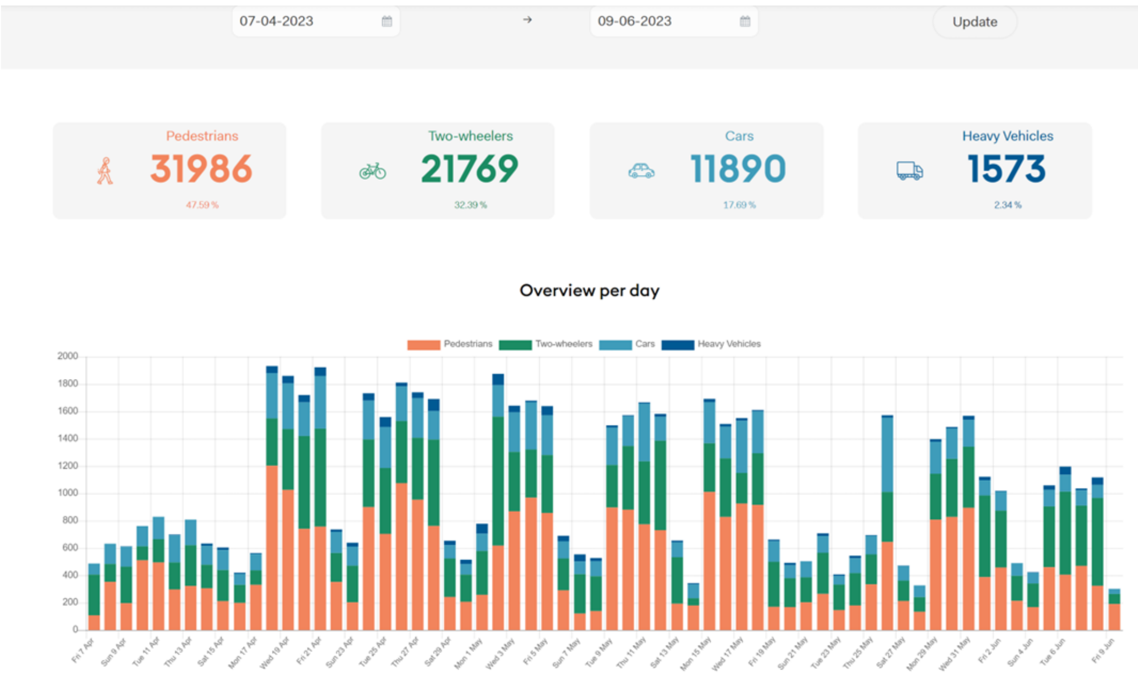


When traffic counts of the school days were plotted as shown in **Figure 59**, it was found that the hourly peaks in NO_2 concentration coincide with the hourly peaks in the number of vehicles. The highest number of vehicles were in the morning, when most parents take their children to school either by car or two-wheeler, the next peak was seen at noon, when some of the children finish their school trips and leave for their homes, and the last peak was around 17:00, when school activities end and once again parents come to take their children back home either by car or two-wheeler.

On non-school days, where the observed NO_2 concentrations are lower than on school days (**Figure 58**), could be related to the number of preventive measures.

Figure 60 plots the traffic counts for the entire duration of the Open Round (April to June). From this figure it is clear that the number of vehicles and pedestrians are higher during the school days (weekdays) than non-school days (weekends and holidays).

Figure 60: *Traffic counts on all days within the Open Round*



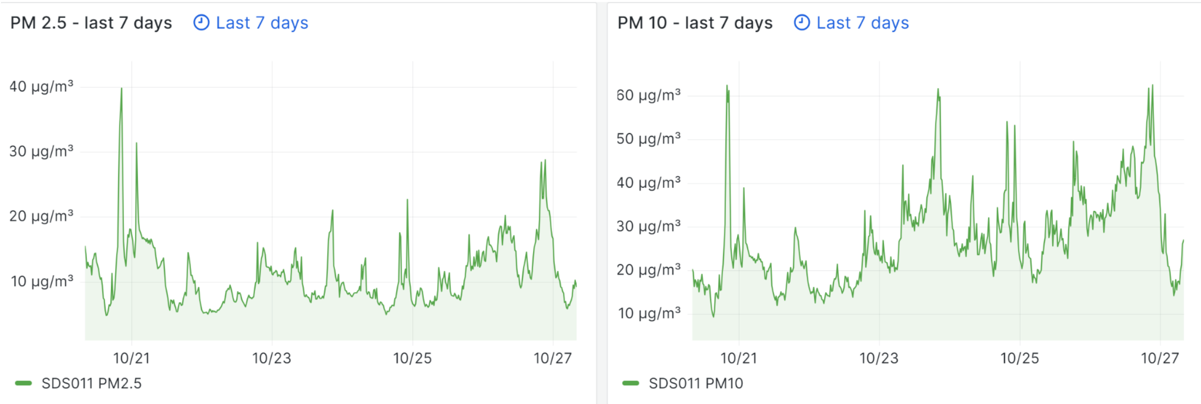
No such trend was observed for PM_{10} concentrations when compared to traffic. Near the school there is a large boulevard, which is under renovation. Probably, the relatively high PM_{10} emissions were a result of construction activities rather than PM_{10} emissions from transport.

It is to be noted here that students wore school uniforms and when they moved in groups the Telraam V1 sensor clusters them and recognizes them as cyclists or cars. This was envisioned to be overcome with the new version of the sensor (Telraam V2), which unfortunately Plovdiv cannot use due to the lack of network connectivity and so for the Public Round measurements using more V1 devices, this will be taken into consideration when drawing conclusions. Also, there are trees around the school that come in the way. For the Public Round, since measurements will be conducted in Autumn (when the leaves would have fallen) the measurements will be more accurate.

One bcMeter was installed, but as mentioned previously the device was destroyed due to overheating from direct sunlight exposure, and so no data was available from it.

COMPAIR *sensor.community* sensor was installed on the school facade in April 2023 and will continue to measure PM levels during the Public round.

Figure 61: *Data from the sensor.community sensors installed in the school*



The volunteers tested SODAQ AIR devices to find that the sensors worked (from the light indicator on devices and the sound from the device when in operation), but couldn't transfer data, due to connectivity issues. For this reason, the sensors were not used until the end of the Open Round and will neither be used during the Public Round.

Telraam v2 sensors that were delivered, also couldn't transfer data due to a lack of LTE-M / NB-IoT network and for this reason, these sensors were also not used until the end of the Open Round and will neither be used during the Public Round.

Plovdiv use case 2 – Primary school Vasil Levski

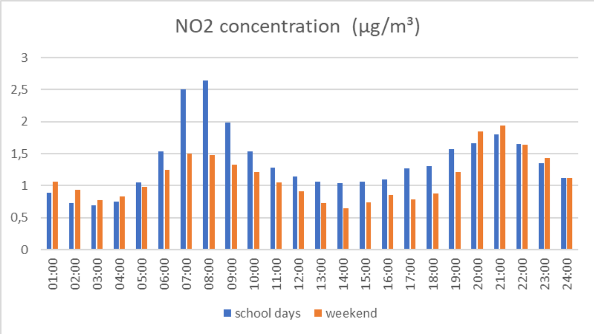
The school is situated near a reference AQ measurement station (around 100m distance). The reference AQ station measures PM_{10}, O_3, NO, NO_2, SO_2, CO, benzene and meteorological parameters.

Due to the connectivity and sensor device unavailability (as of the starting date) issues, we decided to collect data for levels of PM_{10} and NO_2 from the reference station. At the same time, we also had 1 bcMeter and 7 *sensor.community* devices. These IoT devices were installed in the home of volunteers living right across from the school. To add to these measurements in the Public Round, we will use more Telraam version1 devices as mentioned earlier.

Data from the reference AQ station for the period April - mid-September were analysed.

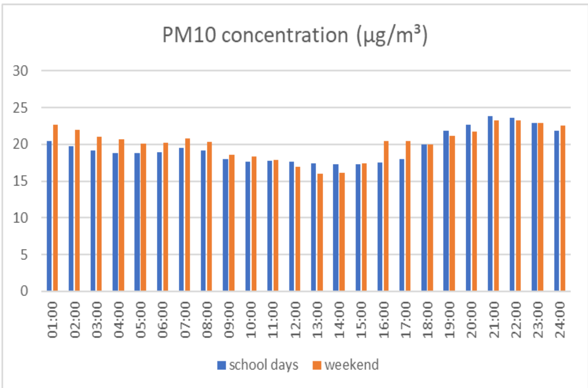
For the period from April 7 (the beginning of the experiment) to June 15 (the end of the academic year), the average hourly concentrations of NO_2 are similar to those of Use case 1.

Figure 62: *Hourly averaged NO_2 concentrations on school days (blue) and weekend days (orange)*



The peak of NO_2 concentration is again 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 Vasil Levski School is located next to 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 NO_2 in the period from 19:00 to 21:00.

Figure 63: *Hourly averaged PM_{10} concentrations on school days (blue) and weekend days (orange)*



During the same period, average daily PM_{10} concentrations did not show such peaks.

The combustion of fuel is the main source of NO_2 in the ambient air and is created as a result of emissions from traffic. PM_{10} emissions from the combustion process in transport depend on the type of fuel and are very low. For example, gas-powered passenger cars haven't PM_{10} emissions. They are due to the resuspended dust, wear and tear of the road surface, tires and brakes.

Figure 64: *PM2.5 (left) and PM10 (right) concentration levels in Plovdiv*

COMPAIR *sensor.community* sensor was installed in the same area.

The main source of PM_{10} for Plovdiv is domestic heating with solid fuels. The municipal air quality program shows that the exceedances of the average daily concentration of PM_{10} are in the winter in the heating season. The heating season in Plovdiv starts in October/ November and ends in March. It is hypothesised that the PM level during this season will be relatively higher. The data from the AQ reference station and *sensor.community* devices will be used to see how low PM values are in the summer season - measurements made from April 2023 to September 2023 (6 months) during the Open Round. The measurements made from October 2023 to March 2024 (6 months) will be used to see how high levels of PM will be during the heating season (Public Round). The comparison of the PM concentration will be used to address the goal for raising awareness of the PM_{10} seasonal variation around this school.

During the Public Round the V1 Telraam traffic sensors will be installed together with the bcMeter and distributed among volunteers living close to the school.

Data for NO_2 concentrations from the reference AQ station is also available which will be used to correlate with traffic measurements in the Public Round.

3.4.3. Lessons learned

During the Open Round testing few issues were identified that will be considered when further planning the Public testing Round. The lessons that the SDA and EAP teams learned from the experiences of the Open testing Round are being analysed and will be incorporated into the preparations of the Public testing Round. Lessons learned have been clustered in three main domains by the SDA and EAP teams and are further explained in the sections below.

Sofia use case 1 – School bus service

Engagement
It is quite easy to get children engaged and willing to participate in a citizen science project, however it is difficult to keep their interest and engagement over a longer period of time. Thus, the SDA team had to work very closely with the teachers in order to ensure constant presence of the topic of air quality and air pollution in their teaching schedule, as well as providing additional materials to support them. A major draw-back in terms of keeping students' engagement was the lack of connectivity of the mobile air quality sensors (provided by SODAQ) which caused some demotivation of the students who were quite eager in the beginning to take part in air quality measurements and take a sensor with them. Another issue, of course, was related to the timing of the activities and the need to schedule all of them very close to the end of the school year which resulted in limited availability of the students. Last but not least, apart from the timing, the need for formal consent from the parents whose children wanted to take a mobile air quality sensor led to delay in providing the sensors to the children which affected their initial enthusiasm.

The use case in the two schools taught the SDA team important lessons that will be considered during the implementation of the Public Round. They can be described as follows:

- Honesty is key - you need to be completely honest, especially when working with children. If the tools that you will be showcasing do not work properly, you need to be able to explain the reasons behind, right away;
- Timing is very important - apart from official vacation a lot of other things are going on for school students throughout the school year. When planning a workshop or any other activity this should be planned well in advance in order to make sure that you will be able to reach out to most of the students and they will be having the capacity to take part in the activities you plan;

- Asking for parents' consent is essential - the sooner you get these consent forms from the parents, the better. No activity can be performed with elementary school students without the explicit consent of their parents;
- Communication is very important - the more directly and closely you communicate with the key stakeholders, the better - e.g. involving parents to participate, and not only focus on kids, as parents can give you more specific and useful feedback.

Communication

During all the activities performed in the Open Round testing, constant communication was kept with school administration and teachers of the participating classes. This was essential in order to ensure smooth implementation of the activities. Teachers served as an intermediary between the SDA team and the parents of participating students. The draw-back was that sometimes there were some delays due to other planned school activities and teachers were preoccupied with other duties and thus unable to respond in a timely manner. In order to ensure that information is clear and detailed, the SDA team prepared couple of information materials that were spread to the schools, as follows:

- Brochures about the school bus routes and time-schedules.
- Online leaflet about the COMPAIR project and the sensors that will be used, containing information about each sensor type, its installation and other properties.
- Survey that was spread among the parents to gather feedback on the school bus service and also report on any issues they have come across when using the sensors.

Figure 65: *Bus service brochure*

The lessons learned within the Open testing Round in regard to communication will be used to better plan the communication activities during the Public testing Round. Most importantly, the SDA team will try to find a better way to directly communicate with parents in order to ensure smoother implementation of activities and shorten the time for receiving feedback.

Data availability/gathering and analysis

Due to the connectivity issues that were mentioned above, limited data was collected for Sofia during the Open testing Round activities. Moreover, the 8 *sensor.community* sensors used in the schools that are served by the school bus service, required Wi-Fi connection which seemed not to be very stable in one of the schools and thus a lot of interruptions in data collection were experienced. LTE-M alternatives were investigated by the technical team but none were viable. In the Public Round Bulgarian pilots will focus on WiFi-based technology and try to deploy devices in stable WiFi environments.

Another issue that the SDA team encountered was that sometimes cleaning staff were unplugging the sensors and again data collection was interrupted.

Even though limited data was collected during the Open testing Round, there is a clear correlation between PM levels and the timing of the school year and vacation period. Measurements will continue during the Public Round testing when the SDA team plans to install additional sensors and gather more data in order to analyse dependencies between traffic and air pollution and also measure the effect the school bus has in terms of limiting traffic around the perimeter of the schools.

Sofia use case 2 - Kindergarten

Engagement
When working with the kindergarten teachers few points were mentioned that the SDA team should consider when preparing the Public Round testing activities:

- When working with preschool children, engagement is very difficult as the kids are too young and can easily get distracted. In order to ensure engagement, constant contact should be kept with teachers and kindergarten's administration. Topics should be presented in such a way that can be easily understood by the kids including mostly pictures and referrals to games;
- During summer months it is very difficult to engage parents as the teachers of the kids are working on a rolling out schedule and kids are gathering in mixed groups.

Communication
Communication with parents of the participating kids is done by the teachers in the kindergarten. In the kindergarten, the schedule is not as busy as in the schools and each group is having dedicated teachers only for the group. Therefore, reaching out to parents of the kindergarten children was not considered an issue. It was suggested by the teachers that the easiest way to communicate with the parents is through the group Viber channel - a commonly used smartphone application in Bulgaria. The SDA team agreed to prepare online communication materials that would be distributed through this channel as part of the Public Round .

Data availability/gathering and analysis
Due to the maintenance downtime of the Canary system during the summer months and lack of data from it for this period, comparative analysis could not be performed as part of the Open testing Round. Initial results from the *sensor.community* sensors showed that there is a clear correlation between the levels of PM when there are kids in the classroom and when they are outside. Another issue that the team came across was a defective power supply adapter that resulted in severe interruptions in data collection during the testing period. The measures that were taken included a couple of visits to the kindergarten in order to check the sensor and try to reconnect and eventually a new power supply adapter was provided.

Final remarks

Both use cases that were implemented in Sofia during the Open testing Round have shown that constant efforts should be made to ensure proper communication, engagement and workability of the technologies used within the COMPAIR project. The SDA team had to adapt to force majeure situations like the connectivity issue related to the IoT network coverage in Bulgaria and re-plan activities in accordance with the available resources. Another very important lesson that was learned from the SDA team during the Open Round testing was that timely feedback from participating users and stakeholders is essential for smooth implementation of the pilot activities.

With the experience and feedback gathered during the Open testing Round, the SDA team feels better prepared and more flexible in terms of preparing the upcoming activities for the Public testing Round.

Plovdiv

In the domains below, the EAP team summarises lessons learnt from both use cases.

Communication

Good communication is a key for successful implementation of the project activities. The municipality of Plovdiv supported the implementation with participation in stakeholder workshops, dissemination of information and sending invitations to the schools.

The local media published information of the project and people were well informed. The publications built trust amongst the people in the respective districts.

Telraam v2 and SODAQ AIR sensors couldn't send data because of connectivity issues in the city of Plovdiv but the enthusiasm shown by volunteers and students to test the connectivity was commendable. Some of them were disappointed because of non-working devices but were in constant communication with the EAP team to try and see if they were able to achieve connectivity to be able to use the devices.

Engagement

The participants were divided into 3 categories according to their age:

- Students (11 - 12 years old), who were very enthusiastic, showed great interest and were very inspired at the workshops (they didn't even use the manuals, but started assembling the sensors on their own). All devices were correctly assembled by all them;
- the middle-aged volunteers, first read the manual and then began to assemble the sensors following the instructions;
- the elderly (retired), also first read the manuals but were afraid to assemble the devices themselves lest they messed something up and were helped by the EAP team to assemble the devices.

The conclusion was that different approaches should be used depending on the age of the participants.

The teachers strongly supported implementation of a school street. The parents were not so positive about the implementation of the school street. For this reason it is necessary to involve them more deeply by presenting the results from measurements, introduction of the tools and asking for feedback, and common discussion (students and parents) on how AQ can be improved.

Data availability/gathering and analysis

The electricity grid in the primary school Dimitar Talevis (use case 1) is not designed for high power consumption, which resulted in data gaps. The available data was sufficient to direct attention to the relationship between NO_2 concentrations and traffic intensity for the Open Round however this may not be the case for the Public Round. The challenge is that the school doesn't have the budget for the reconstruction of the electricity network. With this issue at hand, it is likely that the mobile laboratory will not be usable during the Public Round to measure PM or NO2 levels in which case the EAP team is considering changing the location for the Public Round to another school.

One bcMeter was destroyed and didn't work for most of the Open Round.
Some of the *sensor.community* sensors stopped working during the summer. Either that volunteers switched off the devices during their vacation time and forgot to switch them back on, or during cleaning activities, the devices were switched off but not switched back on.

Final remarks

In the pilot team, it would be good to have a technical expert who can answer the questions of the citizens, be responsible for the maintenance of the devices.

For the Public Round we plan to use more devices that use Wi-Fi connection instead of LTE-M / NB-IoT.
The school streets can improve the AQ around the schools and the citizens need to be convinced of this. It can be achieved by involving more participants in the measurements, widely disseminating the results and organising discussions.

4. Conclusion

This section provides a brief overview of COMPAIR's accomplishments during the Open 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. **Table 22** outlines the experiments in each pilot.

Table 22: *Summary of experiments in all Open Round pilots*

Pilot	Experiments
Athens	- Engaging senior citizens in Neos Kosmos area through Friendship Clubs - Replicating the Neos Kosmos approach in Kipseli area (Public Round) - Raise awareness on the impact of daily activities through the carbon footprint tool (Carbon Footprint Simulation Dashboard) (Public Round)
Berlin	- Determine cyclist exposure to air pollution to stimulate spontaneous and helped behavioural change, while filling gaps in official monitoring data - Evaluating the impact of a parking ban in the Graefekriez neighbourhood
Flanders	- Demonstrate the impact of a school street in Herzele on both traffic and air quality - Evaluating a mobility plan in Ghent (postponed due to legal action)
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 before and after introducing specific window meshes
Plovdiv	- Investigate the relationship between traffic and air pollution in 2 school areas to raise awareness

All pilots faced significant challenges during the Open Round mainly due to delays in sensor delivery 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 for the Public Round. Recruiting choices and workshops seemed to be rather effective, however a greater participation and more attention to involving participants with a lower socio-economic status should be targeted in the Public Round. Despite the challenges faced resulting in a shorter duration of the Public Round, the pilots managed to reach some interesting conclusions during the Open Round.

As a result the COMPAIR pilots managed to organise 12 additional workshops - in addition to the 2 workshops per pilot in the closed round - as well as local recruitment campaigns, school lessons and other engagement events. Through these efforts we managed to **directly** reach about 3 300 citizens with at least an additional 25 000 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 23% or over 700 participants.

In Athens elderly participants were successfully recruited through the existing Friendship Clubs network, confirming the viability of recruitment through existing stakeholder networks. 21 air quality sensors were distributed and are up and running in the Neos Kosmos area. Participants are also filling out logbooks and taking part in discussions on environmental issues. A comparative analysis of air quality observations in the Neos Kosmos and Kipseli areas will be part of the Public Round experiment once the engagement approach has been copied to the Kipseli area, highlighting key differences and linking behavioural choices to air pollution. Initial data analyses already show a clear influence of local topography.

In Berlin citizens participated in an 8 week mobile air quality measurement campaign and engaged on the topic through workshops. In intermediate exchanges with the local pilot team new routes were suggested and participants were nudged to adopt more sustainable behaviours. This was followed by another 2-3 weeks of measurements and a final, interactive workshop where their (changed) perceptions on air quality, traffic and support of public policy measures were discussed. Another set of citizens participated in the evaluation campaign of a local parking ban. This campaign is still ongoing as the parking ban was only implemented over summer, intermediate workshops allowed INTER3 to discuss the sensor measurements in relation to reference measurements. In a final workshop in November citizens will co-evaluate the parking ban's impact on traffic and air quality. About 25 air quality and 2 traffic sensors were deployed in these campaigns.

In Flanders the pilot team focused on the school street case in Herzele, while also setting up base measurements in Ghent and initiating our cooperation with schools in light of Public Round experiments. We deployed 37 traffic sensors in both locations (Herzele & Ghent) and 7 bcMeters and 3 NitroSense devices in Herzele. Additionally, 2 NitroSense devices were deployed at a reference site in Ghent for calibration and performance monitoring. In Herzele we directly involved 1255 students (both primary and secondary school) through an educational package on traffic (primary) and an expert talk on the AI recognition system in Telraam (secondary). 29 inhabitants of Herzele were directly involved in data collection and analysis. They received training and information in 2 workshops (traffic & air quality). The traffic data collected by the citizen scientists clearly showed the positive effect of the school street. Based on these results, the local authority decided to (1) extend the school street implementation and (2) expand it to another school in their territory. The air quality picture is much less clear, mainly due to a lack of data because of connectivity issues.

Both the Plovdiv and Sofia use cases were severely hampered in their execution because of the lack of LTE-M coverage for sensor data communication. As a result only Telraam devices (older Wi-Fi version), 2 bcMeters and 10 *sensor.community* PM sensors were deployed in Plovdiv. The local team cooperated with the Deputy of Mayors for Ecology and Education to recruit primary schools, resulting in 2 schools participating. At one school the team focused on awareness on traffic and air pollution by setting up a mobile reference station, Telraam device and PM-sensor. At the other school the focus was on seasonal variations in PM levels. This school was located fairly close to a reference monitoring site, allowing EAP to use that reference data as well. At the other school site a mobile laboratory was deployed, providing an opportunity to involve another 800 school kids through a visit to this mobile laboratory. At the school with the mobile laboratory, NO_2 pollution levels were related to traffic intensities. The same relation did not hold for PM_{10} values which were likely more influenced by local road works.

In Sofia the local team deployed *sensor.community* devices at two schools participating in the school bus project. Due to connectivity issues no other pollutants were monitored at this time. A survey showed that 33% of respondents (students) used the bus service, this was also evidenced in passenger counts. Based on these results, the bus service was extended for the entire school year of ‘23-’24. Due to budget constraints the installation of the window meshes at the kindergarten was delayed. The local team managed to deploy PM sensors though, showing correlations between indoor and outdoor PM levels. SDA hopes to demonstrate the effectiveness of the window meshes upon installation in the Public Round.

Pilot activities in the Open 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 participant registration and commitment highlighted the importance of clear communication. The "Data Café" approach was effective for knowledge sharing, and extended support was crucial for maintaining participants over prolonged periods. 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 Open Round report provides a summary overview of the lessons learned in the Athens, Berlin, Flanders, Sofia, and Plovdiv pilots during the Open 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

- Senior citizens showed high interest in learning about pollution and contributing to measurements.
- Technical tasks engagement was remarkable among elderly citizens and contrasted with the expectation that this target group would be hesitant on using new technology
- Troubleshooting issues were mostly related to sensor devices, especially for seniors.
- Specific feedback on sensor types and their usability was collected.

Berlin

- Registration and participant commitment were challenging; more detailed information and clear communication were needed.
- "Data Café" format for engagement and knowledge sharing was effective.
- Adequate support for participants over extended measurement periods was crucial.
- Individual behaviour change may not be productive; focus on structural issues as behavioural options can be limited due to poor cycling infrastructure etc. To be confirmed whether this observation was specific to the area of interest.

Flanders

- Local champions played a significant role in engaging and organising participants.
- "Data Café" format enhanced engagement and collaboration.
- Adaptive planning for unforeseen challenges was important.
- Extended data collection periods were necessary for robust assessment (min. 2 months prior and 2 months after policy intervention as a rule of thumb).
- Local political dynamics could impact project timelines.

Sofia & Plovdiv

- Engagement of school students required close collaboration with teachers.
- Timely communication with parents and honesty about device functionality were essential.
- Connectivity issues affected data collection in Sofia.
- Data analysis showed correlations between PM levels and school activities (e.g. moving in and out of classes, playground dust …).
- Feedback from users and stakeholders was crucial for smooth implementation.

Sofia specific lessons

- Engagement varied by age group, requiring different approaches.
- Data gaps occurred due to connectivity issues and device management.

Plovdiv specific lessons

- Engagement strategies varied by age group.
- Electricity grid limitations affected data collection.
- Technical support and availability of experts were important.
- Planning to use more Wi-Fi-connected devices for the Public Round.

Lastly, we found that good communication and trust-building with local stakeholders were key. These lessons will inform the future phases of the COMPAIR project, particularly the Public Round, and help improve engagement, data collection, and communication with participants and stakeholders.

5. Recommendations for Public Round

Based on the lessons learned during the Open Round of the COMPAIR citizen science project, we've developed a set of recommendations to enhance the upcoming Public Round of experimentation:

1. Enhance communication and engagement:
- Prioritise clear, detailed communication with participants, offering a better understanding of the project's goals, requirements, and their roles
- Develop tailored engagement strategies for different age groups to ensure active involvement. Hands-on lessons in schools work well for school kids, look into existing local networks (e.g. cyclists union, Friendship Clubs, NGOs working with Roma community) and use non-standard formats like a “café” setup to spark interest
- Continue to use the "Data Café" and “Friendship Clubs” format for knowledge sharing and engagement, as it has proven to be an effective approach.
- Maintain open and honest communication with participants, providing clear information on device functionality and any limitations

2. Leverage local champions:
- Continue to tap into the valuable role of local champions in engaging and organising participants within their communities
- Identifying local champions requires (1) an attitude and clear communication on our openness to any kind of cooperation and (2) consistent attention to notice when a participant starts indicating they want to be more closely involved
- To facilitate detection of local champions early on, consider using SOCIO-BEE’s[13] questionnaire during initial/kick-off workshops

3. Technical support and training:
- Offer comprehensive technical support for participants, particularly when troubleshooting sensor device issues. Include easy-to-follow guides and be prepared to invest time in house visits to amend issues
- Provide training sessions, especially for elderly participants, to build confidence in handling technical aspects

4. Feedback loops:
- Establish efficient feedback mechanisms to collect specific insights on sensor types and usability. This feedback can guide improvements in sensor technology, consider involving participants who are actively cooperating on these technical aspects in project meetings
- Participants are also motivated by the outcome, keep them apprised of results and host intermediate events to discuss how things are going. In the absence of clear results, this can also just cover issues they encountered
- Keep uncertainties in the outcome to a minimum by ensuring sufficient quality of results, campaign duration etc. As participants are motivated by the outcome, it is

[13] https://socio-bee.eu/

demotivating for them when a campaign fails and there is not a lot of data available or results are inconclusive.

5. Increase leverage on individual behaviour change:
- Focus on the broader picture of behavioural change such as motivators, roadblocks and have participants share their experience and motivate each other. This makes it easier to cross any thresholds regarding behavioural options like transport choices
- Emphasise addressing structural issues related to air quality that present roadblocks to individual behavioural change, as these may lead to more significant and sustainable improvements by increasing the leverage of individuals on their own behaviour

6. Adaptive planning:
- Remain flexible and adaptable to unforeseen challenges, adjusting project plans as needed to ensure successful implementation
- Plan activities in light of participant agendas, host workshops in evenings, provide nourishment etc. to lower any thresholds that might withhold people from participating
- Stay aware of the potential impact of political dynamics on project timelines and be prepared to navigate any resulting challenges.

7. Extended Data Collection Periods:
- Recognize the necessity of prolonged data collection periods for robust and comprehensive assessment, especially in areas with dynamic air quality patterns. Consider changing the setup, moving to a different area or evaluating a different measure in case local plans no longer match up with minimum requirements for before and/or after measurement duration etc. In the Open Round this was accepted in some pilots to also test how far we could stretch sensor data interpretation
- As mentioned in point 3 define a clear minimal campaign configuration, if this minimum configuration cannot be reached (e.g. not enough sensors, policy is implemented too early, etc) consider not starting the experiment as it will have a high risk of demotivation and dropout

8. Technical improvements:
- Address connectivity issues experienced during data collection by exploring alternative data transmission methods or improving network infrastructure
- Address device malfunctions and push to higher TRL levels for devices like bcMeter
- Consider incorporating a variety of devices, including Wi-Fi-connected options, to enhance data collection reliability.

By implementing these recommendations, the Public Round of the COMPAIR citizen science project is poised to achieve even greater success, fostering stronger engagement, improved data collection, and enhanced communication with participants and stakeholders.

6. Annex 1 – Experimental design document May '23 example of living document

Open round experimental designs

This working document summarizes the experimental designs for the open round pilots in COMPAIR. The methodology is based on the recommendations formulated in Together For Clean Air and the LIFE VAQUUMS project. This document was created with the aim to:

- Check the level of preparedness in pilots for open round experimentation from a scientific point of view
- Generate input on topics to be discussed in the open round report (D5.4)
- Provide a comparable basis for ongoing discussions with and between pilots

It is therefore important to note that the aspect of designing participative processes (e.g. workshop outline, recruitment …) is currently **out of scope of this document**. However, timing of recruitment and workshops on using dashboards/data analysis have been included in the template to also jump start that process with the pilots.

Reading notes

One chapter is provided per pilot in which we discuss:

- The exchanges that have taken place
- Expected review by the pilots in the current phase
- A tabled overview of the experimental design highlighting the following elements:
    - Purpose
    - Research questions & hypotheses
    - Experimental design
    - Required analysis steps
    - Remarks

For each step in data analysis it is also indicated whether this can be done using:

- COMPAIR PMD
- COMPAIR DEVD
- External visualisations (e.g. SODAQ, sensor.community)
- Or it requires additional internal analysis in R, Excel … by the pilot

In each chapter a minimal review expectation is formulated, but any other comments on unclarities etc. are welcomed. Regarding the expected review, pilots are asked to make changes (suggestion mode please) and add comments wherever they see fit. Questions in the tables require answering by the pilots. Once an aspect of the design has been reviewed/validated the pilots can tick the checkbox in the left most column.

Athens

bcMeter case:

- Purpose of these measurements: discover BC concentrations at certain locations (public administration)
- How close to the traffic will these be:
    - Close to park and urban area in street
- Some measurements to illustrate differences between park and street locations
- Measurements could be added in the Digital Twin

Experimental design for Athens - use case 1	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
• **Purpose**	Creating awareness on air quality among elderly inhabitants (10) in 1 district + *increase their technology skills?*
• **Research question(s)**	None, focus on awareness
• **Hypothesis**	Variations in PM levels across neighbourhood, variations in PM over time (daily, monthly, seasonal …) + Detect wood burning patterns from peaks observed in data visualisations and data to allow for discussions with elderly to generate insight in own behaviour on air quality mainly for the CO2 dashboard
Type of experiment	Comparative Descriptive Threshold testing
• **Design**	What: - Particulate matter (PM2,5) - 10 sensor.community devices Where: - Deployed in 1 neighbourhood within the district on the balcony of individual residences (apartments preferably on lower floors) of elderly participants - Neos Kosmos Who: - Elderly, as a low SES group, 65+, majority retired - Take part in socialising centre (Λεσχη Φιλιας Νεου Κοσμου "Αναληψις Κυριου") -> friendship clubs - Medical centers etc. also possible when needed to get enough participants - Device assembly = *COMPAIR, Pilots staff, DAEM to assemble probably, perhaps some exceptions if they have a technical background* - Device installation = *Pilots staff together with elderly citizens. Firstly let them try for 1 week, then follow up* - Device monitoring = *Pilots staff in the dashboard and elderly citizens in the field*

<table>
<tr><td></td><td colspan="5">When:
- Start as soon as devices are delivered with assembly workshop, useful to maintain at least 1 year to capture all seasons.
- Friendship clubs have activities every day, mostly in the morning. In previous this was typically done on a monthly basis but frequency can be increased

How:
- Device monitoring = Using s.c dashboard/compair dashboard/compair data manager/device/device data manager? Preferably access directly from mobile, but online platforms will be difficult. Monthly reports to trigger discussions.
- Logbook (example) = elderly citizen keeps track of outdoor activities that could help correlate to sensor data? Yes, if we can provide it in printed form</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>Daily plots at various aggregation levels (5min, 15min, 1h, daily …) (smooth noise),
monthly averaged daily plots,
seasonal average daily plots,
weekday vs. weekend …
neighborhood 1 vs neighborhood 2
Compare plots with logbook inputs to correlate (e.g. Wood burning)
* with data from data manager/device
How will data be processed? Does PMD suffice? Is in house data science capacity available?</td><td>No
No
No
No</td><td></td><td></td><td>Yes
Yes
Yes
Yes
Yes</td></tr>
<tr><td>● Workshop</td><td colspan="5">What is planned for the workshop:
- device demonstration?
- dashboard demonstration?

When is the workshop planned:
- device demonstration
- dashboard demonstration</td></tr>
<tr><td>● Remarks</td><td colspan="5">Redistribution after 1 year can be considered, added value of longer campaign might be low

Behavioural options: activity

Drafting monthly reports → VMM to provide cases that could be measured (typical PM events) and EN logbook</td></tr>
<tr><td colspan="6">Experimental design for Athens - use case 2</td></tr>
<tr><td>Tick checkbox if validated</td><td colspan="5">Provide answers and make changes in “suggestion mode”</td></tr>
<tr><td>● Purpose</td><td colspan="5">Same as uc #1 but second neighbourhood</td></tr>
<tr><td>● Research question(s)</td><td colspan="5">Same as uc #1</td></tr>
<tr><td>● Hypothesis</td><td colspan="5">Same as uc #1</td></tr>
</table>

Type of experiment	Comparative Descriptive Threshold testing
• **Design**	What: - BC - 2 BC-meters Where: - on public administration sites maintained by staff - Kipseli - 1 at a park area and 1 at an urban street area Who: - Device assembly = COMPAIR - Device installation = *Pilots staff* - Device monitoring = *Pilots staff* When: How: - Device monitoring = *Using compair dashboard/compair data manager/device/device data manager* - Logbook (example) = *Pilots staff*
• **Planned analysis**	**Analysis** | | | **Ext.** | **Int.** *How will data be processed? Does PMD suffice? Is in house data science capacity available?*
• **Workshop**	What is planned for the workshop: - device demonstration? - dashboard demonstration? When is the workshop planned: - device demonstration - dashboard demonstration
• **Remarks**	Concerns, points of attention …
Experimental design for Athens - use case 3	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
• **Purpose**	*Calculating carbon footprint using dashboard*
• **Research question(s)**	*Raising awareness on daily activities and on the carbon footprint that is produced at a household level*
• **Hypothesis**	*Citizens can contribute to reduction of CO2 if they familiarize with their carbon footprint*
Type of experiment	Comparative Descriptive

	Threshold testing				
• **Design**	What: - CO2 Dashboard Where: - online Who: - CO2 Dashboard = citizens When: How: - CO2 Dashboard				
• **Planned analysis**	**Analysis**			**Ext.**	**Int.**
	How will data be processed? Does PMD suffice? Is in house data science capacity available?				
• **Workshop**	What is planned for the workshop: - device demonstration? - dashboard demonstration? When is the workshop planned: - device demonstration - dashboard demonstration				
• **Remarks**	Concerns, points of attention …				

Flanders

Experimental design for FLANDERS- use case #1	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
Purpose	Demonstrate the impact of a school street on traffic and air quality.
Research question(s)	Questions that **must** be answered through experiment A. Is there less motorized traffic because of the measure in the neighborhood of the school? Or does this not result in a reduction in traffic, but rather in a change in the traffic flow (TELR sensors) B. Is the air quality better because of the measure (NO2/BC sensors)? Questions that **can** be answered through experiment C. Does a school street create awareness about air quality by the citizens (all the sensors)? A possible modal shift?

	D. Does a temporary implementation of a school street provide more support to the permanent implementation of this measure in the future? E. Can you pinpoint the source of air pollution? Eg. increase in PM2.5 but no increase in BC start-up wood fire e.g. bbq
Hypothesis	A. Less traffic after introduction of a school street B. Better air quality (less NO2/BC pollution) after introduction of a school street C. A school street creates awareness with the citizens (creates dialogue about this topic, knowledge about air quality…). This may lead to more citizens opting for cycling, walking or public transport. Whether this is also influenced by the weather can only be verified if the measure is introduced for a whole year. D. The advantages of a school street (safety, health...) will outweigh the disadvantages provided that it does not merely change traffic flow and not reduce it E. This is possible if the citizen also logs possible incidents
Type of experiment	Comparative Descriptive Threshold testing

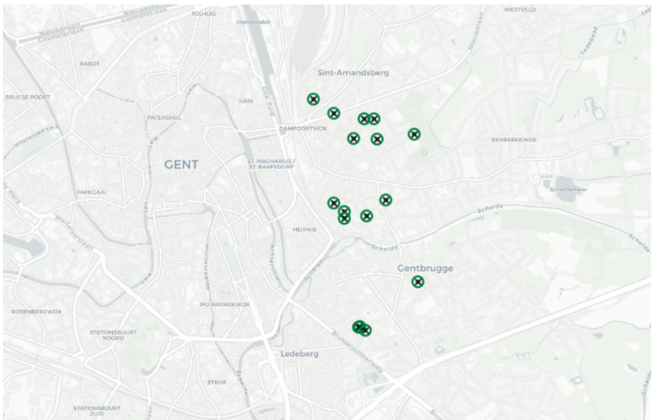

Design
	WHAT, WHEN & WHERE:
	- **3 NO2 sensorboxes: 1/5/2023-30/6/2023**
	  - 1 sensorbox at the school Sint-Paulus Institute- Burgemeester Matthysstraat
	  - 1 sensorbox on a street similar at the Burgemeester Matthysstraat, similar to the school street, but the measure was not introduced here and no impact is expected from the school street in this street
	  - 1 sensorbox, at a background location where no impact is expected form the school street
	- **8 BC sensors: 3/4/2023-30/6/2023**
	  - 3 at the same locations as the NO2-sensorboxes
	  - 2 at the schools nearby Sint-Paulus Institute
	  - 3 at citizens who have already a TELR sensor
	- **21 TELR-sensors: 1/5/2023-31/12/2023**
	
	- **15 PM-sensors: 1/5/2023- until the sensors are not working anymore**
	  - Same locations as the BC-sensors (7)
	  - Others with citizens
	WHO:
	- NO2-sensors:
	  - Initial calibration + benchmarking: IMEC & VMM
	  - Placement of sensors: VMM
	  - Follow up data during the project: IMEC? Depending of the data is on the CompAIR dashboard
	  - Data-analysis: IMEC? & VMM
	- BC-sensors:
	  - Update software & making it rainproof: VMM
	  - Placement of the sensors: VMM
	  - Follow up data during the project: VMM
	  - Data-analysis: VMM
	- TELR-sensors:
	  - Information workshop to the citizens: TELR
	  - Placement of the sensors: citizens
	  - Follow up data during the project: citizens & TELR
	  - Data-analysis: TELR & citizens
	- PM-sensors:
	  - Information workshop to the citizens: VMM
	  - Placement of the sensors: citizens
	  - Follow up data during the project: citizens & VMM
	  - Data-analysis: VMM

• **Planned analysis**	**Analysis**			**Ext.**	**Int.**
	Impact of a school street on traffic Impact of a school street on air pollution Can you pinpoint the source of air pollution? Eg. increase in PM2.5 but no increase in BC start-up wood fire e.g. bbq *How will data be processed? Does PMD suffice? Is in house data science capacity available?*	x			x
• **Workshop**	TELR-workshop1: - Device- & dashboard demonstration TELR-workshop2: - Data-analysis with the citizens? VMM-workshop - Device (PM & BC sensor)- & dashboard demonstration - Information about air quality (different pollutants, different sources…)				
Remarks	NO2 boxes and the BC sensors gave good results in the lab but have not yet been used in the field. The BC sensors require a filter change of 2 times a week, which can possibly be intensive for citizens, so there is a chance that the citizens will get tired of this (loss of data). When selecting the citizens for a BC-sensor, we will pay extra attention to the motivation of the citizen.The filters will be replaced by the students at the schools. This may be forgotten, or not done at all. Good follow-up is necessary, either in the data manager datastream (attenuation) or via the CompAIRdashboard (1-5 score). The BC sensors need WiFi, there may be a bad connection during the measuring period (loss of data). A new version of the TELR-sensor (TELR2.0), which has not been tested in the field for a longer period of time. Part of the pilot is to gather feedback on user experience with particular emphasis on ease of installation and general experience with the sensor. This is to validate the sensor is indeed "de-teched"				
Experimental design for FLANDERS - use case #2					
Tick checkbox if validated	Provide answers and make changes in "suggestion mode"				
Purpose	Raise awareness among school kids through participatory experiments about traffic and air quality (Herzele).				
Research	Questions that must be answered through experiment: A. Raise awareness among school kids on healthy cycling routes through participatory experiments (Herzele).				

question(s)					
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**			**Ext.**	**Int.**
	How will data be processed? Does PMD suffice? Is in house data science capacity available?				
• **Workshop**	What is planned for the workshop: - device demonstration? - dashboard demonstration? When is the workshop planned: - device demonstration - dashboard demonstration				
Remarks	Concerns, points of attention …				

Experimental design for FLANDERS - use case #3	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
Purpose	Demonstrate the impact of a neighborhood mobility plan on traffic and air quality
Research question(s)	Questions that **must** be answered through experiment A. Is there less motorized traffic because of the measure in the neighborhood? B. Is the air quality better because of the measure (NO2 sensors)? C. Validate the new TELR2.0 by comparing them with other formal validation counts done by the city administration as well as manual count by the volunteers Questions that **can** be answered through experiment D. Creates a neighborhood mobility plan awareness about air quality by the citizens (all the sensors)? E. Will the support for the measure increase by evaluating the impact of the measure together with citizens? F. Can you pinpoint the source of air pollution? Eg. increase in PM2.5 but no increase in BC start-up wood fire e.g. bbq
Hypothesis	A. Less traffic after introduce a neighborhood mobility plan B. Better air quality (less NO2 pollution) C. TELR2.0 works as expected from the lab test

	D & E. Introducing a neigborhood mobility plan and measure together with the citizens the impact of it on traffic leads to more confidence in the evaluation process of the measure. And hopefully for better informed citizens and more awareness about this topic. F. This is possible if the citizen also logs possible incidents
Type of experiment	Comparative Descriptive Threshold testing

Design	**WHAT, WHERE and WHEN:**
	- **16 TELR sensors: 02/02/2023 - 31/12/2023**
	
	- **4 NO2-boxes: 1/7/2023- probably 31/12/2023**
	    - Location have to be determined yet- in places where an impact is expected form the neighborhood mobility plan
	- **7 BC-sensors**:**1/7/2023- depending on the implementation of the neigborhood mobility plan**
	    - School the Criquet
	    - Reference station Ghent (R702)
	    - 4 citizens who have already a TELR2.0
	- **15 PM-sensors:1/7/2023- until the sensors are not working anymore**
	    - Same locations as the BC-sensors-exception of the one at the reference station from the VMM (5)
	    - Other with citizens (10)
	WHO:
	- NO2-sensors:
	    - Initial calibration + benchmarking: IMEC & VMM
	    - Placement of sensors: VMM
	    - Follow up data during the project: IMEC? Depending of the data is on the CompAIR dashboard
	    - Data-analysis: IMEC? & VMM
	- BC-sensors:
	    - Update software & making it rainproof: VMM
	    - Placement of the sensors: VMM
	    - Follow up data during the project: VMM
	    - Data-analysis: VMM
	- TELR-sensors:
	    - Information workshop to the citizens: TELR
	    - Placement of the sensors: citizens
	    - Follow up data during the project: citizens & TELR
	    - Data-analysis: TELR & citizens & local mobility officers of Ghent
	- PM-sensors:
	    - Information workshop to the citizens: VMM
	    - Placement of the sensors: citizens
	    - Follow up data during the project: citizens & VMM

	- Data-analysis: VMM				
Planned analysis	**Analysis**			**Ext.**	**Int.**
	Impact of a school street on traffic Impact of a school street on air pollution Validation of the TELR2.0 Can you pinpoint the source of air pollution? Eg. increase in PM2.5 but no increase in BC start-up wood fire e.g. bbq	x			x
• **Workshop**	TELR-workshop1: - Device- & dashboard demonstration TELR-workshop2: - Data-analysis with the citizens? VMM-workshop - Device (PM & BC sensor)- & dashboard demonstration - Information about air quality (different pollutants, different sources…) What is planned for the workshop: - device demonstration? - dashboard demonstration? When is the workshop planned: - device demonstration - dashboard demonstration				
Remarks	NO2 boxes and the BC sensors gave good results in the lab but have not yet been used in the field. The BC sensors require a filter change of 2 times a week, which can possibly be intensive for citizens, so there is a chance that the citizens will get tired of this (loss of data). When selecting the citizens for a BC-sensor, we will pay extra attention to the motivation of the citizen.The filters will be replaced by the students at the schools. This may be forgotten, or not done at all. Good follow-up is necessary, either in the data manager datastream (attenuation) or via the CompAIRdashboard (1-5 score). The BC sensors need WiFi, there may be a bad connection during the measuring period (loss of data). A new version of the TELR-sensor (TELR2.0), which has not been tested in the field for a longer period of time Due to disappointing results of the SODAQ NO2 sensor boxes in the benchmark (see results in closed round report). Is the development of these sensors discontinued in this project. A solution was sought, the NO2 boxes from IMEC. These could not be delivered in time to carry ot pre-measurements of 3 months. Hopefully we will have 2 monthly pre-measurements and can we also draw conclusions from that.				

Experimental design for FLANDERS - use case #2					
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”				
Purpose	Raise awareness among school kids through participatory experiments about traffic and air quality (Ghent).				
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**			**E xt .**	**In t.**
	How will data be processed? Does PMD suffice? Is in house data science capacity available?				
• **Workshop**	Education package: - Air Quality: English version, Dutch version - English version - Traffic: School on the counter- teaching package public and the password: SchoolopdeTeller! (by Mobiel21)				
Remarks	Concerns, points of attention …				

Plovdiv

The table below resulted from exchanges during the pilot calls and a targeted discussion on the Plovdiv LEZ on February 6th. The pilot is kindly asked to answer all questions in the tables below as soon as possible and validate each segment of the table (i.e. tick check box if you agree or have made the changes you feel are necessary).

Experimental design for PLOVDIV - use case 1 - Primary school Dimitar Talev	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
Purpose	Raising awareness on 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 NO2 concentrations? C.
Hypothesis	- A: Correlation between traffic intensity and PM concentrations - B: Correlation between traffic intensity and NO2 concentrations - -
Type of experiment	Comparative Descriptive Threshold testing

Design	What:
	- PM10,, NO2 and traffic
	- 3 sensor.community devices
	- 1 Telraam v1 device v1-- the network issues was not overcome
	- 7 SODAQAIR (or 15 on a rotation with uc2) - if the devices will be delivered - not used - the netwok issues was not overcome
	- 1 bc meter - not used, was overheated and destroyed
	- 1 mobile laboratory for AQ meashurement - NO2, PM2.5, PM10
	
	Where:
	- , 1 primary school (Dimitar Talev)Both indoor and outdoor PM measurements → precise device count and location breakdown? - outdoor meashuremnts of PM
	- Will some sensors be deployed at kids/students' homes? - yes
	
	Who:
	- Device(s) assembly =
	  - PM10: COMPAIR / Pilots staff /+teachers Traffic: COMPAIR
	  - Need for educational pack to organise workshop with students?
	- Device(s) installation = Pilots staff
	  - PM2.5: ?- Pilots staff - not used
	  - Traffic: ? -Pilots staff
	- Device(s) monitoring = Pilots staff?
	  - PM2.5: ? Pilots staff
	  - Traffic: ? Pilots staff
	
	When:
	- Upon device delivery? (April) Following timeline of uc #2?- yes
	- When will schools be selected? How will it be determined which class/grade is participating? - the schools are selected, the classes are selected, open round will strats on 7th April in primary school D Talev, Plovdiv, Bulgaria.
	
	How:
	- Device(s) monitoring =
	  - PM10: Using s.c dashboard/compair dashboard/compair data manager/device/device data manager?
	  - Traffic: Using compair dashboard/compair data manager/device/device data manager?
	- Logbook (example) = Pilots staff/school kids+teachers keeps track of indoor & outdoor activities that could help correlate to sensor data?

Planned analysis	Analysis			E xt.	Int .
	- Time series and correlation plot of PM2.5 vs. traffic counts at various aggregation levels (5min, 15 min, 1h, daily …)				
	- Daily, weekly, monthly and seasonal averaged concentrations for each location + weekday & weekend day profiles per month/season				
	- Indoor/Outdoor ratio for specific setups with both measurements + time series & peak analysis of indoor sensor + peak matching/mismatching indoor/outdoor for selection of days				
	Does pilot lead have available data analysis capacity? - yes Data classes with kids in professional schools? - now we are focused on a primary schools General education on insights with primary school kids? - yes, the learning material includes lessons on the environment and air quality				
• Workshop	What is planned for the workshop: - device demonstration? - the workshop was organised on 7th April for devices demonstrations - dashboard demonstration?- no When is the workshop planned: - device demonstration - dashboard demonstration - when all devices are connected and visible on compair dashboard a workshop will be organised				
Remarks	Concerns, points of attention … - Do schools have usable WiFi and both in/outdoor power supply? (or possibility to run a power cord outside through e.g. a window)-yes - Do class windows meet Telraam siting requirements? Telraam S2 device uses LTE-M, so no need of WiFi but needs power supply. - power supply is available - Data from device cannot be differentiated if deployed indoors/outdoors. This needs to be documented manually in logbook? -only outdoor measurements				

Experimental design for PLOVDIV - use case 2Primary school Vasil Levski	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
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. Is there a correlation between traffic and air pollution for NO2 and BC? B. What is the effect of school related traffic? Questions that **can** be answered: C. How well do these correlate? What other factors contribute?

Hypothesis	- A: Correlation between traffic and NO2/BC concentrations - B: Lower pollution levels or peaks on days with school closure - C: Correlation becomes clearer depending on the amount of data cleaning (i.e. filter days with more wind, more rain and worse sensor performance)
Type of experiment	Comparative Descriptive Threshold testing

Design	What:
	- PM10, NO2, BC
	- Levels of PM10 and NO2 - data from reference station
	-
	- ~~NO2 passive samplers (email discussion on 24/03)~~
	- ~~1~~ BCmeters (+1 backup)
	- 8 SODAQAIR - if we have we could distribute to students - used only for testing, no network coverage
	
	Where:
	- Deployment at schools - (, 1 primary school as follows:
	    - Sensors.comunity - 7 sensors at least one at school and aroud the school - volunteers
	    - 8 Sodaqair (we can use them on a rotation with the other school)- static and dynamic- used only for testing, no network coverage
	    - Telraam traffic sensors - 0 - at scholl or around ares- used only for testing, there is no network coverage, they will be repalced with Telraam v1
	    - BC meter near to the school
	    - Will the same schools be selected as for uc #1?- different school
	
	Who:
	- Device(s) assembly = COMPAIR
	- Device(s) installation = Pilots staff/school kids+teachers
	    - NO2: - data from official monitoring station
	    - BC: - pilot staff/volunteer
	    - Traffic: pilot staff/ teachers/ volunteer
	- Device(s) monitoring = Pilots staff/school kids+teachers, same as use case 1?
	
	When:
	- To start asap and preferably April 8th at the latest to demonstrate effect of school closures between April 8th and 17th + some single closing days in May
	- Measurements will continue to form baseline assessment prior to LEZ introduction?
	
	How:
	- Device(s) monitoring =
	    - NO2: - data from
	    - BC: Using compair dashboard/compair data manager/device/device data manager?
	    - Traffic: Using compair dashboard/compair data manager/device/device data?
	- Logbook (example) = Pilots staff/school kids+teachers?
	- Pilot staff will organise workshop how to build up and use the devices with schools and volunteers

Planned analysis	**Analysis**			**E xt.**	**Int .**
	- Correlation plots pollution vs. traffic intensity for various periods and aggregation levels				
	- Correlation statistics per day + analysis of meteorological conditions in relation to these statistics + color coding of correlation plots for T, RH, rainfall, wind … + updated				
	- correlation plots for subsets (time periods)				
	- Average concentration levels (with/without data cleaning) comparison (PMD!) for analysis of school closing effect - color coding of school open/closed in correlation plots				
	Data processing by EAP in particular for mobile reference PMD is well suited for analysis of school closing effect, less for correlations				
• **Workshop**	What is planned for the workshop: - device demonstration? - yes - dashboard demonstration?- yes When is the workshop planned: - device demonstration -in may 2023l - dashboard demonstration - in may 2023				
Remarks	Concerns, points of attention … - Do deployment locations have usable WiFi and power supply for BCmeter and Telraam? The BC meter will be located at home of one volunteer very close to the school with ensured power supply and wifi Telraam sensors and sensorcommunity.com- in school is available wifi connection, at studets/ tehacers/ volunteers homes will have wifi and power supply (note: Telraam S2 device uses LTE-M, so no need of WiFi but needs power supply.)				

Sofia

The table below resulted from exchanges during the pilot calls and a targeted discussion on the school bus routes on February 22nd. The pilot is kindly asked to answer all questions in the tables below as soon as possible and validate each segment of the table (i.e. tick check box if you agree or have made the changes you feel are necessary).

Experimental design for SOFIA - use case #1.A

Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
Purpose	Determining the impact of the introduction of school bus routes for morning and noon **transport to school** through a community building exercise with 2 schools on the outskirts of the LEZ
Research question(s)	Questions that **must** be answered: A. Is the amount of traffic reduced due to the school bus scheme at the schools? B. Is an impact observed on air pollutant concentrations at the schools? ○ Is the difference more clear on BC than PM? C. Is there a difference between morning and afternoon peaks in traffic at the schools? D. Is there a difference between morning and afternoon peaks in air pollutant concentrations at the schools? Questions that **can** be answered: E. Summer/winter difference based on outside PM devices (requires continuation into public round)
Hypothesis	- A, C: Reduction in car traffic to school of 50 vehicles in morning peak only (based on questionnaire) - B, D: No effect on PM2.5 - B: Impact on BC can be expected - D: Reduction of the BC morning peak in absolute value or relative to the afternoon peak
Type of experiment	Comparative Descriptive Threshold testing
Design	What: - Traffic, static PM & static BC - 10 Telraam devices, 6 sensor.community devices, 5 BCmeter - Backup (for BCmeter and later Nitrosense): mobile reference station Where: - area of interest is limited to 2 schools with following configuration - Telraam: across school entrances (2/school) most likely in commercial building as residential floors are 2 and up (totals 4) - Where will the other 6 Telraam devices be used? - Sensor.community: 2 sensors at various locations in or around each school (2 entrances) + 1 at a background location (green area) nearby (totals 6) - BCmeter: school entrances (2x2) + 1 background? Who: - Device(s) assembly = ? - Traffic: COMPAIR - PM: Workshop with volunteers - BC: COMPAIR - Device(s) installation = ? - Traffic: COMPAIR + volunteers - PM: COMPAIR + volunteers - BC: COMPAIR - Device(s) monitoring = Pilots staff/participants with the device? Yes When: - Implementation was confirmed on 23/02/2023, operation will start mid-March ‘23 - School bus scheme will go in effect end of March until June 15th

<table>
<tr><td></td><td colspan="5">- So policy period will be April 15th to June 15th and reference/business as usual period will be the remainder of the open round

How:
- Device(s) monitoring =
    - Traffic: Using compair dashboard/compair data manager/device/device data manager?
    - PM: Using s.c dashboard/compair dashboard/compair data manager/device/device data manager?
    - BC: Using compair dashboard/compair data manager/device/device data manager?
- Logbook (example) = ?
- Pilot lead will organise workshop to build s.c devices with schools
- Pilot lead will contact local shop owners and/or residents for measurements across the school entrances</td></tr>
<tr><td rowspan="5">Planned analysis</td><td>Analysis</td><td>PMD</td><td>DEVD</td><td>Ext.</td><td>Int.</td></tr>
<tr><td>- Before/after analysis of traffic intensity, PM and BC in relation to a background location
    - Advanced: boxplot statistical analysis</td><td></td><td></td><td></td><td></td></tr>
<tr><td>- Calculation of ratio between morning and afternoon peaks for traffic, PM and BC
    - Timeseries of ratio, boxplot statistical analysis before/after (since it is a ratio, no need to be in relation to background location)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>- Comparison of observed effect for PM vs BC both in overall and peak specific analysis
    - Comes from boxplots in previous analyses</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Pilot lead has a network of NGO’s and partner organisations with expertise in air quality to assist in data analysis and translation into communication campaign.

How will data be processed? Does PMD suffice? Is in house data science capacity available?</td></tr>
<tr><td>● Workshop</td><td colspan="5">What is planned for the workshop:
- device demonstration?
- dashboard demonstration?

When is the workshop planned - 8.05.2023: during the workshop a brief introduction on air quality training was performed together with device demonstration and assembly of DIY sensor.community sensors. SODAQ Air sensors were provided to the students together with consent forms that their parents had to sign. In each of the 2 schools 2 sensor.community sensors were installed.
- device demonstration - once the delivery dates are set the workshop will be planned - preferably before 15th April
- dashboard demonstration - what was demonstrated during the workshop was the way data from sensors is seen on different platforms.</td></tr>
</table>

Remarks	Context:
	School bus project based on addresses of children in 2 schools (service focused on 1st to 4th grade) on outskirts of LEZ, route designed to serve as many children as possible (bus stop within 350m) and no longer than 30 mins. total ride. 2 new bus stops were made next to the schools
	
	Concerns, points of attention:
	- Are the following locations suitable to provide wifi and charge for:
	    - Telraam: across school entrances most likely in commercial building as residential floors are 2 and up (note: Telraam S2 device uses LTE-M, so no need of WiFi but needs power supply)
	    - Sensor.community: school entrances, playground, background location (green area)
	    - BCmeter: school entrances, background location (green area)
	- BCmeters arrive mid April. April 15, 2023 is the start of "policy period"

Experimental design for SOFIA - use case #1.B	
Tick checkbox if validated	Provide answers and make changes in "suggestion mode"
Purpose	Establishing the typical air pollution exposure profile of older kids in schools with school bus service implementation in public transportation (metro vs. tram vs. bus vs. trolley), while walking or traveling by car (not many cycling) as a community building exercise with the schools to start raising awareness on every citizen's behavioural choices.
Research question(s)	Questions that **must** be answered through experiment: A. Compare exposure in different transport modes B. Compare mobile exposure to exposure at school (classroom, outside (lunch) breaks, outdoor gym class) C. Is SODAQ AIR usable in public transport conditions?

Hypothesis	- A: Exposure varies across transportation modes and depends also on the route followed and time spent in transportation
	- B: Outdoor pollution exposure is higher than indoor (classroom or inside mode of transport), school playground and outdoor gym classes are preferably at locations with lower concentration/exposure
	- C: SODAQ AIR is usable in public transport with some exceptions:
	    - Data loss in underground transportation modes due to loss of data connection
	    - Exposure is calculated for the entire route, but some segments might be without GPS-data and thus not visible on the map

Type of experiment	Comparative Descriptive Threshold testing

Design	What:
	- mobile PM2.5 monitoring (+limited fixed monitoring)
	- 2 sensor.community devices (alternative could be static SODAQ)
	- 27 SODAQ AIR devices
	    - 42 devices will be delivered, so more might be used to increase sample size?
	    - During open round 15 SODAQ Air devices were available and 11 were distributed to students, however only 1 or 2 were sending data.
	
	Where/who:
	- Device(s) assembly = ?
	    - SODAQ: pilot team

<table>
<tr>
<td></td>
<td colspan="5">- s.c: - pilot team together with participating students during the workshops
- Device(s) installation = Carried around by school kids (5th grade and above) on their backpack, during their way to and from school and while in school classroom, outside (lunch) breaks, outdoor gym class
  - Indoor measurements will not be calibrated (makes no sense), is pilot aware and agreeing to this? - yes, agreed.
  - At school measurements could be performed with the SODAQ devices carried around by kids (e.g. plugging some devices in and leaving them on) or with sensor.community devices. What is the preferred option for Sofia?
- Public transportation, car and walking - cycling is not expected
- Deployed statically in school class room and on playground in 2 schools (cf. uc#1.A)
- Can 3 devices be deployed at a reference station of the 42 devices or are those from the closed round to be used? - difficult to organise due to difficult communication and feedback from the National Environment Agency
- Device(s) monitoring = Pilots staff/participants with the device

When:
- As soon as devices arrive and until end of school year (June 15th)
- Assumption: May 15th to June 30th

How:
- Device(s) monitoring =
  - SODAQ: using compair dashboard/compair data manager/device/device data manager/knowyourair platform
  - s.c: using s.c dashboard/compair dashboard/compair data manager/device/device data manager
- Logbook (example) = ?
- Pilot will facilitate using SODAQ AIR on backpack etc. based on closed round experience
- Pilot will organise startworkshops with kids
- Pilot will provide GDPR-consent forms to parents of participating kids</td>
</tr>
<tr>
<td rowspan="4">Planned analysis</td>
<td>Analysis</td>
<td></td>
<td></td>
<td>Ext.</td>
<td>Int.</td>
</tr>
<tr>
<td>- Cumulative exposure calculation for single trips
  - Advanced: mean, median, min, max, percentiles
  - Compare those values across trips</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Comparing average, min, max, percentiles of cumulative exposure from one transport mode to another</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Correcting cumulative exposure for varying “time in transport” (e.g. adding concentration at home address for a period of time corresponding to the difference with longest travel duration? (assumption: less travel time = longer at home)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</table>

	- Again comparing time-corrected cumulative exposures				
	- Assessing cumulative exposure during outdoor school activities				
	Pilot lead has a network of NGO's and partner organisations with expertise in air quality to assist in data analysis and translation into communication campaign. *How will data be processed? Does PMD suffice? Is in house data science capacity available? Yes, PMD will suffice. If it turns out in house data science capacity is not sufficient, an Data Science NGO will be asked for help.*				
• **Workshop**	What is planned for the workshop: - device demonstration - dashboard demonstration When is the workshop planned: - device demonstration - dashboard demonstration				
Remarks	Concerns, points of attention …: - Pilot lead has indicated that attaching SODAQ AIR to backpack etc. is feasible based on closed round test and will facilitate this with students. - Devices should be checked for charge regularly as device can last without charge for only 2-4 hours. - Data from device cannot be differentiated if deployed indoors/outdoors. This needs to be documented manually in logbook? - When will it be planned to look at the data with the kids as part of the community building - beginning of the new school year - September 2023				

Experimental design for SOFIA - use case #2	
Tick checkbox if validated	Provide answers and make changes in "suggestion mode"
Purpose	Evaluate the efficiency of window meshes at reducing indoor PM levels at a kindergarten school - due to delay in contracting the air meshes installation the use case #2 during the open testing round will monitor how the sensor.community sensors measure against the already installed Canary system. Indoor measurements are planned only. Measurements started on 18th July and 2 sensors were installed in each of the two buildings of the kindergarten.
Research question(s)	Questions that **must** be answered through experiment: A. What is the efficiency of the window mesh at reducing the indoor to outdoor ratio of PM under varying ventilation regimes (including current everyday use)? Questions that **can** be answered through experiment: B. How do the current canary sensor devices and their alert thresholds compare to sensor.community devices for indoor measurements?
Hypothesis	- A: Efficiency <<< 92,5% (reported PM2,5 efficiency by manufacturer) - B: Hypothesis on canary devices to be formulated when we have more information on that system (might e.g. also or only take CO2 into account). Have asked Antonia for this
Type of experiment	Comparative Descriptive Threshold testing
Design	What: - static PM2.5

	- 2 Sensor.community indoor)
	- Existing indoor canary system (T, RH, CO2, PM2.5, PM10)
	
	Where:
	- 1 kindergarten in Sofia with existing canary system alerting staff to open windows
	- 1 indoor measurement near existing canary system
	- 1 outdoor measurement near window with window mesh
	
	Who:
	- Device(s) assembly = pilot staff, with participaring teachers and kindergarten staff
	    - PM2.5: ?
	- Device(s) installation = ?
	    - PM2.5: ?
	- Device(s) monitoring = Pilots staff/participants with the device
	
	When:
	- Start of measurements asap after delivery of devices - worshop and sensor installation on 18th July
	- Installation of window meshes to be planned, likely during summer months in June. Kindergarten open during the summer months.
	    - Exact timing depends also on removability of window mesh (e.g. alternating regimes with and without mesh -> How)
	
	How:
	- Device(s) monitoring = Using s.c dashboard/compair dashboard/compair data manager/device/device data manager
	- Logbook (example) = ?
	- Dual tracking of window opening: logbook and canary data
	- Regimes to be tested (each with and without mesh):
	    - Current use (opening and closing based on canary) natural ventilation
	    - Current use (opening and closing based on canary) forced ventilation (fan either in door of “class room” blowing towards hallway OR fan outside of window blowing into “class room”)
	    - Always open (should be feasible given summer period) natural ventilation
	    - Always open (should be feasible given summer period) forced ventilation
	- 8 combinations to test, ideally 2 weeks per combination = 16 weeks (4 months) in total
	    - Alternative duration: reduce length for some or all to 1 week (e.g. effect will be lowest with natural ventilation, so maintain 2 weeks for those and use 1 week for forced ventilation)
	- Preferred scenario = same regime with and without mesh are planned consecutively
	    - Backup scenario = all regimes without mesh prior to installation, all regimes with mesh after installation
	- What is the kindergarten policy regarding shoes? If the kids wear shoes both outside and inside, we can also consider a scenario where they no longer use shoes inside (source of indoor PM somewhat reduced) - they are using slippers indoors

Planned analysis	**Analysis**			**Ext.**	**Int.**

	- Timeseries of indoor/outdoor ratio over time				
	- Boxplots for every week/regime-combo				
	- Regression analysis for model: CONCindoor=a1 + a2*CONCout + a3*MESH(0/1) + a4*FAN(0/1)				
	- Correlation plot of canary vs. sensor.community data (indoor)				
	Pilot lead has a network of NGO's and partner organisations with expertise in air quality to assist in data analysis and translation into communication campaign. *How will data be processed? Does PMD suffice? Is in house data science capacity available?*				
● **Workshop**	What is planned for the workshop: - device demonstration - dashboard demonstration When is the workshop planned - 18.07.: - device demonstration - dashboard demonstration				
Remarks	Concerns, points of attention … - Is the outdoor measurement location suitable to provide charge? - Data from device cannot be differentiated if deployed indoors/outdoors. This needs to be documented manually in logbook? - Effects are expected to be small and difficult to discern because also indoor sources will be present (kids moving, playing)				

Berlin

The table below resulted from exchanges during the pilot calls and a targeted discussion on the mobile use case on February 21st. The pilot is kindly asked to answer all questions in the tables below as soon as possible and validate each segment of the table (i.e. tick check box if you agree or have made the changes you feel are necessary).

Experimental design for Berlin - use case #1.A	
Tick checkbox if validated	Provide answers and make changes in "suggestion mode"
Purpose	Ascertaining exposure of cyclists and school kids on their way to school/work and evaluating both spontaneous and "helped" behavioural change with the overarching aim to push this experience to other cyclists and schools across Berlin.
Research question(s)	Questions that **must** be answered through experiment: A. What is the cumulative exposure across a cyclist/school kid's route? What are hotspots along the route? B. How does an individual participant's exposure relate to his/her peers? C. How does individual behaviour change based on the data presented?

	◦ Behaviour assessment: Pre vs. self-reflection (spontaneous) vs. professional insights (helped) Questions that **can** be answered through experiment: D. Does behavioural change align with changes in group exposure? E. Is individual behavioural change reflected in the individual's exposure and/or position in relation to their peers?
Hypothesis	- A: Both cyclists and school kids encounter PM hotspots along their individual routes - B: Cumulative exposure at the group level follows a normal/Gaussian distribution - C: Participants will be triggered to varying extents of behavioural change when examining their own data - C: Participants will further change their behaviour when "expert analysis" is provided to increase their insight - D, E: Behavioural change will lead to a decrease in exposure both at the group and individual levels
Type of experiment	Comparative Descriptive Threshold testing
Design	What: - mobile PM2.5 monitoring - 35 SODAQ AIR devices - 51 devices will be delivered, 16 will be for uc 1.B Where/who: - Device(s) assembly by whom = Participants, initially helped by pilot staff - Device(s) installation by whom = participants themselves through 1 workshop for cyclists and 1 workshop for school kids (parents to take care of installation) - Device(s) monitoring = Pilots staff/participants with the device? Pilots staff - School kids from a selected school in Friedrichshagen -> 1 class? 1 grade? Are only students cycling to school selected? What is the age group? - Citizens/cyclists living or working in Friedrichshagen ->1 living closeby, 15 live in similar areas across Berlin (open round) how many? - Devices are used during commutes for uc #1.A (home-work-home or home-school-home)~~, possibility to also use static data for uc #1.B~~ When: - Priority will be given to uc #2 as the time path for communication on and implementation of the parking ban will be fixed and determined externally (public authority) - Most likely start is August'23 - Co-location of devices in August/Septemberto train calibration algorithm → more feasible for the public round How (proposal, to be validated): - Device(s) monitoring = Using compair dashboard/compair data manager/device/device data manager? Reminder e-mails and some follow-up, to be refined by pilot (likely no monthly gathering)? Also, via knowyourair dashboard - Logbook (example) = Data from the German weather service will be used 1. Baseline behaviour assessment through questionnaire 2. Baseline exposure measurement 2-3 weeks 3. Workshop or other information moment to start self assessment (can be in last week of baseline measurement) -> only data on individual tracks/routes for all participants are provided, no other data analysis

<table>
<tr><td></td><td colspan="5">4. 2-3 week spontaneous changing of routes
5. Workshop collecting self-reported behavioural change, insights etc. + introducing expert analysis and advice (e.g. histogram, route advice, maps of collated data …)
6. 2-3 weeks helped exposure evaluation
7. Workshop/Questionnaire reflecting on helped behavioural change, expert advice, useful metrics etc.
8. Can have: follow-up period to monitor whether behavioural change is sustained. Alternative: repeated questionnaire after 3 months</td></tr>
<tr><td rowspan="6">Planned analysis</td><td>Analysis</td><td></td><td></td><td>Ext.</td><td>Int.</td></tr>
<tr><td>- Individual exposure assessment</td><td></td><td></td><td></td><td></td></tr>
<tr><td>- Participative sessions on exposure, comparing routes etc</td><td></td><td></td><td></td><td></td></tr>
<tr><td>- However comparing routes driven at different times etc. might require further analysis.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>- Creating maps will definitely require additional analysis (currently out of scope DEVD v0.1)</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Does pilot lead have sufficient capacity to generate in depth analysis required for helped behavioural change?</td></tr>
<tr><td>• Workshop</td><td colspan="5">What is planned for the workshop:
- device demonstration? yes
- dashboard demonstration? Yes (knowyourair)
- TBD

When is the workshop planned:
- Training workshop - July 26</td></tr>
<tr><td>Remarks</td><td colspan="5">Concerns, points of attention …

- Proper expectation management: PM2,5 is typically not the pollutant showing the greatest local gradients in space and time. It is however the most health pertinent.
- When comparing routes between participants: aim to measure them at approximately the same day and time
- When comparing routes by a single participant: take into account perturbation by meteorology, varying traffic intensity etc.
- Effects of behavioural change on exposure will be challenging to assess as experimental conditions will also change (weather etc.) -> consider working with control group and/or phasing groups? (feasibility depends on number of participants)
- Ideally data manager should tag static and mobile data points in SODAQ AIR data stream so these can be picked up in PMD and DEVD respectively
- Devices should be checked for charge regularly as device can last without charge for only 2-4 hours.</td></tr>
</table>

Experimental design for Berlin - use case #1.B	
Tick checkbox if validated	Provide answers and make changes in “suggestion mode”
Purpose	Increase the information on air quality available in the Friedrichshagen area on the city outskirts as only 1 reference station is located there, demonstrating the use of citizen science to accomplish this.
Research question(s)	Questions that **must** be answered through experiment: A. How much does the measured data during static use of the devices (e.g. at home, work, school) deviate from the reference location? B. Identify pollution hotspots in the area - if any => how many?
Hypothesis	- PM levels might be higher in traffic intense locations during morning and evening rush hours - A: Sensor data will be more scattered than reference data, but will also provide sub-hourly information - B: Potential local PM sources can be discovered (e.g. diesel trains (are they use in that area?), ships/boats, restaurants/kitchens/pizza ovens …
Type of experiment	Comparative Descriptive Threshold testing
Design	What: - static PM2.5 - 16 SODAQ AIR devices - 51 devices will be delivered, 35 will be for uc 1.A Where/who: - Device(s) assembly by whom = participants - Device(s) installation by whom = participants - Device(s) monitoring = participants with the device - At a selected school in Friedrichshagen -> different locations around the school? how many? by students/teachers? - Around homes and working spaces in Friedrichshagen -> where? how many? By whom? - Devices used statically, focus on home addresses and perhaps schools for educational aspect When: - Priority will be given to uc #2 as the time path for communication on and implementation of the parking ban will be fixed and determined externally (public authority) - Most likely start is 2024 - Co-location of devices in August to train calibration algorithm - Pilot lead to consider minor experiments over summer to build experience with device (e.g. usability static outdoor/indoor) How (proposal, to be validated): - Device(s) monitoring = Using compair dashboard/compair data manager/device/device data manager? - Logbook (example) = ? - Assuming some participants are same as uc 1A - Participants are asked to leave devices outside (+charged!) in the “spontaneous behavioural change” period - The baseline period is less suitable as participants might not yet be allowed to access data (see uc#1.A), which might lower their motivation to put in this additional effort

<table>
<tr><td></td><td colspan="5">- Can be extended to helped period as well, but will require longer sustained effort
- Focus is on home address, but could be on work/school if it is easier to have them charged and outdoors at those locations</td></tr>
<tr><td rowspan="6">Planned analysis</td><td>Analysis</td><td></td><td></td><td>Ext.</td><td>Int.</td></tr>
<tr><td>- Day by day investigation of daily averaged map, morning rush hour, afternoon rush hour and evening</td><td></td><td></td><td></td><td></td></tr>
<tr><td>- Aggregated maps of typical concentration levels during rush hours</td><td></td><td>?</td><td></td><td></td></tr>
<tr><td>- Aggregated maps of typical nighttime and/or office hours concentration levels at fixed locations</td><td>?</td><td></td><td></td><td></td></tr>
<tr><td>- Correlation analysis of hourly averaged sensor data vs. reference data</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Will DEVD and PMD features be implemented to create the required hotspot maps? PMD is more suitable here
Does the pilot lead have the capacity to generate these maps offline if necessary? Yes
Does the pilot lead have the capacity to perform correlation analysis? Yes
Does the pilot lead have the capacity to analyse the maps and other data produced to draw conclusions regarding research questions? Yes</td></tr>
<tr><td>• Workshop</td><td colspan="5">What is planned for the workshop:
- device demonstration? yes
- dashboard demonstration? Yes
-
When is the workshop planned:
-</td></tr>
<tr><td>Remarks</td><td colspan="5">Concerns, points of attention …
- Proper expectation management: PM2,5 is typically not the pollutant showing the greatest local gradients in space and time. It is however the most health pertinent.
- Is access to reference data in place? Will it be available in time or does validation lag behind?
- Devices should be checked for charge when placed outside as device can last without charge for only 2-4 hours.</td></tr>
<tr><td colspan="6">Experimental design for Berlin - use case #2</td></tr>
<tr><td>Tick checkbox if validated</td><td colspan="5">Provide answers and make changes in “suggestion mode”</td></tr>
<tr><td>Purpose</td><td colspan="5">Demonstrate the positive effect of a local parking ban on liveability in the affected neighbourhood. Get the neighbourhood involved and build support for this specific measure through monitoring and data workshops</td></tr>
<tr><td>Research question(s)</td><td colspan="5">Questions that must be answered through experiment:
A. Can “looking for parking” traffic be distinguished in Telraam data? (i.e. time of day etc.)</td></tr>
</table>

	○ Because of the ban, has incoming traffic at key moments reduced? B. What effects on PM2,5 can be observed, before and after implementation? C. What is the effect on BC concentrations before and after implementation? Questions that **can** be answered through experiment: D. Comparing pollutant concentration with weather? E. Discerning other sources such as wood burning etc. related to non-mobility behavioural choices
Hypothesis	- A: Clear reduction in traffic intensities at times when non-inhabitant traffic is largest (should be close to 0, but might be difficult to distinguish) - B: No effect on PM, perhaps some other PM-related events can be picked up? - C: Effect on BC-concentration at specific time of day, either on absolute level or in the ratio to the background location - D: Wind speed, wind direction, temperature may have an effect on pollutant concentrations at a given location - E: Over time, the occurrence of certain elevated levels (e.g. PM) could be explained by things like e.g. wood burning…
Type of experiment	Comparative Descriptive Threshold testing

Design	What:
	- PM2.5, BC and traffic
	- 10 sensor.community devices
	- 5 BCmeters
	- 10 Telraam devices
	
	Where:
	- At background location, preferably adjacent to the Hasenheide park region, 1 s.c device, 1 BCmeter
	- In Graefekriez which is a mixed zone area of small stores/coffee shops/restaurants on the lower floor and residences in the upper floors, 3 s.c. devices, 3 BCmeters co-located with 3 Telraam, 3 s.c. co-located with 7 Telraam
	- At unaffected street location outside Graefekriez, 3 s.c. devices, 1 BC
	- Locations to be chosen in light of expected decrease, typical incoming traffic entry points etc. (as discussed in November)
	- Exact locations to confirmed by pilot lead after site inspection and outreach
	
	Who:
	- Device(s) assembly = ?
	    - s.c: COMPAIR/Participants, initially helped by pilot staff
	    - Traffic, BC: COMPAIR/ Participants, initially helped by pilot staff
	- Device(s) installation = ?
	    - s.c: Pilots staff? Participants? Participants, initially helped by pilot staff
	    - BC: Pilots staff? Participants? Participants, initially helped by pilot staff
	    - Traffic: Pilots staff? Participants? Participants, initially helped by pilot staff
	- Device(s) monitoring = Pilots staff/participants with the device? Regular check-ups via email and monthly meetings
	
	When:
	- Communication on traffic ban will start in March
	- The "after" or "policy" measurements will start on July 17

	- The "before" or "baseline" measurements will start in Junebefore the ban has been implemented
	
	How:
	- Device(s) monitoring =
	  - s.c: Using s.c dashboard/compair dashboard/compair data manager/device/device data manager? s.c. dashboard and Grafana
	  - BC: Using compair dashboard/compair data manager/device/device data manager? Device data manager, asking citizens to send .csv files
	  - Traffic: Using compair dashboard/compair data manager/device/device data manager? Telraam dash and PMD
	- Logbook (example) = Data from the German weather service will be used
	- Devices will be provided to participants and assembled at workshops
	- Pilot lead will host monthly meetings with participants to discuss ongoing results, observations, etc.				

Planned analysis	**Analysis**			**Ext.**	**Int.**
	- Before/after analysis of traffic and air quality data				
	- Correlation plots of PM2,5 and BC with traffic before and after the ban at various aggregation levels (5min, 15 min, 1h, daily …)				
	- Data cleaning to filter out e.g. rainy days and perform before/after analysis again	?			
	- Color coding of parking ban in/out of effect in correlation plots				
	- Compare type of traffic (bike, car, truck) to pollutant concentration				
	- Correlation statistics per day + analysis of meteorological conditions in relation to these statistics + color coding of correlation plots for T, RH, rainfall, wind … + updated correlation plots for subsets (time periods)				
	- Daily, weekly, weekday/weekend day and other time aggregated plots to discern changing behaviour in relation to sources like wood burning				
	Does the pilot lead have the capacity to perform the above analyses? We have staff with experience in statistical analysis but support by VMM and/or other technical partners is welcome				
• **Workshop**	What is planned for the workshop: - - Air quality - pollutants (particulate matter, N02, black carbon), impacts and development trends. - - Sensors - components, setup (sensor.community/bcmeter), use, calibration and maintenance				

	- - Research - principles of data collection, accuracy testing, analysis of data based on pattern recognition and deviations, visualisation of data (policy monitoring dashboard) - When is the workshop planned: - June 13

Remarks	Concerns, points of attention …
	- Finding a suitable background location with power supply and WiFi connectivity as soon as possible for s.c and BCmeter
	- Are the following locations suitable to provide wifi and charge for:
	    - In Graefekiez for Telraam (note: Telraam S2 device uses LTE-M, so no need of WiFi but needs power supply.), s.c and BCmeter: across school entrances most likely in commercial building as residential floors are 2 and up
	    - At unaffected street location outside Graefekiez for s.c. devices and BC
	    - Increased street canyon effect due to tree canopy, might make parking ban effect easier to spot