



DELIVERABLE

D5.3 DIY Citizen Science Lab

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1. Introduction

This deliverable is part of WP5, the pilot activities, specifically Task 5.1: “air quality and sensor training”.

The goal of task 5.1 is to provide technical guiding materials for everyone engaged in the project to start a citizen science lab in any of the project’s pilots (Flanders, Athens, Sofia, Plovdiv, Berlin). While other deliverables of the COMPAIR project provide extensive information on various parts of the project (details about the sensor, the dashboard, sensor calibration, citizen engagement/recruitment, etc.), this deliverable aims to be the “one stop shop” for everything you need to know, if you want to do a citizen science experiment with any of the COMPAIR components. Because of this, this deliverable will contain many cross-links to other COMPAIR deliverables.

Also, as the project is still ongoing, not all components are fully ready and some of the components discussed in this deliverable to be used in a citizen science lab, are currently still under development. As such, we’ll document the current state of each of the components as they stand when writing this deliverable.

COMPAIR’s approach to the citizen science labs can be broadly grouped as follows:

1. Sensors:
 - a. with self-installation by citizens
 - b. with self-assembly & self-installation by citizens
2. Data:
 - a. Understanding sensor data; how to use and interpret the data
 - b. How to perform own data analysis with the sensor data made available in COMPAIR

Apart from these possible approaches to engage with citizen scientists, this deliverable aims to provide some support for setting up an activity (e.g. defining the scope, building and keeping your community of citizen scientists)

There are obviously different levels of ambition in each of the components. The different citizen science labs for all citizens engaging in the project, require different skill sets. In the following chapters, we dive into some examples of sensor installation/assembly and data analysis, highlighting required expertise and target audience for specific citizen science labs.

As such, the target audience for this deliverable are citizen scientists involved in the project and partners who want to organise citizen science labs in their pilot.

2. Introducing Citizen Science Labs in COMPAIR

Citizen science labs can take many shapes or forms. In COMPAIR, we distinguish between two main approaches: [1] citizen scientists contributing by installing and/or assembling DIY sensors and [2] citizen scientists who engage with the data generated from the sensors.

Within COMPAIR, we believe that no a priori technical expertise should be required to engage in a citizen science lab and that anyone can join in. In instances where some training and/or technical support is necessary, it will be provided by the respective project partners.

With the lowest threshold for participation, sensor installation should be possible for all citizen scientists. More challenging is sensor self-assembly, but with proper guidance, a large audience can be reached. Specific expertise is required when citizen scientists are engaged in data analysis. However, it's not required to own a sensor to engage in data analysis, potentially a larger audience can partake in your citizen science lab, which would not be limited to the number of sensors distributed in the project.

In terms of methodology, our starting point for the citizen science labs is face-to-face interaction in small-scale workshops, ideally in groups no larger than 50 participants. Recruitment of participants can be done by tapping into local initiatives and communication channels. The stakeholder canvas of each city is a good starting point.

Detailed methodological aspects of the Approach To Citizen Science as a field is not in scope of this deliverable. We refer to COMPAIR's deliverable D7.1 for tactics to recruit citizen scientists, with particular emphasis on vulnerable groups. There are many public guides on setting up a citizen science project, for example by Scivil (<https://www.scivil.be/en/book/getting-started>), project partner ECSA (<https://ecsa.citizen-science.net/ecsa-guidelines-and-policies/>), the handbook "Practicing Citizen Science in Zurich" (<https://eu-citizen.science/resource/239>) and ETOPIA-TRAIN's Citizen Science Starter kit (<https://eu-citizen.science/resource/342>), among others.

In the next chapters, we dive into detail of the sensors used and the data generated in COMPAIR and how these components can be used to organise citizen science labs.

3. DIY Sensors in COMPAIR

The core of COMPAIR is the use of low-cost sensors, to be hosted, preferably installed and maybe even assembled by citizen scientists.

First and foremost, we distinguish between sensors which are ready “out of the box” but (only) require self-installation by participating citizens, and sensors which are partly or fully DIY which require self-assembly by participating citizens. The former requires less effort and skills from the engaged citizen scientists.

We first briefly touch upon the pre-assembled sensors which only require self-installation, followed by a more elaborate description of self-assembly guides of sensors available in COMPAIR. For more detailed information on sensors used, we refer to COMPAIR deliverables [D3.1 “Sensor Strategy, Requirements Report”](#) and [D3.2 “Sensor Device Functional and Technical Design Report”](#).

3.1. Pre-assembled sensors

A citizen science lab focussing on sensor installation only can comprise a workshop, explaining sensor functionality and installation instructions. For example, with Telraam, this is a common approach and provides an opportunity for the researchers to interact and engage with the citizen scientists. The format of such an “installation workshop” can be quite light, reducing any threshold for participating citizens. In this chapter, we provide materials for each of the (pre-assembled) COMPAIR sensors used.

3.1.1. SODAQ AIR

About the SODAQ AIR and how it works

The SODAQ AIR is a portable air quality monitor that provides insights into the air you breathe. It monitors particulate matter (PM1, PM2.5, PM10), temperature, and humidity of the air. Besides the air quality, AIR also monitors the device movement and location, sending the data to the cloud through LTE-M or NB-IoT. AIR operates on a super capacitor as a substitute for a rechargeable battery, which enhances the environmental sustainability of the device.

Before you start

Charge your AIR for 2 hours before first use (LED's turn off when fully charged). Caution: although the device is rainproof, it should not be charged in wet conditions as there is a risk of causing heat/burn damage.

Mounting & Using the AIR

To activate your AIR, use the magnet included in the bicycle mount. When the magnet is close to the designated area on the AIR, it powers on and starts measuring. When removed, it turns off.



Active Mode

The AIR is designed to be used with your bicycle, so it comes with a bicycle mount that allows you to attach it onto your handlebars and capture the air quality while you ride. When in motion, AIR will measure the air quality every 10 secs. The AIR has a run time of approximately 5 hours of continuous usage, after which the LED will pulse RED indicating that your AIR needs to be recharged.

Static Mode

SODAQ AIR needs to be connected to a power source and have the fixed magnet inserted to operate in the static mode. Besides, placing it outside in a well-ventilated place will guarantee more insight on the actual air quality (placing it next to a kitchen or heating vents for instance will influence the readings). In static mode, AIR measures the air quality every 5 minutes. Please note that for static outdoor use, the AIR needs to be continuously connected to power and therefore needs to be protected from rain. Either install the AIR under a roof (rain protected) or use the special/custom rain shield.

LED

AIR QUALITY	
Colour	PM2.5 levels in $\mu\text{g}/\text{m}^3$
BLUE	below 9
YELLOW	between 9 and 24
ORANGE	between 24 and 60
RED	above 60

DEVICE STATUS	
Colour	Pulsing LED colours indicates
GREEN	AIR is charged or, when plugged to a power source, AIR is charging
RED	AIR needs to be recharged
WHITE	firmware update in progress

Viewing the Data

You can see the (anonymised) data on a map at knowyourair.net. The data from a specific device can be seen on the same page, by entering the IMEI and CODE of the device. The data is downloadable as an open-access CSV file. An open API is under development in the COMPAIR project. The API will be further integrated into the COMPAIR end-user applications like, e.g. policy dashboards.

User Guide

For a detailed description, reference is made to the SODAQ AIR user guide which is available on [this page](#).

3.1.2. Telraam S2

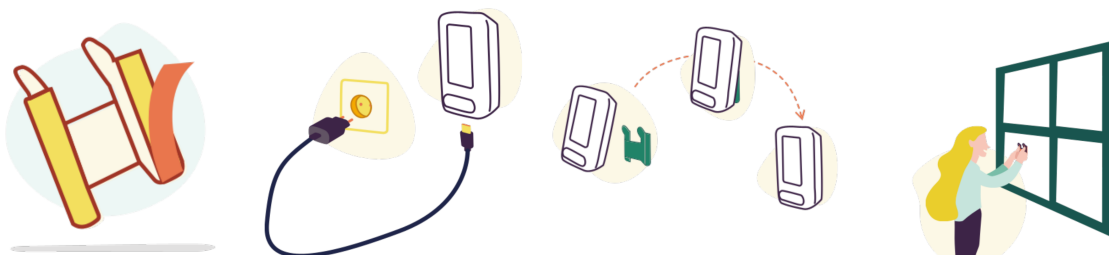
The Telraam S2 sensor is designed for easy installation. The device is packed in a custom built package, which includes all the individual components (sensor, power plug, cable and window mounting bracket) as well as a basic installation guide printed on the inside of the packaging.



The installation is very easy and requires 5 simple steps:

1. Create an account on www.telraam.net and link the device to your account by scanning the QR-code when powering the device
2. Add the user's address
3. Find a suitable window
4. Attach the device using the mounting bracket
5. Select the segment where the Telraam is/will be counting

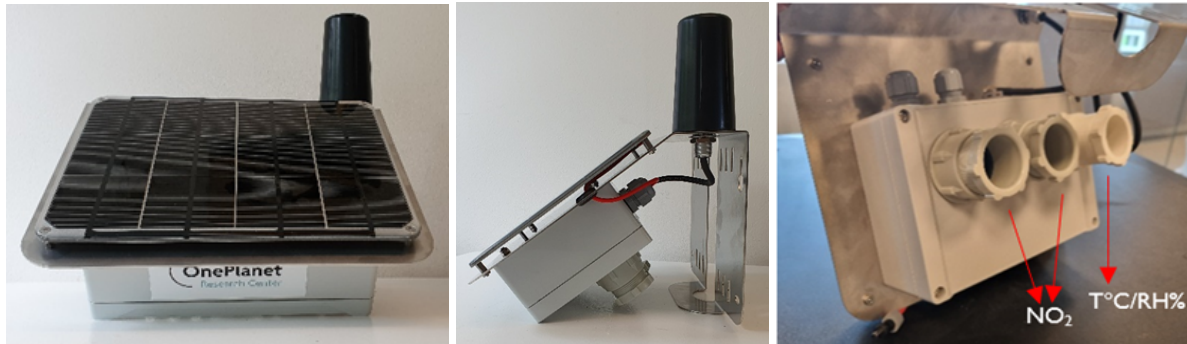
The installation instructions are also explicit when creating an account, guiding the user through the installation process, using a pictogram to also reduce any language barrier:



Once installed, the user can interact with the device, exploring counting data on the LCD-screen, visualising data in the last 24 hours or 15 minutes for four grouped modes in overview or in detail. The user can toggle between the different screens by using the Telraam-button. The sensor LCD-interface also gives an indication of the signal strength of the data connectivity, showing the user if the device can send data to the database. Finally, users can disable the screen with a long-press on the button. This is to reduce light pollution at night. The LCD screen can be reactivated with a simple button press.

3.1.3. OnePlanet NitroSense

This air quality device was developed by OnePlanet Research Center consisting of two Nitrogen Dioxide (NO₂) electrochemical sensors (NO2-A43F, Alphasense Ltd, UK), a Telaire T9602 sensor for temperature (T°C) and relative humidity (RH%), and a solar panel.



The device also includes an internal battery which is charged by the solar panel to allow continuous operation away from the electricity grid. The battery capacity is sufficient for 3-months without sunlight. The internal storage matches the timeframe with a capacity that can store data up to 3-months to prevent data loss. The device is capable of providing 3-minute monitoring resolution that is sent to the cloud in 1-hour intervals. The environmental sensors (NO₂ and T°C/RH%) are exposed outside of the device to avoid measurement interferences inside the enclosure. Based on our research, the NO₂ electrochemical cells of Alphasense are one of the NO₂ sensors that can reach ambient ppb detection levels. Based on initial lab tests of OnePlanet Research Center, the device shows good performance in terms of linearity, accuracy and correlation. The [datasheet](#) of the NO2-A43F Alphasense electrochemical sensors outlines its specifications.

Being a pre-assembled device, when deployed for conducting citizen science experiments, the installation is fairly straightforward for any person(s) with an ability to handle the required tools and consumables listed below:

Required tools:

- Ladder, minimum reachable height is 3m.
- Cordless drill (adjustable to 4Nm).
- 7mm socket.
- 1/4" external square to 1/4" hexagon adapter.

Consumables: 2x Hose clamp 60-180mm (Manufacturer part number: QIP180)



With the above required tools and consumables, installation of the device includes the following steps:

1. Place the device within a radius of 3m of the intended location (of known GPS coordinates):
 - a. If available, use existing infrastructure (e.g., lamppost, traffic sign, advertisement pole) to place the device. In advance, determine if permission is required for installation at the given location.
 - b. Place the device avoiding any obstruction (e.g., tree).
 - c. Place the device such that the solar panel on the device is pointing in the direction with the most sunlight.
 - d. Firmly fix the device to the chosen infrastructure with two hose clamps. In sensitive areas, it is suggested that the device is placed out of reach, e.g. 2.5m high.
2. Once installed, take a photograph with GPS tagging enabled, of the device up close to include the device ID. Then take another photograph with GPS tagging enabled, of the device from a distance to capture how the installation is positioned with respect to the reference station (if present) and the wider surrounding area.
3. Capture 'exact' GPS coordinates below the device.
4. On an excel file take note of the following:
 - a. Device ID.
 - b. Installation Date.
 - c. Location Name (e.g., municipality name, cite name, nature name, company name).
 - d. GPS Location (exact location).
 - e. Any remarks if applicable (e.g. height difference if more than 1 metre, infrastructure is unstable but works for now, difficult to get to the installation location, etc.).
5. Provide the excel file and photographs to OnePlanet for recordkeeping.

It is important to note that at some point in time, like all devices, the Nitrosense devices will also require some maintenance depending on the age and status of the sensor device. While it may not apply for citizen science experiments, it is good practice to perform some common maintenance actions from time to time. These include sensor replacement, device reset due to loss of communication, battery inspection due to failing to charge because of the absence of sunlight or a fault in the charging electronics, device cleaning from being exposed to the outdoor environment, inspection in case the device has been tinkered with by unauthorised people without sensor knowledge, etc.

Of the three pre-assembled, self-installation sensors in COMPAIR, the OnePlanet NitroSense is the most complex. Given the limited number of this type of sensor and the level of complexity also with the installation, it is recommended to only promote self-installation of the OnePlanet NitroSense sensor with proper guidance.

3.2. Self-assembled sensors

A citizen science lab focussing on sensor assembly is more challenging for the participants but allows for a deeper citizen science experience. Typically, in such a setup, a physical workshop with a good preparation is mandatory. Also, the size of the sensor-assembly workshop should not be too large. In case only one or two researchers can conduct the workshop, the group of citizen scientists preferably should not exceed 30 participants.

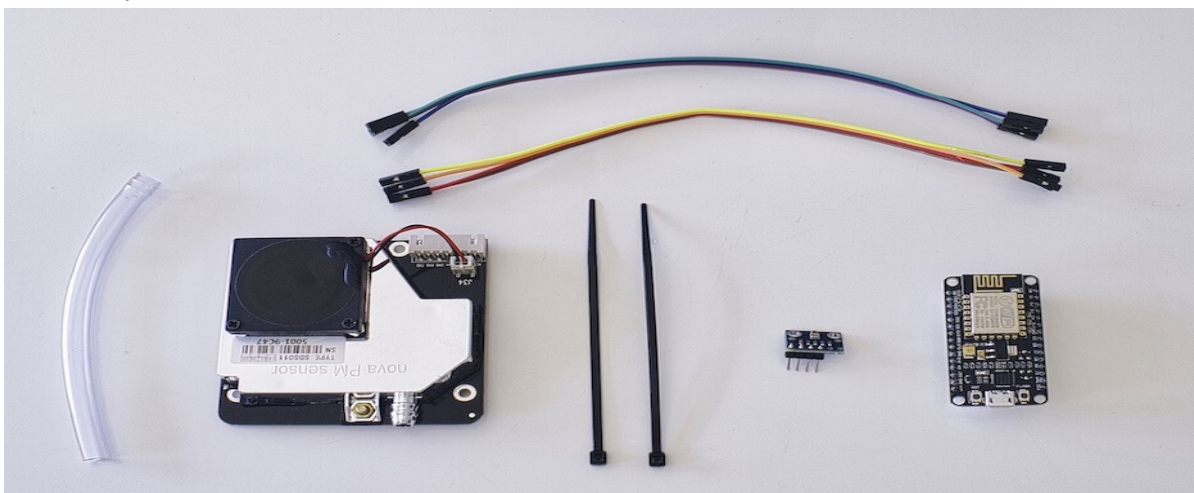
Sensor-assembly workshops should focus on the sensor assembly. A generic introduction explaining sensor functionality is still useful, but the bulk of the time should go to assembling sensors.

The format of such a “sensor-assembly workshop” requires thorough preparation by the researcher. The researcher should be able to address any question of the citizen scientist, even if the researcher is not a sensor-specialist. That means, depending on the sensor used, the researcher needs to have previously aligned with the sensor designer/manufacturer to gain sufficient knowledge of the sensor used. In this chapter, we provide materials for each of the self-assembly COMPAIR sensors used.

3.2.1. Sensor.Community

One of the air quality sensors being used to measure particulate matter (PM2.5 and PM10), is from [Sensor.Community](#). This is a very basic and low cost sensor with a long track record of being used in a citizen science context. At the time of writing this deliverable, there are >13.000 such sensors active worldwide and 57 “community labs”. Being a well-established sensor kit that has been used in many projects in the past, it was easily incorporated as one of COMPAIR’s self-assembled sensors. The assembly & installation guides are refined and improved from time to time.

The sensor setup deliberately has a strong “DIY-feel” and uses off-the-shelf and trivial, universally available low-cost components:



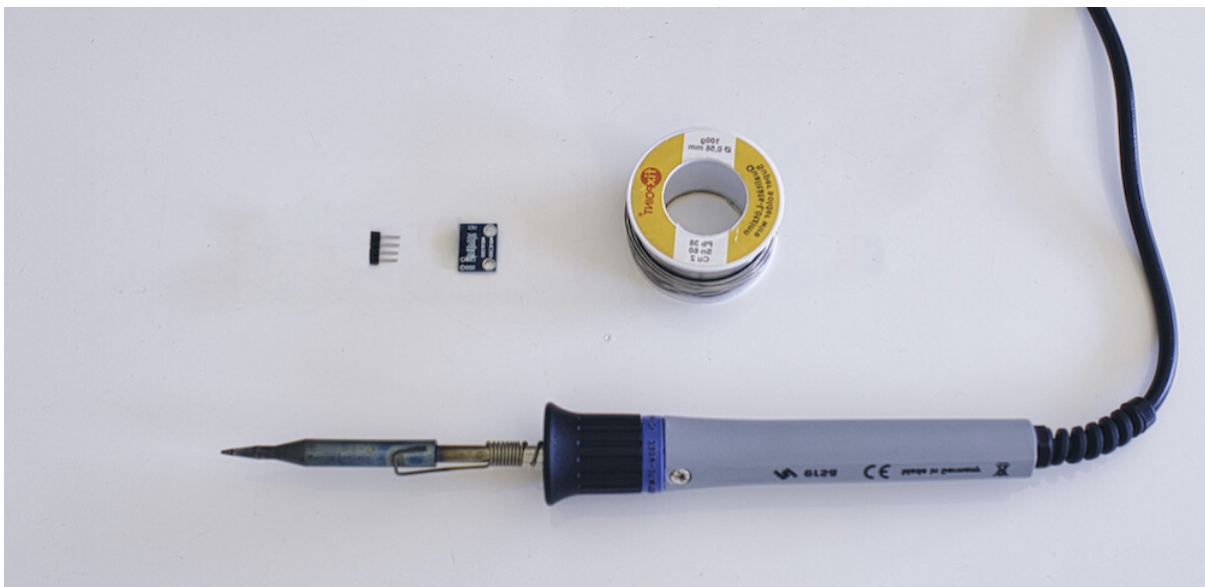
The critical components are:

- NodeMCU ESP8266 CPU/WLAN: the micro-processor and data communication component.
- SDS011 Fine dust sensor: the actual particulate matter sensor

Components can be sourced from one's own channels (the Bill Of Materials is specified on the website), but there's also a self-assembly kit available [here](#).

The assembly of the sensor firstly requires physical assembly of the components, which basically comes down to connecting the components with wire-connectors, then mechanical mounting of the components and lastly installing ("flashed") the sensor computing unit with the software.

Components can be connected via soldering (using the soldering equipment shown), which can provide a nice learning opportunity for citizen scientists/students but is quite challenging for non-experienced users. However, soldering is not strictly necessary as components can be connected via custom connectors available as part of the kit.



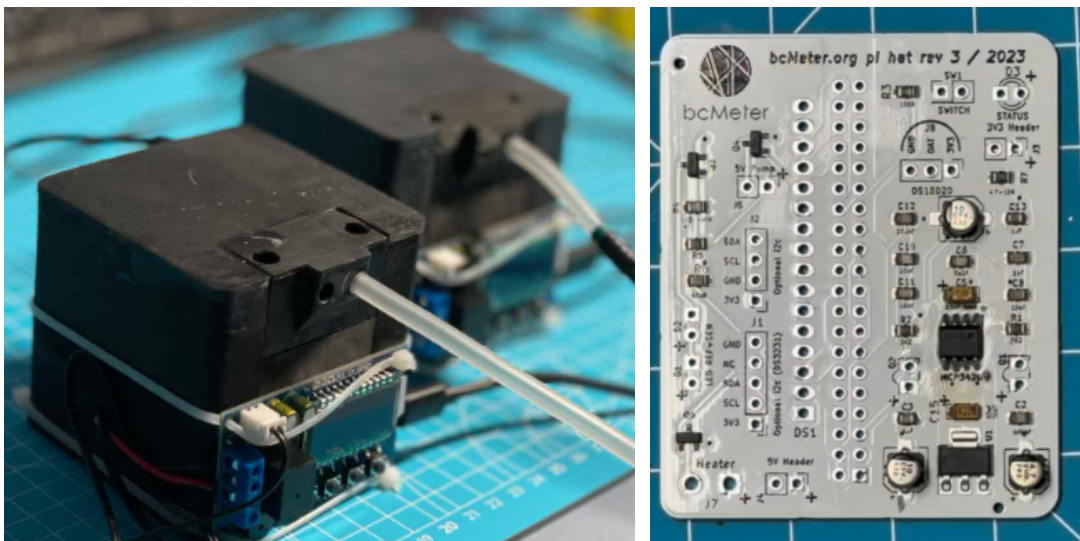
A [full assembly guide](#) is available on Sensor.Community's website. More simplified sensor assembly guides are available from derivative projects such as project "luchtpijp" in Belgium. There are also Dutch and English versions of the manual to self-assemble the sensor [here](#).

Because of the long track record of Sensor.Community (previously known as "Luftdaten"), there is a rich set of materials available on public fora, including workshop script/formats that can be applied in COMPAIR. The one stop shop for these materials is the [Sensor.Community forum](#).

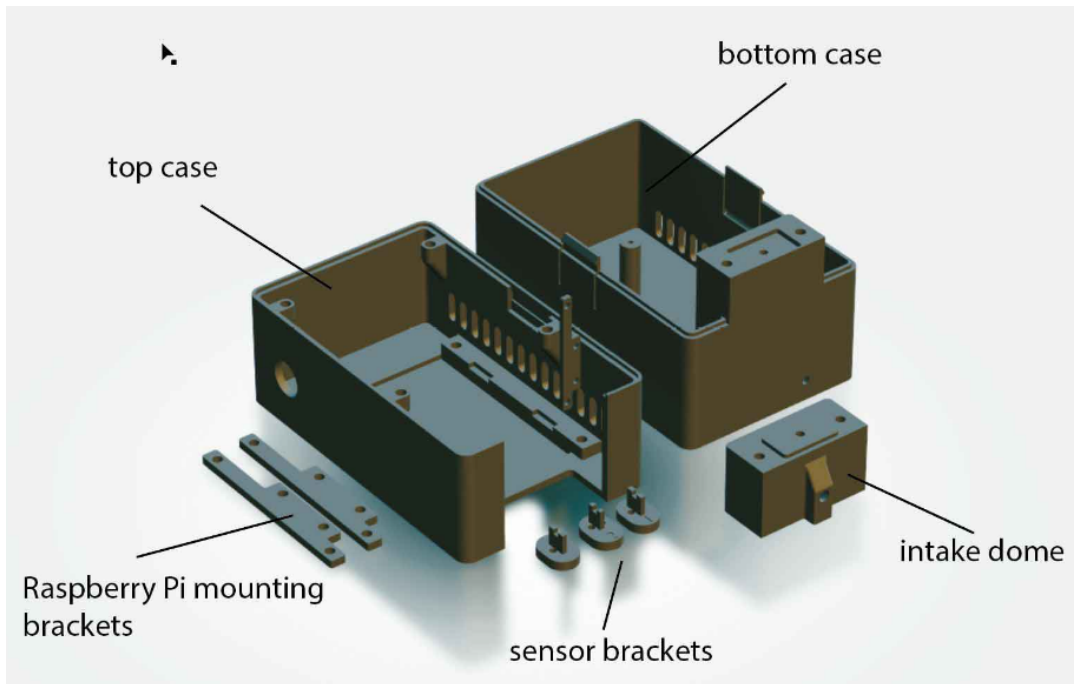
3.2.2. bcMeter

bcMeter (<https://bcmeter.org/>) is similar to Sensor.Community, apart from that the device is measuring black carbon (bc) and not PM2.5/PM10. However, the sensor technology used is different, a bit more complex and as such a bit more expensive and having a higher level of technical complexity. However, the device is still low cost and does not require specific technical skills, so it's still within reach of use in a citizen science lab.

The device consists of a custom 3D-printed casing with an aethalometer as the core sensing component. Sensor “governance” is done with a Raspberry Pi Zero, and an off-the-shelf hardware single-board-computer.



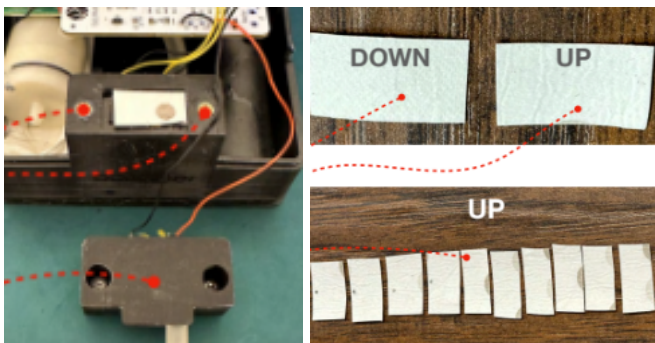
bcMeters are used in the COMPAIR project as a ready-built sensor, but it is possible to also organise sensor-assembly workshops to assemble the sensor, as all components can be sourced separately. The casing is 3D-printed and as such provides an additional opportunity for citizen science labs by organising printing of the casings by citizen scientists who have 3D-printers or with citizen scientists in a 3D-printing lab. 3D-files for case printing are available through the [GitHub repository of bcMeter](#).



With bcMeter, there is the option to buy a fully pre-assembled kit, which also allows for plenty of interaction with citizen scientists in a DIY lab approach. There's a bcMeter guide ([available in the COMPAIR folder](#)), made specifically for use in COMPAIR which describes both procedures.

bcMeter is not as well established as Sensor.Community, but it does have full documentation of components, assembly guides and any other information that non-experts need to get started. The [bcMeter-wiki](#) is the go-to place to access all necessary materials. Due to the sensor technique used, regular maintenance is required which can be performed by the citizen scientist. Below we've briefly described the process for device maintenance which requires replacement of the filter paper:

- Stop measurement before change
- Unscrew the top of the air inlet
- Replace old filter. Make sure the inlet for bc measurement is completely covered. The top and bottom side of the filter have a different scattering value. Using it upside down may show wrong bc values.
- Screw air inlet back on



The sensor uses Wi-Fi for data communication, meaning that a data-connection still needs to be configured on site by the participating citizen scientist (similar to the original [Telraam v1](#), see below). We'll briefly touch upon the process for Wi-Fi configuration below, but refer to the guide for a detailed explanation:

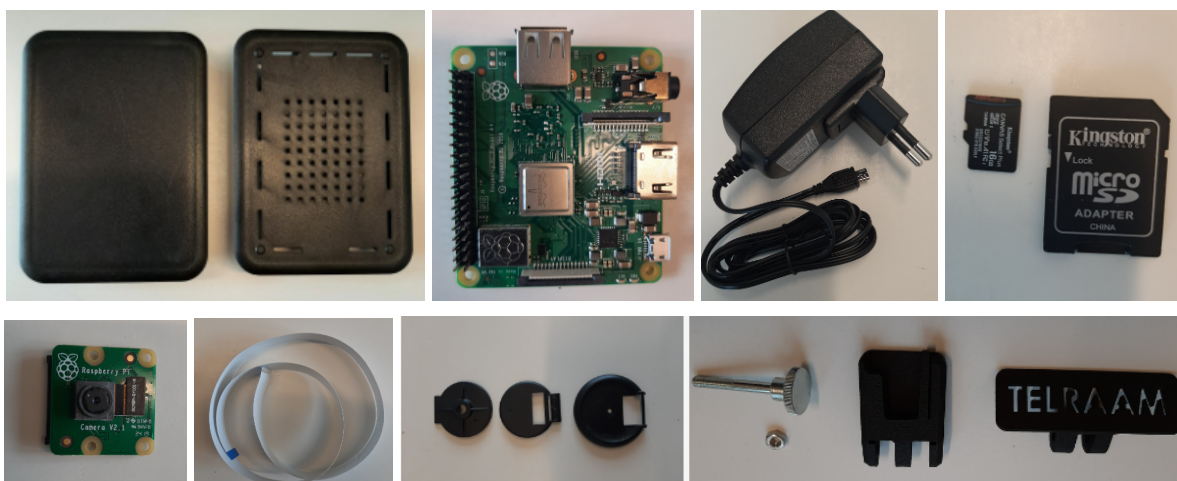
- The sensor creates its own hotspot for 10 minutes after connecting it to power
- Connect with any mobile device to the hotspot “bcMeter” with password: “bcMeterbcMeter”
- After logging into bcMeters Wi-Fi, open a browser at <http://bcmeter.local> and go to “Wi-Fi config”
- Select your own Wi-Fi from dropdown Menu and enter Password
- When “Saved”, bcMeter logs into the specified Wi-Fi within 1-2 minutes and can be reached via <http://bcmeter.local>. The device is now linked to the local Wi-Fi and pushing data to the cloud.

3.2.3. Telraam (v1)

In COMPAIR, we will test the user friendliness of the newly developed [Telraam sensor “S2”](#), specifically to reduce the technology hurdle and to reach a larger audience. However, it is also possible to use the original, open source, Raspberry Pi-based Telraam sensor (v1) which can also be completely self-assembled. As with Sensor.Community and bcMeter, the Telraam v1 components are generic and can be sourced via different channels or purchased as a package. The core component is a Raspberry Pi 3 A+ and a camera module v2. Telraam can provide a 3D-printed camera holder, but also generic Raspberry Pi camera holders are available on the market. A citizen science lab involving Telraam v1, could involve assembly and software installation of the sensor in a workshop.



The component list is as follows (starting top left, clockwise) Black enclosure, Raspberry Pi 3 A+, Raspberry Pi power cable, SD card in adapter, Camera holder - either generic or specific 3D-printed version for Telraam, Raspberry Pi Camera module v2 + cable.



The [Telraam FAQ](#) provides a full step-by-step description of each step of the mechanical assembly process.

Apart from the assembly process, as with bcMeter, software installation can also be done by citizen scientists. In the case of Telraam v1, it involves flashing the SD-drive. As Telraam uses Raspberry Pi as a hardware platform, it's easy to use existing tools to program or install software for Raspberry Pi's, i.e. Balena Etchers. The Telraam v1 software is open source and can be accessed via the Telraam [GitHub](#). However, for non-programers, the software is also available as a simple image which just needs to be flashed using Balena. The procedure is well documented in an [FAQ article](#) on the Telraam-website. The steps involved in flashing the SD-drive are:

Step 1: Remove the SD card from the black box: Unplug your Telraam and remove the micro SD card from the black box. You will probably need tweezers for this.

Step 2: Download the Telraam software: You can download the Telraam software here: <https://telraam-api.net/telraam-sd-image.zip>. Note where this big ZIP file (about 4 gigabytes) has been saved on your computer.

Step 3: Download Etcher: Etcher is a program which you can use to copy the Telraam software in step 1 from your computer to your SD card. It works on Windows, Linux and MacOS.

Step 4: Upload the Telraam software to the SD card: You need a micro SD card reader. Now insert the SD card into your computer's card reader. If you do not have a micro SD card reader on your computer, you can use the adapter that was provided with your Telraam.

Step 5: Insert the micro SD card into the Raspberry Pi: Once everything is ready, you can close Etcher, remove the SD card from your computer and insert it into your Raspberry Pi. Make sure you insert the micro SD card into the Raspberry Pi the right way round, with the metal part facing up.

These steps can be performed together with citizens in a workshop.

More challenging options with Telraam v1 are possible by directly working on the code of the detection script, which is open source on GitHub. This is more interesting for an in depth hackathon for a very niche audience so we do not discuss this further here.

As with bcMeter, there are some 3D-printed components in Telraam v1 (the camera mount) which allow citizen scientists who own a 3D-printer, to make their own Telraam sensor. The design files are available in [Telraam's Github repository](#).

Summarised in this [FAQ article](#) at Telraam, are many of the DIY outdoor variants of Telraam v1 that have been attempted. This article can function as an inspiration to organise citizen science labs with the sole purpose of making modifications to the sensor that can be made suitable for outdoor use.



3.3. Summary sensors DIY labs

This chapter provides a list of potential citizen science labs, focused on the sensors used in COMPAIR. Potential activities range from low threshold with minimal skill-level to very niche with specific skills, required from the citizen scientists. The table below is a non-exhaustive list of potential sensor DIY labs in COMPAIR:

<u>CS DIY lab</u>	<u>Skill level</u>	<u>Recommended format</u>	<u>Specific requirements</u>
Telraam S2 sensor installation instructions	low	Workshop (max 50)	none
SODAQ AIR sensor installation instructions	low	Workshop (max 50)	none
OnePlanet NitroSense sensor installation instructions	high	On location where the sensor is installed	Preferably with guidance for installation in situ
Sensor.Community sensor self-assembly	medium	Workshop (max 20)	Option for in depth labs with soldering
bcMeter sensor self-assembly	medium/high	Workshop (max 20)	Option for in depth labs with 3D-printing
Telraam v1 sensor self-assembly	medium/high	Workshop (max 20)	Option for in depth labs with 3D-printing or software adaptations

4. Sensor data

COMPAIR's low-cost sensors will provide a wealth of data that are not only waiting to be analysed by the project's researcher and domain experts outside of the project, but also the citizen scientists themselves engaged in COMPAIR.

While the previous section focused on data gathering and how citizen science labs are set up in the context of sensors, in this section, we discuss citizen science labs focused on the sensor data collected.

We first briefly discuss low cost sensor data and interpretation, and then proceed to provide options for citizen science labs on data analysis.

4.1. Introduction to data interpretation

Compact low-cost air quality sensors used in citizen science projects have simple measurement principles, and as such, their response may suffer from sensitivity to their environment (temperature, humidity, interfering pollutants), as well as drift during their deployment. In COMPAIR we plan to calibrate the data from the SODAQ AIR and OnePlanet NitroSense sensors to minimise these influences (such as sensitivity and drift). To do so, these sensors will be co-located with high-end reference stations and the sensor data acquired during this period will be used to train a calibration algorithm which will be applied to the sensors when deployed in the pilot regions by the citizens.

However, the devices typically used in citizen science projects will be less accurate, even with calibration. To compensate for this, the following quality assurance steps can be performed:

- Determine the device's precision
- Determine the device's accuracy
- Identify outliers (faulty or erroneous data)

These concepts are explained more elaborately in COMPAIR's [Guide to air quality monitoring \(D5.1\)](#), and an overview of the process is provided below. These can be the first steps in any data workshop with citizen scientists and will help them in understanding the value but also limitations of the measurements they conducted.

4.1.1. Determining precision & accuracy

A device is considered precise when multiple devices of the same type yield comparable results. A device is considered accurate when it yields results comparable to a high quality reference measurement (e.g. the official monitoring network in your country).

The ideal way of determining precision and accuracy is by conducting a field test prior to your citizen science experiment. The LIFE VAQUUMS¹ project developed a [test protocol](#) for this purpose, it contains both lab and field testing protocols. Lab testing can be ignored in light of citizen science experiments. This protocol recommends deploying 3 devices at a

¹ https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=6159

reference site for a long enough period (long enough = variation in concentrations that is expected during the experiment) and calculating accuracy and precision metrics as described in the document.

This rigorous approach is not always feasible in a citizen science project and might increase timing or costs beyond what is tolerable. A trimmed down accuracy and precision check can therefore be done by looking at how well the data compares between devices (precision) and to the reference (accuracy) at times when concentration levels in the project area are very similar. We recommend using the official monitoring network's data to look for moments when all sites in a region have comparable levels of pollution. Typically you can expect these at night (because of the absence of local sources) and on rainy days, but exceptions can occur. You can then do a qualitative assessment of how well the devices match among themselves and to the reference measurements, taking note of an overall under- or overestimation.

4.1.2. Identifying outliers

To identify outliers, have a critical look at your data and ask the following questions:

- Does a specific device differ strongly from the others?
- Do you see very high spikes?
- Is there a pattern in pollution peaks occurring?

Investigate these events and assess whether you can consider these measurements valid. Whether you consider a measurement valid actually depends on what you are trying to achieve, i.e. when trying to elucidate traffic impact on air quality, you can consider high particulate matter concentrations due to road works as invalid data. It is also well known that on foggy days, air quality sensors will overestimate the particulate matter concentration. This can also be a reason to reject data on such days.

These data interpretation aspects are guiding principles when performing citizen science labs. It's highly recommended to involve domain experts in the preparation and preferably execution of the citizen science labs, to avoid pitfalls in data interpretation by non-experts.

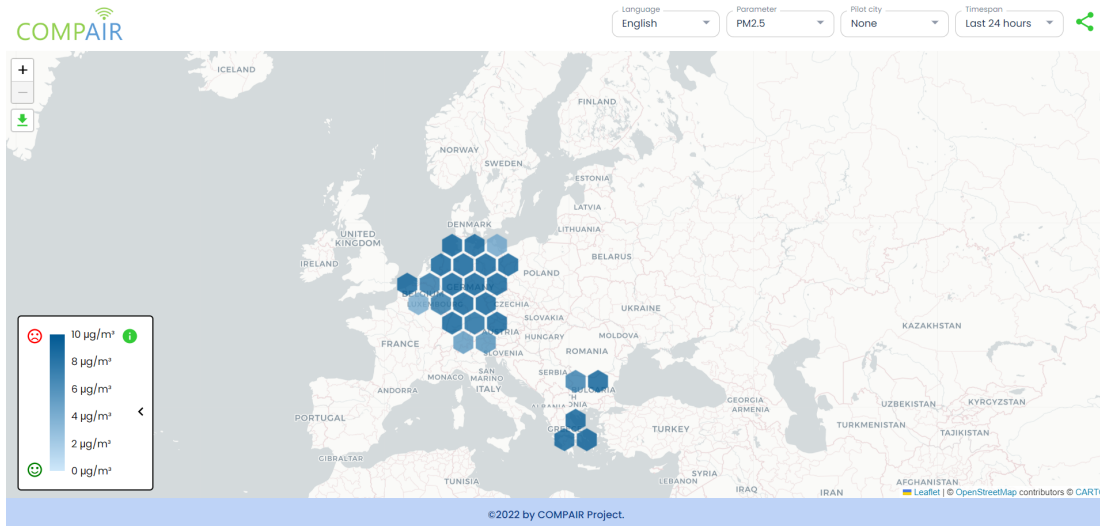
4.2. The COMPAIR dashboard

First, the lowest threshold citizen science lab focusing on data, is just to start from COMPAIR's data dashboard. It already provides indicators and insights from the sensor data, allowing for simple interpretation by non-experts.

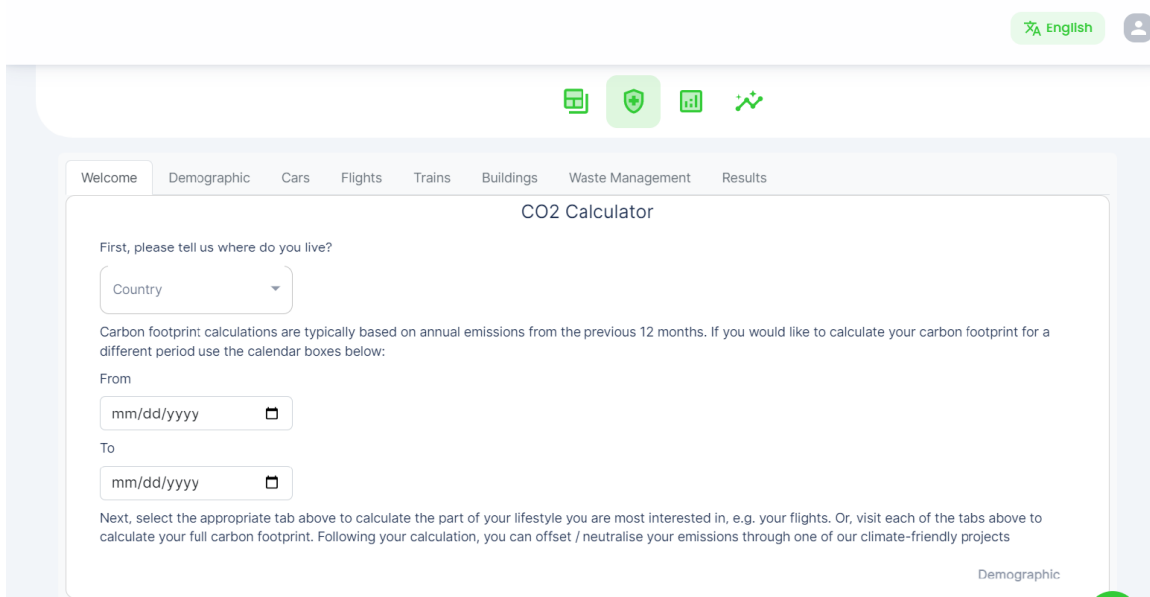
COMPAIR provides historical and real-time information directed to target groups, i.e. governmental organisations, businesses, academia and citizens as has been identified in deliverables [D2.1: "Value Network Canvas"](#) and [D2.4: "Pilots Operation Plan"](#), focusing on awareness-raising and communication, behaviour modelling and policy development by creating easy to understand and scientifically sound dashboards. More specifically, COMPAIR has released the following two dashboards:

The **Policy Monitoring Dashboard (PMD)**: enables users to interact with the citizen science (CS) data coming from different sensors in order to help users understand and compare how environmental situations change under different actions. The PMD is described as a tool that

manages and processes air and traffic datasets and enables the concise reporting, accessing, visualisation and analysis of the data. As a result, the users are able to generate data reports, visualise and share the data. The Policy Monitoring dashboard is customizable to specific user requirements and presents an easier way to apply analysis to data, interpret data from different sources and disseminate data appropriately - all of which assist with important project decision making.



The **Carbon Footprint Simulation Dashboard (CO₂)**: is designed to support specific experiments around carbon footprints or indeed footprint for any chosen air molecule. Visualisation of algorithm results help users see and compare how future CO₂ and other pollutants' emissions will change based upon different individual actions, e.g., washing during day or night, driving or cycling, recycling food, plastic, paper, glass, etc. The aim is to guide user behaviours towards more environmentally friendly choices like limiting waste and maximising recycling, replacing polluting stoves and ovens with less energy consuming household appliances, opting for a more environmentally friendly car use (car sharing), etc.



Both dashboards are available under <https://monitoring.wecompair.eu/> and instructions on how to use them are available in deliverable [D4.2: Digital Twin CS data integration and prototype 1²](#).

Citizen science labs focussing on COMPAIR's sensor data using the COMPAIR dashboard can be very low threshold. Engagement/interaction options are limited to interacting with the dashboard directly (e.g., setting different time periods and investigating data for a local subset of sensors). Formats should allow to engage a wide audience and specifically involve lower SES-groups as well.

4.3. Interpreting sensor data

This chapter provides options for citizen science labs with data interpretation, beyond the dashboard itself. We'll distinguish between the two main types of data in COMPAIR: air quality and traffic data.

4.3.1. Air Quality

In spite of assuring the quality of your measurements (e.g., through calibration, outlier detection, etc.), just visualising the data you collected will not result in clear conclusions. Interpreting what you see can often be the most difficult step in the process. Whether you are a citizen scientist or guiding citizen scientists through this process, these are some examples of analyses that you can do (e.g., in the second part of a data workshop) either using COMPAIR tools, Excel, a statistical package such as [R](#) (and the [openair](#) extension) or any combination thereof:

- **Time series:** represent the evolution of your measurements over time. Use this visualisation to explore your dataset and look for phenomena occurring over time
- **Boxplot:** displays the distribution of all measurement values (e.g., for a single device) in relation to the mean, median and certain quartiles. Use this visualisation to compare the overall distribution of pollution (or traffic) levels across devices
- **Correlation plot:** compares the (cor)relation between two datasets. Typically used to look for a (linear) relation between two parameters, e.g., motorised traffic and black carbon
- **Daily averaged plot:** displays the average measurement value for each hour of the day for one or more of your devices. It thus represents the “average day” for that device in the given measurement period. Often divided further into weekday vs. weekend day or even each day of the week. Typically done for the entire measurement period, individual seasons or individual months. Used to look for continuously occurring patterns (e.g., rush hour peak at traffic sites) and differences in patterns between devices/locations, which may indicate the existence of local sources

Many more visualisations and analyses exist. COMPAIR dashboards present specific visualisations tailored to the impact assessment of local measures. A good starting point to explore additional analyses is the aforementioned [openair](#) package for R.

² Updated version of this report will be available at the end of June 2023

4.3.2. Traffic

Traffic data in COMPAIR is coming from the Telraam-sensors. Telraam has been used in citizen science settings before this project and as such, scripts are available for citizen science labs, working on the traffic counting data produced by Telraam. One of those is the format of a “data workshop”, together with sensor-owners as well as residents of the area with knowledge of the local (traffic) situation. This data workshop follows a fixed script with four main blocks:

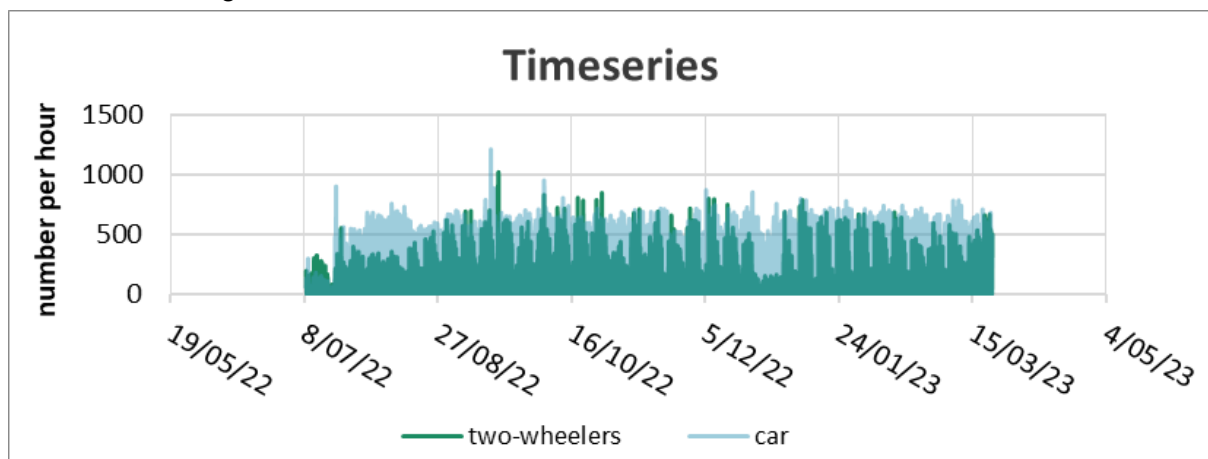
1. Recap of the data collection campaign (i.e. how many devices deployed, amount of data collected, location of sensors)
2. An introduction to (generic) data-analysis techniques for traffic counting data
3. Examples of analysis for the sensors owned by the participants
4. Interactive component with additional analysis in the workshop, based on discussions with the participants

To highlight some aspects, we explain the data-analysis techniques for traffic counting data used in those data workshops, including what can be learned from it and what are the draw-backs of each approach.

Technique 1: Time-series analysis

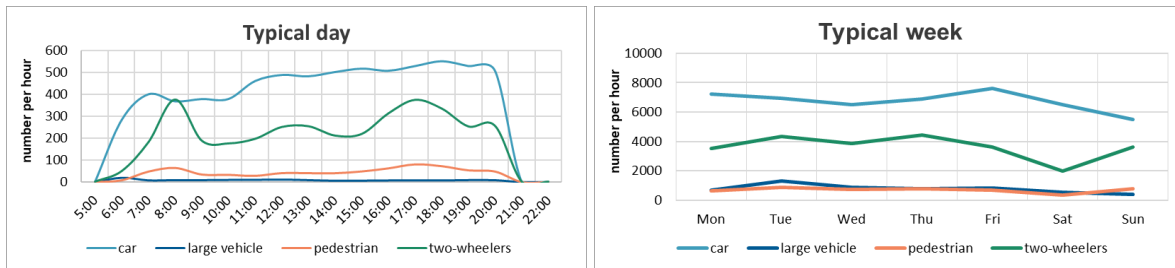
A raw data time series plot allows for an “on the glance” view of how traffic has evolved over time. It’s typically quite stable, with logical patterns with reduced traffic during weekends and holiday periods. As such, time series allow us to quickly spot deviations to the patterns that can trigger a deeper investigation.

In the example below, it is evident that traffic increased at the end of August which could hint at an event/change.



The risk with time series is that (faulty) outliers can obscure the overall picture. Caution is always needed when looking at raw data. Specifically for Telraam, counting traffic only during daylight, daily totals will thus also exhibit a seasonal variation (with hours of sunlight). For that reason, it’s always better to plot hourly traffic data from Telraam.

Technique 2: Typical profiles



Typical traffic profiles can be derived when selecting a long time series. For traffic, typical profiles make sense at a daily level for each day of the week and at an hourly level for weekday/weekend. The former allows the interpreter to understand what days of the week are the busiest. Usually, weekdays have similar intensity, with Saturday's lower level and Sunday's the lowest of traffic volumes. However, deviant traffic patterns are nonetheless common, for example roads with increased traffic on Saturday due to nearby shopping areas.

For the intra-day traffic pattern, the most common pattern is the one with a short and sharp morning peak and a less pronounced but longer evening peak. Also for the daily profile, there are other patterns possible such as a peak near lunch or an earlier peak of bikes, signalling the presence of a school nearby.

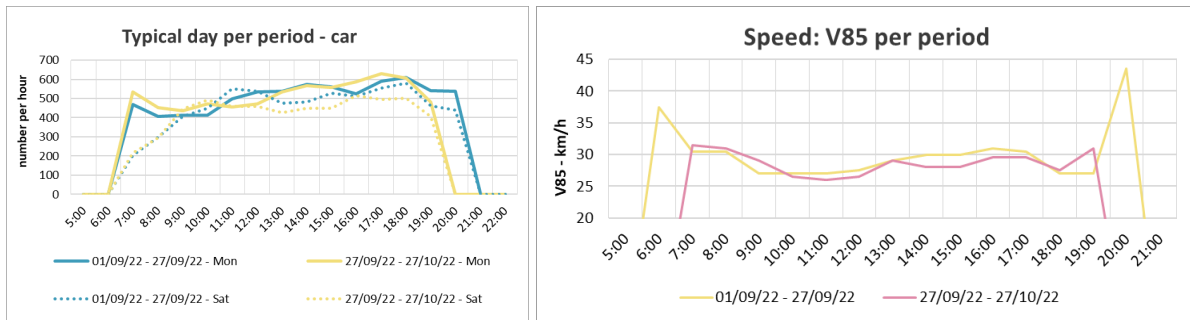
This technique can be really valuable to assign a "typology" of the street-segment measures.

The risks associated with typical traffic patterns, is of course that you have to select a representative time period for which you want to understand what the typical profile is. This is different during a holiday period, for example. Also, any traffic-related events during this period will be "masked" and invisible. For this reason, it's important to combine different data analysis techniques.

The citizen science lab, in a workshop format, allows for interaction between researcher and citizen scientist, helping to understand observed patterns, especially when they seem counterintuitive. The knowledge of the citizen scientists of the local traffic situation can be extremely valuable to help the researcher to interpret the data. Such workshops represent a "win-win situation" for researchers and interested and engaged citizens. They also portray the essence of Citizen Science where everyone benefits and participants who are interested are able to join not only during data collection, but also at several stages of the research project.

Technique 3: Comparing periods

A third generalised analysis technique for Telraam traffic data, builds on the previous one: comparing typical profiles of two distinct periods. This is particularly useful if an intervention or change has happened which is expected to influence traffic patterns. In such a case, you typically select a period of a few months before the intervention, as baseline, and a few months after the intervention. In the figures below, you'll see daily typical traffic for two periods (left) and typical speed profiles for 2 periods for a period before the introduction of traffic calming measures. Such a comparison allows the interpreter to understand if the measures have had any effect.



The same risks apply for this technique, i.e. the selected time interval should be appropriate to derive a typical traffic profile and any changes with the selected period are masked.

The Telraam-platform can generate these graphs in an MS Excel format and these can be generated on the spot during workshops, taking just a few minutes to generate. This allows for the 4th block of a “data workshop”: interacting with sensor owners and local residents to investigate specific streets segments for specific periods, to verify changes to traffic patterns, based on local knowledge of the participants, with data.

This type of citizen science lab can be low threshold, as the researcher is the one pulling the traffic data analysis, so provides a good opportunity to involve lower SES-groups as well.

4.4. API's

API stands for “Application Programming Interface” and is used in this context for access to data directly from the source (i.e. cloud database) to extract and process data for interpretation and in some cases design of other indicators and new data dashboards. Obviously, interacting with an API requires programming skills, so citizen science labs working with API's will have a niche audience of programmers. In this section, we briefly describe options of API's in COMPAIR.

4.4.1. COMPAIR's data manager

To facilitate groups of citizens to get as much value as possible out of the sensors and the citizen science project as a whole, the data used in the different tools and dashboards will be made available through an open API. As such, the data can be used in dashboards and/or tools built by citizen scientists.

Choosing the OGC Sensorthings API³ between different components in the COMPAIR toolkit facilitates this, as it's the de facto standard for all things sensor, it's well documented and there is great tooling available, e.g., Fraunhofer's FROST server⁴.

At the time of writing this deliverable, the API is not yet publicly available and documented. It's foreseen to write documentation similar to the British Geological Survey Sensors API⁵.

³ [Link to the standard](#)

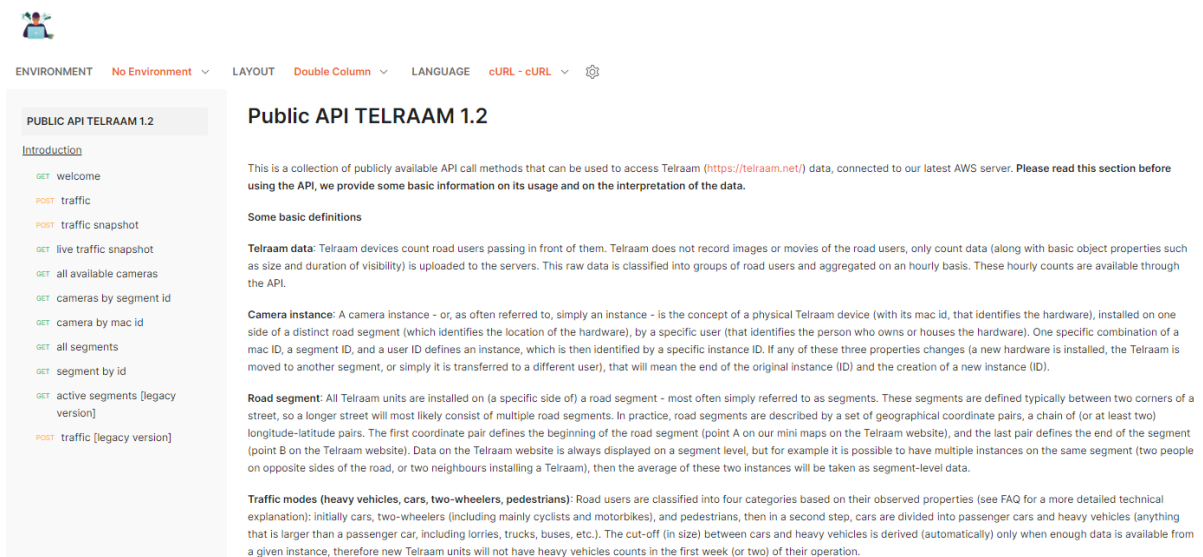
⁴ [FROST home page](#) and [Github home](#)

⁵ [OpenAPI documentation](#)

4.4.2. Telraam API

While Telraam data are accessible via COMPAIR’s data manager, there’s also an open API directly to the Telraam data. This API has more “end points” (i.e. data interactions with the database), allowing more options to design own data productions or analysis.

Telraam’s API is well documented using [PostMan’s documenter](#):



The API includes definitions of terms used, so no prior knowledge about Telraam or traffic data in general is required. Also, it includes Python code snippets which can be used by users not experienced at all with coding. The Telraam API is mature and has been used extensively in the past. As such, it is streamlined and fine tuned for immediate use. Examples of applications include the development of own dashboards, inclusion of Telraam data in existing home-dashboards and data analyses, by university students. The [Telraam Talks platform](#) includes forum discussions with other API users to exchange experiences.

COMPAIR citizen science labs using the Telraam API could be a hackathon for a niche audience, providing challenges to produce specific outputs. However, given the well documented API and easy to understand data, the Telraam API can also provide a generic use case, training citizen scientists and/or students how to work with datasets, potentially as an introduction to coding (e.g., Python), directly with real world data.

4.5. Summary data

This chapter provides a list of potential citizen science labs, focused on the data from sensors used in COMPAIR. Potential activities again range from low threshold with minimal skill-level to activities requiring indicative specific skills from the citizen scientists. The table below is a non-exhaustive list of potential citizen science labs focussing on data in COMPAIR.

<u>CS DIY lab</u>	<u>Skill level</u>	<u>Recommended format</u>	<u>Specific requirements</u>
COMPAIR dashboard	low	Workshop (max 50)	none
Air quality data analysis workshops	medium	Workshop (max 20/30)	Preferably with domain expert
Traffic data analysis workshops	medium	Workshop (max 20/30)	Preferably with domain expert
API's	high	hackathon	Requires involvement of data scientist(s)

5. Conclusion

This report provides an overview of citizen science labs in the context of the COMPAIR project. We outlined a few different formats possible, focussing on sensors and/or data. Citizen science labs in COMPAIR can be shaped to serve different types of audiences of citizen scientists, specifically including lower SES-groups as well with simple sensor hosting (e.g. Telraam S2, SODAQ AIR), basic sensor assembly (e.g. Sensor.Community) or basic data analysis using the dashboard. On the other hand, the components in COMPAIR also allow for in-depth citizen science labs for a more skilled but niche audience.

This report focuses on the used IoT sensor roll-out and the related data-gathering actions and possibilities of COMPAIR. The results of the Citizen Science experiment and its impact on policy and society aren't discussed. Still, they will be part of future actions in WP6, "Environmental Benefits Realisation and Impact", and WP7 "Scientific, Public and Ethical Recommendations". As a result, the use and outcomes of Citizen Science activities will go beyond the IoT Citizen Science device roll-out, data gathering and interpretation.