COMPAIR

DELIVERABLE

D5.2 Closed Testing Report

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Executive Summary

Deliverable 5.2 is part of the WP5 activities and Tasks related to pilot implementation. It is a public report aiming to depict the activities of pilot teams that were executed for Task 5.2 Closed Testing (M7 - M12), hence testing the up-to-date tools of **COMPAIR**. Namely software developed by M12 and sensors available from **COMPAIR** partners Telraam and SODAQ.

This deliverable is a first document referring to the preparation of pilot execution and foresees to be followed up by the Tasks on Open pilot Round and Public pilot round and their relevant reports foreseen for the forthcoming period of **COMPAIR**.

1. Introduction

Purpose and Scope

The objective of this document is to report on the activities that took place for Task 5.2 on Closed Testing of **COMPAIR** technologies at a consortium level. This document includes feedback from the 5 pilot sites of **COMPAIR** both on software and hardware tools. Since the development of these tools is ongoing, the current report includes feedback on the available software versions by the Sprint of 28/9/2022 - hence M11 - and for the sensors by October 2022, hence M12.

The closed testing activities were coordinated by DAEM under the monitoring of WP5 Leader SDA and were inline with the use case scenarios and pilots as foreseen in the 4 regions. The aim was to formulate lessons learned for the forthcoming pilot rounds and foresee bugs, constraints, but also feedback on usability, ease-of-use and other metrics. Also the activities took into account the target group of low SES population as well as the methodology that was defined and described in Section 3. Regarding the sensors, all sensor types were sent and deployed in the field of the 5 **COMPAIR** areas (Flanders, Athens, Berlin, Sofia and Plovdiv).

Structure of the document

This deliverable is organised as follows:

- Section 2 includes a short description of the **COMPAIR** sensors, hence Telraam for traffic, SODAQ Air and SODAQ NO2, that were distributed to the pilots in order to be used for the pilots activities of the Closed Round. Also it includes the state of development of the **COMPAIR** software that was available to pilots for the Closed Testing
- Section 3 includes the methodology followed for software and sensors testing
- Section 4 includes a description and results from all pilot sites, also structured in table for better summary of feedback
- Section 5 is dedicated to lessons learned and outputs by each pilot site as well as a specific sub-section on low SES group involvement by the experts from ECSA
- The deliverable concludes with outputs in Section 5.

2. COMPAIR Technologies

In the current Section the tools of **COMPAIR** PAIR available during the Closed Testing task are described and Section 2 is divided in two parts. Initially the sensors are reported, thus SODAQ for air quality - both SODAQ Air and SODAQ NO2 - and Telraam for traffic monitoring. In the second part of Section 2, hence 2.2, the software of **COMPAIR** is reported focusing on its state-of-the-art and development by the time of Closed Testing.

2.1. COMPAIR sensors

2.1.1. SODAQ sensors

2.1.1.1. SODAQ Air sensor

Description.
SODAQ AIR (Also referred as AIR in this document) has been designed keeping in mind that the device will be used by participants from all age groups to collect air quality data about their surroundings in both mobile and static conditions.

Figure 1 SODAQ AIR for air quality monitoring

The device resembles a slightly larger bicycle bell and records the timestamps, location of the device, concentration of fine particulate matter (PM2.5,1.0,10), temperature and humidity. The data is then transmitted to the cloud via LTM/NB-IoT (Cellular networks). The frequency of sending data depends on whether the device is moving or stationary. The device can act as a static environmental sensor to measure air pollution from a fixed location over an extended period of time, making it the ideal solution to be used at home or in the garden. LED lights on the device instantly display the local conditions and notify the user of the air quality. Each data point is not associated with a device ID due to data protection considerations.

The manual for SODAQ Air is provided to the **COMPAIR** pilots and product owners in the link.

2.1.1.2. SODAQ NO2 sensor

Description.

One of the key requirements of the COMPAIR project is the ability to measure NO2 related air parameters. This can be achieved by using the NO2 sensor developed by SODAQ in the past as shown in Figure 2 below. The NO2 device is also equipped with other sensors such as PM, temperature and humidity sensors. This makes it an independent unit that sends sensor data and meta-data to SODAQ's cloud platform. As the NO2 sensor is in prototype phase, under the COMPAIR project, effort would be taken to improve its user experience and make it production friendly thereby reducing its cost.

Figure 2 SODAQ's NO2 sensor (source: SODAQ)

In the deliverable D3.1 "Sensors Strategy, requirements Report", a device concept was suggested for a AIR+NO2 device but due to technical limitations the concept was not found to be feasible, a decision was made to continue with the NO2 device as it is to meet the time frame of the project. The main issue with developing the AIR+NO2 device was combining all the sensors in one casing leading to a comparable weight and form factor as that of the suggested prototype device. Further, following the regular design process, developing a fully tested device would have taken at least 1 year. As there is already a ready to use design for NO2 measurements, it makes more sense to use the available one and further, use the development time available to incorporate the necessary features in the NO2 device itself.

Installation prerequisites and configuration.

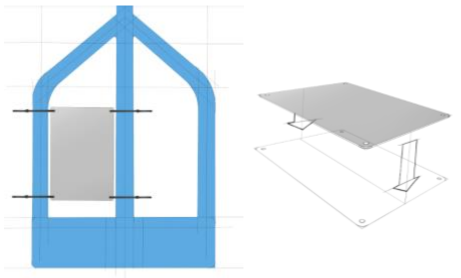
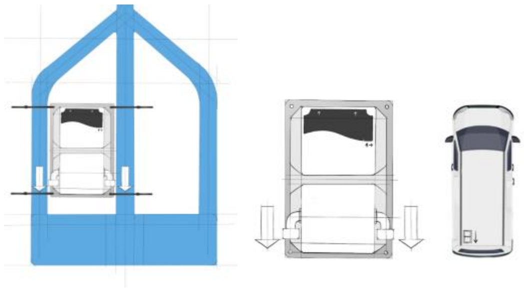
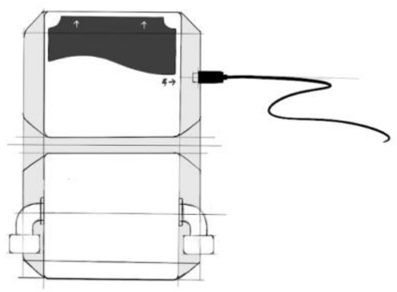
	**Install the mounting plate:** **1. Bicycle:** fix the plate to the frame of the bicycle with 4 tie wraps**.** **2. Car:** Stick the plate to the car with the 3M tape. The 3M tape is already attached to the plate.
	**Place the device:** The device is magnetic. Place it against the newly installed mounting plate. **1. Bicycle:** Make sure the side pipes are pointing downwards! **2. Car:** Make sure your side pipes point towards the back of the car!
	**Charging device:** Place the device on the charging station and use the supplied charger. The device must be charged daily. It is not possible to see if the device is charged.

Figure 3 NO2 installation

The manual for NO2 sensors was not available for production but it was formulated for **COMPAIR** project purposes. It is available in Annex 1.

2.1.2. Telraam sensors

Description

For the closed testing round, the current Telraam sensor was used, as the new sensor is still under development and will only be ready early 2023. Nonetheless, the experience of users (i.e. consortium members) with the existing sensor, does give a good impression of the handling required by citizens later in the project and gives further direction for changes/features to the final version.

What follows is a visual representation of the sensor functionality of the existing Telraam sensor and the new, upcoming sensor, from an architectural point of view.

Both sensors follow 5 sequential steps:

1. Object detection

2. Object tracking
3. Object classification
4. Data transmission
5. Data storage and visualisation.

While V1 uses OpenCV Python scripts for detection and tracking and uses a common hill-climbing algorithm for classification, the new upcoming sensor will complete detection, tracking and classification with a trained AI neural network.

More details on the classification algorithms for the current sensor are available on the Telraam website. All scripts on the current sensor are available via GitHub.

Data connectivity is done via WiFi, requiring participants to connect the device to their personal WiFi network. This is a cumbersome and error-prone procedure. Therefore, the new upcoming sensor will rely on cellular networks for data communication, not requiring connectivity configuration from the citizen, greatly simplifying the installation procedure.

The existing Telraam platform for data publication is maintained (www.telraam.net).

Figure 4 Telraam sensor architecture

Accuracy of the Telraam sensor is about 85-90% for cars, on suitable locations. Data quality for pedestrians/bikes is lower (70-80%) and greatly depends on the location, if walkways are in field of view of the camera or not.

With suitable location, we mean those sites that have a clear view on the street to be measured, without any blocking items (trees, lamp posts etc), preferably on a first floor window to ensure a downward looking angle. More details on suitable locations are given on the helpdesk page.

On the Telraam blog, there is a lengthy article demonstrating findings of validation counts (manual, pneumatic tubes and lidar radar).

A Telraam onboarding manual has been developed and expanded over the last 2 years and integrated in an online helpdesk, embedded in Zendesk software. In particular, all instructions regarding installation are included in this webpage.

Obviously, when the new sensor is ready, instruction manuals will be updated. Installation will be strongly simplified, allowing to include a very simple start-up guide, printed on the sensor packaging as can be seen in the prototype version of the packaging below:

Figure 5 Telraam S2 sensor

2.2. COMPAIR software

2.2.1. COMPAIR main page

A webpage built in React that provides an entry point for the **COMPAIR** visitors. It acts as a dissemination portal where visitors can find information about the Policy Monitoring dashboard and the CO2 dashboard. General information about the aim of the dashboards as well as the benefits behind the usage of the tools is provided.

2.2.2. CO2 Carbon Footprint Calculator

The purpose of the Carbon Footprint Simulation Dashboard is to guide users to improve their behaviours through more environmentally friendly choices, regarding their carbon footprint. This is achieved through the two tools available on the Dashboard, the Carbon Footprint Calculator and the Scenario Simulation. The first tool allows the users to calculate their carbon footprint. They are, then, presented with their total carbon footprint broken down into categories, as well as comparison with the average of their country and the EU. Finally, they also receive recommendations on how to lower their carbon footprint in each category, based on their results.

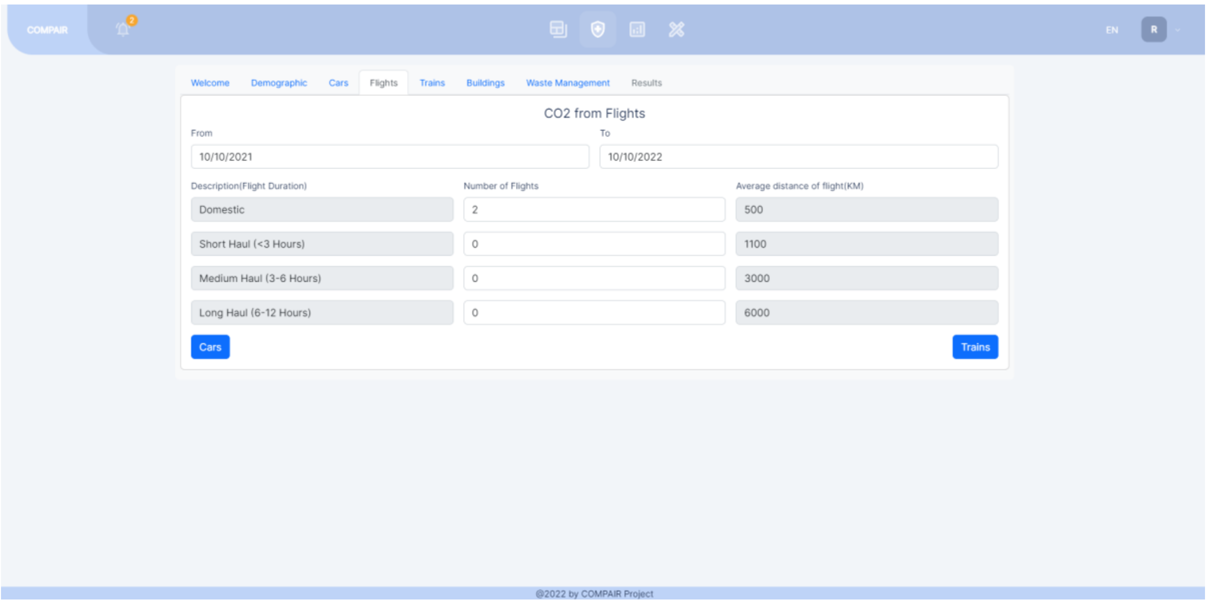


Figure 6 Carbon Footprint Calculator

The Scenario Simulation allows the users to participate in policy making, by submitting their opinion in the form of scenarios regarding a specific quantified environmental goal. These scenarios are comprised of actions they can adopt and government actions they are willing to accept.

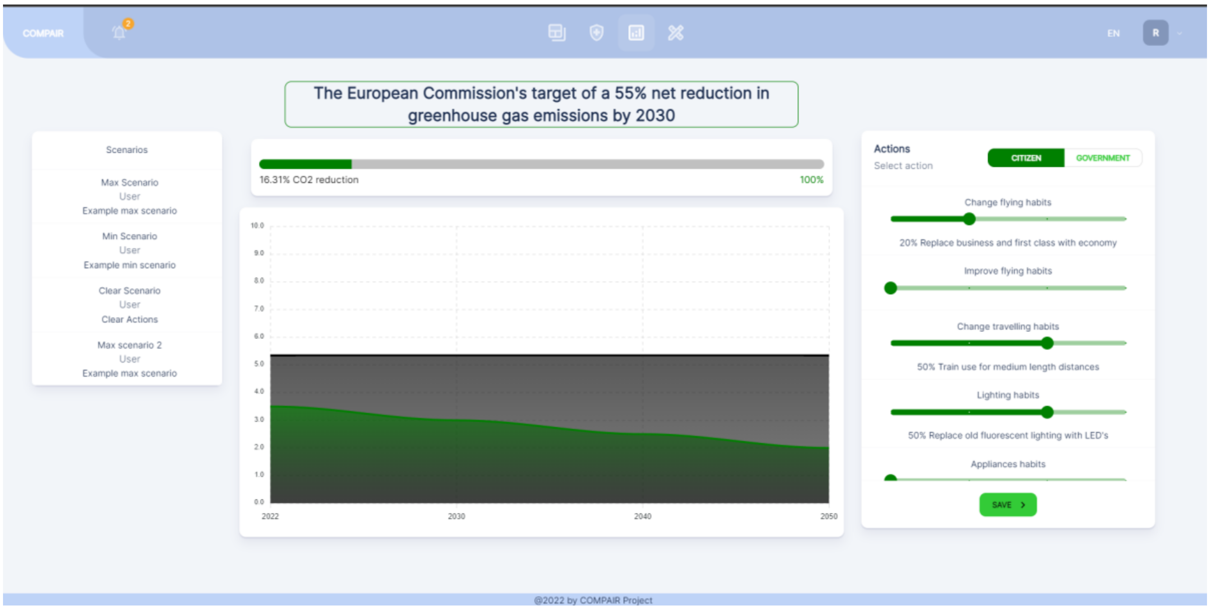


Figure 7 Scenario Simulation

A more detailed presentation of the Dashboard's design and current interface is available in the deliverable D3.4 Dashboards Design.

The following functionalities are available:

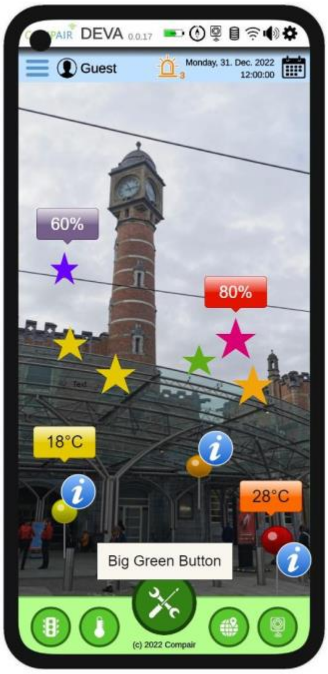
- The user can calculate their carbon footprint.
- The user can see the impact of each carbon footprint domain
- The user can compare their carbon footprint with averages at country and European levels.
- The user can receive a list of recommendations on how they can reduce their carbon footprint, based on their results.
- The user can create scenarios comprised of citizen and government actions.
- An admin can create example scenarios.
- An admin can create actions for the scenarios.
- An admin can create recommendations.

2.2.3. DEVA AR Application

The Dynamic Exposure Visualisation App (DEVA) or Augmented Reality (AR) app, aims in a first stage to attract and engage people to take part in CS experiments, which are performed in four different pilot countries. The main idea is to enable people to explore their surroundings via their smartphone or tablet camera, so they see a visual overlay of environmental information such as air quality or traffic information. Hence, the AR app will be the link between citizen science environmental sensors provided by the project, public environmental data, CS experiments and the users. In the final stage, the DEVA will act as the first AR application visualising citizen science environmental data publicly available for download and provided for Android and iOS.

In the Figure to the right, the current state of the user interface with some example visualisations is shown. For more details of the user interface, visualisation concepts, data formats, communication aspects and many more, we refer to the deliverable D3.3 AR Design submitted by the end of September 2022.

In this section, we will briefly explain the current state of development of the application that will be provided to the pilot partners for the open round testing.



The following developments and functionalities are available:

- The overall design of the GUI is completed.
- The user can login in the system and edit his/her parameters.
- Setting forms for parameters of most important modules are completed.
- Connectivity to the **COMPAIR** Data Manager is running.
- Visualising 3D observation data in the see-through window is running.
- Filtering and selecting some sensors by type is completed.

It is important to note that the current software framework is implemented in a very flexible way. Therefore, any user feedback concerning the UI, the current functionalities and so on can be easily changed and adopted to the user requirements.

2.2.4. Policy monitoring Dashboard

The Policy Monitoring Dashboard (PMD) is responsible to provide dashboards that will help to assess the impact of policy changes to air quality and traffic. For that, there will be a mode to browse the map, see what sensors are there and inspect. When interested, users can group sensors in groups, so they can be compared. This can be considered as an explorative mode, where users can investigate what the status is.

Next to that, there will be a mode for specific projects to help monitor the efficacy of policy measures in dedicated projects such as schoolstreets, playstreets etc.

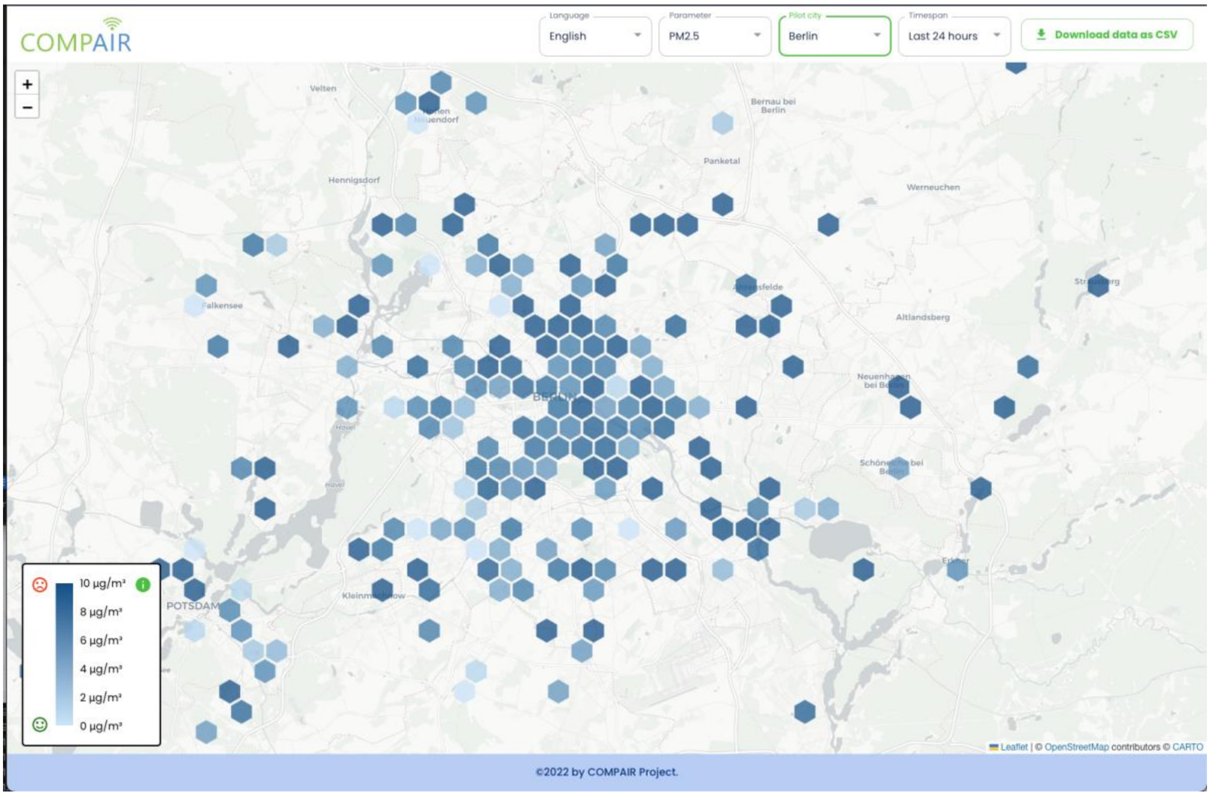


Figure 8 Browsing the map in browse mode

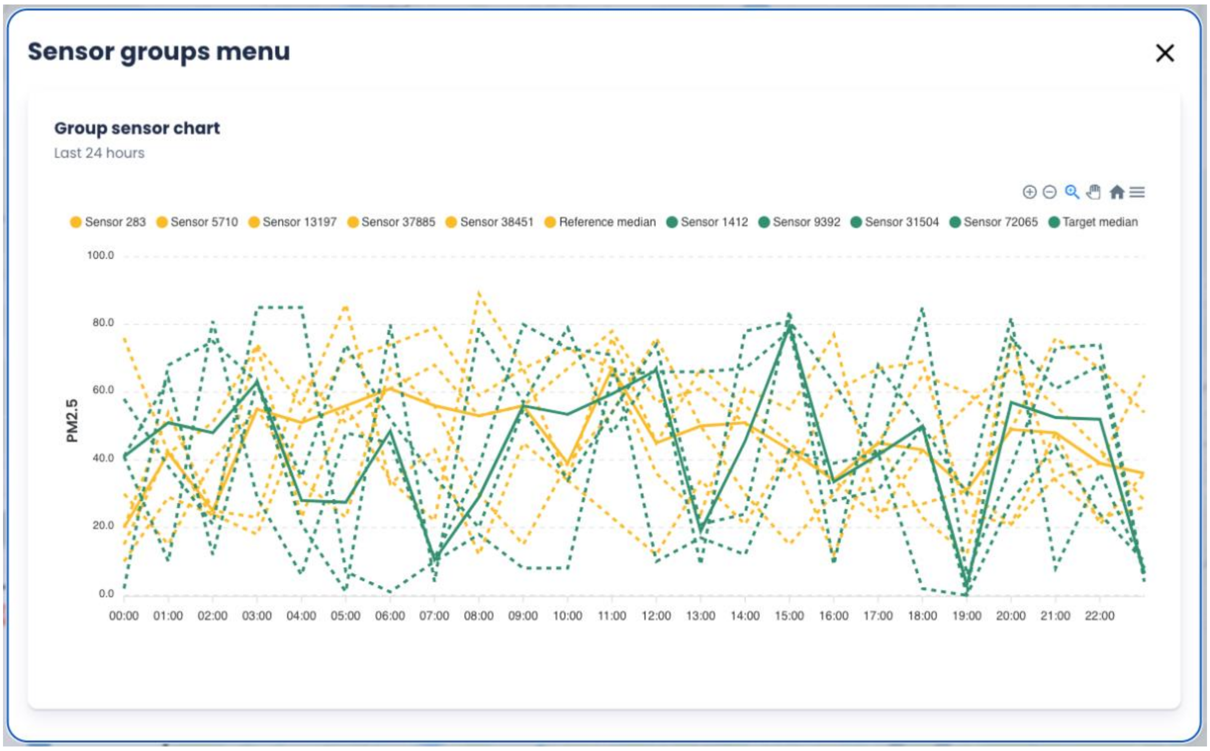


Figure 9 Current implementation of sensors mapped in 2 groups

3. Closed Testing Methodology

The task of Closed testing was foreseen to be executed by consortium members only in order to familiarise with the software and hardware prior to opening the technologies to the end-users at the next Open Testing Round. Also the aim of this task is to identify the baseline functional requirements while using **COMPAIR** tools, to provide lessons learned for the actual in the field pilot execution e.g. obstacles and constraints for end-users, to report feedback in the technical team and finally to provide transferable conclusions for Open Testing Round. Thus, pilots have tested the functionalities under specific user stories as they have been prioritized by Product Owners.

The Closed testing activities refers to the sensors to be used by pilot teams as described in Section 2 and to software tools as developed by the last Sprint meeting of the consortium at 28/9/2022.

More specifically, the Telraam and SODAQ sensors were distributed to each pilot team for internal testing in the field of each pilot location (Athens, Sofia, Plovdiv, Berlin), while the Flanders pilot executed the lab and benchmarking testing reported in Section 4.4. Hence two testing processes are followed: Lab testing from VMM and Pilots Closed Testing both reported in this deliverable. For that reason, Flanders team VMM reports mainly on the results of the laboratory calibration and testing. However, this process will be finalized by M14. After the installation in each pilot limited data were collected and pilots followed 4 use case hypothetical scenarios while actions were proposed in order to test the sensors in various conditions. More specifically the 4 scenarios and relevant actions are as follows:

1. Indoor scenario: sensors are tested in indoor environments. Proposed actions/conditions to check data collection and connectivity:
    a. Move sensor to another position
    b. Create noise
    c. Unplug and plug
    d. Restart sensor
2. Outdoor scenario: sensors are tested in the outdoor environment while moving. Proposed actions:
    a. Take the sensor while cycling
    b. Take the sensor while walking
    c. Take the sensor while on motorbike
    d. Expose at several weather conditions
    e. Place it outside of the window in the office/home
3. Public transport scenario: sensors are tested inside but in a moving vehicle. Proposed actions:
    a. Bus
    b. Tram
    c. Car
4. Leisure scenario: sensors are tested outdoors but in activities that require specific environment. Proposed actions:

a. Take the sensor with you while walking in the park (under many trees)
b. Take the sensor with you while running in various locations
c. Take the sensor with you in the theatre, cinema or somewhere with a lot of people.

The criteria for testing the sensors are listed below:

- Smooth operation of device
- Availability of data
- Interruptions in data collection
- Accuracy of sensor location
- GPS signal availability
- Observation of error data or not correct data collected
- Changes in data measurements due to speed of movement
- Changes in data measurements due to vibrations caused by the movement
- Changes in data measurements due to weather conditions
- Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)
- Duration of power/battery
- Usability
- Issues with connecting devices to backpacks, bikes, etc.
- Ease of interpretation of data
- Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.

Regarding the software, its testing is an ongoing process for the pilot teams. Every month at the Sprint meeting the technical team presents and demonstrates the advancements in the tools and the pilots report on bugs/fixes continuously through their communication with the technical team and a Google form. In order to structure the contents of this deliverable pilots tested the software as developed by 28/9/2022 and the parameters that had to be taken in account and the diverse functionalities to be checked error-prone are:

- future use of the tools by no-consortium members hence, simple citizens
- usability
- User-friendliness
- attractiveness and UI in terms of colours, screens etc
- Future use by low SES groups
- Sufficient insight on air-quality (particles vizualization, graphs, explanation, labels etc)
- The potentiality of the tools to reach wide recruitment targets
- The potentiality to be used by all demographic balances of citizens
- Feature to facilitate policy measures
- Their potentiality to increase awareness for behavioural change.

4. Pilots Closed Testing

4.1. Athens

The Athens pilot is mainly targeting the behavioural change at a household level of the citizens of Athens focusing at their carbon footprint reduction and improvement of air-quality. Also the concept of Citizen Science is aimed to be introduced and adopted by athenians. The tools and hardware of **COMPAIR** must facilitate the engagement of citizens and also support them in having an insight on the environmental footprint of their everyday activities. Hence, usable and simple tools and sensors are the main enabler for this process.

In parallel, on the city administration side, **COMPAIR** will provide to Athens a framework where the city can overview the environmental conditions in terms of air-pollution at neighbourhood level and hence, be supported in the policy making in the environmental field. Finally the same tools are expected to have features for the promotion of public dialogue among citizens and the city.

Thus, for the Athens pilot the main tools to be used and experimented are:

- Policy Monitoring Dashboard: for policy recommendation
- DEVA App: through the AR feature can help citizens understand and interpret the data on air-quality
- CO2 Carbon Footprint: this will be main tool that will be introduced to citizens and demonstrated on its use especially at the first phase of the pilot
- SODAQ Air sensors: it is provisioned to hand over 50 sensors in total to citizens that will also use the **COMPAIR** tools (CO2 Carbon Footprint) in order to instal them in their households
- SODAQ NO2 sensors: it is provisioned to install 6 items in 2 districts of Athens at municipal buildings.

It must be highlighted that the Athens pilot will not use Telraam sensors in the Open and Public pilot round, since the count of traffic is not in the objectives of the pilot as described, but 1 sensor has been tested locally in the Closed Testing Round.

In terms of engagement and recruitment, in the Athens pilot two districts of Athens have been identified. Both locations are in the city-center and the criteria is that one of them - Kispeli - is an area of generally lower SES population, while the other one - Neos Kosmos - has generally higher QoL. In the two locations citizens will be recruited while the senior population will be especially targeted.

Hence, the above-mentioned targets set the conditions and criteria for the closed testing task. Namely, we tested tools and sensors taking into account: the usability and user-friendliness especially for elderly population or other low SES, the attractiveness in order to keep our end-users engaged in both areas, the facilitation of policy measures planning according to the local landscape on public administration, the level of insight that our end-users will gain from the CO2 Carbon Footprint etc.

4.1.1. Description of actions for field testing on sensors

<u>SODAQ installation, use, bugs</u>

The SODAQ Air sensor and NO2 were received in October 2022, however upon arrival it was discovered that the SIM card of the NO2 sensor is not compatible with the telecommunications providers in Greece. Dedicated calls with SODAQ and the pilots for troubleshooting were held since the NO2 sensor in Athens was not operating after its charging.

The SODAQ Air sensor requires tactical charging and a specific position in the magnet part of the sensor in order to be mounted. From the manual it is not clear that a specific position of the magnet is necessary for the sensor operation. This has to be explained to the end-users and updated in the manual.

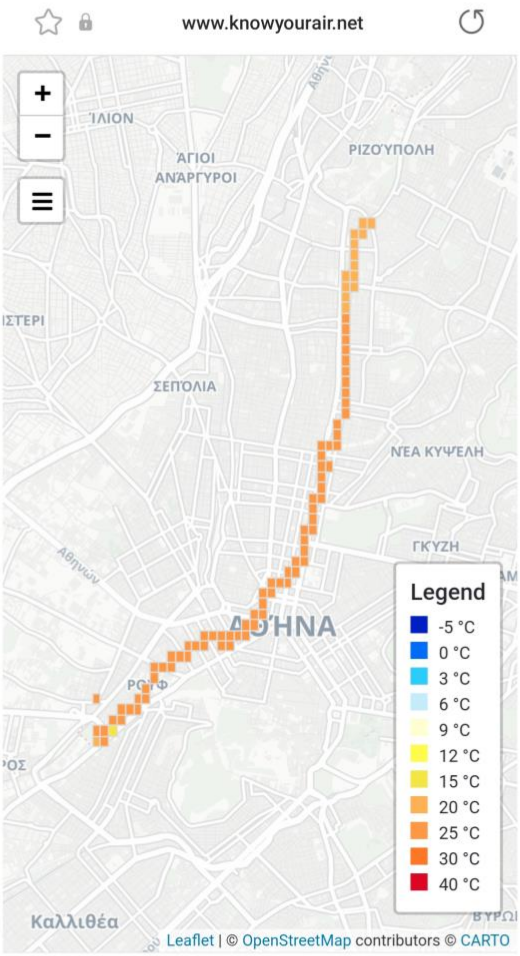
The SODAQ Air was tested in the indoor scenario, however - as it was mentioned before - the sensor does not transmit data to the knowyourair.net[1] platform while indoors. As soon as the sensor was charged and placed outside the premises of DAEM it started collecting data, hence there are results for the outdoor scenario.

Also the sensor was carried in bus drives for the transport scenario and the results are presented in the Tables below. Also, the Figure above depicts the measurements of air pollution PM2.5 for one of the bus drives.

Finally the sensor was tested on leisure activities while walking in the city center where many interventions are present (trees, high buildings etc) and some indicative results are presented in the Figures below (temperature and PM2.5).

The SODAQ Air needs charging daily, while the status of the battery is not evident somewhere on the device nor on the platform. This is expected to create issues with the end-users and interruption in the collection of data. Also the knowyourair.net platform should cache the location of the device and present it when loading an approximate location, in this case to load the map around Athens or Greece. It is not useful that the user has to shift the maps from the Netherlands on every visit.

[1] https://www.knowyourair.net/



<u>Telraam installation, use, bugs</u>

The Telraam sensor installation was completed in August 2022 and is tested for a duration of 1,5 months. The installation process is rather detailed and although it includes many steps, they are guided for use by an everyday citizen. Low SES population or other might need assistance since the guidelines and the Dashboard are in 3 only languages. It must be again highlighted that the Telraam sensors will not be used for the Athens pilot, only one device for testing purposes.

Prior to the installation the instructions were detailed on the selection of the appropriate location. The sensor is located in the premises of DAEM on the 2nd floor, in the window facing the street. In Figure 10 is the sensor's installation and in Figure 11 the street view where data is counted.

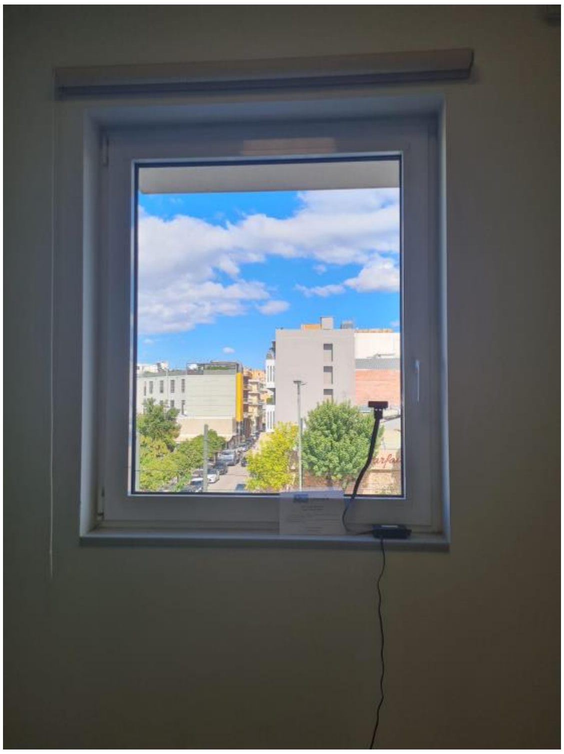


Figure 10 Athens Telraam position

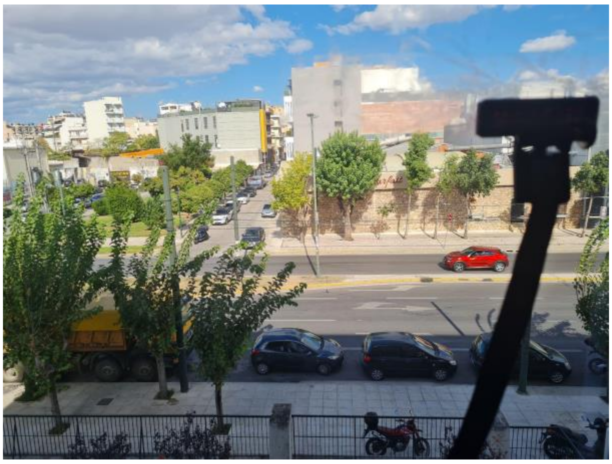


Figure 11 Athens Telraam street view

The sensor is plugged and a note is added in order to inform users of the building on its purpose and avoid any incidents (disconnecting it etc) (Figure 12).

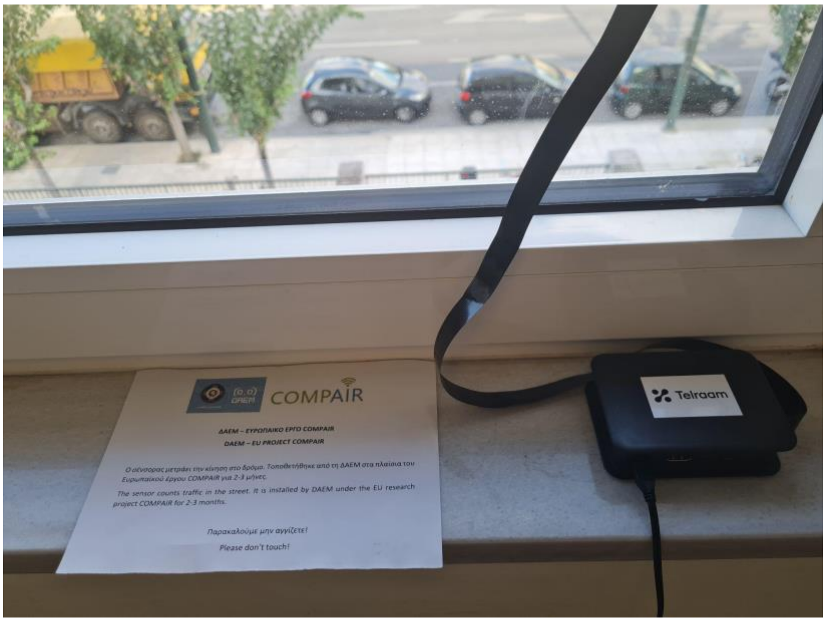


Figure 12 Athens Telraam installation

The sensor is tested in Athens only for the indoor scenario by connecting to the 1st floor of the same building, where it was noticed that there was no difference in the quality and collection of data. The sensor performed correctly in the different uses of the building: during cleaning that created vibrations and during internal renovation that took place in September 2022. The only incident was that several users unplugged the sensor, but still a notification was sent via email and the Athens pilot admins were informed to re-connect it.

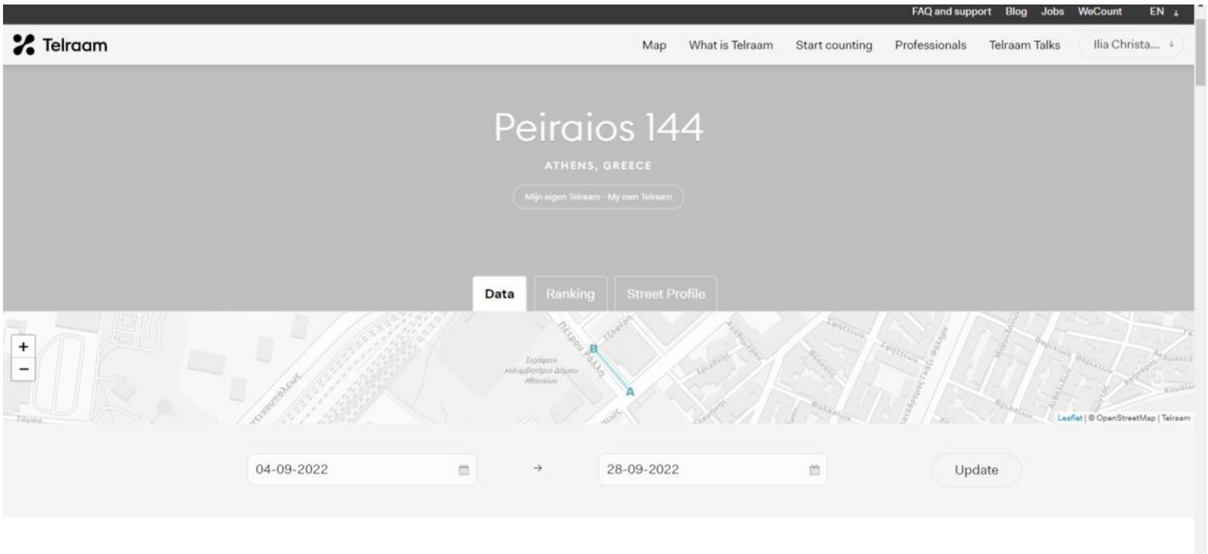
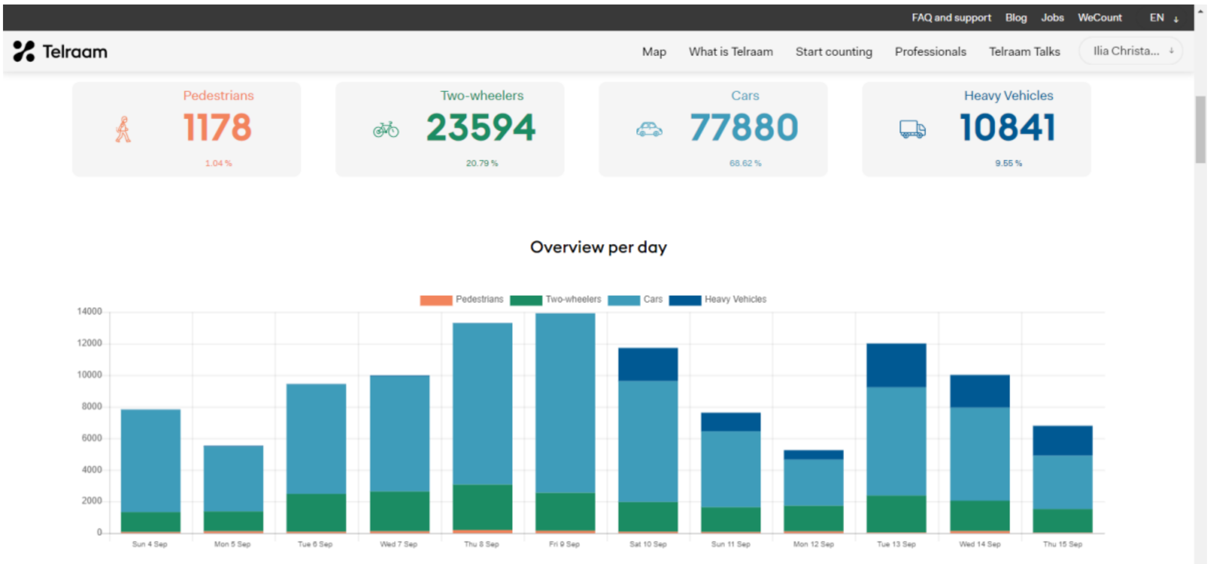
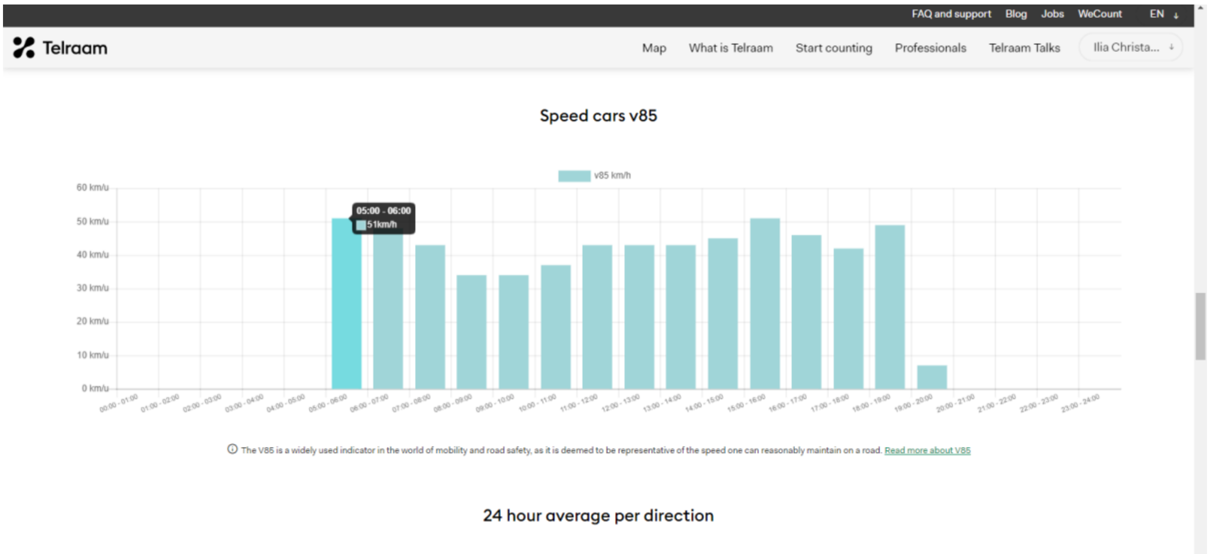
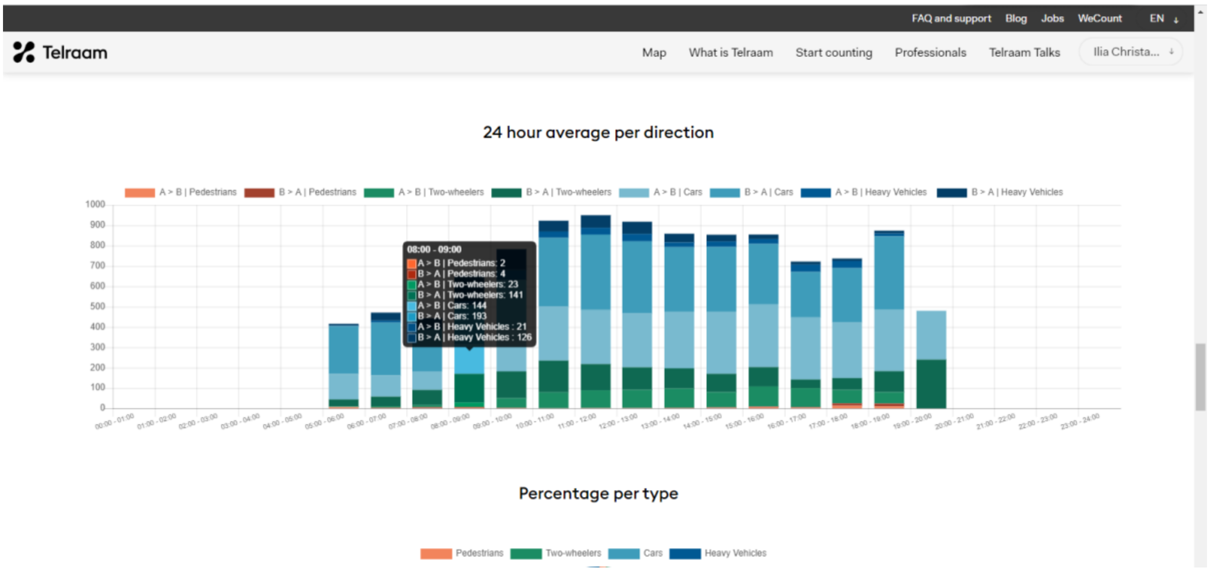


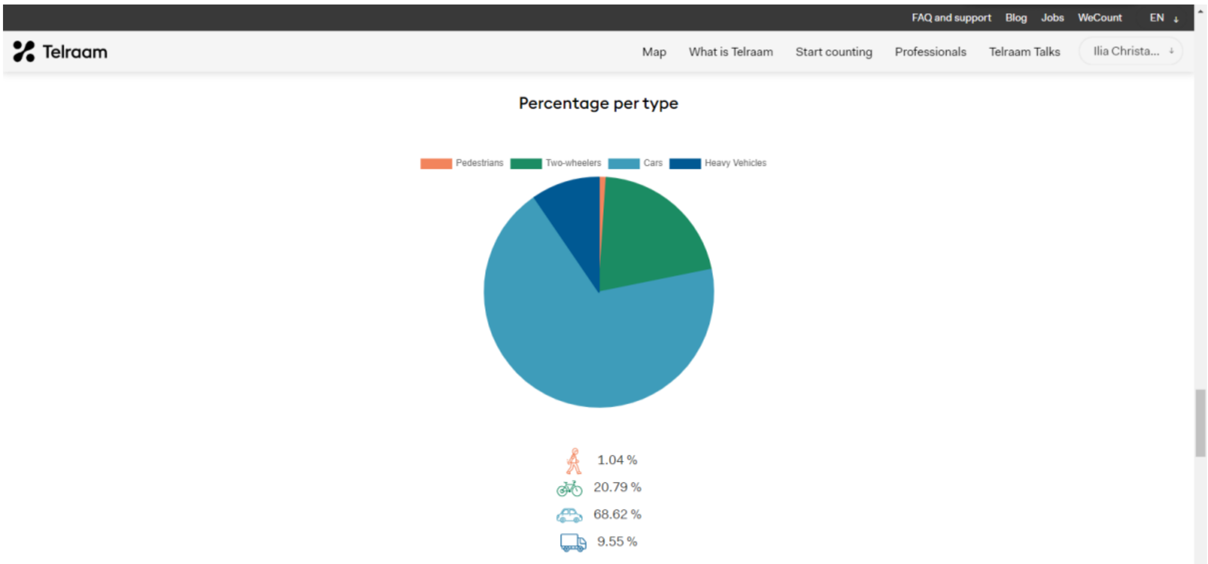
Figure 13 Telraam dashboard

Above is a screenshot of the login page Telraam Dashboard and in the screenshots below the measured data are depicted.


FAQ and support
Blog
Jobs
WeCount
EN
Telraam
Map
What is Telraam
Start counting
Professionals
Telraam Talks
Ilia Christa...
Pedestrians
1178
1.04 %
Two-wheelers
23594
20.79 %
Cars
77880
68.62 %
Heavy Vehicles
10841
9.55 %
Overview per day
Pedestrians
Two-wheelers
Cars
Heavy Vehicles
14000
12000
10000
8000
6000
4000
2000
0
Sun 4 Sep
Mon 5 Sep
Tue 6 Sep
Wed 7 Sep
Thu 8 Sep
Fri 9 Sep
Sat 10 Sep
Sun 11 Sep
Mon 12 Sep
Tue 13 Sep
Wed 14 Sep
Thu 15 Sep


FAQ and support
Blog
Jobs
WeCount
EN
Telraam
Map
What is Telraam
Start counting
Professionals
Telraam Talks
Ilia Christa...
Speed cars v85
v85 km/h
05:00 - 06:00
51km/h
60 km/u
50 km/u
40 km/u
30 km/u
20 km/u
10 km/u
0 km/u
The V85 is a widely used indicator in the world of mobility and road safety, as it is deemed to be representative of the speed one can reasonably maintain on a road. Read more about V85
24 hour average per direction


FAQ and support Blog Jobs WeCount EN
Telraam
Map What is Telraam Start counting Professionals Telraam Talks Ilia Christa...
24 hour average per direction
A > B | Pedestrians B > A | Pedestrians A > B | Two-wheelers B > A | Two-wheelers A > B | Cars B > A | Cars A > B | Heavy Vehicles B > A | Heavy Vehicles
08:00 - 09:00
A > B | Pedestrians: 2
B > A | Pedestrians: 4
A > B | Two-wheelers: 23
B > A | Two-wheelers: 141
A > B | Cars: 144
B > A | Cars: 193
A > B | Heavy Vehicles : 21
B > A | Heavy Vehicles : 126
Percentage per type
Pedestrians Two-wheelers Cars Heavy Vehicles


FAQ and support Blog Jobs WeCount EN
Telraam
Map What is Telraam Start counting Professionals Telraam Talks Ilia Christa...
Percentage per type
Pedestrians Two-wheelers Cars Heavy Vehicles
1.04 %
20.79 %
68.62 %
9.55 %

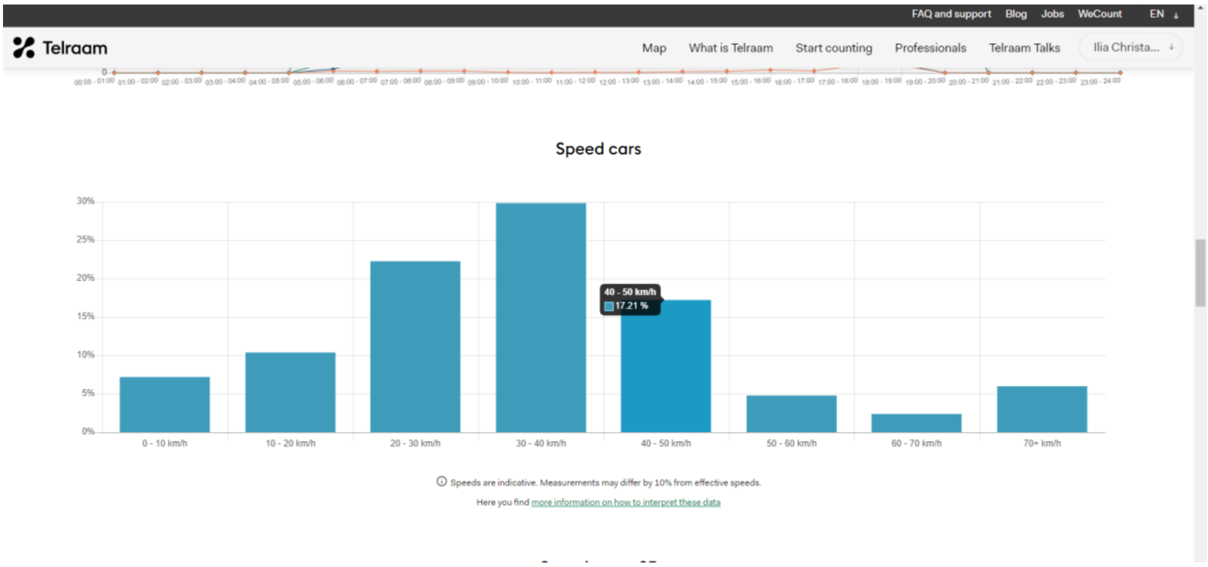

FAQ and support Blog Jobs WeCount EN
Telraam
Map What is Telraam Start counting Professionals Telraam Talks Ilia Christa...
Speed cars
40 - 50 km/h
17.21 %
0 - 10 km/h
10 - 20 km/h
20 - 30 km/h
30 - 40 km/h
40 - 50 km/h
50 - 60 km/h
60 - 70 km/h
70+ km/h
Speeds are indicative. Measurements may differ by 10% from effective speeds.
Here you find more information on how to interpret these data

Table 1 Athens Observations from Indoor Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	The device operated smoothly	No because indoors there was no data presented in the platform	Not tested
Availability of data	There was no interruption in data availability. The lack of availability is only due to the selection of the measured road (e.g. presence of trees etc)	No because indoors there was no data presented in the platform	Not tested
Interruptions in data collection	Only in cases when the sensor was unplugged	No because indoors there was no data presented in the platform	Not tested
Accuracy of sensor location	The sensor location is determined by the use during registration	When the user exits the building the sensor locates the position accurately	Not tested
GPS signal availability	Not applicable	When the user exits the building the sensor locates the position accurately	Not tested
Observation of error data or not correct data collected	No observation of error data	Yes because indoors there not data presented in the platform	Not tested
Changes in data measurements due to speed of movement	It was not used in movement	No because indoors there was no data presented in the platform	Not tested
Changes in data measurements due to vibrations caused by the movement	It was not used in movement	No because indoors there was no data presented in the platform	Not tested
Changes in data measurements due to weather conditions	Data were collected for diverse outdoor conditions	No because indoors there was no data presented in the platform	Not tested
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	The cleaning service of the building a few times unplugged the sensor by mistake	No because indoors there was no data presented in the platform	Not tested

Duration of power/battery	It was plugged constantly, hence there must a power outlet for its use	The battery needs charging daily and the status of the battery is not evident somewhere on the device nor on the platform	Not tested
Usability	It must occupy one window that must not be opened and it requires a power outlet closeby.	It is intuitive and useful. The light indication is easy and the collection of data requires no actions from the end-user	Not tested
Issues with connecting devices to backpacks, bikes, etc.	This is not applicable	No issues on connection however the screw is not a friendly mechanism. It could a secure clip easier to open/close	Not tested
Ease of interpretation of data	The collected data are labelled sufficiently in the Dashboard both in terms of type of vehicles/pedestrians, and of speed and statistics.	No because indoors there was no data presented in the platform	Not tested
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	The sensor has a double tape to keep stable on the window	The sensor is stable but a bit heavy	Not tested

Table 2 Athens Observations from Outdoor Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	N/A	The sensor operated with no interruptions	Not tested
Availability of data	N/A	The sensor constantly is collecting data	Not tested
Interruptions in data collection	N/A	No interruptions	Not tested
Accuracy of sensor location	N/A	High accuracy	Not tested
GPS signal availability	N/A	High availability	Not tested
Observation of error data or not correct	N/A	No observation	Not tested

data collected			
Changes in data measurements due to speed of movement	N/A	It was on a stable position in the outdoor scenario	Not tested
Changes in data measurements due to vibrations caused by the movement	N/A	It was on a stable position in the outdoor scenario	Not tested
Changes in data measurements due to weather conditions	N/A	It was tested in various weather (rain, high wind) and no changes were noticed	Not tested
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	The outdoor testing was performed in a noisy location and no changes were noticed	Not tested
Duration of power/battery	N/A	The battery needs charging daily and the status of the battery is not evident somewhere on the device nor on the platform	Not tested
Usability	N/A	It is very usable for the collection of data on the 5 indicators	Not tested
Issues with connecting devices to backpacks, bikes, etc.	N/A	No issues on connection however the screw is not a friendly mechanism. It could a secure clip easier to open/close	Not tested
Ease of interpretation of data	N/A	For an everyday user the distinction among PM2.5, PM 10 for example is not evident. However on the map the colour degradation and label are helpful on interpretation as well as the light on the sensor.	Not tested
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	N/A	It was placed in a stable position	Not tested

Table 3 Athens Observations from Public Transport (vehicle) Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	N/A	Yes	Not tested
Availability of data	N/A	Yes, during all the routes	Not tested
Interruptions in data collection	N/A	No	Not tested
Accuracy of sensor location	N/A	Yes, during all the routes	Not tested
GPS signal availability	N/A	Yes, during all the routes	Not tested
Observation of error data or not correct data collected	N/A	No changes	Not tested
Changes in data measurements due to speed of movement	N/A	No changes	Not tested
Changes in data measurements due to vibrations caused by the movement	N/A	No changes	Not tested
Changes in data measurements due to weather conditions	N/A	No changes	Not tested
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	No changes	Not tested
Duration of power/battery	N/A	The battery needs charging daily and the status of the battery is not evident somewhere on the device nor on the platform	Not tested
Usability	N/A	The sensor was usable for transport scenarios (in the bus in Athens) and attracted interest from other passengers	Not tested
Issues with connecting devices to backpacks,	N/A	No issues on connection however	Not tested

bikes, etc.		the screw is not a friendly mechanism. It could a secure clip easier to open/close	
Ease of interpretation of data	N/A	For an everyday user the distinction among PM2.5, PM 10 for example is not evident. However on the map the colour degradation and label are helpful on interpretation as well as the light on the sensor.	Not tested
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	N/A	It was placed on a backpack in buses and it was stable but heavy	Not tested

Table 4 Athens Observations from Leisure Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	N/A	Yes, while walking for a large distance	Not tested
Availability of data	N/A	Yes, while walking for a large distance	Not tested
Interruptions in data collection	N/A	No	Not tested
Accuracy of sensor location	N/A	Yes, while walking for a large distance	Not tested
GPS signal availability	N/A	Yes, while walking for a large distance	Not tested
Observation of error data or not correct data collected	N/A	No error was observed	Not tested
Changes in data measurements due to speed of movement	N/A	No charges	Not tested
Changes in data measurements due to vibrations caused by the movement	N/A	No charges	Not tested
Changes in data measurements due to	N/A	No charges	Not tested

weather conditions			
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	No charges	Not tested
Duration of power/battery	N/A	The battery needs charging daily and the status of the battery is not evident somewhere on the device nor on the platform	Not tested
Usability	N/A	It is very usable	Not tested
Issues with connecting devices to backpacks, bikes, etc.	N/A	No issues on connection however the screw is not a friendly mechanism. It could a secure clip easier to open/close	Not tested
Ease of interpretation of data	N/A	For an everyday user the distinction among PM2.5, PM 10 for example is not evident. However on the map the colour degradation and label are helpful on interpretation as well as the light on the sensor.	Not tested
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	N/A	The sensor is stable but it is heavy for leisure activities	Not tested

4.1.2. Feedback on software tools

The exercise of Closed Testing for the software of **COMPAIR** includes in Athens, the Athens **COMPAIR** team responsible for the pilot execution, as well as internal colleagues of DAEM that are not relevant to the project in order to ensure a simple-user's feedback.

The main page of **COMPAIR** is aimed to provide a dashboard with statistics and figures for the different pilot locations. Currently it is still in an initial version and with fake data.

As a first comment it is suggested to have 2 types of users for the first page: one version for administrators and pilot leaders that can provide an overview of the end-users and logins/accounts created. Since the current version includes a users' overview even if the figures include fake data. A second version should be for the actual end-users, for citizens and city representatives, that when logged in they can have a common page redirecting to all **COMPAIR** tools. The register and login pages include all the familiar features hence are easy-to-use for every type of user.

In terms of UI the menu on the left is very comprehensive and another positive feature is that the graphical representations have many obvious and usable details such as sufficient labelling that explains the values in the figures. Finally, the theme setting for light and dark mode is highly positive as well as the language setting since a localization for each pilot location will be very helpful for recruiting and engaging citizens especially seniors and low SES groups.

Table 5 Athens Feedback on main page

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	Yes, since it can be used as the main page where a user can be re-directed to all **COMPAIR** tools
Usability	Yes, simple and comprehensive
User-friendliness	Yes
Attractiveness and UI (colours, screens etc)	The menu on the left is very comprehensive. The graphical representations and statics that currently are fake data but will be added in the main page, have many obvious and usable details (e.g. sufficient labelling explaining the values in the figures)
Future use by low SES groups	Yes, it is a simple page for all types of users
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	Not applicable for this page
Could the tools reach wide recruitment targets?	Yes, it is a simple page for all types of users
Do they refer to all demographic balances of citizens?	Yes, it is a simple page for all types of users
Feature to facilitate policy measures	Not applicable for this page
Do they have the potential to increase awareness for behavioural change?	Not applicable for this page

DEVA

The first screen of the DEVA App is very inviting to the user. On the login screen the types of user accounts should be horizontal for all the types of users of **COMPAIR** tools. The background screen of the App should be localised with a photo of each pilot site.

The DEVA is currently at a mockup stage hence sufficient feedback cannot be provided, however as an initial comment the App looks attractive and with many functionalities to support the project. The menus are well-designed, it is an asset that the user can select themes, dark mode and different visualisations for the values of the parameters (pins, spheres etc).
For a tech savvy user it is comprehensive, hence a user that will explore all menus, options and features. For lower SES and less tech savvy users the App contains many options that will need to be demonstrated and also these users will need technical support to remind them of the functionalities and guidance. It would be an option to have a lighter version of the App where less functionalities are enabled and the user can mainly have an overview in AR mode of the different environmental parameters and their values.

Table 6 Athens Feedback on DEVA

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	Yes
Usability	Comprehensive for tech savvy users
User-friendliness	High
Attractiveness and UI (colours, screens etc)	Yes, menus well-designed, selection of themes, dark mode and different visualisations for the values of the parameters
Future use by low SES groups	For lower SES users will need to be demonstrated and also will need continuous technical support and guidance. Potential use of a lighter version with less enabled options/functionalities
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	The visualisations in the App are an important asset, they are well-explained with different colours for each parameter, expanding visuals according to the values (high/low-bigger/smaller) and possibility to add the actual values
Could the tools reach wide recruitment targets?	This depends on the mobile phones of the end-users and their compatibility with AR functionality
Do they refer to all demographic balances of citizens?	Same as for lower SES groups applies to citizens less tech savvy
Feature to facilitate policy measures	This is not relevant to DEVA
Do they have the potential to increase awareness for behavioural change?	The DEVA supports behavioural changes since it visualises the air pollution and other environmental parameters in the air around the users. Hence it is expected to highly contribute.

Carbon Footprint Dashboard

The main page of the Carbon Footprint Simulation Dashboard is explanatory to its use and includes sufficient information on the tool, referring also to both the Carbon Footprint Dashboard and the Scenario Simulation feature. Menu and options such as notifications are easy-to-use and useful.

The section referring to the calculation of the user's habits for extracting his/her CO2 footprint is simple and each tab is comprehensive. It should be possible to calculate the results even if one tab is not completed by the user since e.g. some users might use the train.

In the Results section the visuals are nicely represented. It would be proposed not to use yellow as the colour for the highest percentage, since it is distracting for the users. The comparison of the habits with the country and the European statistics is very insightful. The recommendations section would be preferable to appear in a new tab, since the user might scroll down at the end of the results page, hence a new tab could provide emphasis and stimulation to the user for the recommendations.

The Scenario Simulation Dashboard is a feature that requires some time for familiarization or more training. The policies proposed are not included in the CO2 calculation tool for example domestic appliances, types of lightning, insulation of homes etc should also be included in the Calculator even if their contribution to the footprint is less than transport and flights. The timespan in the figure is useful since it foresees the results of actions in the forthcoming years. Also the distinction of actions for users/citizens and government/decisions-makers is important. The distinction of scenarios to minimum and maximum is not very clear to a user and requires labelling, walkthrough etc.

In the administrator settings tab, the titles and scenarios can be configured and it is highly usable for officials and policy-makers. It is possible to rename scenarios and actions, edit, delete or add new ones.

Table 7 Athens Feedback on Carbon Footprint

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	Citizens can easily use the calculator, for the Scenario Simulation Dashboard further explanatory demos will be necessary
Usability	Overall the CO2 Calculator is usable, the tab-logic is comprehensive. The Scenario Simulation Dashboard is a tool for more advanced users. The policies proposed in the Scenario Simulation are recommended to be included in the CO2 calculation tool e.g. domestic appliances, types of lightning, insulation of homes etc.
User-friendliness	Overall the tool is user-friendly, features such as drop-down lists, adjustable slidebars are facilitating the use

Attractiveness and UI (colours, screens etc)	Colours and screens generally follow the projects approach. In the Results section it is proposed not to use yellow as the colour for the highest percentage, since it is distracting for the users
Future use by low SES groups	The CO2 Calculator is suitable also for this category of users. It is recommended to be possible for the user to calculate the CO2 footprint even if one tab is not completed since e.g. some low SES users might use flights.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	The main insight is provided in the Scenario Simulation section. The target of emission is evident in the graph and values are included. Also in the calculator the results of the calculation are insightful.
Could the tools reach wide recruitment targets?	Yes
Do they refer to all demographic balances of citizens?	Yes
Feature to facilitate policy measures	The Scenario Simulation Dashboard is the main tool that can input policy creation and it is a feature that requires some time for familiarization or more training. This tool should be connected with the Policy Monitoring Dashboard.
Do they have the potential to increase awareness for behavioural change?	Yes

Policy Monitoring Dashboard

The UI of the PMD is proposed to be modified with other colours, since at the moment the main colour palette is blue/light blue both for the maps but also for the cells referring to air-pollution in the map. It is proposed to have another colour for the **COMPAIR** cells. The legend with the colour variation is very user-friendly and helps to interpret the air-pollution level measures, also matching with the values and thresholds. Still it is proposed to include a different colour. The same comment applies for all the parameters measured (temperature, noise etc).

The labelling of cells during mouse hover over is very useful since it provides information on the quantity of sensors in the area of the specific cell.

The map is highly responsive and suitable for all types of users, zooming in/out both via the mouse and the buttons provided. The upper menu is intuitive and easy-to-use and to understand.

In each cell the user can select each individual sensor, as well as a group of sensors given that it is created. The graphs of each sensor follow the look and feel of the main page and are usable. The option of creating a group of sensors, adding a name and selecting sensors to include is highly preferable in order to overview the values of a parameter at a local level, however it should be more obvious adding an info to explain the steps, since we are referring also to individual users.

For the end-users of Athens that will have a sensor installed in their households, the initial page of the PMD should load the parameters, language and location/city of their sensors.

Generally the PMD requires a level of familiarisation from the end-users in environmental parameters and a level of IT literacy. Lower SES groups are expected to need a demonstration/training to use it.

Table 8 Athens Feedback on Policy Monitoring Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	For the Athens end-users that will have a sensor installed in their households, the initial page should load the parameters, language and location/city of their sensors.
Usability	The tool is usable for monitoring environmental sensors and measurements in order to interpret them for policy creation. The option of creating a group of sensors, adding a name and selecting sensors to include is highly preferable in order to overview the values of a parameter at a local level, however it should be more obvious adding an info to explain the steps
User-friendliness	The menus, look-and-feel, and legends are overall very detailed and friendly to the users.
Attractiveness and UI (colours, screens etc)	The UI of the tool is intuitive and easy-to-use, but it is proposed to include another colour other than blue/light blue
Future use by low SES groups	When necessary, demonstration and training will be offered to low SES groups.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	The labelling of cells during mouse hover over is very useful. The graphs of each sensor follow the look and feel of the main page and provide enough insight.
Could the tools reach wide recruitment targets?	Yes
Do they refer to all demographic balances of citizens?	Requires a level of familiarisation in environmental parameters and a level of IT literacy.
Feature to facilitate policy measures	To support policy making this tool is targeting officials/academics/other end-users with a specialty in environmental conditions and their impact. Surely the tool visualises the values sufficiently, but a citizen might not be able to extract their actual impact.
Do they have the potential to increase awareness for behavioural change?	Requires a level of familiarisation in environmental parameters and a level of IT literacy.

4.2. Berlin

The testing of the SODAQ and Telraam sensors in the Berlin pilot was performed based on the predefined scenarios described above in Section 3. Where possible, testing locations and routes were chosen that approximate areas where Berlin's two pilot experiments – Liveable city environment and Car-free streets – will be implemented in the future.

The Telraam sensors were tested during two instances at two different homes in Berlin. In both cases, the testers (inter 3 employees) followed the instructions on the Telraam website and made sure that the locations were adequate for a clear view of the traffic. The testing was performed in August 2022 and lasted for a week per instance. The experience is summarised in the Table below.

The SODAQ NO2 sensor was tested in the indoor and outdoor scenario at the inter 3 office. In the indoor scenario, the device was tested for several days in order to check its usability and to gather initial data and information on measurement irregularities as well as the location precision. In the outdoor scenario, the device was attached outside of the window for several days with the aim to test the validity of the data, measurement irregularities as well as the stability of the device.

Finally, SODAQ Air was used in all four scenarios. In the indoor scenario, SODAQ Air was used for 4 days at inter 3's office to gather information on the validity of the data, location precision and measurement interruptions. In the outdoor and leisure scenario, the device was tested for 3 days while walking and biking around areas similar to those where the Liveable City Environment pilot experiment will take place. The device was also tested, as described in the public transport scenario, in closed vehicles such as metros and cars. The measurements here lasted 4 days. Both SODAQ devices were tested in October 2022.

4.2.1. Description of actions for field testing on sensors

<u>SODAQ installation, use, bugs</u>
The device was received on 28/9/2022 and tested indoors on October 13th. Installing and using the device was very simple. Initially, it was difficult to register on the website to see the results on the dashboard. The device needed to be charged, so no data appeared on the NO2 dashboard in the beginning. However, a few moments after the device was connected to the computer via USB, the device received a GPS signal on the NO2 dashboard and began to capture air pollution data and display them on the dashboard. All data points - NO2, PM, temperature, humidity, as well as battery usage - were visible (Figures 14 to 17). Of course, if the users are unaware that they have to click on the **Entity name** to see the results, no data will be displayed and there will be a feeling that the data collection has not been done correctly. Some abbreviations such as *NO WE* and *NO2 AE* may be meaningless to users. There may be times when the battery level drops suddenly (see Figure 17) and the battery needs to be recharged to avoid problems with data collection. If the user forgets to charge the device, the data recording will face problems. Some bugs are seen in displaying the results on the dashboard, most importantly, negative NO2 (µgm3) recorded values (see Figure 15).

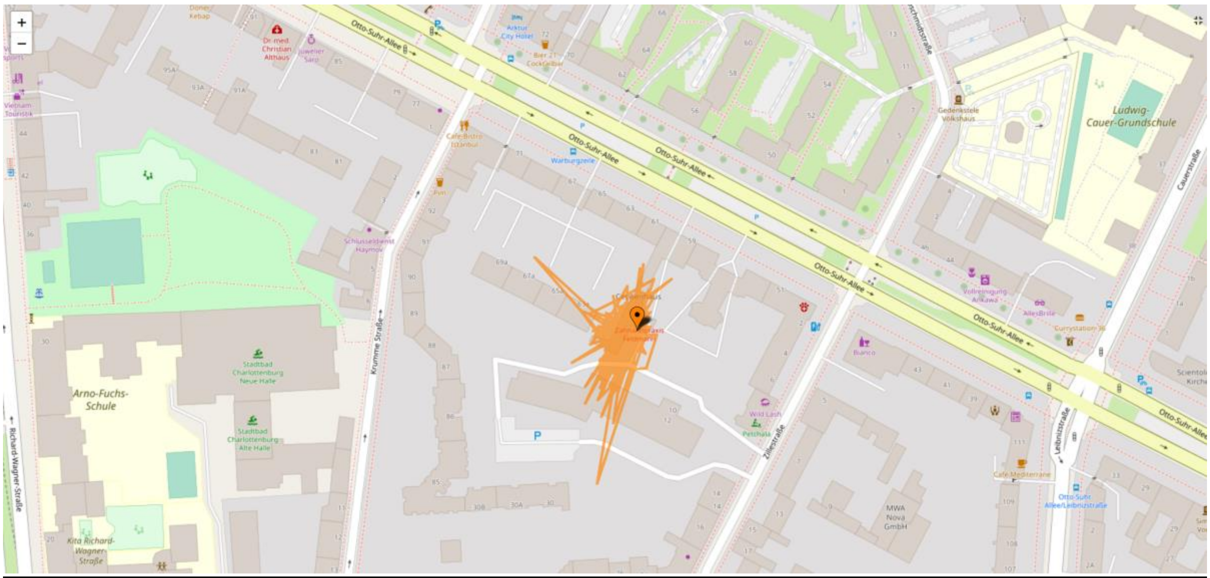


Figure 14 Sensor installation location in Berlin (indoor)

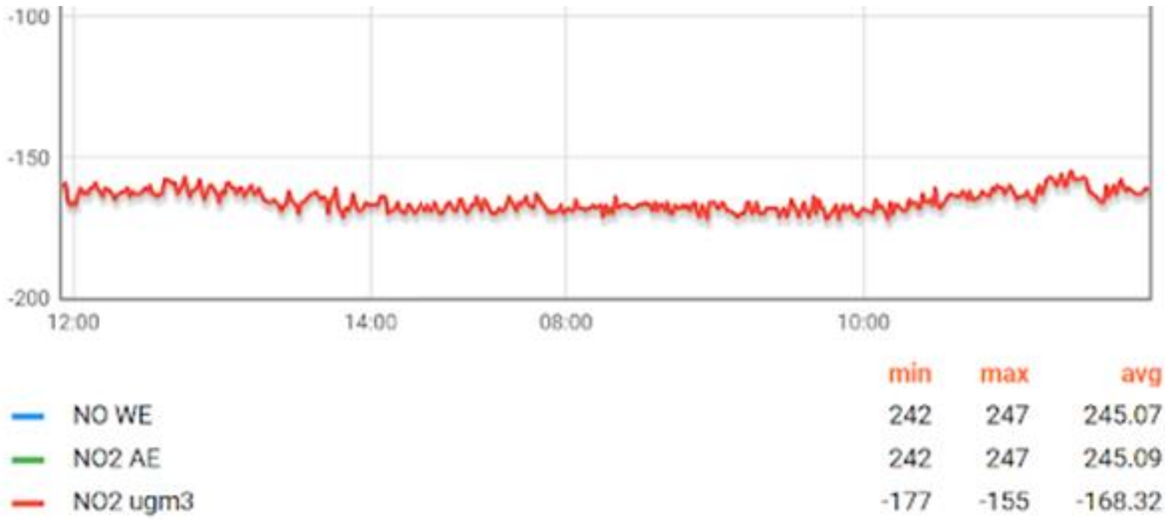


Figure 15 NO2 values (µgm3 values are negative)

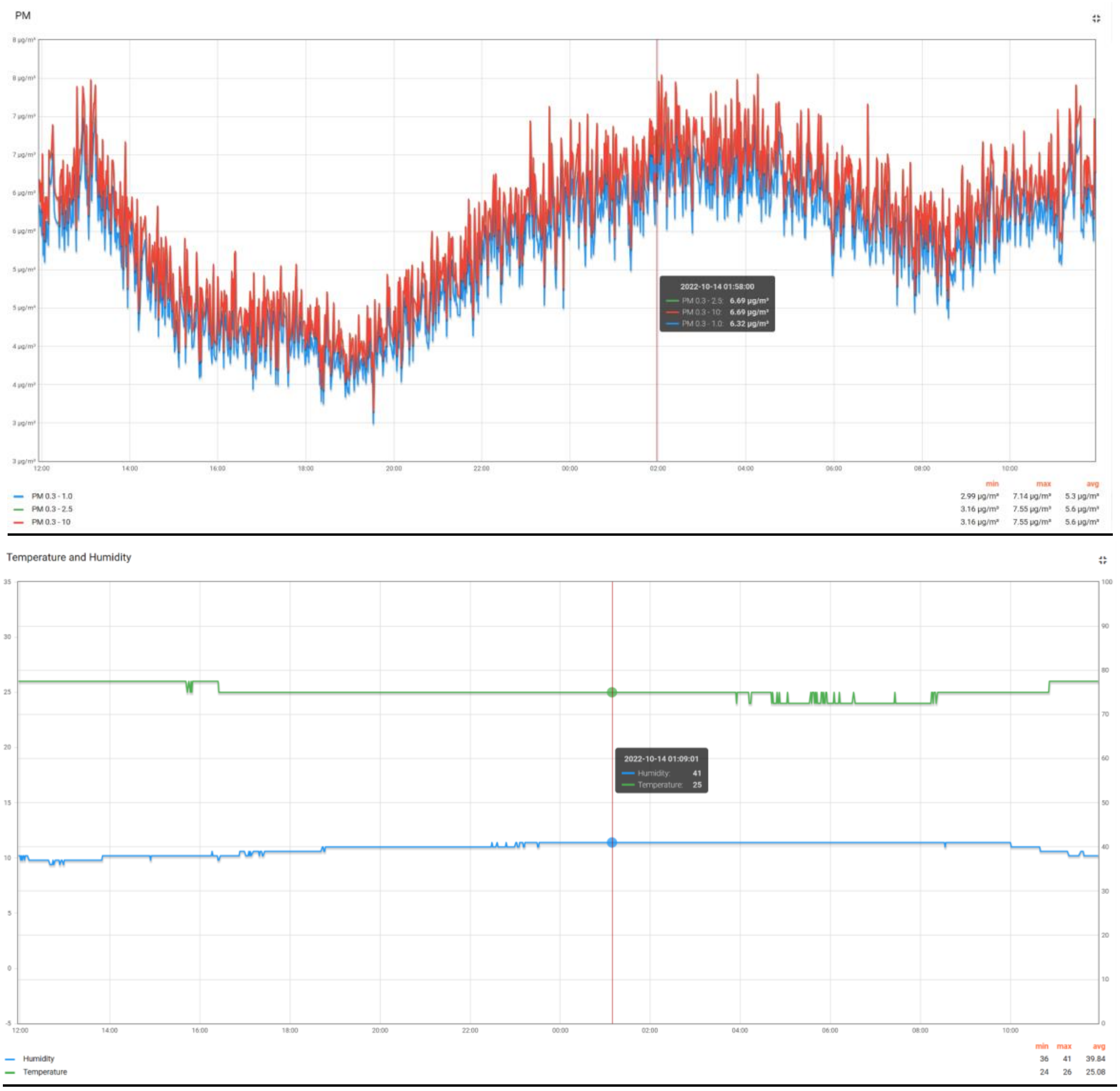


Figure 16 Measurement results of Temp, Humidity, and PM

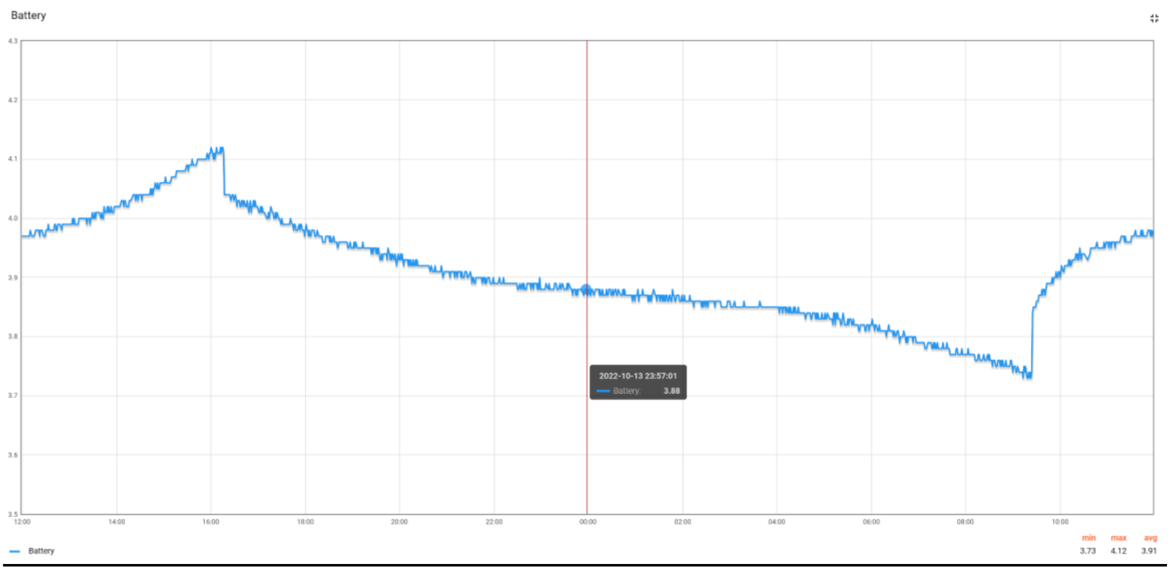


Figure 17 Battery charge changes over time (sometimes there is a sudden drop in battery charge).

Telraam installation, use, bugs

The Telraam sensor was tested in August 2022 on two different streets in Berlin for a period of 3 weeks. The sensor was installed in the right place on the second floor, in the window facing the street. Figure 18 shows the view of one of the streets where the sensor has been installed and data collected. Before installation, the instructions about choosing the right place and how to install must be studied, otherwise, choosing the wrong place for installation will not produce the right results. The available instructions describe in detail how to install and choose the right place. The installation process is very detailed and involves many steps and use of the sensor by an ordinary citizen or SES population might be difficult. The device itself works perfectly, however; there were some WiFi connection problems.

Date image: Thu 11 August 2022 12:00

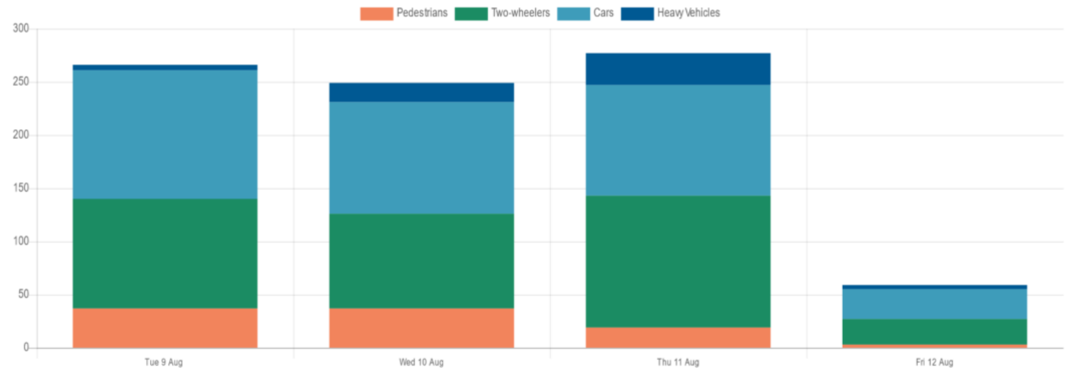
Telraam Software Version: v11c

Figure 18 The view of one of the streets in Berlin where the sensor was installed

The selected streets were suitable for data collection and therefore we could work with a sufficient amount of data and infos. Data analysis and presentation are quite satisfactory and provide useful information to users. Furthermore, the classification of information in the form of various graphs provides a better understanding of the data situation for the user. Some of the results for the measurements in one of the tested streets in Berlin are presented as follows:

Pedestrians	Two-wheelers	Cars	Heavy Vehicles
96	340	358	58
11.27 %	39.91 %	42.02 %	6.81 %

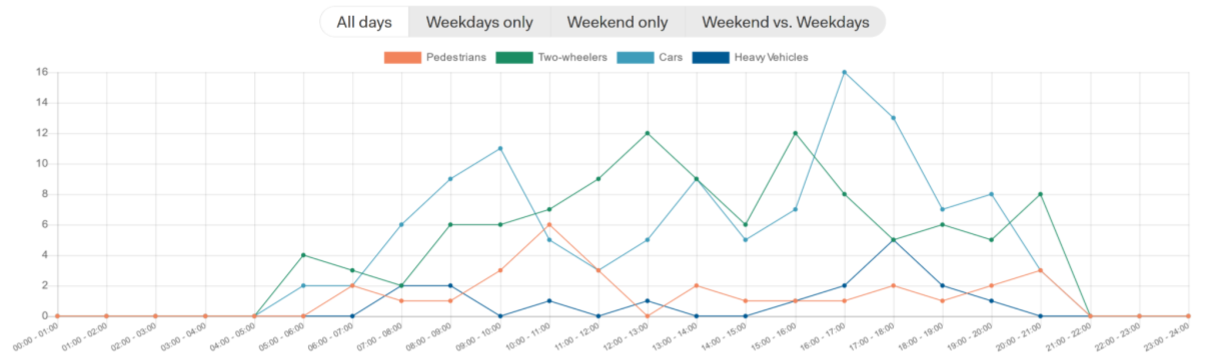
Overview per day



How should I interpret the Telraam data?

Overview in detail

24 hour average



24 hour average per direction

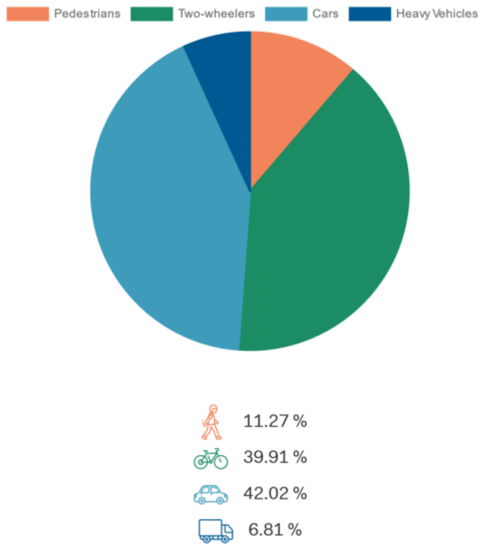


Figure 19 Some of the results for the measurements in one of the tested streets in Berlin pilot.

Table 9 Berlin Observations from Indoor Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	The device itself works perfectly. Before installation, the instructions about choosing the right place and how to install must be studied, otherwise, choosing the wrong place for installation will not produce the right results. The installation process is very detailed and involves many steps. Using the sensor by an ordinary citizen or SES population may be difficult. There were some WiFi connection problems.	Device is very easy to use. About half a minute after the device is attached to the mount, a (blue) light appears, signalling the air quality. The device works as described in the manual.	The device needed to be charged, which is why no data appeared on the NO2 dashboard at first. However, a few moments after the device was plugged into the computer via USB, it started picking up ambient air pollution and displaying data on the dashboard. As described in the manual, the device is running for as long as the battery isn't empty. From this point of view, the device operates smoothly.
Availability of data	The selected streets were suitable for data collection and therefore we could work with a sufficient	The data was almost immediately available on the knowyourair.net platform.	The data is immediately available on the dashboard. All data related to NO2, PM, temp., humidity as

	amount of data.		well as battery usage appears on the dashboard. Specifying a time period also shows the appropriate data
Interruptions in data collection	Due to the fact that the sensor lost the WiFi signal, there were interruptions in data collection for several hours and even days.	No interruptions in data collection were noticed	The only time period when data measurements were interrupted was when the battery was depleted. There were no interruptions otherwise.
Accuracy of sensor location	The accuracy of the sensor location was very precise.	The accuracy of the sensor location was very precise.	The accuracy of the sensor location was very precise.
GPS signal availability	The device picked up the GPS signal on the Telraam dashboard	The device picked up the GPS signal on the knowyourair.net platform	The device picked up the GPS signal on the NO2 dashboard
Observation of error data or not correct data collected	Errors in data collection are not known.	No errors in data collections have occurred.	Most notably, the NO2 values (µgm3) were recording negative values (see Figure 15). For about 2 hours after the battery was depleted, the dashboard was also displaying data. PM and NO2 values were increasing irregularly during that period.
Changes in data measurements due to speed of movement	No changes are known	When walking from one room to another, two locations with different data values were picked up on the platform.	N/A
Changes in data measurements due to vibrations caused by the movement	No changes are known	No noticeable changes	No noticeable changes
Changes in data measurements due to	If the WiFi signal and the mounting were	N/A	N/A

weather conditions	stable, there were no limitations in the measurements due to the weather.		
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	No changes were identified.	The sensor was placed next to an open window in order to test the noise effect of nearby construction works. During that period, the PM values were noticeably larger, although it is not possible to tell whether this was caused by the noise or the outside air quality.	No changes were identified.
Duration of power/battery	Since the sensor has a power plug, there were no battery or accumulator problems.	The battery lasted for several hours.	Sometimes there is a sudden drop in battery charge (see Figure 17). The moment the device stops being charged, the battery level drops by 0.1V. The battery also needs to be recharged frequently.
Usability	On the Telraam web site there is a step-by-step guide, which is written in a detailed, easy to understand way and makes the usability of the sensor very clear and easy.	The usability of the device is as easy as it gets. It is easy to transport and carry the device around and start measuring and using the knowyourair.net platform.	Using the device is very simple. It only needs to be installed and then everything works on its own. Registering on the dashboard to view the results was a bit problematic.
Issues with connecting devices to backpacks, bikes, etc.	N/A	N/A	N/A
Ease of interpretation of data	Thanks to the coloured graphs, the interpretation of the results was clear and easy.	Given that there are only 5 data types, it was very easy to interpret the data. The min, max and avg values of each sensor, as well as the legend values, are also readily	The data is displayed in various interactive graphs, which makes initial interpretations easy. The NO2 graph's y-axis, however, does

		interpretable for each data type.	not have any units. There are 3 different variables in different units, ranging from negative to positive values, making interpretation difficult. In addition, the temp/humidity graph overlays the two variables. The lack of units on each y-axis makes interpretation difficult for the common user. The same applies to the battery graph. It would be advisable to add a downloadable manual describing each graph.
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	Due to the slippery surface of windows, the sensor has come off the tape device twice; a safe mounting needs to be secured.	N/A	N/A

Table 10 Berlin Observations from Outdoor Scenario testing (not applicable to Telraam)

Tested Functionalities/parameters	SODAQ Air	SODAQ NO2
Smooth operation of device	Most parts of the instruction manual of the SODAQ Air sensor were clear. The description of the IMEI (6-digit number) and the passcode (5-digit number) should be labelled as such at the device. In the end, it worked to use the sensor by just plugging the mount with the magnet on the device (without using the IMEI and passcode). Then the sensor already appeared on the map. After that, the sensor worked fine.	See comment in the Indoor scenario
Availability of data	The data was available on the	See comment in the Indoor

	knowyourair.net platform throughout the entire measurement period. It is possible to choose a time frame for the measured data. Data that is easier to interpret/understand data (e.g. graphs) are not available. When two sensors are used next to each other, both are displayed on the map, yet the sensor number is not indicated there, making it impossible to distinguish between them. So, the map should be supplemented with the indication of the sensor number.	scenario
Interruptions in data collection	Not known	No interruptions were observed
Accuracy of sensor location	The location identified on the map is very precise.	The accuracy of the sensor location was very precise.
GPS signal availability	The GPS signal worked fine, also when the sensor was used while in motion.	The device picked up the GPS signal on the NO2 dashboard
Observation of error data or not correct data collected	The measured temperature often appeared to be about 3 to 5 degrees higher than the actual temperature. When the sensor was used on the bike, it measured a temperature of about 20/21 degrees, although the outside temperature felt closer to 16 degrees. Despite data being collected near a cemetery with sufficient greenspace, the parameter PM has at certain times shown inconsistent values (spikes in measurements) while in motion, even within a small radius.	See comment in the Indoor scenario
Changes in data measurements due to speed of movement	The frequency in data measurement has increased in motion as it was announced in the instruction manual. No other changes were observed, except for the above-mentioned inconsistent data measurements. It is unclear whether this was caused by the movement speed.	N/A

Changes in data measurements due to vibrations caused by the movement	The sensitivity of the sensor seems to be very high, because even the smallest shifts or touches of the sensor lead to an increase in the measuring frequency.	N/A
Changes in data measurements due to weather conditions	When the sensor was placed inside a flat,the colour of the LED changed rapidly after opening a window from green to orange.	The sensor recorded data through different weather conditions such as changing humidity levels, temperature and wind speed. Since the device was active overnight, the expected change in humidity and temperature levels was displayed on the dashboard. NO2 values remained stable despite varying weather conditions. On the other hand, PM values fluctuated between 5 and 9 µg/m3 between late afternoon and early morning. This fluctuation might have been caused by changing wind speed or rising humidity.
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	No changes regarding activities were observed, other than the above-mentioned inconsistent data measurements	As noted above, no changes in data measurement were recorded except for fluctuations in PM values. While high noise levels from a nearby construction site could have been the cause, fluctuations were recorded after the end of the workday so it is more likely that changes in PM values were affected by changing weather conditions over night.
Duration of power/battery	The battery lasted for several hours, as expected.	See comment in the Indoor scenario.
Usability	The mounting device is unsuitable for use on bikes as well as for backpacks to be used on the train. It's not very user-friendly.	The device is quite bulky and as such needs to be attached to a post/outside of the window by a strong tape or other similar means. This may make the use of the device upractical, especially if it's going to be attached to a post.
Issues with connecting devices to backpacks, bikes, etc.	The diameter of the handlebar mount of the bike is too small. It measures 25.4 mm and therefore only fits some/a few bikes. Common	N/A

	racing bikes or tracking bikes usually have a diameter of 31.8 mm. The sensor needs either an adapter to adjust it to different sizes or a completely different mounting option for the bicycle handlebars (or other biking parts).	
Ease of interpretation of data	The data shown on the map are easy to read and understand because different colours are used. Exporting data as CSV files and converting them to a readable format may be too difficult a task for people without a scientific background, hindering the interpretation of data. The access and graphical elaboration of the data from the Telraam sensor was very descriptive and helpful. Something similar could be used for the SODAQ Air sensor as well. Furthermore, the website/results could use some guided information about the meaning of values.	See comment in the Indoor scenario
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	The mount with the magnet that is attached to the device comes off relatively easily and could fall off while cycling. A device that attaches more firmly to the unit or an additional breakaway cord may be needed.	The sensor was duct taped to the building's facade just outside the window and was relatively stable. The stability depends on the strength of the tape and may be compromised by strong winds or other outdoor disturbances, making this a less than ideal setup for mounting the sensor and taking outdoor measurements.

Table 11 Berlin Observations from Public Transport (vehicle) Scenario testing (not applicable to Telraam and SODAQ NO2)

Tested Functionalities/parameters	SODAQ Air
Smooth operation of device	The device worked as described in the manual and in the aforementioned scenarios.
Availability of data	The device was tested in two types of public transport - the metro and the bus. The data was available during the whole

	ride on the bus and shows up on the knowyourair.net map.
Interruptions in data collection	When the device was used in the metro, no data seems to have been collected. The data didn't show up on the map, presumably due to lack of GPS signal availability.
Accuracy of sensor location	The location identified on the map is very precise.
GPS signal availability	As stated above, no GPS signal was available during the metro ride.
Observation of error data or not correct data collected	No noticeable errors
Changes in data measurements due to speed of movement	No noticeable changes
Changes in data measurements due to vibrations caused by the movement	No noticeable changes
Changes in data measurements due to weather conditions	N/A
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	No noticeable changes
Duration of power/battery	The battery lasted for several hours, as expected.
Usability	The usability of the device is as easy as it gets. It is easy to transport and carry the device around, start measuring and use the knowyourair.net platform.
Issues with connecting devices to backpacks, bikes, etc.	Attaching the device to the backpack wasn't an issue. However, the mount ring is of a fixed size so attaching the device on a variety of bags/backpacks might not be possible.
Ease of interpretation of data	The data was easily interpretable, especially in the bus scenario. However, the device didn't measure any data when it was used in the metro, which was evident in the clear gaps between metro stations. See previous scenarios for comments on the interpretation of measurements and values.
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	The sensor was stable when carried around.

Table 12 Berlin Observations from Leisure Scenario testing (not applicable to Telraam and SODAQ NO2)

Tested Functionalities/parameters	SODAQ Air
Smooth operation of device	The device worked as described in the manual and in the aforementioned scenarios.
Availability of data	The device was used in public parks as well as in a lively neighbourhood. All data was recorded and is showing up on the knowyourair.net platform.
Interruptions in data collection	No interruptions seem to have occurred.
Accuracy of sensor location	The location identified on the map is very precise.
GPS signal availability	The GPS signal worked fine, also when the sensor was used while in motion.
Observation of error data or not correct data collected	No noticeable errors
Changes in data measurements due to speed of movement	No noticeable changes
Changes in data measurements due to vibrations caused by the movement	Some variation in the PM data was noticed during a walk around a neighbourhood.
Changes in data measurements due to weather conditions	No noticeable changes
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	No changes were observed, other than the above-mentioned variation in PM data, which might have been caused by different noise levels in different areas of the neighbourhood.
Duration of power/battery	The battery lasted for several hours, as expected.
Usability	See comment from Public transit scenario
Issues with connecting devices to backpacks, bikes, etc.	See comment from Public transit scenario
Ease of interpretation of data	See previous scenarios for comments on the interpretation of measurements and values.
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	The sensor was stable when carried around.

4.2.2. Feedback on software tools

DEVA

Table 13 Berlin Feedback on DEVA

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	DEVA offers a multitude of visualisation possibilities based on the users' backgrounds (expert, child, etc.), which has the potential to tap into different user needs and reach a broad user base. In order to differentiate itself even further from competitors (e.g. AIRE and AiR), additional features should be implemented, such as gamification, best route mode, previous measurements and UI customizability. This way, DEVA has the potential to become a useful tool for a variety of users. This, however, depends on DEVA's development process and the ability to integrate the different features into the app at a future point in the project.
Usability	At present, the exact usability of DEVA cannot be determined, as it is not yet available for smartphones and tablets. Nonetheless, a key component influencing usability is the location and movement of the user. Specifically, the usability and usefulness of the app will in large part depend on how relevant data is presented to the user. What data is or is not relevant may, for instance, be determined by the users themselves (e.g. selecting particles of interest). But more critically, relevant data is data that is displayed in the user's immediate vicinity. The spatiotemporal component is crucial because users a) change their location and move away from a measurement source, and b) data that is "left behind" after the user moves to a different location should not necessarily be displayed for a long time period. The usability, then, depends on how far-away data is defined, whether it should be visualised and how long certain data points remain on the screen after they are no longer relevant to the user's immediate environment. One option may include allowing the users to determine their immediate vicinity themselves and then display data that is within a certain radius.

User-friendliness	Cannot be determined, app is not yet available for smartphones/tablets
Attractiveness and UI (colours, screens etc)	The colours of the login screen and the menu elements mainly adhere to **COMPAIR**'s standard green and blue colours, which adds to its recognisability. However, because DEVA is still in its early development stage, many of the boxes' (e.g. login, user profile, etc.) colours and shapes are still basic and could be enhanced with a more appealing UI design. The notification bar currently has too many symbols that clog the screen. Some symbols, such as the notification audio button, can be moved to the settings menu.
Future use by low SES groups	DEVA tailors its functionalities and information to users based on their experience and background knowledge. This makes the app attractive to a variety of users and specifically enables groups with less understanding of air pollution to actively engage with the data, thereby fostering their engagement. A colour scheme for users with colour blindness should be added. This setting could be activated from the UI Themes section. In addition, the UI customizability, which may be implemented at a later time, should include an option to change the text size for people with impaired vision.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	Since the app is still in its early development phase, the visualisation of particles, temperature and other data points is still quite rudimentary. The selection of different visualisation elements such as balls, pins or squares from the AR Theme menu adds to interesting visualisation options, although a few more "obvious" ones (such as clouds for disseminated air pollution) would enhance the experience. While different colours represent different particles, it may be more appropriate to have different shapes represent different particles. Colours may be used to display different kinds of information, such as values (e.g. green for low, red for high) or calibration status, a great feature that has already been implemented. The appearance of labels and data information above each element can be toggled on and off, although it remains to be seen if this will clog the screen with too much text. Other than that, clicking on each element should display a variety of information (depending on user level specified), such as graphs, simple numbers or more in-depth explanations.
Could the tools reach wide recruitment targets?	Without additional information that citizens can draw on, DEVA, in its current state, is not sufficiently optimal to inform citizens

	about the prevalence and significance of air quality. By itself, DEVA may not be able to persuade users to join the project as citizen scientists. Regardless of its state, DEVA was always going to serve as a complement to other recruitment, knowledge building and awareness raising methods, such as sensor trainings. Nonetheless, more work is needed to address user needs in order to put the app over the top and raise consciousness about the importance of air quality measurements. This mainly means developing features that will give it an edge compared to its competitors, as described in "Future use of the tools by non-consortium members".
Do they refer to all demographic balances of citizens?	See "Future use by low SES groups".
Feature to facilitate policy measures	Not applicable, DEVA serves mainly as an awareness raising tool among citizens.
Do they have the potential to increase awareness for behavioural change?	See "Could the tools reach wide recruitment targets?"

Carbon Footprint Dashboard

Table 14 Berlin Feedback on the Carbon Footprint Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	In general, the website would profit from a broader explanation and introduction of carbon footprint, maybe even its history (created by British Petroleum) and therefore, the limits of the individual impact when it comes to carbon footprint. In addition, explaining the Scenario Simulation Dashboard in more detail would enhance the understanding among the users. A broader introduction can guarantee that all users start with a common ground of definitions.
Usability	The dashboard explains the tool of the Carbon Footprint Calculator well. The explanation of the second tool, the Scenario Simulation Dashboard, might overwhelm citizens who aren´t yet familiar with the concepts of carbon emissions calculation or scenario analysis. It would also be helpful to explain the differences between the scenarios. Furthermore, there is no legend that explains what the value on the y-axis represents as well as the clear difference between the indicators *current* and *target*. Also, the aim of this simulator should be highlighted better.
User-friendliness	See box above.
Attractiveness and UI (colours,	The Carbon Footprint Calculator could use more colours. The site

screens etc)	with the results is clearly arranged and it's great that there are different coloured graphs. The Scenario Simulation Dashboard could use more colours, explanations and icons. In general, the use of icons (for both Dashboards) and smileys would improve the understanding. For example: Icons/smileys to show in which part the individual impact is already good and in which there is space for improvement.
Future use by low SES groups	The whole website would need to be translated into the four **COMPAIR** languages to ensure a wide and low-threshold access to the two simulators. The use of icons, colours and an easily written (non-scientific) language site are needed.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	There are no explanations on air quality in those two calculators.
Could the tools reach wide recruitment targets?	Currently, the website, including its explanations of the simulators, assumes a high level of basic/common understanding about terms such as carbon emissions. Those short explanations as well as the English language reduce the range of recruitment targets and might make it very difficult to reach low SES groups.
Do they refer to all demographic balances of citizens?	An option *other* for gender should be added. Since they have an impact on the carbon footprint it would also be good to add the options for ethnical background, educational background and income. These categories should however be considered in light of GDPR.
Feature to facilitate policy measures	The Scenario Simulation Dashboard is mainly geared towards citizens, although policy actors can obtain some valuable insights from it. The default actions in the 'government' tab on the scenarios page do provide some good first examples of how certain measures can lower CO2 emission and reach predefined emission targets. However, the site heavily relies on user input, particularly through the editing page where further actions and scenarios can be defined. It is unlikely that policy makers will take the time to set new actions, so adding more real-world scenarios and actions would lend itself to a greater facilitation of relevant policy measures among policy makers.
Do they have the potential to increase awareness for behavioural change?	The first simulator definitely has the potential to increase awareness for behavioural change. It could be helpful to add that usually the carbon footprint calculation consists of even a wider range of questions and aspects, such as nutrition and meat consumption (and an explanation why they are left out in this calculator). On the other hand, individual impact is still limited because of the amount of non-changeable factors such as infrastructure.

Policy Monitoring Dashboard

Table 15 Berlin Feedback on the Policy Monitoring Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	Inspired by the world's largest air pollution data platform – sensor.community, the PMD's implementation of a proven data visualisation design undoubtedly offers a familiar feel to experienced and new users alike, making it an accessible tool for a broad swath of citizens. The current version of the PM-dashboard has some defects and bugs that were forwarded to the technical team via a Google Docs form. Once the bugs are fixed, the dashboard has the potential to take advantage of different user needs and reach a wide user base. How frequently the tool will be used depends, of course, on the development process of the dashboard and the ability to resolve bugs and integrate further features in a future phase of the project.
Usability	Undoubtedly, the usability of the dashboard will largely depend on how to solve existing problems and develop it further. One of the important features that is still not fully functional and that can have a great impact on its usability, especially for raising the awareness of citizens and the use by decision makers, is the grouping function and the possibility of comparing pollution parameters in different places.
User-friendliness	The dashboard has a simple and user-friendly design. Although there is a bit of complexity in some functions such as creating groups and comparing the sensors, which can be improved so that users can use this function more easily, the navigation through the platform is smooth and clear.
Attractiveness and UI (colours, screens etc)	We find the design and colours used in the dashboard to be appropriate and suitable, adhering to the project logo. There are, however, some shortcomings that were mentioned in the technical form. For example, a pale blue colour is selected in the PM-dashboard for the minimum values of the parameter PM2.5, which makes the hexagons with a pale blue colour not clearly visible on the screen. This will be a major problem especially for users with impaired vision. Perhaps it would be much better to use a similar and distinguishable colour scale for all parameters. The colours could also be used in such a way as to display different kinds of information, such as values (e.g. green for low, red for high).
Future use by low SES groups	The dashboard is completely understandable for people with

	little knowledge about air pollution, although having a definition of PM and other parameters on the screen can provide a better understanding for this group. As mentioned, some of the colours used (especially the pale blue colour for the minimum values of the parameter PM2.5) can cause problems for people both with and without vision problems alike.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	The dashboard provides an adequate insight into air quality for the available parameters. Resolving the above-mentioned bugs regarding the comparison of parameters in different areas could greatly increase the attractiveness of the dashboard. Colours could be used in such a way as to display different kinds of information, such as values (e.g. green for low, red for high). The unit of relative humidity in the graphs and labels is g/m3, which is incorrect and should be changed accordingly. In the legend on the left-hand side of the dashboard, there is a smiley icon for the highest value of PM and a sad icon for the lowest value! This should be the opposite. The icon which is for sharing the PMD page with others is not active. It would be great to open the project website when the user clicks on the project icon on the top left side of the PMD page.
Could the tools reach wide recruitment targets?	The dashboard looks attractive and user-friendly, and after the technical improvements, it seems capable of achieving widespread acceptance and reaching recruitment targets.
Do they refer to all demographic balances of citizens?	See other feedback, especially the feedback on "Future use by low SES groups".
Feature to facilitate policy measures	It seems that after the bugs and defects are fixed and the dashboard is completed, it will not only serve as a tool for raising awareness among citizens but also for facilitating administrative actions and policy measures. The wide coverage of different areas makes it a versatile tool for policy-makers responsible for their local districts.
Do they have the potential to increase awareness for behavioural change?	See feedbacks "Feature to facilitate policy measures" and "Could the tools reach wide recruitment targets?"

4.3. Sofia & Plovdiv

The testing of the SODAQ and Telraam sensors in Sofia and Plovdiv was performed based on the agreed upon scenarios by the pilot teams and described in Section 3 above.

Telraam sensor in Sofia was tested at the SDA office, located in the city-centre where there is a lot of traffic, it was also brought to one of the SDA's employees home to try connectivity and usability there. Information on the performance and usability of the sensor is listed below in the Table. It is noted as a very positive feature that within the installation process the user can see the position of the camera and can take measures to locate and align it in the best position, based on the availability of the windows at their home or office. A minor issue for Sofia and Bulgaria as a whole will be finding the right volunteers living at lower floors of buildings (as most people in both Sofia and Plovdiv are living in big blocks of flats with more than 4 floors).

Three SODAQ Air and three SODAQ NO2 sensors were delivered in Sofia for the closed testing round. The manuals for operation and installation of devices were provided to the team to ensure a smooth process of installation and set up. The team started two of the SODAQ Air sensors that are tested in multiple scenarios - while walking to work, at the office, at the public transport (metro and bus), at a public event and while doing some leisure activities. The SODAQ Air sensors indicated through LEDs installed on them that they are working. In the beginning when the team started using the sensors for 3 days no data was visible at the KnowYourAir.net platform. The data started coming on the fourth day of the tests. Once data became available the team started extensively to test in the different scenarios that were discussed. One SODAQ NO2 sensor was installed at the office building of SDA. A link to the platform where measurements should become available was provided with login details. The team started the sensor as advised in the manual that was provided, the sensor was charged for a period of 24 hours. To the present moment no data is currently seen at the dashboard. The sensor is installed outside the office building of SDA facing a street with pavement and relatively heavy traffic. After performing discussions with the SODAQ team, it became clear that the SIM card of the sensor is not operating in Bulgaria and thus the sensor is unable to send data to the dashboard. Actions are planned in order to change the SIM card and continue the testing of the device.

The Telraam sensor in Plovdiv was tested at 3 different places - on two different floors at the same building positions in the same building and in another building. The locations were: at the office of the EAP on the second floor of the building and in another office on the first floor of the same building. Also in a shop at a different address.

Two SODAQ Air and two SODAQ NO2 sensors were delivered in Plovdiv for the closed testing round. Two SODAQ NO2 sensors were installed at the office of EAP. The sensors were charged for a period of 24 hours. There is no indication if the devices work or not. The sensors were tested under different scenarios - walking, in public transport, on the top of a car, and driving. A link to register on a platform to monitor measurement results was provided. To the present moment, no data is currently seen on the dashboard.

4.3.1. Description of actions for field testing on sensors

SODAQ installation, use, bugs

Three SODAQ Air and three SODAQ NO2 were delivered in Sofia. Two Air sensors were used during the closed testing round and one NO2 sensor. The manuals provided by SODAQ provided information on charging and operation of both sensors. Manuals are easy to understand and follow the instructions. The main issues that were experienced with the installation were related to the unavailability of data in the first days from the SODAQ Air sensors. Also, it turned out that when used as static sensors SODAQ Air data is not visible on the platform. The team informed the SODAQ team in order to find a solution to this issue. On the fourth day of tests data started to appear on the platform and became visible for the pilot team. As regards the NO2 sensor to the present moment no data is available to report. After discussions and investigation of the issue causing the problem by pilot teams and SODAQ team it turned out that the SIM card that is sending the data to the dashboard is not supported in Bulgaria, currently the process for the ordering the right SIM card has started and tests will continue after it is installed in the sensor. Both sensors need to be charged daily which needs to be well communicated to citizens that will volunteer to use the sensors during the open and public rounds. Sofia team plans to translate both manuals in Bulgarian in order to make the setup process easier for locals. SODAQ NO2 current design is not very attractive to car owners who would be willing to attach it to their cars while moving around the city as the bolts that are on the side of the magnet look quite rough and users will be afraid some scratches may occur.

Two SODAQ Air and two SODAQ NO2 were delivered and used in static and active mode during the closed testing round in Plovdiv.

In static mode, the SODAQ Air devices must be located in such a place that the GPS coordinates can be determined. If the coordinates cannot be detected, then the measurement data cannot be reported either. In the active mode devices were used under different scenarios- during a walk, in the car, in public transport, and in leisure time. There is no indication of the battery level and after its discharge the device stops measuring. If the device is used in static and dynamic mode, it cannot be determined for what period of time measurements can be made before the battery discharges and the device stops working.

Two SODAQ NO2 sensors were installed at the office of EAP. The sensors were charged for a period of 24 hours. There is no indication if the devices work or not. A link to register on a platform to monitor measurement results was provided. To the present moment, no data is currently seen on the dashboard. The sensors were tested under different scenarios - walking, in public transport, on the top of a car, and driving. No data available to report at this time. The SIM card used to transmit data from the sensor is not compatible with Bulgarian conditions. Inquiries were made to mobile operators and new SIM cards were ordered. Once the EAP team receives the new cards, they will continue the measurements with the sensor.

The sensors need to be charged daily, and the SODAQ Air possibly twice daily if measured throughout the day. Volunteers should be very well instructed, but the need to recharge the sensors frequently may discourage people from participating.

<u>Telraam installation, use, bugs</u>

Sofia started the installation process of the Telraam sensor at the office of the team working on the **COMPAIR** project. Registration process on the Telraam website was very smooth and easy. However, during the first try, there was an issue with the Telraam website and the team was not able to zoom in on the map to locate the street segment. This first try was done through Chrome browser on the Windows PC. As it did not work out with Chrome, the team tried to start the process with Microsoft Edge, everything worked out fine there. Afterwards, once the street segment was selected and the device was attached to the window, an issue appeared due to the inability of the device to connect to the WiFi network. This network seems to be not very stable with usual interruptions, however the team tried a few other options - make a hot spot of the computer to connect, try another network but none of them worked out. The issue that was experienced with Chrome browser was resolved during the second try, so the team assumes it was a temporary problem. Currently, login and installation activities work out fine in all tested browsers - Chrome, Microsoft Edge and Safari.

Instructions on the Telraam webpage and tips on the positioning and installation of the sensor are very accurate and helpful. The main issue here is ensuring electricity connection close to the window that will be used for sensor installation, however we do not consider this to be a blocker for volunteers to use the sensor, also in the new version of the sensor that will be used for the Open and Public rounds, the new Telraam device will be used which will not need constant power connectivity.

As a second option, one of the team members brought the device at their home to complete the installation process. There a Mac computer was used with Safari browser. It worked out very smoothly but again some issues were experienced due to inability of the sensor to connect to the wi-fi network. The signal at this home seems to be quite stable one. Nevertheless, the installation process was reported as completed on the Telraam webpage.

Generally, working with the device is easy and enjoyable, the Sofia team will put efforts in providing advice and support to citizens willing to install Telraam devices in order to ensure that if similar issues are experienced by them, they will be prepared to solve them.

The EAP office is situated in a building on one of the main boulevards in Plovdiv. The boulevard starts with a roundabout and the speed is not very high. The boulevard has two lanes of traffic in each direction. A bike lane is between routes (between the trees) and wide pedestrian sidewalks on both sides of the road.

During the first counting period, the sensor was positioned on the second floor of the building. In this position (because of the angle) it couldn’t count all the pedestrians on the sidewalk near the building. There is a bicycle lane between the two routes and we supposed that the sensor counted cyclists, motorcyclists, scooter riders, and mothers with baby carriages as Two-wheelers.

During the second counting period, we changed the sensor position on the first floor of the building. The number of pedestrians was higher, but the new location was probably not so good for counting the number of trucks and buses. The results and recommendation from the Telraam team were that the first position of the sensor is better than the second one.

For the third counting period, the sensor was installed at a different address - a small street between two universities - the Plovdiv university and Technical University. The street connects a main boulevard with other high-traffic streets.

It is possible to change the counting from one point to another with the same sensor. Then you need to change the sensor position on a dashboard manually. It’s very easy, just to find on a map the new street segment and select the proper street side.

The sensor counts only during the daylight hours. As the day gets shorter, so do the hours during which the sensor reads traffic. This can be seen in the Figures below.

This leads to data loss. During the night there is still traffic on the streets, but it couldn't be counted.

The installation process is easy. But some of the volunteers are afraid to install the sensor by themselves and prefer this to be done from somebody else with experience.

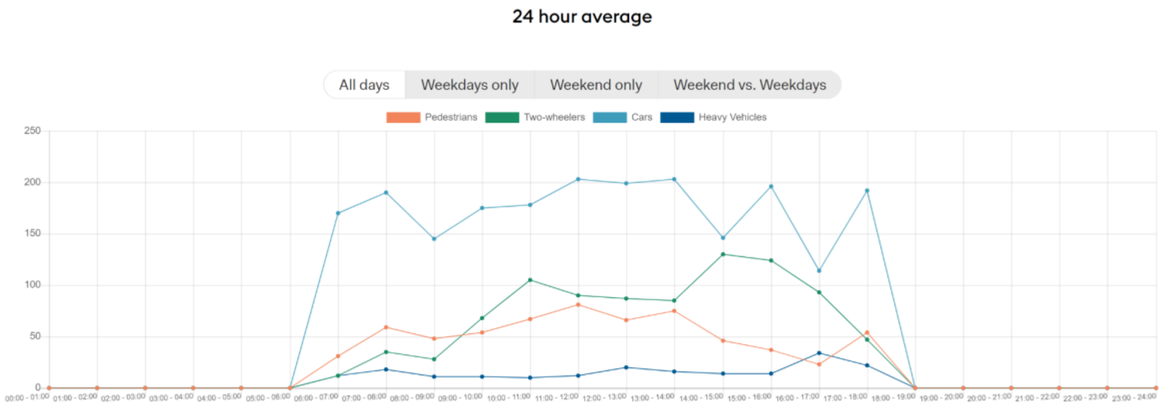


Table 16 Sofia & Plovdiv Observations from Indoor Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	The device works out fine, the main problem is related to the connectivity if the wi-fi connection is not stable.	Installation process is quick and easy. The device has LED signalling that indicates battery life and operation. Device is very light in terms of weight and is equipped with a mounting component in order to be easily attached to bikes, suitcases, backpacks, etc.	Installation process is very easy and straightforward. Only needed to charge the device with the provided cable in the box.
Availability of data	The sensor counts only during the light part of the day.	Some issues were experienced until data became available to the knowyourair.net. It became visible only after the first day of operation in Plovdiv and after the third day of operation in Sofia.	Data still is unavailable for Sofia and Plovdiv on the ThingsBoard platform.
Interruptions in data collection	If WiFi signal drops or there is no electricity the sensor stops operating.	Interruptions in data collection were experienced during the first 3 days of testing, as even though the sensors were indicating that they are working through the LED light, no data appeared on the platform.	Cannot report on interruptions as no data is currently available.
Accuracy of sensor location	Location is very easy to set up through the Telraam portal and can be manually selected by the user to be most accurate.	Location of the sensor is quite accurate, even when moving.	Cannot report as no location is shown at the dashboard.
GPS signal availability	N/A	Yes.	Cannot report at present moment.
Observation of error	During the night is not	No errors were	No data currently

data or not correct data collected	possible to collect data	observed during the tests. However, it seems that when used indoors and without moving around no data is displayed on the dashboard.	available to report on any errors.
Changes in data measurements due to speed of movement	N/A	No significant changes were observed.	Cannot report at present moment.
Changes in data measurements due to vibrations caused by the movement	N/A	No changes were observed.	Cannot report at present moment.
Changes in data measurements due to weather conditions	N/A	No changes were observed.	Cannot report at the current stage.
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	No severe changes were experienced. At one moment during the tests, the sensor was located very close to a smoking person and the LED signalled in red for a moment.	Cannot report at the current stage.
Duration of power/battery	If there are no interruptions of electricity the device works continuously without problems.	Even though in the manual it is listed that the sensor battery lasts around 5 hours, during tests it lasted quite longer, even when used in dynamic conditions - measurements were seen for 12 consecutive hours without having to charge the sensor.	In the manual it is indicated that the device needs to be charged every day.
Usability	Easy to use and set up, installation process is well navigated by the Telraam website, steps are easy to follow.	Easy to use and set up. User manual is very straightforward and understandable.	User manual is very concise. No issues related to the usage, apart from the missing data.
Issues with connecting devices to backpacks,	N/A	Very easy and straightforward,	The device is big but not too heavy to be

bikes, etc.		however one needs to be equipped with a screwdriver. Putting the sensor on a bike, backpack, etc. is the same as installing a bike bell.	installed on a bike or car. However, the magnet and the bolts that are attached to it make it not very attractive to attach to cars or other vehicles as some scratches might occur.
Ease of interpretation of data	Data is easy to interpret as it is related to the number of vehicles/ pedestrians, no issues were found there.	Data is relatively easy to interpret as it shows minimum, maximum and average measurements.	Cannot report on that at present moment.
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	The device is meant to be installed on windows (in the indoor side of the window). It is easy to attach it to the window with a duck tape and also the image from the camera position is depicted in the dashboard so the user aligns it in the best possible way.	The sensor is quite stable, no issues were found related to its installation.	Sensor seems stable to attach.

Table 17 Sofia & Plovdiv Observations from Outdoor Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	N/A	The Setup and installation process is very smooth and easy. LED light indicates that the sensor is working.	The setup process was quick, the only advice was to charge for more than 24 hours before using it for the first time.
Availability of data	N/A	Some issues were experienced till data became available to the knowyourair.net. It became visible only after the third day of	No data is available at present.

		operation.	
Interruptions in data collection	N/A	Only before the sensor started appearing at the knowyourair.net platform there were issues to see the data. Once data became available it could be seen while moving.	Currently cannot report on that.
Accuracy of sensor location	N/A	Very accurate during movement, exact streets and location were clearly seen.	Cannot report on that.
GPS signal availability	N/A	Yes	Cannot report on that, no location is shown at the ThingsBoard platform.
Observation of error data or not correct data collected	N/A	It measures a higher temperature than the actual temperature.	Cannot report on that.
Changes in data measurements due to speed of movement	N/A	Not seen any severe changes. Very clearly it indicates an increase of PM levels when crossing big streets with heavy traffic.	Cannot report on that.
Changes in data measurements due to vibrations caused by the movement	N/A	No	Cannot report on that.
Changes in data measurements due to weather conditions	N/A	No	Cannot report on that.
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	Only while someone that was located very close to the sensor smoked, the LED light indicated in red for a moment.	Cannot report on that.
Duration of power/battery	N/A	Very stable battery life, can be used for more than 5 hours on the move without the need to be recharged.	In the manual it is suggested to charge the device every day, which is easy to follow.

Usability	N/A	Easy to use and bring along during outdoor activities.	No issues in terms of usability, except the missing data.
Issues with connecting devices to backpacks, bikes, etc.	N/A	No issues, only need to be equipped with a screwdriver.	The bolts on the side of the magnet make the sensor not very attractive to car owners willing to attach it to their cars.
Ease of interpretation of data	N/A	Easy to interpret, very clear when clicking on a rectangle on the platform to see the measurements for this particular place.	Cannot report on that.
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	N/A	Sensor is acting quite stable.	Seems relatively stable.

Table 18 Sofia & Plovdiv Observations from Public Transport (vehicle) Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	N/A	No issues found while using the sensor at the public transport, even while using the metro and being underground. No problems were found when using the sensor while driving.	Not tested
Availability of data	N/A	Data was visible during the usage at the public transport. Data was visible even in a fast-driving car.	Not tested
Interruptions in data collection	N/A	No interruptions were observed.	Not tested
Accuracy of sensor	N/A	Accurate location was	Not tested

location		presented even while underground.	
GPS signal availability	N/A	Yes, a stable one.	Not tested
Observation of error data or not correct data collected	N/A	No observation of errors.	Not tested
Changes in data measurements due to speed of movement	N/A	No.	Not tested
Changes in data measurements due to vibrations caused by the movement	N/A	No.	Not tested
Changes in data measurements due to weather conditions	N/A	No.	Not tested
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	No.	Not tested
Duration of power/battery	N/A	Stable battery life, even longer than the reported one of 5 consecutive hours.	Not tested
Usability	N/A	Easy to use.	Not tested
Issues with connecting devices to backpacks, bikes, etc.	N/A	No issues were experienced when connecting the device to backpack or a bag.	Not tested
Ease of interpretation of data	N/A	Easy to interpret, the .csv file shows location and concentrations.	Not tested
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	N/A	Stable when installed on bags and backpacks.	Not tested

Table 19 Sofia & Plovdiv Observations from Leisure Scenario testing

Tested Functionalities/parameters	Telraam	SODAQ Air	SODAQ NO2
Smooth operation of device	N/A	Device operates quite well.	Not tested
Availability of data	N/A	Yes, data was seen on the dashboard.	Not tested
Interruptions in data collection	N/A	No interruptions were experienced.	Not tested
Accuracy of sensor location	N/A	Very accurate location.	Not tested
GPS signal availability	N/A	Yes.	Not tested
Observation of error data or not correct data collected	N/A	No errors were observed.	Not tested
Changes in data measurements due to speed of movement	N/A	No observations on changes.	Not tested
Changes in data measurements due to vibrations caused by the movement	N/A	No observations that movements caused any changes in measurements.	Not tested
Changes in data measurements due to weather conditions	N/A	No changes were experienced due to weather conditions.	Not tested
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	N/A	No changes were observed, even when loud music was played at a local dining place.	Not tested
Duration of power/battery	N/A	Battery lasts even longer than reported.	Not tested
Usability	N/A	Easy to use and bring along due to small size and lightweight. Sometimes the light attracts the attention of the passengers.	Not tested
Issues with connecting devices to backpacks, bikes, etc.	N/A	No issues.	Not tested
Ease of interpretation of data	N/A	No issues interpreting data, very straightforward .csv	Not tested

Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	N/A	Stable when attached to clothes (jacket).	Not tested

4.3.2. Feedback on software tools

DEVA

Table 20 Sofia & Plovdiv Feedback on DEVA

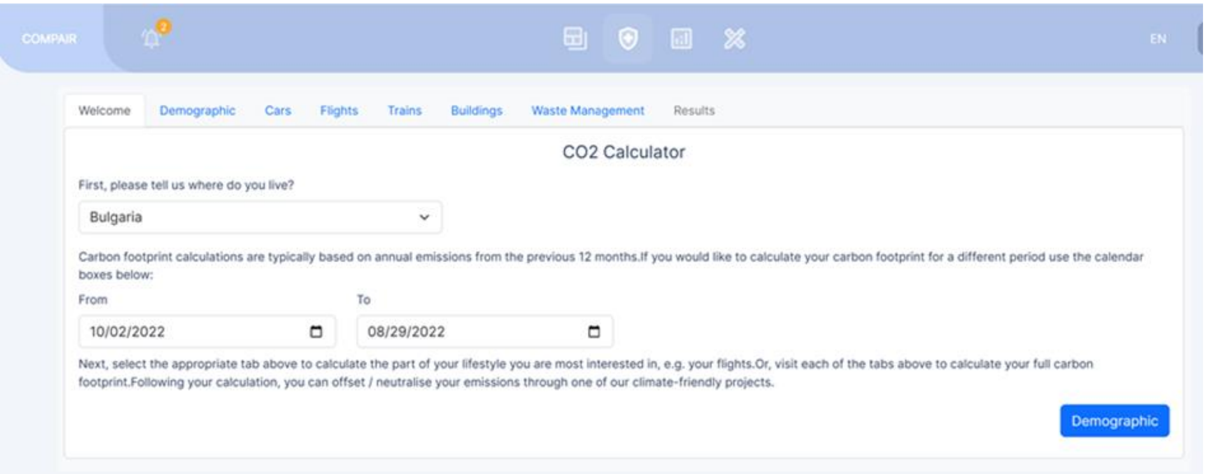
Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	DEVA app has the potential to be used by non-consortium members in the future, as it will provide more understandable information on air quality around you. However, it depends on the gamification aspect that will be developed as part of the DEVA app and also the data availability to visualise while using the app.
Usability	At the present stage of the development of the DEVA app its usability is difficult to determine, as it is in an early development stage and real feel of the app's performance is not available.
User-friendliness	Cannot be determined, app is not yet available for smartphones/tablets
Attractiveness and UI (colours, screens etc)	The colours that are used and the screens that were presented to the pilot teams are using similar colours of the other **COMPAIR** software tools which brings recognition and the feeling that all these software products are under one umbrella. Still, as the DEVA app is at its early development stage the designs will be further discussed by project partners to choose the most appealing ones.
Future use by low SES groups	This aspect should be further investigated by the pilot leads in both Sofia and Plovdiv. Initially, the DEVA app was perceived as a very good tool to engage lower SES groups as it will provide information in a more user-friendly and understandable way. However, taking into consideration some requirements (e.g. specific new model of smartphone/ tablet to support AR) there are some doubts. Nevertheless, DEVA app will be also promoted to school students as part of the pilot actions that will be implemented where the Sofia team do not expect any issues to arise. The other aspect is the requirements of the app. If it can work only with the latest version of a smartphone probably the SES groups couldn't use it.

Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	Current visualisations that were shown to pilot teams look good. More discussions are needed on how those will be presented once the app is available for smartphones/tablets and can be tested by pilot teams. Of course, considering the availability of sensors and thus data to be visualised on the DEVA app, it must be taken into account that some information for users regarding where the exact locations the app can be run at should be provided.
Could the tools reach wide recruitment targets?	This depends on air quality data availability, number of sensors that will be visualised in the app and also the communication used to promote the tool. Moreover, the gamification element that is planned to be added in the future will act as the main driver for recruitment of users. DEVA app is rather seen as a communication tool that will be used to explain the air quality issues and **COMPAIR** project objectives in a more user-friendly and easy to understand way, especially to those that primarily do not really care about environmental issues. DEVA app will be also used to make the topic about air quality more appealing to children in elementary school.
Do they refer to all demographic balances of citizens?	It really depends, as the DEVA app needs specific phone/tablet specification in order to be run on those devices it may somehow limit the number of potential users, especially among lower SES groups. However, considering that the app also has the potential to provide features that will address colour blinded or visually impaired users is a great advantage.
Feature to facilitate policy measures	N/A - the tool will be mainly used for awareness raising and gamification of air-quality data.
Do they have the potential to increase awareness for behavioural change?	Difficult to answer this question at the present stage as the app is in very early development. Its attractiveness will highly depend on the available data it can show while being used at a certain location.

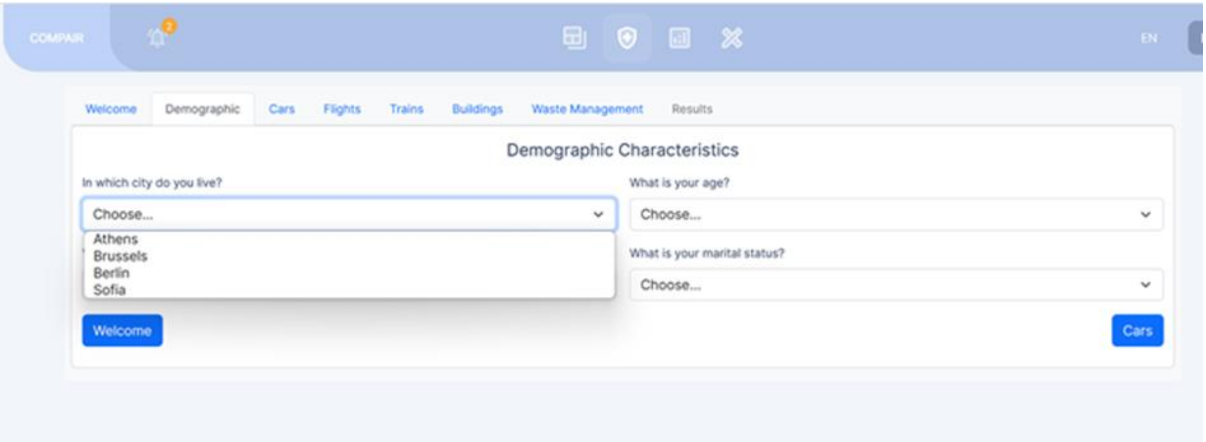
Carbon Footprint Dashboard

General remarks: Main page looks good and simple for navigation. The message at the top also provides a clear statement on the goal that the CO2 dashboard aims to support. The link works on Chrome, Safari and Microsoft Edge. Page loads quickly on all the three browsers. On mobile phones the view needs a bit of optimisation (resizing to better fit smartphone screen) but is still quite well visible and digestible.

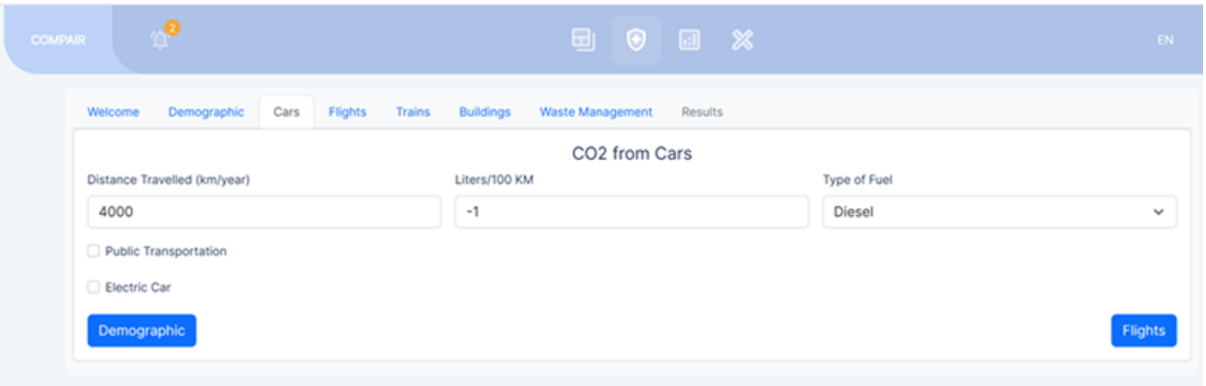
In the Welcome tab the user can select the period for calculation of the CO2 footprint. The calculator allows you to add data in the field “To” before adding data in the field “From” :



In Bulgaria, there are two pilots - Sofia and Plovdiv. The City of Plovdiv was initially missing from the selection menu. However, after reporting this to the development team, the City of Plovdiv was added and the issue was resolved.

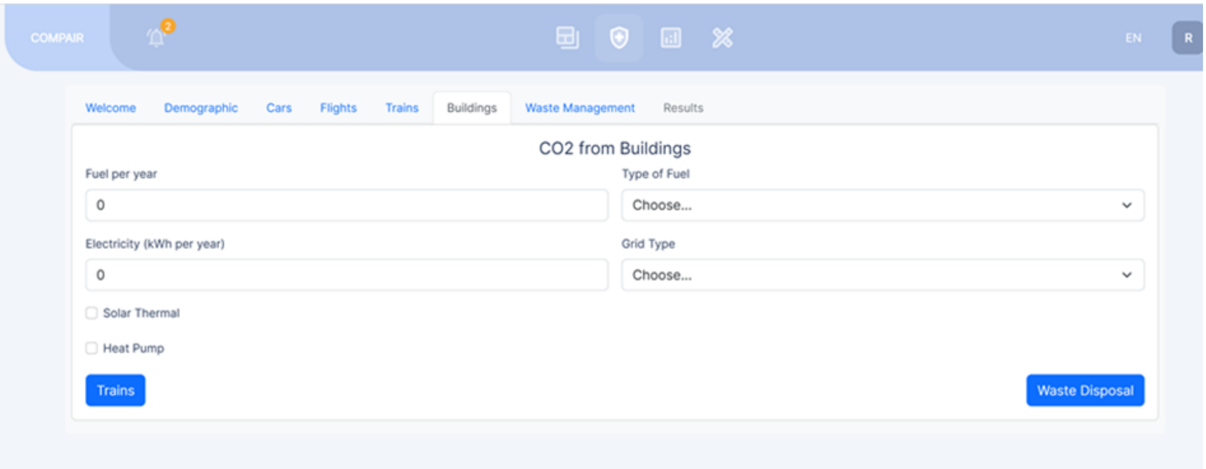


For the fuel consumption of the cars the calculator allow to be added negative values:



Sector Buildings

There is no dimension for fuel consumption per year.



All the suggested fuels have a different dimension:

- coal – possible dimensions kg or tons;
- biomass – there are several types of biomass: pellets, chips, wood – and the possible dimensions are kg, tons and cubic meters;

It's not clear if the diesel type of fuel is the same as oil for heating or not. However, all the reported issues that were mentioned above by the Sofia and Plovdiv teams were resolved by the development team before this deliverable was submitted.

Table 21 Sofia & Plovdiv Feedback on the Carbon Footprint Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	Of course in order to be more user friendly for local citizens in the future all the content needs to be available in local language but this is something that is already in the loop of planned development activities. Apart from that in the section that is related to the calculation of the CO2 of the buildings some advice on how and where a user can get this information from, will be quite useful. Some tooltips might be useful in this regard.
Usability	Easy to use and navigate through the different stages.
User-friendliness	User friendly, having drop-downs at each step makes it very easy to fill out.
Attractiveness and UI (colours, screens etc)	Colours seem ok. Screens are well seen on different kinds of devices. Attention should be paid to using colours that are recognisable by colour blinded and visually impaired people.
Future use by low SES groups	The dashboard seems easy to use, fields are self-explanatory, navigation between steps is clear and could be used by representatives from low SES groups in the future.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	N/A - this is not the intent of this dashboard. However it provides a nice visualisation on the results from the user's input.

Could the tools reach wide recruitment targets?	Yes, if the CO2 is communicated properly to the wider public, it has the potential to reach a large number of users.
Do they refer to all demographic balances of citizens?	If very clear instructions on how you can calculate your CO2 footprint are available the CO2 calculator can be easily used by all demographic groups (that have internet connection).
Feature to facilitate policy measures	Maybe a feature that can facilitate policy making is providing statistics that will show the willingness of users to adopt certain personal actions to decrease their carbon footprint (e.g. start composting or use more public transport) , this will allow policy makers with more confidence on which measures will be easily accepted by citizens and thus prioritise based on this information.
Do they have the potential to increase awareness for behavioural change?	Absolutely, especially the part related to the results and the advice on how one can actually improve their performance. This could make a great difference for some users and can lead to a positive change of their behaviour.

Policy Monitoring Dashboard

General remarks: Main page looks good and simple for navigation. The link works on several browsers - Chrome, Safari and Microsoft Edge. Page loads quickly on all the tested browsers. Landing page looks good. Registration process is easy to follow and complete. Colours used are nice and recognisable. Some effort must be put to optimise the size for mobile phones when used on devices with smaller screens.

Table 22 Sofia & Plovdiv Feedback on the Policy Monitoring Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	Ease of access and usability. Registration process is quick and easy. If available in all **COMPAIR** languages as planned it will be very easy to promote to local users of Sofia and Plovdiv.
Usability	Intuitive and user-friendly interface, steps come one after the other in a logical way. Once all features are implemented it could be good to add some tooltips (e.g. on how to group sensors and what this would mean and provide as additional information).
User-friendliness	The currently available features for testing are user friendly. Navigation of the page seems intuitive and easy to navigate. Zoom in and out works well and drop downs are easy to use and understand.
Attractiveness and UI (colours, screens etc)	Colours and screens are looking good. The visualisation decision on using hexagons for sensors' data and localisation is already well-known and accepted by the population of

	Bulgaria as other platforms on air quality use similar visualisation.
Future use by low SES groups	As in Bulgaria, the population from low SES groups is not very aware of the issue of air quality. More information about the pollutants and their EU standard can be added to make the information more understandable by these groups. Apart from that, colours, the map and drop downs are quite well developed and easy to use even by people with limited knowledge and no education on air quality.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	Yes, however the sufficiency of the information depends on the availability of sensors. The graphs and visuals that are currently available give enough information.
Could the tools reach wide recruitment targets?	Yes, of course proper communication should be used to promote the dashboard among the local population.
Do they refer to all demographic balances of citizens?	This will mainly depend on the additional information and explanations available on the platform. Also it is good to be noted that the number of sensors will be limited which will also limit the availability of data on the platform (e.g. some neighbourhoods can be left out with no sensors), apart from that the fact that the users will be able to see the data from other pilot locations is very useful in terms of seeing that we are not alone in the fight for better air quality, this will definitely provide also more credibility and increase citizens' trust.
Feature to facilitate policy measures	Yes, especially the feature to group sensors, e.g. policy makers can group sensors that are close to referral national / municipal stations in order to see the credibility of results. If at later point more data layers with different sensors are able to be added this will allow for better policy decisions based on reliable data.
Do they have the potential to increase awareness for behavioural change?	Yes, depending on the number of sensors

4.4. Flanders

Given the prior experience in setting up air quality sensor comparisons at the Flanders Environment Agency (VMM) in projects like LIFE VACUUMS[2], the Flanders pilot focused on the performance evaluation of SODAQ devices. We adhered to the standard testing protocols for both lab and field tests provided by the VAQUUMS-project. A brief description of the testing parameters is provided in the next Section. Field tests were performed at the R801-Borgerhout reference site in Antwerp, Belgium. Interesting about this test site is that depending on the

[2] https://vaquums.eu/

direction of the wind this site can be classified as either an urban traffic or an urban background location. This dual character also guarantees more variation in pollutant concentrations and characteristics.

Telraam sensors have been deployed in the past years across Flanders. The Flanders pilot therefore did not specifically deploy additional sensors but summarises past experience with the Telraam v1 device #9000002385 in the period from June 25th 2021 to September 30th 2022.

4.4.1. Description of actions for field testing on sensors

SODAQ installation, use, bugs

Test protocol
The benchmark study consists of :

- preliminary limited lab testing
- co-location of the devices at a reference station of VMM (at Borgerhout)
- analysis of the measurement results and if necessary, rescaling to minimise the deviation from the reference measurements and to avoid variability among sensors of the same type
- Qualitative assessment of the devices for mobile use

Lab tests for NO_2 (duration: ~3-4 weeks):

- Lack of fit test NO_2: 0, 40, 100, 140, 200 µg/m3,~2 hour/concentration step
- Effect of relative humidity (RH): 15, 50, 70, 90% (±5%) @ 20°C
- Effect of temperature: 5, 10, 20, 30°C (±3°C) @ 50% RH
- Interference O3 @ 1 concentration (120 µg /m^3) and 0 and 100 µg/m^3 NO_2
- Response time
- REF: Thermo Scientific 42iQ-TL

Lab tests for PM (duration: 1 week):

- Linearity PM sensors: “number of concentrations of dolomite dust 0-200 for $PM_{2.5}$ µg /m^3 and 0-350 for PM_{10} µg/m^3”
  - 0-25-50-75-100-200-300 PM_{10}
  - 1 hour / concentration step
  - Evaluation response to $PM_{2.5}$ and coarse particles based on the linearity test with a comparable amount of $PM_{2.5}$ and PMcoarse.
- REF: type Grimm 11 D with heated inlet

A Mobile test was done with a cargo bike. A route in Antwerp was driven, consisting of open and more closed areas (incl. street canyon).

- Evaluation of the GPS track
- Noise outliers jumps PM/NO_2 signal ~ turbulence, speed, vibration
- REF: Grimm (battery), MA200 (BC)

Co-location at reference station (duration: 3 months):

- Use of Pourbaix shelter
- Between-sensor uncertainty at a time resolution of 5min, 1h and 24h.
- Comparison with REF: time resolution of 1 minute, 5 minutes, 1h and 24h (timeplot, scatterplot with linear fit and statistics (R^2,MAE,RMSE)). The ratio between sensor and reference is also plotted to check whether there are changes during the comparison (due to drift, meteo effects etc).
- Comparison with EU reference method (24h & hourly average) (or an equivalent method for PM, in case no reference method is available) > uncertainty at limit value, R^2
- REF:
    - NO2: Thermo 42i Chemiluminescence NO-NO2-NOx Analyzer
    - PM: Palas Fidas 200 (=equivalent to the gravimetric reference)

Preliminary results

Lab tests for PM:

- SODAQ AIR: the results were linear, but we see a large intersensor variability, which means that each sensor has to be calibrated separately (cf. Figure 20).

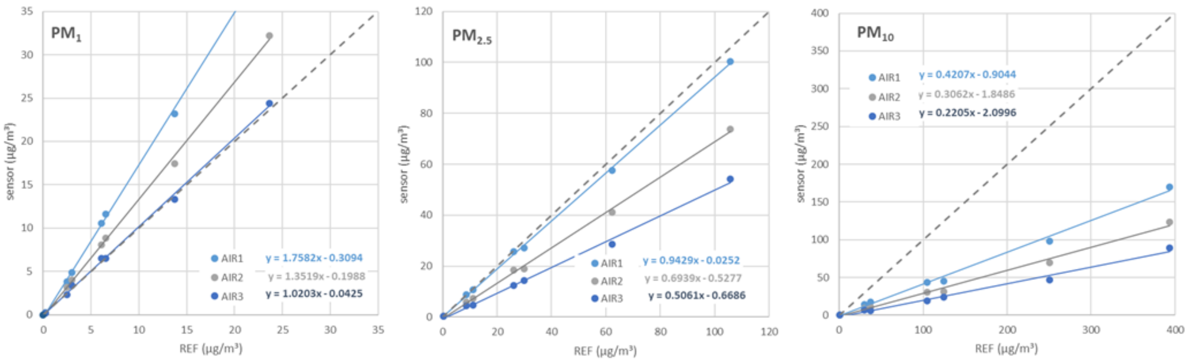


Figure 20 comparison SODAQ air devices vs reference device

- SODAQ NO_2: too much lacking data to say something meaningful, the few data available suggest that the SODAQ NO_2 is less accurate for measuring PM than the SODAQ AIR device (cf. Figure 21).

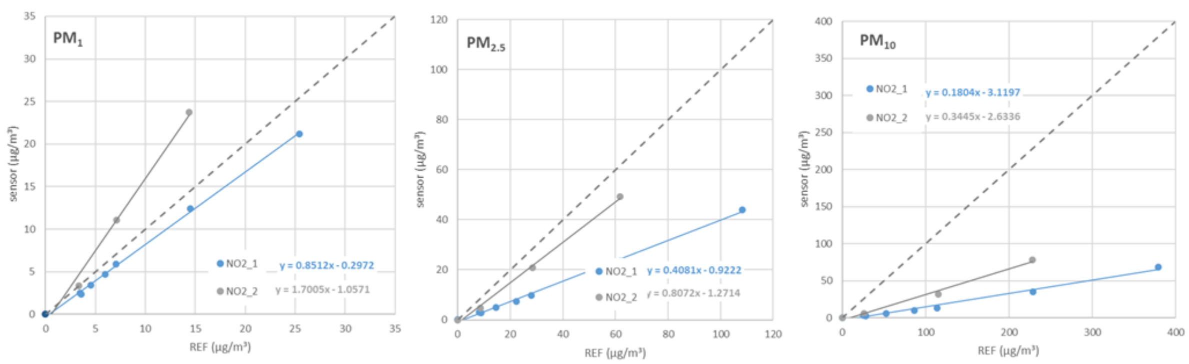


Figure 21 comparison SODAQ NO2 devices vs reference device

- PM coarse: SODAQ devices barely perceive PM coarse (cf. Figure 22).

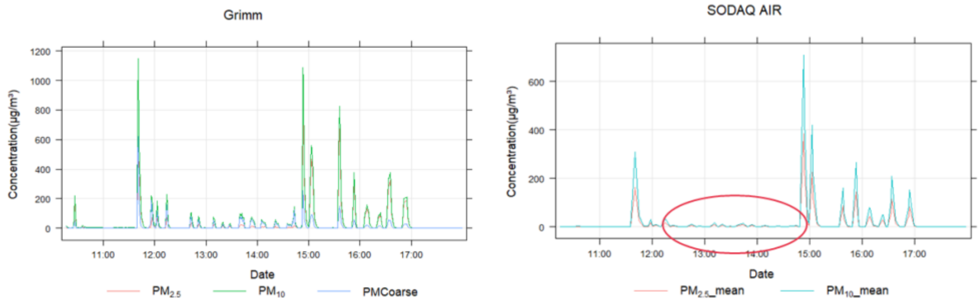


Figure 22 detection of PM coarse spikes with reference device vs with SODAQ AIR devices

Lab tests for NO_2:

- SODAQ NO_2: time resolution changed sometimes (due to connectivity issues), large intersensor variability, one of the three sensors lacked a lot of data, the results were linear, but in the wrong direction (when the concentration rose, the measurement values became lower) (cf. Figure 23), a lot of noise on the data (cf. Figure 24).

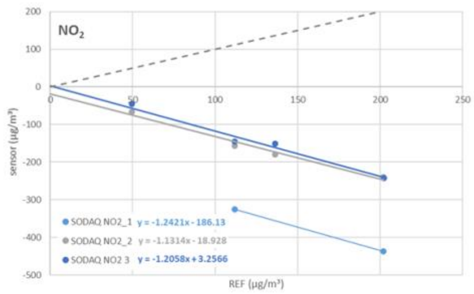


Figure 23 comparison SODAQ NO2 devices vs reference device

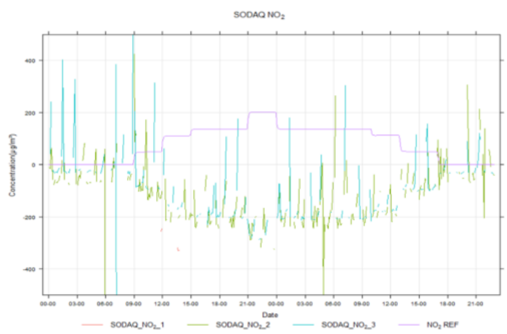


Figure 24 noise in NO2 measurement data of SODAQ NO2

Mobile test:

- The time-resolution of the SODAQ NO_2 device is 1 minute, which seems too large for mobile measurements.

<u>Telraam installation, use, bugs</u>

No benchmark study or lab test was performed in Flanders for Telraam.

Table 23 Flanders Observations from Indoor Scenario testing

Tested Functionalities/parameters	Telraam
Smooth operation of device	The device operates smoothly during the entire testing period providing relevant bi-directional information on passers-by, cyclists, passenger cars and large vehicles. Due to the training period for object classification no information was reported during the first 3 days and no information on large vehicles was reported in the first 17 days of monitoring. From July 15th 2021 onwards all classes were reported successfully.
Availability of data	Excellent data availability was observed. During the testing period 5 consecutive hours with data loss were observed on November 29th 2021 and 1h interruptions on October 4th 2021 and May 30th 2022.
Interruptions in data collection	The 1h interruptions could be traced back to general power interruptions due to road works in the vicinity of the monitoring location. The longer period of data loss was caused by an interruption in internet connectivity, again due to the road works. An additional WiFi interruption was detected on December 9th but did not result in noticeable data loss.
Accuracy of sensor location	Not applicable
GPS signal availability	Not applicable
Observation of error data or not correct data collected	In total 909 hours of poor quality data were labelled by the Telraam device indicating an uptime lower than 50% during those hours. Out of a total of 11005 hours that makes 8,26% of poor quality data. Additionally in dark conditions no information can be collected. This covered 4758 hours or 43,23%. Hence 48,51% of the total time very good quality data was collected or 85,45% of the “active” time (i.e. not dark). Poor quality is clearly caused by deteriorating lighting conditions during morning and evening hours (cf. Figure 25). This is more prominent for morning hours, possibly caused by the North Western orientation of the device leading to better lighting in evening hours. Additionally a cluster of poor quality hours is noticeable between 15h and 17h. Given the orientation of the devices the most likely cause is intense direct sunlight hitting the camera at that time.
Changes in data measurements due to speed of movement	Not applicable

Changes in data measurements due to vibrations caused by the movement	Not applicable
Changes in data measurements due to weather conditions	Not applicable
Changes in data measurements due to nearby activities (e.g. vacuum cleaning, noise etc)	Not applicable
Duration of power/battery	Not applicable
Usability	
Issues with connecting devices to backpacks, bikes, etc.	Not applicable
Ease of interpretation of data	Data is easily interpreted. Dashboard contains: daily averages, hourly averages, day profiles for each class, speed distribution, v85 distribution and share of each class overall and in day profile. All visualisations can be filtered for vehicle type, period, direction and/or type of day (e.g. week vs. weekend). An online description of the visualisations is provided as well as the possibility to export the raw data. Finally a newer feature is provided in which an advanced “street sheet” can be obtained to help visualise the effect of certain events. This has been summarised in a data story for the sensor tested in the Flanders pilot.
Stability of sensor when installed in a window, on a bike/motorbike, places in a balcony etc.	The device was installed once and remained firmly attached to the window throughout the testing period.

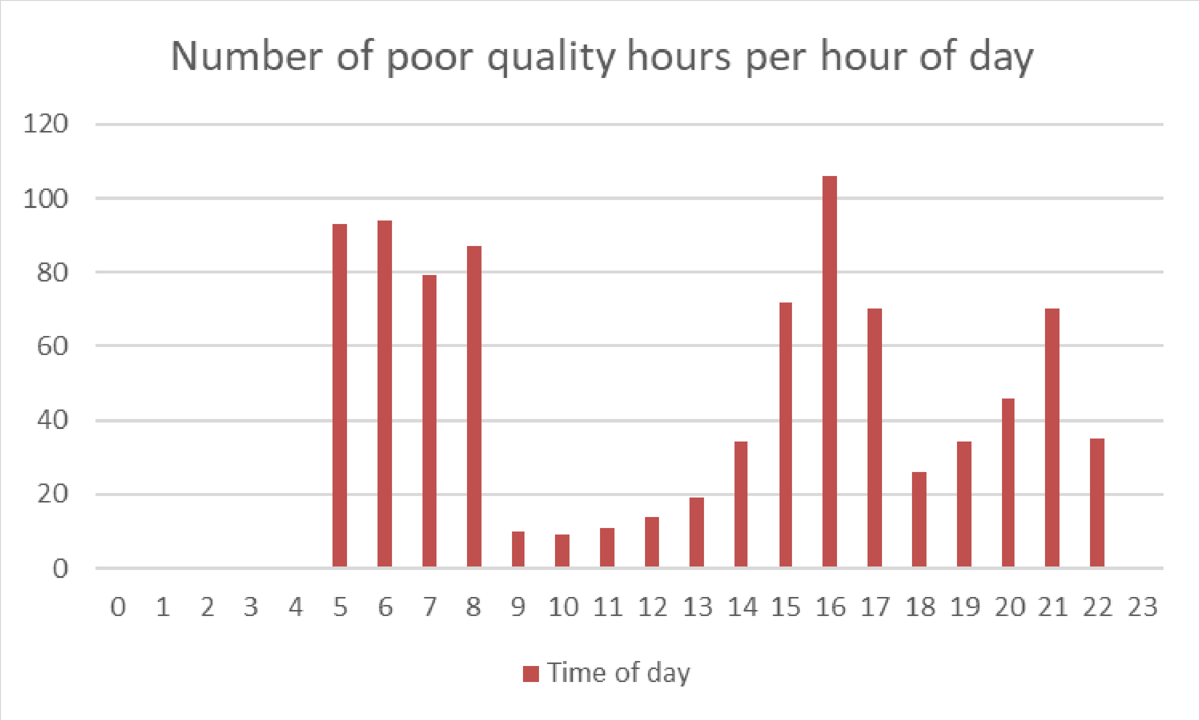


Figure 25 diagram on quality of sensors data

4.4.2. Feedback on software tools

<u>DEVA</u>

Table 24 Flanders Feedback on DEVA

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	At the moment it is not clear whether the tool will be able to hold the interest of citizens. This could be addressed by adding a gamification aspect.
Usability	Not yet applicable
User-friendliness	The login screen is very clear. It should be an option to remember the user so that he/she will not have to login every time. Sign up process for users might be a barrier. The red flickering lamp at the top h should be explained to the users, so they know what the icon means. It is proposed an option to click on the icon and thereby receive information about the icon and its operation.

Attractiveness and UI (colours, screens etc)	The possibility of using a landscape view is very pleasant and the possibility of using the night mode also seems very useful, certainly to save battery. The visualisation of all different components as bulbs, squares, etc. is special. It is proposed to use e.g. a thermometer icon for temperature, a water droplet for relative humidity, etc. This suggestion would also make it easier to interpret the data. Finally, the use of green, yellow and red is proposed in order to give an indication if the value is being low, medium or high.
Future use by low SES groups	Keep the tool as accessible (e.g. possibility to use it without registration) and as simple (e.g. easy language, clear icons, not too many buttons / icons on the screen etc) as possible. Make sure they can use the tool for a use case that matters to them.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	An explanation about air quality in the app Is necessary. At the moment the interpretation of the visualisations by citizens seems rather difficult.
Could the tools reach wide recruitment targets?	If the tool is accessible and simple, with a clear use case for the different types of users, wide recruitment is possible.
Do they refer to all demographic balances of citizens?	Idem.
Feature to facilitate policy measures	Not applicable
Do they have the potential to increase awareness for behavioural change?	If it is to give the citizen a clear vision of his/her exposure and how it varies as he/she moves around, it can lead to behavioural changes like taking other routes to school, work etc.

Carbon Footprint Dashboard

Table 25 Flanders Feedback on the Carbon Footprint Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	This tool will definitely appeal to citizens who are environmentally aware. The tool can be handy for teachers to make students more aware of the subject.
Usability	The tool will be useful to make citizens aware of their carbon footprint. However, the tool should also explain somewhere what this actually means. (What is a carbon footprint, what does this mean, why should we try to limit our footprint Etc.) An interesting feature of the tool is the part where it suggests actions to take to reduce the user's footprint and visually shows the effect of each action.

User-friendliness	The use of dropdown fields lowers the threshold to use the tool. It saves time and helps citizens to get an idea of what kind of response is expected. It seems difficult to estimate the exact distance driven by car, even though knowing the exact number is the best estimate for your CO2 emission. Maybe give the possibility - like in the Flights tab - to choose from predefined distances and the possibility to fill in multiple lines. Maybe add a hover functionality that makes clear what the 4 icons above stand for.
Attractiveness and UI (colours, screens etc)	The use of soft colours is pleasant and the dashboard UI looks good. It is proposed to replace the words in the blue buttons to go to a next / previous tab, with “next” / “previous”. This seems clearer than the subjects’ names. There is little text on each tab, which makes the tool more attractive and clear.
Future use by low SES groups	Keep the tool as accessible (possibility to use it without registration) and as simple (easy language, not too many buttons / icons on the screen, etc.) as possible.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	The tool should also explain somewhere what a carbon footprint actually means. (What does this mean, why should we try to limit our footprint Etc.) QAxis titles could be added to the graphs to make them easier to interpret.
Could the tools reach wide recruitment targets?	Yes, if we can link it to specific use cases, relevant for each type of user/citizen.
Do they refer to all demographic balances of citizens?	Yes
Feature to facilitate policy measures	Policymakers can use this tool for awareness raising campaigns, to determine what measures they will take and to justify their choices to their citizens.
Do they have the potential to increase awareness for behavioural change?	The tab with possible actions to take is certainly useful to achieve behavioural change. Policymakers can use this tool to raise awareness among citizens on this topic.

<u>Policy Monitoring Dashboard</u>

Table 26 Flanders Feedback on the Policy Monitoring Dashboard

Parameters	Feedback
Future use of the tools by non-consortium members (ordinary citizens)	This tool can be used by citizens and policy makers. Citizens can use it to get an idea about the air quality in their neighbourhood, the measurements of their sensor, etc. It can be used in citizen science projects. Policy makers can get a better idea of the air quality on their territory.

Usability	The tool seems very user-friendly and therefore certainly seems usable. It is handy that you can divide the sensors into groups and then compare these groups with each other. This will allow us to compare the AQ-sensors of the pilots to our reference stations.
User-friendliness	The dashboard looks nice and is very intuitive and clear. Some explanation of how a graph can be interpreted is needed.
Attractiveness and UI (colours, screens etc)	It is proposed the same colour scale for the different pollutants and take into account the WHO and EU-limit values for the colour transitions. Citizens intuitively rely on the colours to get an idea on how good / bad the air quality is. Use the colours to indicate whether a concentration is still good (e.g. blue, green), average (e.g. yellow) or bad (e.g. orange, red,etc). Relative humidity should be expressed in percentages rather than g/m³. It is proposed to remove the faces in the legend of temperature and relative humidity.
Future use by low SES groups	If we want people from all SES groups to use the tool, we will have to link it to a specific use case that is relevant to them, to make clear what the benefits are for them (e.g. via their children). Keep the tool as accessible (possibility to use it without registration) and as simple (easy language, not too many buttons / icons on the screen, etc.) as possible.
Sufficient insight on air-quality (particles visualisation, graphs, explanation, labels etc)	To use the tool as it is, a minimal knowledge of air quality is required, as well as being able to interpret graphs. What are (these) pollutants, what are their sources, health effects, etc. Maybe add some minimal information or link to websites on the subject. Some explanation of how a graph can be interpreted is needed.
Could the tools reach wide recruitment targets?	Yes
Do they refer to all demographic balances of citizens?	Yes.
Feature to facilitate policy measures	Policymakers can use this tool for awareness raising campaigns, to determine where they need to take measures and to justify their choices to their citizens.
Do they have the potential to increase awareness for behavioural change?	This tool can confront citizens with the air quality/pollution in their environment. This can lead to behavioural changes.

5. Lessons learned for the open testing

5.1. Lesson learned for COMPAIR pilots on sensors and software tools

5.1.1. Athens

The lessons learned from the Closed Testing task in Athens refer to the two main types of tools, sensors and software.

Regarding the Telraam sensors for traffic data collection, their use in the Athens scenario is not foreseen, however the testing was performed in order to draw some comments also for the other **COMPAIR** pilots. Regarding the appropriate location of Telraam sensors in Athens where the vast majority of the population lives in high buildings, it would have been a difficult and time-consuming task to find end-users with appropriate windows to dedicate them to the sensors. Also in our premises, it was advised not to open the window where the sensor was installed since the movement would lose the correct camera position.

It is foreseen that 50 SODAQ Air sensors will be distributed during the pilot implementation to citizens in order to install them at their households and 6 NO2 sensors will be installed in municipal buildings in the 2 Athens districts (hence 3 buildings in each area). The NO2 sensor's SIM card had a mis-compatibility with the Greek providers of telecommunications, hence no major lessons learned were derived. However, the weight of the sensor surely validates the initial planning of the pilot that foresees the sensors to be installed in a stable place in a building and not transported.

The Athens team will consult end-users to install SODAQ Air in their balconies preferably at a position not exposed to rain, wind etc. Also during the recruitment a training should be made in order to:

- inform them on the functionality,
- mounting process,
- how to interpret the data in the knowyourair platform,
- avoid use indoors,
- necessary charging etc.

It is proposed to cache in the knowyouair platform the location of the device so that Athens users can see the Athens area when visiting the website.

For both types of SODAQ sensors it should be considered a backend for the Athens pilot team administrators in order to periodically check the battery level in both devices and inform end-users for charging in case they have forgotten. Also a more user-friendly approach is to receive notifications (e.g. by email) in case one NO2 or SODAQ Air sensor is not charged for a predefined period of time (e.g after a few hours). Since the manual monitoring of 50 sensors will prove the scalability of **COMPAIR** for CS projects with higher audience. Also taking into consideration that there is no indication on the level of battery remaining on both devices. This issue will surely create interruptions in data collection.

Also in terms of the Athens pilot team capacity and organization, appointed representatives have to be available for periodical follow up meetings and communication with groups of end-users. They have to be available by email and/or phone for emergency cases e.g. an error in the operation of a sensor.

The long experience of DAEM in preparing and executing pilot activities with end-users reveals that for extensive use of sensors such as the SODAQ Air, an excess in the devices should be available in the local pilot site in cases of errors, failures, broken devices, even lost devices. For the **COMPAIR** Athens pilot, it is proposed for 50 end-users to have availability of minimum 55 devices.

Regarding the **COMPAIR** software tools and taking into account that they are still under development with specific goals already set, it is proposed to give attention to the types of user accounts that they will support, in order to include all types of users and their respective rights to access several features: consortium members, citizens, policy-makers/city officials, pilot team administrators. The localization in pilot languages is already in the agenda of development for the technical team.

A lighter/easier version of the DEVA app is proposed for less tech savvy end-users, since AR technology is already quite advanced for some groups of citizens. The Athens pilot team should be available to support end-users groups on the use of the tools and also organize demonstration and training meetings. Regarding the DEVA App an updated list of the AR compatible devices should be available for the pilot teams in order to know how to guide the end-users.

For the Carbon footprint dashboard that will be a primary tool for the Athens pilot it is proposed that users should insert more information and data on the consumption in their households and their habits, even for statistical purposes (e.g. types of appliances, other questions on the percentage of recycling, actions like unplugging appliances when away or not in use, turning off electrical devices etc).

For the end-users of Athens that will have a sensor installed in their households, the initial page of the PMD should load the parameters, language and location/city of their sensors.

5.1.2. Berlin

The testing of the air quality and traffic sensors closely followed the script set forth in the four testing scenarios. Each device had its advantages and drawbacks, which will be considered during the open round's onboarding phase. The Berlin pilot team will draw up a list of aspects that need to be considered during the open and public round's training phase in order to ensure a smooth implementation of the devices and measurement campaigns.

Considering the importance of choosing the right location to install Telraam sensors in Berlin, which is a green city and most of the buildings are covered by tall trees, it seems that finding end users with appropriate windows to assign to the sensors would be a difficult task and time consuming. Furthermore, despite the comprehensive and sufficient information on the Telraam website about the right place for the installation, installation and operation of the sensors, the Berlin pilot team has learned that in the future it will be necessary to help users when choosing the right place for the Installation of the sensors and to support the installation and operation.

With regards to the SODAQ NO2 device, one key aspect that needs to be resolved before the next phase is the calibration of the data. While calibrated data was not as relevant in the closed round, correct data measurements will become important in the upcoming phase, mainly because they will inform the team about the most appropriate setup of the experimental design (e.g. sensor locations). Moreover, correct data is needed because citizens will be curious about the results of their measurements. In addition, the (relatively short) battery duration of both the NO2 and Air devices needs to be communicated up front in order to accommodate users' expectations and allow them to come up with their own measurement plan as befits their needs.

While all devices operated quite smoothly during the closed round, the Berlin pilot team will need to test them in the field, at specific locations, before they are distributed among citizens. This will be done in order to ascertain the usability of the sensors as well as the validity of the collected data. All in all, the activities during the closed round informed the team about the strengths and weaknesses of each device, allowing it to plan the upcoming phase.

5.1.3. Sofia & Plovdiv

From all the activities performed during the closed testing round in Sofia and Plovdiv, specific actions were considered as mandatory to ensure the effectiveness of the activities during the open and public rounds. As a result a checklist will be developed that will be used to plan and execute onboarding and training for the upcoming rounds. Activities that will be added in the checklist include assigning a point of contact that will be available at all times to support volunteers on sensors' installation and operation. Also, all the sensors that will be provided by the team to citizens will be tested in advance by the Sofia team to ensure that they are operating correctly. Moreover, specific actions related to the calibration of the sensors that will be used will be performed, to make sure the data that will be gathered during the open and public rounds is reliable. Training of the volunteers will be organised, as well as all the manuals will be translated in Bulgarian. Apart from that, specific requirements of the usability of sensors will be properly communicated to volunteers to ensure that the sensors will be located appropriately to gather data.

The activities during the closed testing round provided the team with insights on how to better prepare for the upcoming open and public rounds. The issues that came up during the testing were discussed within the consortium and steps to overcome them were identified. This allowed the team to become better prepared for the upcoming rounds and assess the actions needed to successfully implement the pilot actions.

5.1.4. Flanders

Telraam sensors have been deployed in the past years across Flanders. The Flanders pilot therefore did not specifically deploy additional sensors. The Flanders pilot focused on the performance evaluation of the SODAQ devices through a benchmark study in which they were compared to other similar PM/NO_2-sensors. As the benchmark study is still continuing, only preliminary results can be shared. The lab-tests are completed, the field tests continue until the end of November. For the lab-tests of PM, the results of the SODAQ AIR were linear, but the intersensor variability was larger than in the other PM-devices. The SODAQ NO_2 lacked too much data in order to have strong conclusions, however the few data available suggest that the SODAQ NO_2 devices are less accurate for measuring PM than the SODAQ AIR devices. Both the SODAQ AIR and the SODAQ NO_2 barely perceive the PM coarse. For the lab-tests of NO_2, the SODAQ NO_2 had some issues with its time resolution, which changed sometimes probably due to connectivity issues. There was also a large intersensory variability and one of the three devices lacked a lot of data. The results were linear, but in the wrong direction.

For Flanders, the main tool will be the Policy Monitoring Dashboard. This will be a useful tool for showing citizens their personal exposure to air pollution. The tool is currently being developed for static air quality sensors, and thereby showing the air pollution at certain locations. But as we will equipe citizens with mobile sensors, our pilot will also require a dashboard for dynamic air quality sensors. The DEVA app and the CO_2 dashboard will probably not be used in the Flemish pilot.

5.2. Lesson learned and challenges for the engagement of LSES.

COMPAIR, being a project committed to include all SES, is actively trying to engage people belonging to lower SES. In Berlin this was reflected already during the stakeholder mapping, where associations representing or involved with LSES, women and migrants are considered as stakeholders and participated in co-creative activities. Even though the project has advanced since then, it would still be a valuable exercise for all pilots to revisit the stakeholder map and include such associations.

In Athens a piloting area is specifically known to have lower SES population, which can be another valid approach of engagement. In all cases we need to be mindful of how we approach people and to know that **COMPAIR** aims to make the project approach easier, accessible and available for all SES to participate.

Regarding the technological aspects of **COMPAIR**, all participants that need it, will have the possibility to attend demonstrations/training for the apps, as well as technical support for guidance. One thing that could become a concern for LSES are the costs of mobile data, and whether it can be used in older versions of smartphones or only the latest ones.

In general, one of the most important aspects of Citizen Science is inclusion and democratisation and for that we need co-creation and involvement of the specific groups (or their representatives) from the planning phases.

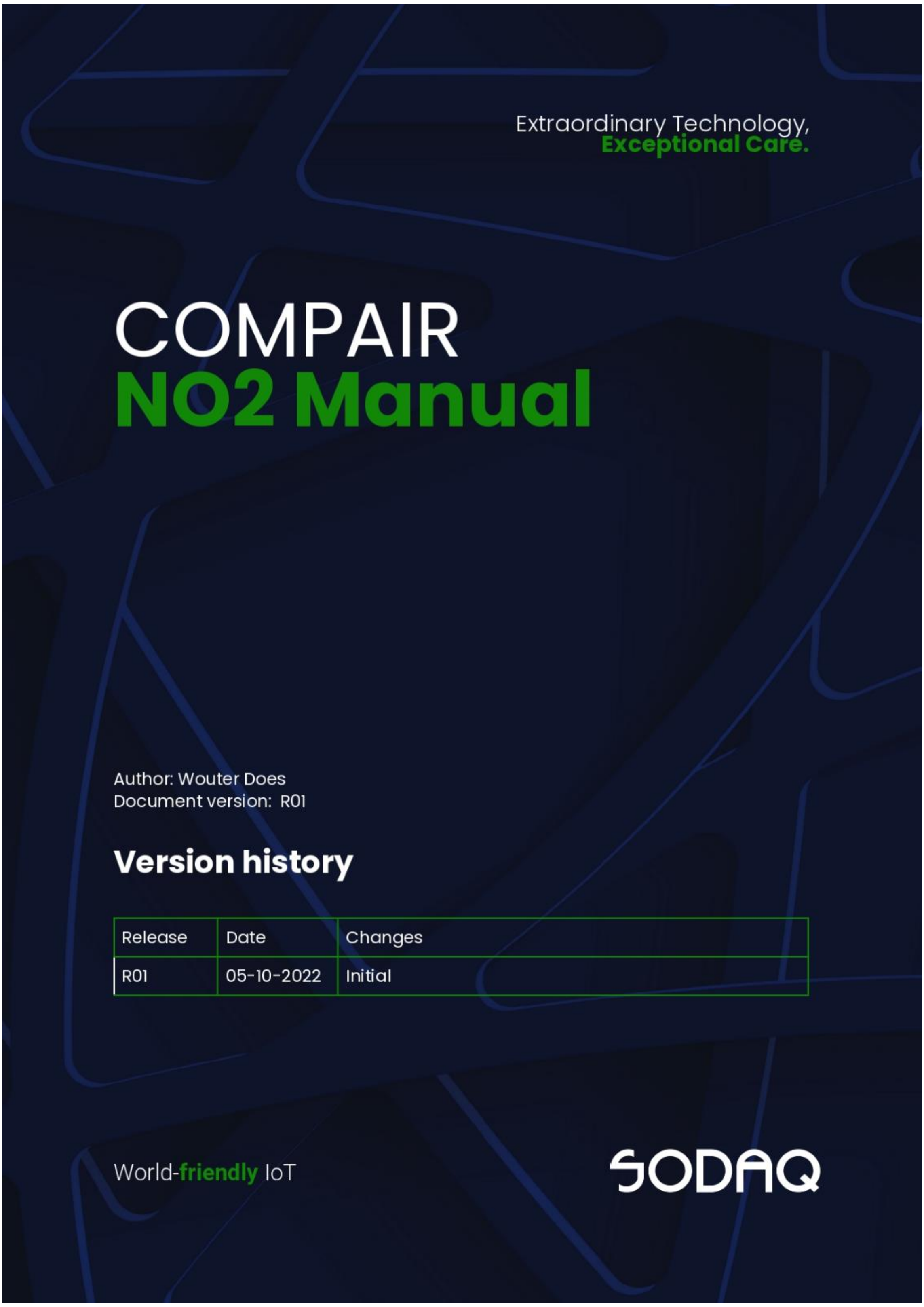
6. Conclusions

This deliverable is a detailed report of the Closed Testing Round and it consists of the first preparatory phase of **COMPAIR** pilots implementation. The findings are reported from the first set of sensors sent and deployed in all pilot locations both in the lab for the Flanders pilot, but also in the field for the rest of the pilots.

A methodology was followed according to four predefined scenarios for hardware testing namely indoors, outdoors static, outdoors in transport and during leisure activities. The outputs of the sensors testing are elaborated as lessons learned for **COMPAIR** pilots and the main results refer to: the identification of the appropriate locations for the sensors deployment during the Open Round and the training and continuous support of end-users to ensure collection of data and the citizens' active engagement both on the Open and the Public Round. Suggestions for improvements in the sensors' platforms and devices are shared as well.

Finally, the up-to-date versions of the software were tested under the scope of each pilot foreseen use cases, namely the Policy Monitoring Dashboard, Carbon Footprint calculator and DEVA App (in mockups). It should be highlighted that the testing of the software is an agile process monitored by the technical team through Sprint period meetings, a dedicated google form to add bugs, proposed fixes and suggestions for development. Hence in the Open Round all software tools will be in newer versions. The main feedback is positive from pilot partners with suggestions on the look-and-feel of the tools and on proposed features and functionalities to be added taking into consideration the end-users to be engaged and most importantly low SES groups.

7. Annex 1


Extraordinary Technology,
Exceptional Care.

COMPAIR
NO2 Manual

Author: Wouter Does
Document version: R01

Version history

Release	Date	Changes
R01	05-10-2022	Initial

World-**friendly** IoT

SODAQ

Content

Version history	**0**
Description	**1**
Technical specifications	**1**
Installation Manual	**2**
Consumption	**2**
Insight of data	**3**

SODAQ
+31 35 300 0301
Bussumerstraat 34 1211 BL
Hilversum, The Netherlands
info@sodaq.com

Description

This document will shed light on several topics such as the battery consumption & charging, how the data forwarding works, and also how to view gathered data. These topics will be broken down into several chapters explaining everything the customer needs to know about the device.

Technical specifications

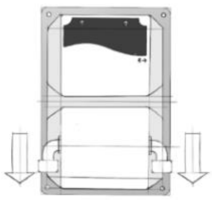
The SODAQ NO2 device is a portable air quality monitor that provides insights into the pollution outside.

Each NO2 contains:

- PM Sensor for measuring Particulate Matter (PM1, PM2.5, PM10)
- Temperature Sensor
- Humidity Sensor
- Gas sensor
- An Accelerometer for detecting if the NO2 is in motion
- GNSS modem for positioning (eg: GPS, Galileo, Glonass, QZSS)
- An LTE-M / NB-IoT Modem which allows it to upload the data to the platform

Installation Manual

The prototype consists of two separate wiska boxes. Both boxes have their own function, one is the dry side containing the SFF R410. And the other one will be the wet side, with the tubes sticking out of the wiska box. These will be useful for the airflow, one of the two tubes has a small fan installed on the inside. This will stimulate the airflow even more. Also, on the wet side there will be the Gas sensor and the PM sensor located.



On the top casing of the dry side there is a sticker indicating which side should be pointing to the top. On the back there is a big metal plate mounted with small magnets attached. This way it is possible to mount the device to a metal surface.

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Consumption

After a one hour test the consumption results state that the NO2 device uses around 523mW. Turning mW to mA: 523mW / 3.75V = 139mA. Since the capacity of the battery is 6000mAh, it is needed to divide 6000mAh / 139mA = 43hrs. Because of the outcome it is recommended that the device gets recharged every day since the battery only lasts +/- 1.5 day.

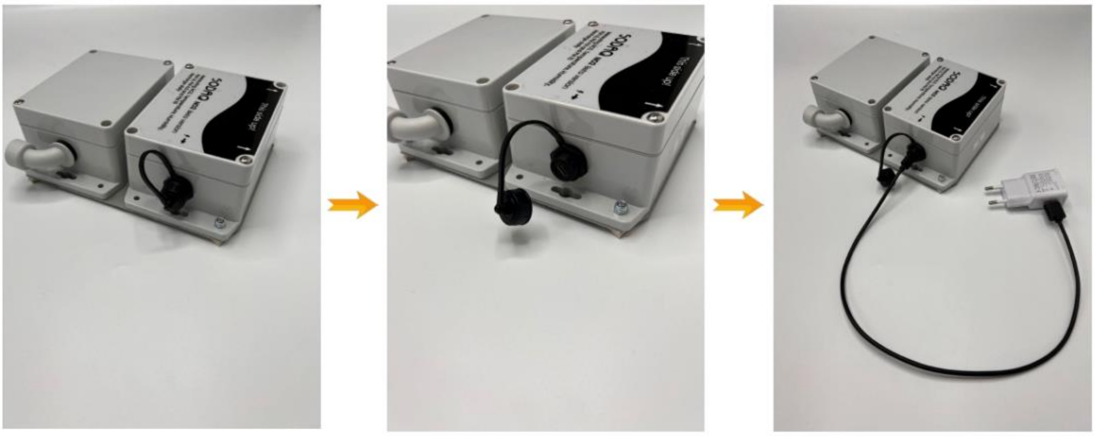
On average you are able to charge around 500mA per hour, and since the battery consists of 6000mA it takes a minimum of 12hrs to be fully charged. To recharge the device, please start by plugging the Micro-USB into the black knob on the right side of the device containing the usb port that is placed on the right side of the device. For the charging adapter it will be sufficient to use a regular phone charger, as long as it has USB-A access.

It is necessary to charge daily since otherwise the battery will be drained during the next day. There is no way to know from the outside if the battery is fully charged. But if you look into the provided dashboard you will be able to see if the voltages are sufficient to measure.

Note: To be completely sure that your device is properly charged we recommend to leave the device on charge for 24 hours. See *Images 1, 2 & 3* how to properly charge your device. Also note that the black cap should not be closed too tight as this might cause the connection internal to be lost since the Micro-USB might get pulled out on the inside of the device.

There is only one mode, the device is always turned on. This means that the consumption will stay like this, since there is no sleep mode. Measuring during the day and charging during the night (0:00 - 6:00) is recommendable since there are less factors causing pollution.

Images 1,2 & 3



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Insight of data

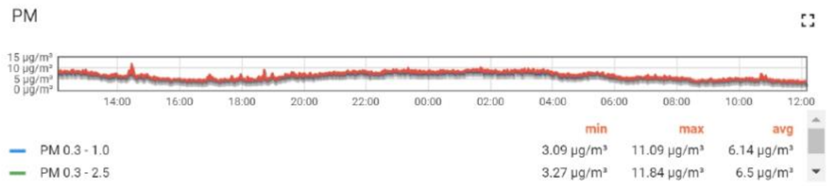
The data gathered by the NO2 devices will be stored on Thingsboard. This is a website used for data collection as well as data displaying. To get a better understanding of the data collected, there will be several graphs as well as a map where it is possible to see the active location of the device.

The data that is being collected and displayed: NO WE, NO2 AE, NO2 µg/m³, PM: 0.3 - 1.0/ 0.3 - 2.5/ 0.3 - 10, battery voltage, temperature and humidity, temperature of the board and timestamps. *See Example 1 & 2 below.*

Thingsboard URL: https://air.sodaq.com/home

If the customer has a personal account, please sign into Thingsboard and go to the personal dashboard. The ID of the device and most recent messages will be displayed there.

Example 1 & 2.



Timestamp ↓	Battery	NO WE	NO2 AE	NO2	PM 0.3 - 1.0	PM 0.3 - 10	PM 0.3 - 2.5	Temperature	Humidity	BoardTemperature	TimeToFix
2022-10-04 14:00:00	4.13 V	242 mV	238 mV	-102 µg/m3	6.36 µg/m3	6.73 µg/m3	6.73 µg/m3	18 °C	61 %	29 °C	0 s

SODAQ +31 35 300 0301 Bussumerstraat 34 1211 BL Hilversum, The Netherlands info@sodaq.com