DELIVERABLE

D8.4 Advanced Exploitation Plan

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Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
BC	Black Carbon
C&D	Communication and Dissemination
CDE	Communication, Dissemination and Exploitation
CD4E	Communication and Dissemination for Exploitation
CO2	Calculator Carbon Footprint Simulation Dashboard
DEVA	Dynamic Exposure Visualisation App
DEVD	Dynamic Exposure Visualisation Dashboard
EU	European Union
EC	European Commission
MOOC	Massive Open Online Course
ML	Machine Learning
NO2	Nitrogen Dioxide
OGC	Open Geospatial Consortium
PMD	Policy Monitoring Dashboard
PM	Particulate Matter
USP	Unique Selling Point
WHO	World Health Organisation

Executive summary

Exploitation is different from communication and dissemination (C&D) in that it aims to make project results not just known but also used by target audiences. Continued use of results is what ultimately makes a project sustainable. As long as our results are used after the project, COMPAIR will continue to exist even though we will no longer be around as a consortium of 15 partners.

The scale of exploitation determines the potential for sustainability. If results are bad, are limited in number, and have few stakeholders interested in them, sustainability will be hampered and impact short-lived. By contrast, results that are valued and widely used across different communities will last longer and will continue generating impact long after the project has ended.

Exploitation framework: COMPAIR understands exploitation in a broad sense, as the use of results by citizens (social exploitation), researchers (scientific exploitation), policy makers (policy oriented exploitation), innovation communities (technical exploitation) and companies (commercial exploitation). Such a broad focus makes our framework resilient as we de-risk our sustainability by making it less dependent on any one pathway. The breadth creates opportunities for results to be used by more than one community. So, if some pathway is deemed a poor fit for a particular result, it still leaves four other options where the fit may be better.

Project results: COMPAIR results are spread across six categories: apps and dashboards, sensor improvements, citizen science data, technical processes (data calibration and management), written outputs, and other results e.g. online courses, landing pages. In this deliverable, we show that all results are conducive to multi-use and measures are being taken on different levels (pilot, technical, CDE) to achieve scale.

Improvements: With regards to technical tools, for example, some of our dashboards are on par with competitors in some aspects. But there are also things we can add/improve to make them better. For Policy Monitoring Dashboard (PMD) we propose aligning the AQI limits to EU standards, adding calls to action and filters for active/inactive sensors, creating more options for users to engage with sensors and their users, and specifying how PMD data should be used (data policy). The main recommendation for the Carbon Footprint Simulation Dashboard (CO2 Calculator) is to integrate elements of environmental psychology to turn the tool into a vehicle for behavioural change. For Dynamic Exposure Visualisation App (DEVA) developers, we have one encouraging and one worrying finding (respectively). DEVA faces almost no competition, however the market is strewn with ‘dead’ apps that tried but failed to survive. We therefore need to treat the lack of competition with cautious optimism. Why are there no consumer apps left in this space? Perhaps social exploitation is not the right pathway for these kinds of apps, which may have a better fit in the innovation track. One tool we didn’t cover in D8.4 (but will include in the next edition) is Dynamic Exposure Visualisation Dashboard (DEVD) as it’s a new app that was developed recently.

CD4E: For all its importance, exploitation needs C&D because results with poor visibility, risk remaining unknown and therefore unused. D8.4 outlines several measures, from dissemination platforms to learning resources to pilot channels, that will help results to be discovered and used by potential adopters.

1. Introduction

Advanced Exploitation Plan continues the work started in the previous edition towards project sustainability. The main objectives of D8.4 are to:

- Explain how exploitation is understood in COMPAIR
- Give an overview of project results and mechanisms by which to sustain them (exploitation pathways)
- Capture partners' views on exploitation by identifying their preferred results and plans for the future
- Conduct a market analysis of similar solutions to understand what our competitors are doing and what we can learn from them
- Explain how project-level communication and dissemination, as well as pilot channels, can be leveraged to support exploitation (CD4E)
- Critically examine online learning platforms to see which ones best meet our MOOC requirements[1]

Exploitation can take many forms. In COMPAIR, we take a broad view on exploitation to account for different possible uses of our results: by policy makers, by scientists, by innovation communities, by citizens and civil society representatives, and by for-profit organisations looking to generate additional income. We therefore distinguish five exploitation pathways.

Societal: Results used by citizens to inform individual mobility habits and lifestyle choices; by citizen groups to keep the community spirit alive; by schools to improve the curriculum; by citizen science practitioners to start new or improve existing projects.

Policy-oriented: Results used by public authorities to fine-tune or evaluate a policy measure.

Scientific: Results used by researchers to present the state of the art or to corroborate their findings in a publication.

Technical: Results used by innovation communities to enhance existing services or create new ones e.g. platforms re-publishing our data, developers reusing our code or blueprints to design apps/dashboards.

Commercial: Results used by companies to find new customers and generate revenue.

An important thing worth noting about this framework is that it depicts an ideal-case scenario that may not be realised in some of the tracks. For example, if product owners (technical partners) choose to protect their results by keeping the source code closed, this move will affect opportunities for wider reuse. However, it will not eliminate all exploitation opportunities for the result in question. What it means is that the nature of exploitation will change from 'open and unrestricted' to 'conditional and partner-led.' To know which results fall in the latter category, we surveyed all partners ahead of the project meeting held in Sofia in September 2023, asking questions about IP, planned protection mechanisms, collaboration requirements, and more. We present the findings later in the report, after a brief overview of project results.

[1] COMPAIR MOOC was identified as a critical vehicle for exploitation in the previous edition

2. Project results

To have a meaningful discussion about exploitation it is important to first have a complete understanding of all possible outputs that will come out of the project. As outputs will vary in importance and their potential to generate impact, it is useful to identify a subset of results that will help COMPAIR stand out as a citizen science project.

COMPAIR is a multi-dimensional project with a broad set of results spread across six different categories (Figure 1).

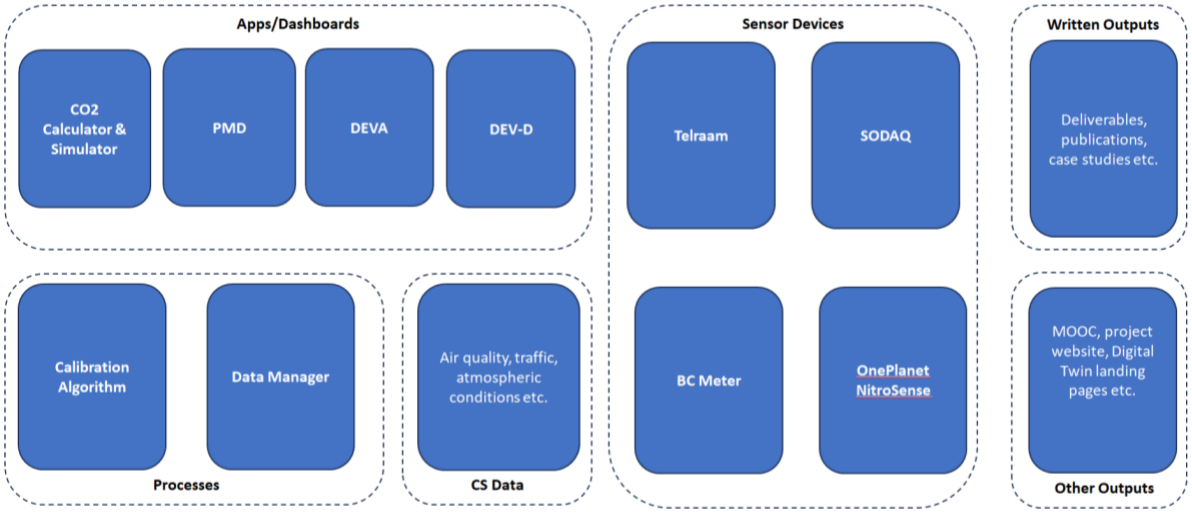

Figure 1. COMPAIR results

Apps/Dashboards
These include four purpose-built digital tools:

- CO2 Calculator measures individual's carbon footprint and simulates actions needed to achieve Green Deal targets
- Policy Monitoring Dashboard (PMD) analyses the impact of policies on traffic and air quality
- Dynamic Exposure Visualisation App (DEVA) uses AR to visualise air pollution in one's immediate surroundings
- Dynamic Exposure Visualisation Dashboard (DEV-D) shows safe and dangerous (polluted) routes recorded with DEVA and/or mobile sensors

Sensor Devices
COMAIR is using various monitoring devices to collect air quality and traffic data:

- Telraam sensors V2 and V1 for measuring traffic
- SODAQ AIR for static and mobile measurement of particulate matter
- OnePlanet Nitrosense for measuring nitrogen dioxide
- BCmeter for measuring black carbon
- *sensor.community* kit for static measurement of particulate matter

All devices except the *sensor.community* kit have seen improvements that can be directly attributed to COMPAIR. These are mostly firmware and software upgrades introduced to meet project requirements. So, when we refer to sensor devices as results, we mean improvements in the performance of these sensors that were achieved as a result of the project.

Citizen science data
This is data collected by volunteers during pilot campaigns i.e. open round, public round. What data is being collected depends on the case study. It's not unusual for pilots to mix and match sensors in a single use case. Whether it's a school street in Herzele or a bus route in Sofia, scenarios chosen by pilots tend to feature both air quality and traffic measurements collected by mix of COMPAIR sensors selected based on their appropriateness for each specific case study.

Processes
Two 'technical' processes were put in place to enhance the value of citizen science data

- Data calibration/harmonisation improves the measurements of low-cost sensors by comparing their readings with those of official monitoring stations. Calibration takes place in the cloud using a multilinear model which considers reference data plus environmental conditions and historic patterns to adjust low-cost sensors' performance
- Data management covers several important tasks that help to 1) acquire data from sensors, 2) convert data into a relevant standard where the data is accompanied by relevant metadata - the OGC Sensorthings API OGC standard[2] in the case of, for example - and 3) transfer data to the apps/dashboards via web sockets and APIs

Written outputs
These are all the official project reports combined with internal deliverables like policy briefs and case studies, as well as publications.

Other outputs
Included here is a mix of official and internal deliverables that can be written or technical in nature, and that don't fall neatly into any of the other categories. Examples include the online course, the project website, and landing pages for the four apps.[3]

3. Exploitation survey

The breadth of our results collection is remarkable. What about the depth? Is it spread equally or do some results carry more weight and are deemed more impactful than others? To understand these differences/nuances and get a sense of what partners would like to do with the results in the future, a questionnaire was sent to the consortium ahead of the meeting in Sofia.[4] 18 people answered the survey.

[2] https://www.ogc.org/standard/sensorthings/
[3] https://monitoring.wecompair.eu/
[4] DEV-D wasn't included in the survey but, after the meeting, it was added to the list of results as some partners deemed it a 'critical' output

Ranking of results

The first question ranked different results based on their perceived importance: critical, quite important, somewhat important. The actual question was: ***Which of the following results will help COMPAIR stand out the most as a citizen science project*** (Figure 2)? Critical results with the highest number of votes (n=11) are CS data, PMD, and BCmeter, followed by SODAQ and calibration algorithm (10 votes each), and Telraam (9 votes).

Only 4 people deemed CO2 Calculator critical because the link between citizen science and the tool was not apparent. And of all the sensors improved by COMPAIR, OnePlanet NitroSense is least critical (6 votes) because it is more expensive and not ready for citizens to operate.

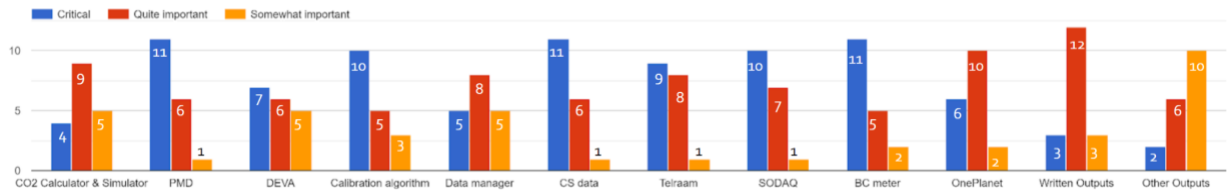

Figure 2. Perceived importance of COMPAIR results

In their responses, partners suggested that what would make COMPAIR stand out even more is a combination of critical results, such as SODAQ-DEVD integration, or the display of BCmeter data in PMD. Both these suggestions are in progress and planned to be undertaken during upcoming developments to these dashboards.

Partners also said that in contrast to reports and behind-the-scenes technical outputs like the data manager, apps and dashboards are tangible results with great visuals, and so are more likely to appeal to a wide range of audiences. However, the tools' uptake is conditional on them being useful and easy to use, two things that still need to be improved if the tools are to have a chance of establishing a foothold in a competitive market.

A few partners were quite pragmatic about digital tools, saying that without significant improvements and guaranteed funding for post-project development and maintenance, there is a risk that PMD, DEVA, DEVD and CO2 Calculator - being new apps/dashboards in a very crowded landscape - might fail to reach a critical mass of users needed to achieve mainstream adoption. An app which is not used is quickly forgotten. That's why this group of partners advised against pinning too much hope on digital tools as main drivers of sustainability. In their opinion, sensor data and intangible results (e.g. knowledge and awareness gained, lessons learned, methods tested in real-life environments) should be viewed more favourably because they are technology-agnostic and therefore lend themselves to wider reuse.

Reflecting on the policy impact, some partners demonstrated a degree of optimism, saying that even if results are not immediately used by decision makers (e.g. for fear that data is still of questionable quality), COMPAIR has nevertheless managed to plant a seed of change in attitude towards citizen science that will come to fruition in the future.

Intellectual property

Results that use partners' background IP[5] are

- ***PMD and DEV-D :*** software components by ATC
- ***CO2 Calculator:*** methodology, data and software by UAEG
- ***Telraam:*** software and hardware by Telraam
- ***DEVA:*** AR visualisation techniques and processing workflows by HHI
- ***Data calibration:*** cloud-based correction algorithms by imec

Partners that would like to apply some kind of protection to foreground IP present in the results are imec, Telraam, HHI, and ATC.

Imec's position is that interested parties are free to use calibrated data generated during the project and other know-how available, such as methodologies in public deliverables. But if they want to use imec's services post-project, a new agreement will be needed. Essentially, imec is willing to provide data calibration for a fee.

Telraam is protecting software used in the sensors and it is also the ultimate owner of traffic count data, which is currently licensed under CC BY-SA 4.0.[6] The licence allows for commercial exploitation, requiring users only to attribute and 'share alike' i.e. share under the same conditions if they remix, transform or build new products/services upon the data.

HHI developed new methods for visualising air quality data in 3D AR environments. Better data processing workflows for managing, sorting and handling data for optimal AR visualisation strategies were also developed as part of the DEVA pipeline. It is this foreground IP that HHI wants to protect through a combination of copyrights and a source-code licence. These restrictions notwithstanding, HHI thinks that DEVA pipeline has a promising potential as an AR data-visualisation framework for Unity.

ATC's position is that interested parties are free to use PMD and DEV-D developed during the project and other know-how available in public deliverables. But if they want to use the products after the project, a new agreement will be needed. ATC is planning to apply a non-exclusive, non-transferable licence to the source code used in PMD and DEV-D.

Collaborations and future plans

The survey asked partners if they foresee joining forces on exploitation after the project. Most partners are in principle interested in working with others if the right opportunity comes. Three partners were quite specific in terms of who they want to work with:

- VMM, DV (imec)
- ATC, DV, inter3, 21C, UAEG (HHI)
- Telraam, DV, ATC, HHI, ECSA (inter3)

At the partner exploitation workshop in Sofia (organised as part of the consortium meeting in September 2023), VMM expressed interest in using PMD after the project internally and, if the tool is mature enough, also in offering it to local authorities across Flanders. However, VMM is conscious that the uptake is not guaranteed, with data quality being a prime concern among policy

[5] Background IP is any prior knowledge, product or service used to create shared outputs in R&D collaborations.

[6] https://creativecommons.org/licenses/by-sa/4.0/

makers. To succeed, data calibration will be necessary (imec's service) plus cities must feel like they are in control of what is being measured, where, and how. This may lead to a new arrangement in the management and governance of a low-cost sensor network where 'top-down' involvement has a bigger role to play than is currently the case in a typical citizen science project.

Finally, the survey was an opportunity to check what specific plans partners have towards 'critical' and 'quite important' results (Figure 3). 16 respondents said they will use them to write a new project proposal, 15 said they will reuse them in another project (e.g. Urbreath H2020 EU project) where DV and ATC are partners), and 14 said they will showcase results at conferences and events. Other exploitation options include adding results to existing products and services (8 respondents), bolstering training and capacity building activities (7 respondents), integrating results into decision making, and creating new publications (6 responses each), developing a business plan, and using results for personal benefit (1 response each).

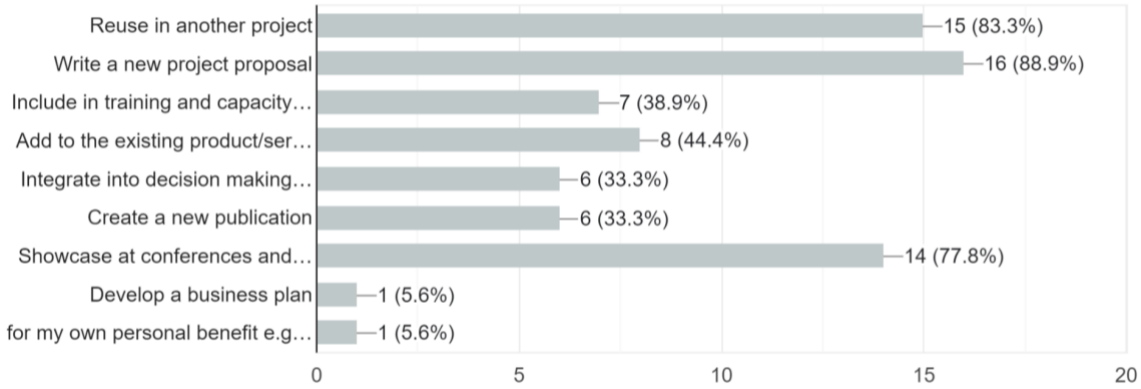

Figure 3. Intended use of results by partners

The main **conclusions** we can draw from the survey and the follow-up workshop are:

- Although there is a general agreement that technical outputs are important for exploitation, some partners worry that our digital tools may struggle to survive in a competitive market without significant support and improvements
- While PMD already received advance interest from potential adopters, other tools still have some way to go before they are ready to use outside the consortium
- IP protection will be applied to some technical outputs which will limit wider reuse in some specific tracks but not across the board. For instance, limitations placed on PMD's source code will affect reuse among developers but not among citizens, policy makers or researchers
- Some technical partners have shown interest in monetising their products and services but as yet don't see how this can be achieved through existing tools and arrangements
- Results expressed in writing may be less visually appealing and engaging than apps and dashboards, but they do contain a lot of knowledge and know-how generated during the project which can be applied in different contexts in the future; thus stimulating their exploitation is an effort worth making

These conclusions guided the focus of the next four chapters:

- ***Chapter 4: Air quality dashboards*** includes a review of 5 popular air quality visualisation platforms that display data from low-cost sensors and can be considered as PMD competitors. Findings from the review are distilled into recommendations for improving PMD, including how it may be used as a vehicle for commercial exploitation
- ***Chapter 5: Perceptions of CO2 calculators*** is based on a literature review of past studies that assessed effectiveness of CO2 calculators from a user perspective. We use the main conclusions from these studies to highlight areas for improvement in our own tool
- ***Chapter 6: AR apps for air quality*** includes a brief horizon scan of an almost non-existent landscape of apps that qualify as DEVA competitors (or what's left of them). Past solutions that looked promising disappeared from the market. Those that currently exist are AR apps for air quality in name only. We try to understand why, despite early enthusiasm, the field remains incredibly undeveloped
- ***Chapter 7: Platforms and pilot channels*** is where we a) identify a number of third party resources to stimulate exploitation of written and other outputs and b) give an overview of pilot efforts to sustain and scale their results

4. Air quality dashboards

The survey showed that PMD is considered a crucial output by more people than other digital tools. Moreover, VMM already expressed interest in offering the dashboard to local authorities in Flanders after the project. All these signs bode well for PMD. However, there is no room for complacency. Even if PMD gains steam in Flanders, what about other pilots? Citizens in Athens, Berlin, Plovdiv or Sofia who want to monitor air quality in their neighbourhood have many alternative sources of information to choose from. Why would they go to PMD and not a competitor dashboard that also visualises citizen science data?

To understand what makes PMD unique, as well as its shortcomings, we carried out an in-depth review of PMD-like dashboards. The draft exploitation plan identified some two dozen platforms that share air quality data. We went through the list recently and discovered that some have been discontinued e.g. AirBezen, Mechelen Meet Mee, CurieuzeNeuzen. Some specialise exclusively in data from national environmental agencies (e.g. World Air Quality Index) and so are out of scope because of absence of citizen science sources. Some are mere copies of the sensor.community platform e.g. HasselAIR, Luchtpijp. Some specialise in odour pollution (e.g. OdourCollect), thus are also out of this deliverable's scope. After removing these entries, we are left with a modest but much more relevant sample of five platforms: PurpleAir, Clarity, IQAir, OpenAQ, and SmartCitizen.

Individually and as a group these five make an interesting case for comparison because they:

- Share citizen science data, sometimes in combination with government data (multiple data sources);
- Focus on air quality and other conditions/nuisances like noise pollution (multiple data types);
- Cover all or some of the pilot cities (multiple locations);
- Invest in data quality (calibration); and

- Use the platform to drive sales (commercialisation potential) and engagement (community hub).

In other words, they offer what we are already doing and want to achieve with PMD. By studying them, we will be able to identify which PMD features should be highlighted as our Unique Selling Proposition (USP) (if it's a strength), which ones should be improved (if it's a weakness) and which ones should be added (if currently missing). Crucially, if we manage to turn these insights into actual improvements, PMD will become even more appealing both as a go-to platform for citizen science data, and a potential revenue source for partners like SODAQ, Telraam and imec, as well as third parties that manufacture low-cost air quality sensors.

What will follow is a discussion-cum-critical appraisal of the five dashboards, centered around these six points:

- ***Data:*** which sources are present (citizen science, government);
- ***GEO:*** which COMPAIR pilots are covered;
- ***AQ data:*** which pollutants are monitored;
- ***Other data:*** not related to air pollution;
- ***Analytics:*** how data is presented/visualised; and
- ***Other:*** anything else that the dashboard is doing differently and that may be worth copying.

PurpleAir

PurpleAir is a US-based company selling sensors for indoor and outdoor particulate matter (PM) monitoring. Unit price varies from USD 200-300. This can still be considered low-cost because professional equipment can easily cost 10-20 times as much.

Data: Data on the PurpleAir platform is taken from PurpleAir sensors. Users include residents, companies, public authorities and education institutions e.g. schools, kindergartens. No other data sources are reporting to the PurpleAir map.[7]

GEO: All pilot locations except Plovdiv.

AQ data: PM1.0, PM2.5, PM10 reported in real-time and, because air quality fluctuates greatly over time, at different averaging periods, from 10 minutes to 1 year.

Other data: N/A

Analytics: Data from each sensor is presented as a score card linked to the air quality index (Figure 4).

[7] https://community.purpleair.com/t/q-can-i-add-data-from-non-purpleair-sensors/820

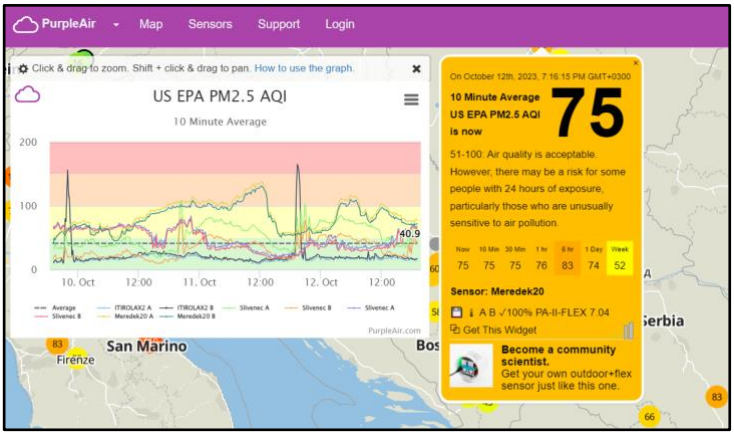

Figure 4. PurpleAir data visualisation

Other

The PurpleAir map allows users to toggle between different data layers to get an idea of what is deemed safe and dangerous in their region. Data layers are based on air quality indices developed by governments to communicate to the public how polluted the air currently is, or is forecast to be. The US index for PM2.5 uses a 300-point semantic scale where, to give a few examples, green means good air quality (0-50), orange - unhealthy for sensitive groups (101-150), and maroon - hazardous (301+). The European PM2.5 index is based on a 75-point scale where 0-10 is good, 20-25 is moderate, and 50-75 is very poor.[8] More than 10 air quality indices are offered on the platform, including from Canada, Australia, India, Mexico.

Comparing this with PMD, not only are we offering just one data layer, the index used is based on the old WHO guidelines for PM2.5, where 10 µg/m3 is the recommended average annual concentration. In the revised WHO guidelines published in 2021, the recommended average annual concentration is 5 µg/m3, but if the averaging time is 24 hours, the recommended limit is higher: 15 µg/m3.[9]

If PMD is to become an authoritative data source, users need to understand if they are looking at real-time information or data that has been averaged, and if it's the latter - which period is used: one hour, one day, one week, one month, one year? We also need to make clear why PMD legend is tied to WHO guidelines and not to the European air quality index. (The legend refers users to a third-party page.)[10] Finally, we may want to revise our colour scheme (currently from light blue to dark blue) to make it easier for users to understand which shades are safe and which ones are dangerous because current gradients are not intuitive.[11]

PurpleAir sensors have built-in WiFi and an SD card slot as a back-up option to record data offline should there be a problem with connectivity. With an active SD card no real-time information can be displayed on a map. The advantage is that monitoring activities can still be performed in areas of interest regardless of signal and telecoms infrastructure (an issue we faced in Bulgaria).

[8] https://airindex.eea.europa.eu/Map/AQI/Viewer/#
[9] https://www.iqair.com/newsroom/2021-WHO-air-quality-guidelines
[10] https://samenvoorzuiverelucht.eu/en/about-air-quality
[11] One trade-off we need to consider is that green-to-red colour scheme is not optimal for colour-blind people

The PurpleAir map has a prominent call to action on the map ("Get a sensor and become a community scientist") and the scorecard ("Become a community scientist. Get your own outdoor sensor just like this one."). Adding an option to buy sensors from the map interface may be a way to commercialise PMD and get Telraam, SODAQ and imec interested in its exploitation. In the future, the offer can be extended to other manufacturers.

Adding a forum to PMD where people can discuss results and issues, as well as get advice from peers, can help attract new citizen scientists and retain existing ones. The PurpleAir forum has multiple categories, threads and statistics (replies, views) that show the platform is very much alive and kicking. The forum helps support societal exploitation and, indirectly, commercial exploitation by facilitating community growth which in turn can increase sales. Running a forum is not without challenges, chief of which is content moderation. Someone would need to be monitoring discussions and responding to reports of illegal content appearing in chat rooms. One way to overcome this could be a community-based moderation.

Clarity

Clarity is also based in the US. The company is selling air quality monitors under the Sensing-as-a-Service model. They have a sensor (Node-S) that measures both PM2.5 and NO2. Node-S can serve as a platform for additional modules to measure ozone, wind and black carbon. Clarity doesn't disclose prices but according to some websites, the Node-S device costs USD 250-500, while the subscription cost is USD 500-650.[12] Device to cloud communication happens via cellular network (2G, 3G, 4G).[13]

Data sources: Clarity's OpenMap[14] displays data from Clarity devices and reference stations. Data from the government reference network is being added to OpenMap through three agencies namely, AirNow,[15] European Environment Agency,[16] and OpenAQ.[17] Air quality indices are calculated for hourly data and daily data coming from low-cost sensors and reference monitors.

GEO: All pilot locations except Plovdiv.

AQ data: Shown on the map is PM2.5 but sensors also measure PM1, PM10, NO2 and - soon - black carbon.

Other data: N/A

Analytics: Data is presented in simple score cards and can be further examined in a line chart. Multiple sensors can be added to the same chart for comparison. This feature is similar to PMD's group feature which is supposed to help users compare readings from selected sensors. However, the group creation process on PMD is not straightforward. Users need to first find a way

[12] https://scistarter.com/tools/792
[13] Clarity Node-S specifications
[14] https://openmap.clarity.io/
[15] https://www.airnow.gov/
[16] https://www.eea.europa.eu/
[17] https://openaq.org/

to create a group name (from 'sensor info'). Then, they need to allocate sensors to it before they can finally do a comparative analysis ('sensor group info'). On the Clarity's OpenMap this is all done in practically one step by clicking 'show in plot' on sensor nodes that one wants to compare (Figure 5).

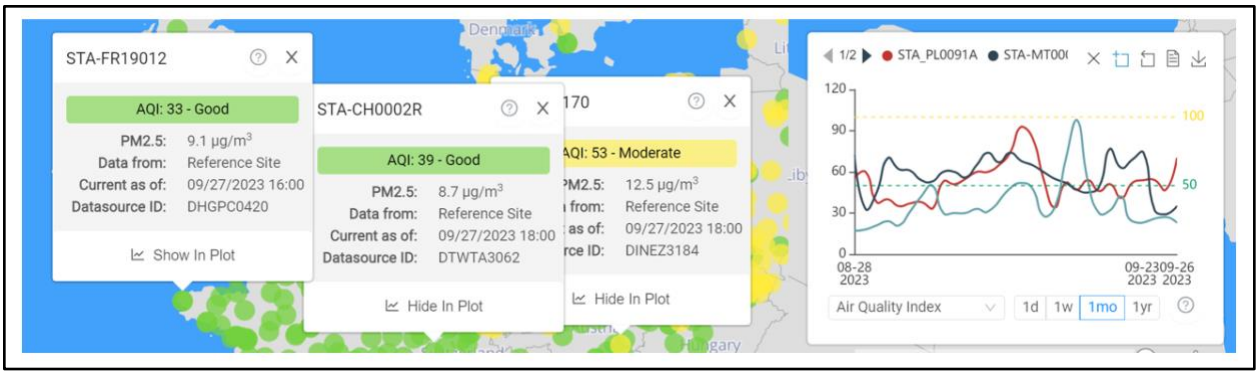

Figure 5. Sensor group analysis on Clarity's OpenMap

Other

Clarity has a comprehensive knowledge base[18] on how to set up and operate air quality monitors, how to colocate them with a reference station, how to view and understand air quality data, and why calibration is important. Like COMPAIR, the company uses remote calibration to improve reliability of findings reported by its low-cost sensors. An extensive collection of white papers, specs sheets, case studies, research papers, webinars etc. creates an aura of authority around Clarity.[19]

Both PMD and Clarity allow download in PNG and CSV. PMD's CSV export presents raw data in a more intuitive way, as sensors are compared side by side with the average score provided horizontally per unit of time. Clarity, on the other hand, provides a table pop-up that lists sensor readings vertically one monitor at a time, making comparison more difficult. Another advantage of PMD is the new XLSX feature that is being developed, which comes with additional features like an option to export history and create summary pivot tables.

IQAir

IQAir is a private company with offices in Switzerland, the US, and China. IQAir is selling a range of products: air monitors, air purifiers, and face masks. It boasts a live index that ranks cities on their air quality, a 3D air quality map (in addition to the classic 2D viewer), regularly updated news section, a mobile app, international awards and partnerships with the likes of UNEP, UN Habitat, and Greenpeace.[20] The cheapest AirVisual sensor costs EUR 319. Connection is via Wi-Fi, LAN, 4G (4G modem stick, SIM card with data plan required).

Data sources: governmental monitoring stations and low-cost sensors. Anyone can become a contributor as long as they use IQAir, PurpleAir, Clarity Node-S, or beta attenuation monitors.

[18] https://click.clarity.io/knowledge
[19] https://www.clarity.io/air-quality-monitoring-resources
[20] https://www.iqair.com/about-iqair

Some contributors are anonymous, some represent schools, universities, charities, and governments (environmental agencies).

GEO: All pilot locations represented.

AQ data: Pollutants include PM1, PM2.5, and PM10. It seems that the only air quality index used is US AQI.

Other data: N/A

Analytics: The scorecard shows real-time measurements for PM2.5 plus the situation in the past 24 hours. In the expanded mode users can see other pollutants (e.g. PM10, NO2, SO2), the number of people following a station (Figure 6), advice on how to protect themselves from air pollution, and a call to become a contributor. The option to follow a station is an interesting one as it a) shows activity and b) allows people without a sensor to keep abreast of air quality in the neighbourhood.

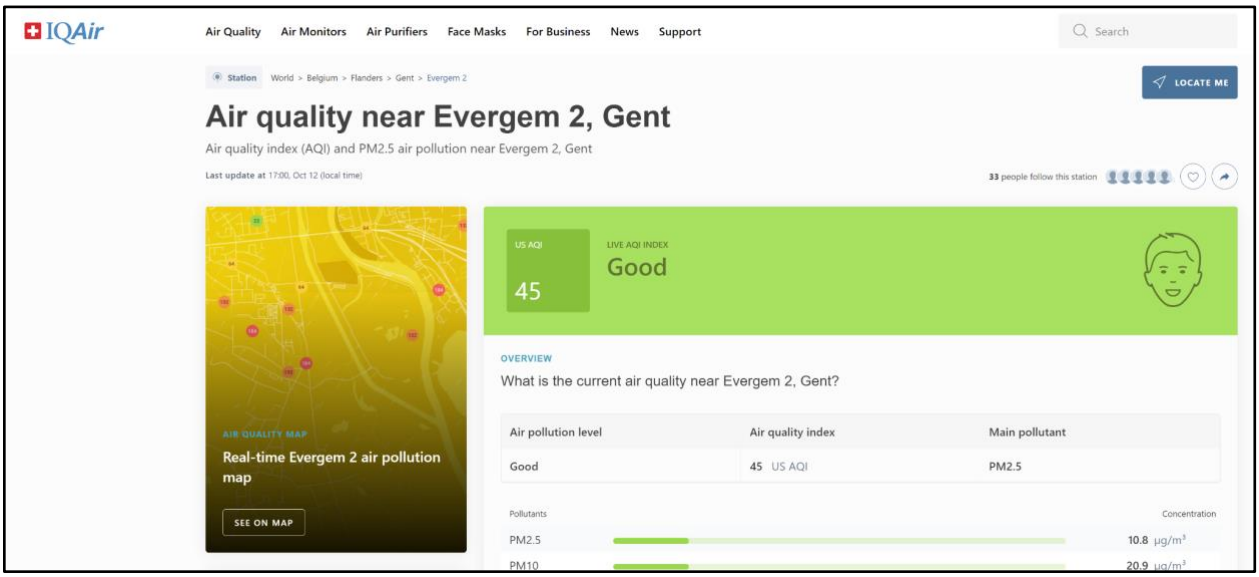

Figure 6. IQAir expanded score card showing the number of station followers

Other

IQAir uses cloud-based validation and calibration methods supported by ML, AI and space data, to detect anomalies and account for environmental conditions when adjusting sensor performance. All measurements pass through this system before they appear on the AirVisual platform.[21]

IQAir invites new users to join the movement,[22] with multiple calls to action located on the website e.g. “Become a citizen scientist. Get a monitor and contribute air quality data in our city.”

[21] Validating AirVisual air quality data

[22] https://www.iqair.com/air-quality-community

IQAir app is available on App Store[23] (35,200 reviews, 4.8 rating) and Google Play[24] (5M+ downloads, 280,000 reviews, 4.8 rating). The numbers show the app has many fans who are generally quite happy with it.

OpenAQ

OpenAQ is another US based organisation that calls itself an environmental tech non-profit. They don't sell any sensors, only provide aggregated open source data through the OpenAQ platform.[25]

Data sources: OpenAQ started with government data in 2015 and as of 2021 has been ingesting data from low-cost sensors (e.g. PurpleAir, Clarity). In total, 165 providers are sharing data.

GEO: All pilots.

AQ data: The OpenAQ database currently ingests data on 13 pollutants,[26] including NO2 and black carbon that are also monitored by COMPAIR. OpenAQ's coverage of air pollutants is the broadest one we've seen among the reviewed platforms. Data is shared via API and CSV download.[27]

Other data: N/A

Analytics: The general scorecard on the map doesn't show any air quality data, only information about the sensor: location, data provider, sensor type, pollutants measured, the time of the latest reading. But when clicking on details, the expanded scorecard pops up, showing the latest readings in a linear and logarithmic scale. Pollution patterns are visualised in a box/whisker plot (Figure 7). This visualisation is more advanced in its analytical depth than visualisations on other platforms. However, without statistical knowledge a user will find it difficult to interpret variance captured in the graph.

[23] https://apps.apple.com/us/app/airvisual-real-time-forecast/id1048912974
[24] https://play.google.com/store/apps/details?id=com.airvisual&pli=1
[25] In the first year of the project we evaluated using OpenAQ API as a single source for non-COMPAIR sensor data, such EU reference stations. Upon evaluation, we saw that data availability of this source was limited, for example some EU reference sensors did not show any data at all, some provided patchy data. That's why we opted for Discomap as a source of reference station data.
[26] PM1, PM2.5, PM4, PM10, BC, O_3, CO, NO_2, NO, NOx, SO_2, CH_4, CO_2
[27] https://docs.openaq.org/docs

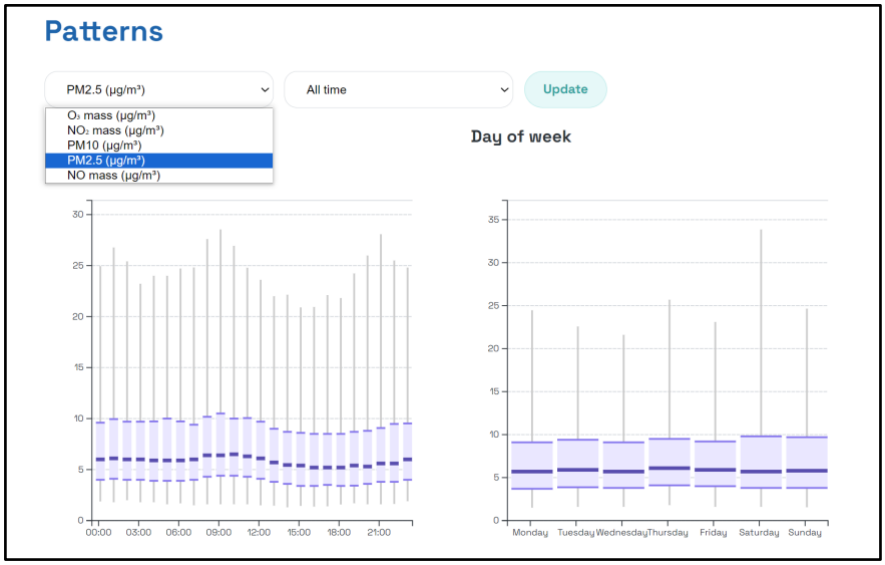

Figure 7. Box plot visualisation on OpenAQ

Other

OpenAQ cements its authority with publications[28] and use cases that show how others have used its data to

- support scientific research (Paul Crutzen Award)
- develop city rankings (Bloomberg)
- build a prediction model for child population density based on violations of WHO recommended limits (AQAI)
- create an app that compares air pollution to cigarette smoking

Use cases follow a simple format: problem, solution, how OpenAQ helped. In COMPAIR, we're currently in the process of obtaining similar information from pilots, which will appear on the website by the end of 2023. Thinking about wider exploitation, it's worth reflecting on whether our data is already of good-enough quality to be used in third-party research and innovation activities.

OpenAQ has a data policy[29] that explains where they take their data from, who owns the data (copyright), license/attribution requirements, terms of use for data publishers, risks involved in using OpenAQ data. PMD would benefit from a similar policy that sets out conditions for data use.

OpenAQ is quite strict about who can upload and share data via its platform. OpenAQ prioritises accuracy and is not rushing to accept data from anyone who uses low-cost sensors, calling it a "tricky business".[30] Governments need to follow a step-by-step process.[31] Professionals need to use a special automatic upload tool.[32] For everyone else (those using low-cost sensors) the process is not straightforward. Suggestions can be submitted via GitHub or Google form, but their acceptance is not guaranteed.

[28] Open Air Quality Data: The Global Landscape
[29] https://github.com/openaq/openaq-info/blob/master/DATA-POLICY.md
[30] https://www.nature.com/articles/535029a
[31] https://openaq.medium.com/how-can-a-government-source-add-data-to-openaq-50b5d83ef13f
[32] https://github.com/openaq/openaq-upload

Smart Citizen

Smart Citizen is a set of solutions comprising sensing devices, engagement tools and software that have been developed as part of multiple EU projects,[33] some finished, some still running e.g. Making Sense (2015-2017), iSCAPE (2016-2019), Minke (2021-2025), TwinAIR (2022-2026). The initiative is now managed by Fab Lab BCN. Smart Citizen is an interesting case to study because it has roots in EU projects and continues to evolve thanks to EU funding, because the kit[34] measures more than air quality (also noise and light pollution), and because the platform is still teeming with activity started by Making Sense and iSCAPE (demonstrates remarkable sustainability).

Data sources: The platform ingests data from Smart Citizen devices that can be simple (kits) or more advanced (stations).[35] Total number of active sensors in Europe is just 157 (but over 3000 with offline devices included). The number of active sensors is expected to increase as volunteers from new projects join the platform.

GEO: Live data from active sensors is available for Berlin and Flanders. With historic data (from inactive sensors) the cities of Athens, Plovdiv and Sofia are also covered.

AQ data: PM1, PM2.5, PM10. Smartcitizen has an API allowing anyone to develop applications and experiments on top of the Smartcitizen platform.[36]

Other data: Noise and light pollution.

Analytics: The main panel is showing data on air pollution, noise pollution, light pollution, and atmospheric conditions. Historic filters are available for the past hour, day, and month, or by specifying a custom date range. Multiple sensors cannot be compared like in PMD and Clarity, however different parameters from a sensor can be compared with one another in a single chart e.g. noise pollution versus PM2.5 (Figure 8). The panel also shows all the other kits owned by the user.

[33] https://docs.smartcitizen.me/Smart%20Citizen%20Kit/#software-updates
[34] https://docs.smartcitizen.me/Smart%20Citizen%20Kit/#what-is-it
[35] https://docs.smartcitizen.me/Smart%20Citizen%20Station/
[36] https://developer.smartcitizen.me/#summary

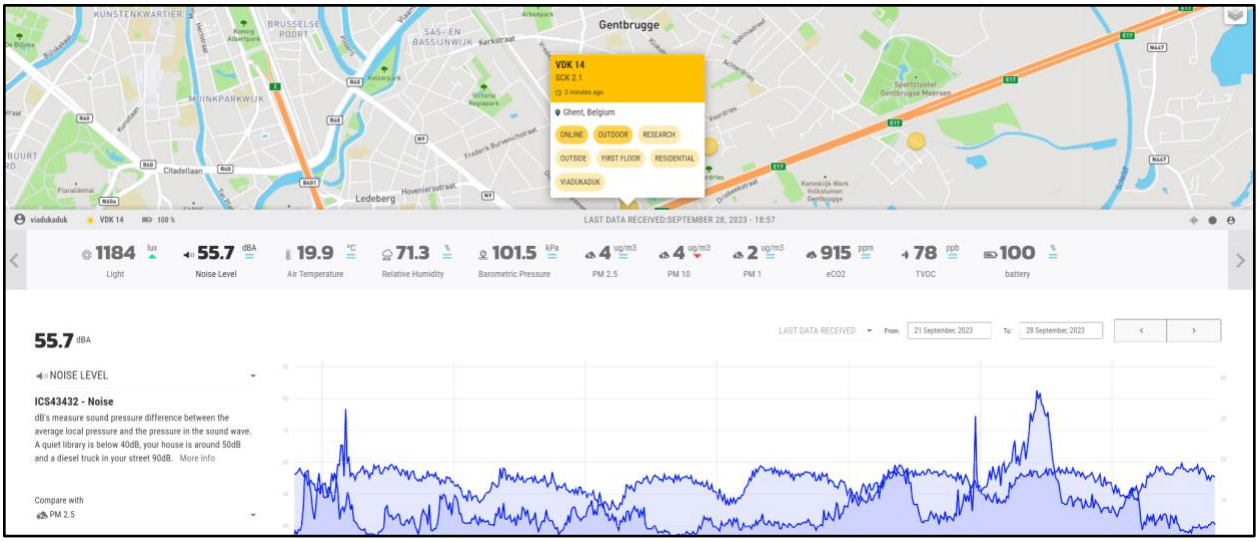

Figure 8. Smart Citizen dashboard

Other

The platform offers 2 simple filters: to display active and offline sensors, and to display data measuring indoor and outdoor pollution. On PMD, some SODAQ sensors transmit erroneous data ('network error') while others show data that is a few days and even weeks old. It might be a good idea to implement a similar filter that can show live and/or inactive sensors depending on user preference.

The platform has two calls to action: one is to buy Smart Citizen kits, another to join the community. The kits cost USD 99 or USD 119 with add-ons included. Both were out of stock at the time of writing. The low price makes Smart Citizen kit the cheapest and therefore the most affordable sensor reviewed in this deliverable.[37,38] The forum has several categories and is regularly updated with information on sensors, hardware, project activities etc.

One important thing we think is missing on Smart Citizen is a legend to help make sense of the air pollution data. For instance, are 2µgs of PM1 dangerous for health or not? Do they exceed or are in line with the limits imposed by the EU or WHO? Also, there is no information as to the averaging period used.

On this note, we **conclude** our review of competitor air quality dashboards. What did we learn from it? First, **PMD in its current state is comparable to the leading platforms**

- ***Data sources:*** Just like OpenAQ, IQAir and Clarity, PMD integrates data from reference stations and citizen science sensors
- ***Data types:*** PMD visualises air quality and traffic. Another platform that visualises information other than air quality is Smart Citizen (noise and light pollution)
- ***Data download:*** The way PMD data is presented in CSV is far more intuitive than that of some other platforms (e.g. Clarity), especially when it comes to displaying data from multiple sensors

[37] https://www.seeedstudio.com/Smart-Citizen-Starter-Kit-p-2865.html
[38] But still more expensive than the sensor.community kit which costs around EUR 50

- ***Air pollutants:*** PMD shows 3 air pollutants: particulate matter, nitrogen dioxide, and black carbon. That's more than some platforms, but on par with Clarity and considerably less than OpenAI, which covers 13 pollutants
- ***Calibration:*** PMD is one of the few platforms that serves calibrated data; two other ones are Clarity and IQAir
- ***Comparative analysis:*** PMD and Clarity both provide sensor-group visualisations, however we found Clarity's way of adding sensors to a group and the subsequent visualisation in a line chart a bit easier and more intuitive than PMD's
- ***Advanced analytics:*** PMD allows users to drill deeper into data by comparing the situation with traffic and air quality before and after a measure like a schoolstreet or a bus route was introduced which might result in policy action. None of the reviewed platforms offer anything remotely similar. The only platform whose visualisation approach is more complex than a line chart is OpenAQ (whisker plot)
- ***Knowledge base:*** Practically all platforms/initiatives position themselves as experts on air quality monitoring by demonstrating their non-data side in the form of publications e.g. research papers, case studies, specs docs, news articles. This is an area where COMPAIR is also making good and steady progress and should continue to do so to further cement its authority

Second, the review identified several **features that can be improved or introduced to PMD to make it better**. Recommendations are as follows

- ***Air quality index:*** Replace the current limit values with those of the EU or allow users to switch between WHO and EU recommended limits. This should be accompanied by a change in the legend with more intuitive colour gradients (shades of blue are not good at capturing air quality thresholds). Because the recommended limits change depending on the averaging period, these differences should be highlighted on the map/chart e.g. the recommended limit of PM10 is 50 µg/m3 if it's averaged daily, 40 µg/m3 if it's an annual mean[39]
- ***Calls to action:*** Add an option for visitors to buy sensors (commercial exploitation) and become a citizen scientist (social exploitation)
- ***Sensor information:*** Allow visitors to follow a station and view other stations managed by the sensor owner
- ***Sensor map:*** Create a filter so that users can select all or only active sensors as currently many devices are not transmitting any data
- ***Data policy:*** Add a note explaining which conditions apply to downloaded data i.e. which license is used? Is it CC BY-SA 4.0 or similar?

With these recommendations we conclude the chapter on PMD competitors and proceed to the discussion of CO2 calculators.

[39] https://environment.ec.europa.eu/topics/air/air-quality/eu-air-quality-standards_en

5. Perceptions of CO2 calculators

The draft exploitation (D8.3) plan briefly analysed 16 carbon footprint (CO2) calculators developed by NGOs, private companies, governments, and EU projects (e.g. PS Lifestyle[40] that shares the same cluster group with COMPAIR). In total, there are several dozen CO2 calculators available online, many of which cover similar domains as COMPAIR (transport, buildings, waste), some cover more (pets, shopping, leisure activities), some are specifically designed for businesses,[41] some are country-specific,[42] some sector-specific e.g. farming.[43]

In this edition, we decided not to create an all-encompassing list of CO2 calculators as we are more interested in how these tools are perceived by users. The rationale behind it is that you may have the most comprehensive and accurate CO2 calculator (assuming it's possible), but if target audiences are not using it or are not following/trusting its recommendations, what good does it serve?

To ensure that our CO2 calculator is an output that people actually like and want to use to change their daily habits - in other words, they see it as a vehicle for behavioural change - we looked at past studies that assessed CO2 calculators from an end-user perspective. So, in this review the focus has been not on the technical implementation[44] but on the perceived usefulness of CO2 calculators, as we think this kind of feedback is urgently needed to make our tool stand out in a crowded landscape.

Questions driving our research are: what did past evaluation studies find? Are CO2 calculators easy to use? Do people use them often? Crucially, do they use results to inform lifestyle choices?

In 2018, the 'Your Carbon Footprint Identity' survey results were published, providing insight into user experience and preferences with CO2 calculators.[45] The sample included 216 responses from the general public. The survey assessed participants' knowledge of greenhouse gas emissions and whether carbon calculators were effective in changing participants' behaviour.

Out of all survey participants, a majority (53%) had used a CO2 calculator in the past. However, less than 10% could remember their calculated footprint measure. Slightly more people (16%) said that a carbon footprint calculator helped them change their daily energy consumption habits.

A 2020 study with a bigger sample (n=4245) assessed the use of the carbon calculator by the Global Footprint Network.[46] While the majority thought the tool was easy to use (93%), only 23%

[40] https://pslifestyle.eu/
[41] https://research.aimultiple.com/carbon-footprint-software/
[42] An evaluation of carbon calculators in the UK
[43] https://www.nfuonline.com/updates-and-information/nfu-carbon-calculator-review/
[44] Many papers talk about the design and characteristics of CO2 calculators, including John Mulrow, Katherine Machaj, Joshua Deanes, and Sybil Derrible. 2019. The state of carbon footprint calculators: An evaluation of calculator design and user interaction features. Sustainable Production and Consumption 18 (April 2019), 33–40. https://doi.org/10.1016/j.spc.2018.12.001
[45] Mulrow, J., Machaj, K., Deanes, J., & Derrible, S. (2019). The state of carbon footprint calculators: An evaluation of calculator design and user interaction features. *Sustainable Production and Consumption.*
[46] https://www.footprintnetwork.org/resources/footprint-calculator/

of respondents indicated the calculator provided them with the necessary information to make behavioural changes and reduce their personal footprint.[47]

Although some calculators are reportedly easy to use,[48] others ask questions that, for most of us, would be hard to answer accurately without preparation. Unless users have had some kind of monitoring system in place to track their habits, answering lifestyle questions quickly and precisely can be challenging. How many people know, off the top of their head, what distance they travel by car in a year, how many flights they have taken that are domestic, short- medium- and long-haul, how many times they travel by train and over what distances, what their fuel and electricity consumption has been, how much waste they generate, how much stuff they recycle? Most of us won't have ready answers to these questions, and quite a few will probably struggle trying to figure out where to look for the information. Is it utility bills? Travel tickets? Google maps?

Even if people find the right information, an even bigger challenge is to convert acquired knowledge from the calculator into actual life changes. Past studies concluded that just presenting numbers from CO2 calculators is not an effective way of trying to influence user's lifestyles.[49] Another challenge is retention. Footprint calculators are typically used by environmentally conscious individuals, and even in this group it is hard to get people to use the tool more than once.

To improve retention and ensure that a CO2 calculator is more than a statistics sharing tool, literature recommends integrating behavioural intervention strategies in the form of pledges, goal setting, and gamification-based challenges oriented towards groups or individuals. One strategy highlighted as being particularly effective involves placing calculators in an educational setting. According to the authors,[50] embedding footprint calculators in a curriculum can enhance sustainability teaching and offer students scientific, transdisciplinary insights that can, at a minimum, increase environmental awareness and potentially inspire them to lead more sustainable lifestyles.

All these recommendations and insights give us a pretty good idea as to **what we can/should do in the final year to improve our CO2 Calculator**.

- ***Raison d'etre:*** Revisit the main objective of the tool: should it be statistics-sharing? Inspiration? Lifestyle change? If we prioritise the latter, introducing elements of environmental psychology will be necessary to motivate users to change habits. Information provision offers a potential pathway to change, however on its own it is hardly an effective strategy. Hence the need for pledges, gamification, and goal setting techniques.

[47] Andrea Collins, Alessandro Galli, Tara Hipwood, and Adeline Murthy. 2020. Living within a One Planet reality: the contribution of personal Footprint calculators. Environmental Research Letters 15, 2 (Feb. 2020), 025008. https://doi.org/10.1088/1748-9326/ab5f96

[48] https://www.wegewerk.com/en/blog/co2-footprint-calculators-put-to-the-test/

[49] Aksel Biørn-Hansen, Cecilia Katzeff, and Elina Eriksson. 2022. Exploring the Use of a Carbon Footprint Calculator Challenging Everyday Habits. In Nordic Human-Computer Interaction Conference (NordiCHI '22), October 8–12, 2022, Aarhus, Denmark. ACM, New York, NY, USA 10 Pages. https://doi.org/10.1145/3546155.3546668

[50] Aksel et al. (2022)

- ***Educating users:*** As well as asking detailed questions about consumption, the CO2 Calculator would need to explain basic energy concepts, as well as how daily activities, energy use and emissions are related. Past studies show that many people don't know what 1 kg of CO2 emissions or 1 kWh means in terms of daily activities.
- ***Balance*** simplicity and complexity to make the tool credible yet easy to use. Ask too many difficult questions and people will lose interest before completing the form. However, we also need users to have confidence in the output, and this can't be achieved by asking trivial questions. The challenge is therefore how to reach both credibility and usability without compromising one or the other. And if we choose to offer the CO2 Calculator to schools (see next point), do we create a simple version for students and a more advanced one for everyone else?
- ***Schools:*** Offer the tool to students participating in citizen science campaigns. According to the literature, education institutions provide a favourable setting for the uptake of CO2 calculators. So far, sensors and PMD have been the focal point of our engagement with schools. By adding the CO2 Calculator to the mix, we increase its chances of post-project exploitation while also delivering benefits to schools (enriched curriculum) and students (better environmental awareness with a potential to change lifestyles).
- ***Feedback:*** Ask people outside the consortium to share their views and preferences. At this stage, we have organised 3 workshops with outside users, mostly experts in the domain, as well as 3 internal testing rounds gathering feedback from project partners. At the beginning of the design a thorough review of the existing research studies and CO2 calculators have been reviewed as presented above.

The list of recommendations concludes the chapter on CO2 calculators. The next one will focus on AR apps for air quality i.e. DEVA competitors.

6. AR apps for air quality

Since the last review, we haven't found many new AR apps for air quality. The absence is striking because, year-on-year, the number of standalone AR apps and apps with embedded AR features continues to grow.[51] What is more surprising is that apps that were previously available on AppStore and Google Play are no longer accessible. (More on them shortly.)

The only new mobile app we found is a deliverable of the GreenSCENT project. The app was still in the making at the time of writing D8.4. The project website provides scant information on the app, stating only that it's meant for use in an educational setting.[52] There are mock-ups but they don't show how exactly AR is used (Figure 9). Does it visualise air pollutants? Or do users simply get contextual information about the environment (temperature, humidity, air quality etc.) by touching the screen? The beta version is planned for a release in January 2024, so we will do a more thorough review of the app in the next exploitation plan.

[51] https://www.statista.com/statistics/608967/mobile-ar-applications-installed-base-worldwide/
[52] https://www.green-scent.eu/greenscent-ar-app/

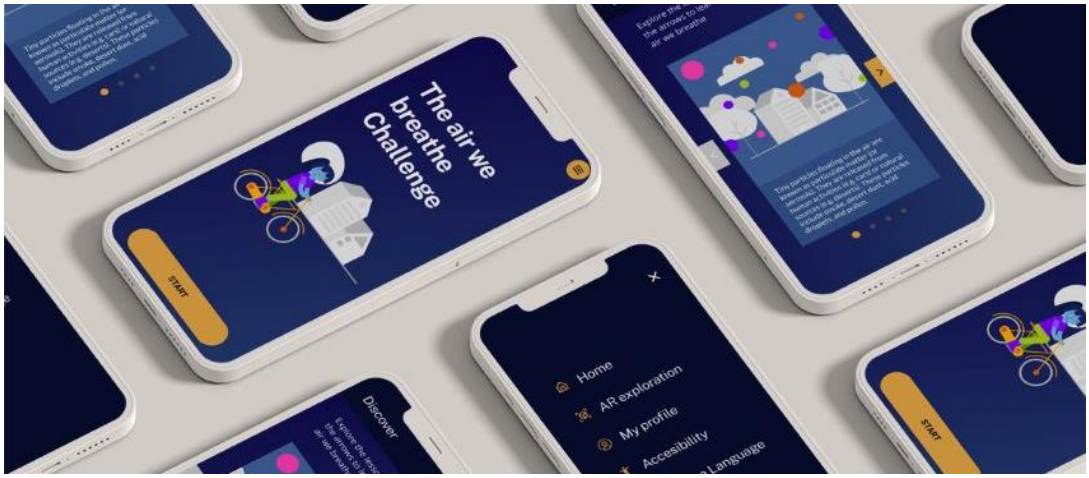

Figure 9. Mock-ups of the GreenSCENT AR app

Looking at some of the 'old' apps, the only one that is still in the public domain is AiR.[53] The current web-version app doesn't really work. Users are asked if they want to know air quality in their location. But regardless of what you press, nothing happens after 'yes' or 'no' (Figure 10), as the app is "initialising" indefinitely.

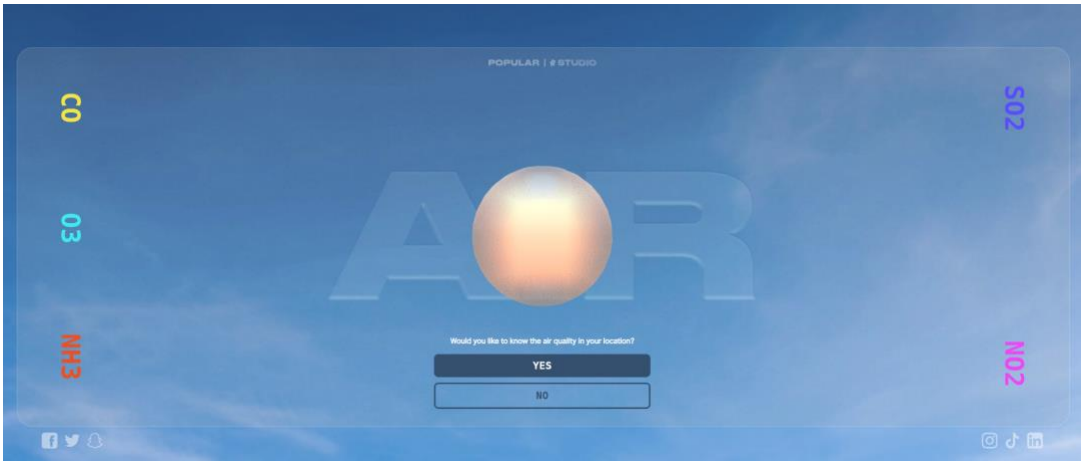

Figure 10. Browser-based AiR app

AiR used to be an Android app. Even though it is no longer available for download from Google Play, some information remains, including usage metrics and comments.[54] The app was downloaded more than 1000 times and reviewed 39 times, with an average score of 4.3 (Figure 11).

[53] https://air.popul-ar.com/
[54] https://play.google.com/store/apps/details?id=com.iittp.air

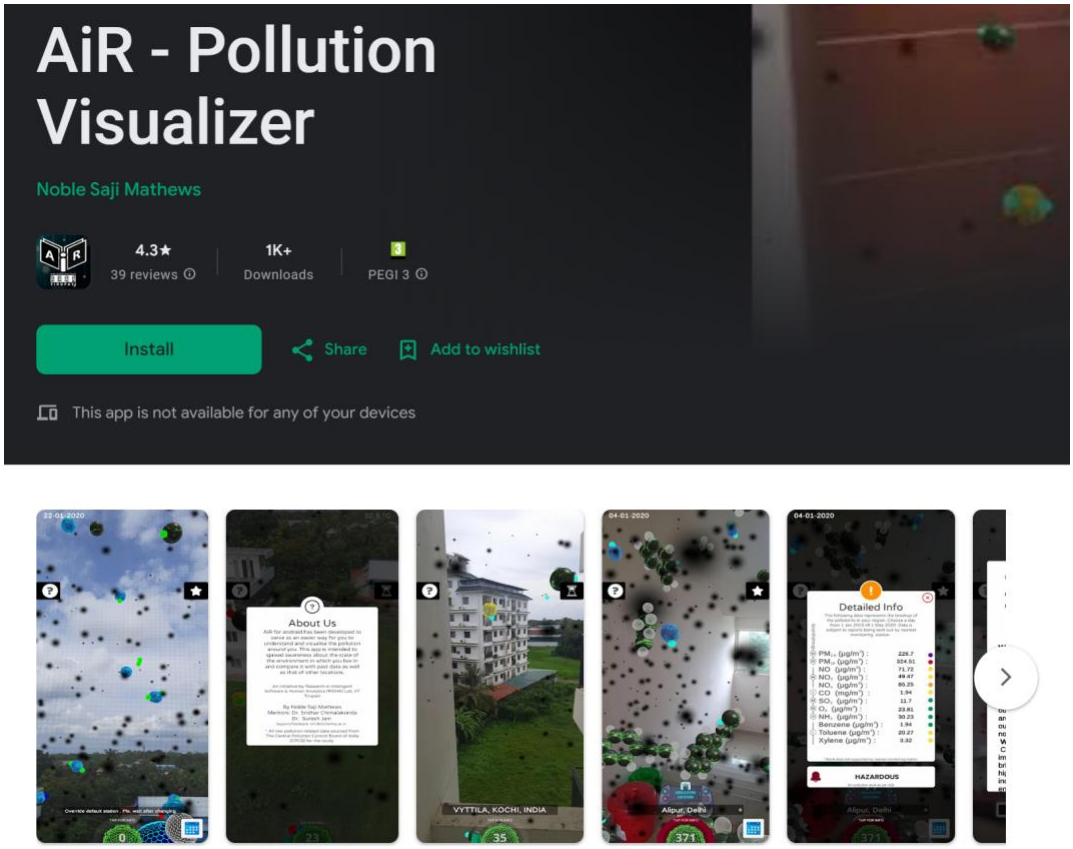

Figure 11. AiR on Google Play (discontinued)

What people liked about AiR:

- ***Environmental awareness and behavioural change:*** Users said that the app offers an innovative way to visualise air pollution and helps nudge people towards eco-friendly practices
- ***Technology blend to stimulate agency:*** Using GPS, AR and air quality data in a single tool can help bring awareness about air pollution and inspire people to make a change
- ***Educational impact:*** A teacher showed the app in an online science class for 10th grade students, all of whom were "fascinated by it"

What people didn't like about AiR:

- ***Imprecise geolocation:*** Some users complained that they were shown a place some 100 km away from their current location
- ***Technical difficulties:*** Some users were not able to figure out how to adjust AR settings on their device to make the app work
- ***No data:*** Some users said they couldn't see any pollutants around them, an issue caused by the lack of monitoring stations in the vicinity

The app was developed for India residents as data was taken from the country's 222 monitoring stations (quite a sparse network given India's size). Developers said they might create an iOS version but this plan never materialised. Furthermore, the last update on Google Play was in

2020, and the last comment in 2021. Despite a promising start (Google Play reviews, publication in IEEE[55]) the team behind AiR discontinued the app.

An app with a similar fate is Air Visualize Air Quality.[56] In 2019, it was available on the App Store but not anymore. In the same year, NYT added an AR feature to its app that visualised air pollution based on location.[57] In 2018, WeatherBug launched its own AR app for Android and iOS devices and even published a press release about it.[58] In recent years, proposals for AR-based air quality apps were made in various publications, but we have yet to see a compelling solution with sustained market traction.

What **conclusions** can we draw from the market scan? First, the period 2018-2020 saw a flurry of activity in this space. Several AR apps for air quality were launched/announced at the same time or before COMPAIR came along. A few received good media coverage, however their existence on the App Store and/or Google Play was rather short-lived. This may have been due to the Covid-19 outbreak caused by the SARS-CoV-2 virus, beginning March 2020. But if the pandemic is the main cause, it doesn't explain why the apps weren't used after all the restrictions were lifted.

Second, literature abounds with publications on the subject, some of them a few years old,[59] some more recent.[60] The main issue with these works is that ideas presented therein don't seem to have transitioned past the concept stage, and are just ideas on paper.

Third, despite repeated attempts to develop the market, the field remains remarkably empty. We can theorise as to why this may be the case. Perhaps it's because users, despite showing early enthusiasm for the tool, got bored with it very quickly. Or maybe because everything that had been designed previously fell short of user expectations, hence the low uptake. Whatever the answer, the findings are alarming - no one stays in this market for long - as much as they are encouraging - we are the only ones left (almost).

The task for the months ahead is to decide which exploitation route is the most viable for DEVA. A promising pathway is the integration into a school curriculum. However, a major outcome of the meeting in Sofia was that DEVA is, as yet, too complex for ordinary experts to use. So the app would need to be simplified considerably before it can be offered to young children. Another pathway indicated in the survey is the integration with Unity. HHI thinks that DEVA can serve as an AR data-visualisation framework for Unity. To what extent this is possible remains to be seen given that Unity has its own AR Foundation, a purpose built framework for AR development.[61]

[55] https://ieeexplore.ieee.org/document/9623287
[56] https://www.youtube.com/watch?v=o_QkgYLqefY&ab_channel=ARCritic
[57] https://vrscout.com/news/nyt-app-ar-air-pollution/
[58] WeatherBug Press Release
[59] Aswin, P., Adhiyaman, M., & Posonia, A. M. (2018). Air pollution monitoring using augmented reality. International Journal of Pure and Applied Mathematics, 118(20), 4171–4176. Retrieved from https://acadpubl.eu/hub/2018-118-21/articles/21e/51.pdf
[60] Fernandes J, Brandão T, Almeida SM, Santana P. An Educational Game to Teach Children about Air Quality Using Augmented Reality and Tangible Interaction with Sensors. Int J Environ Res Public Health. 2023 Feb 21;20(5):3814. doi: 10.3390/ijerph20053814. PMID: 36900825; PMCID: PMC10000929.
[61] https://unity.com/unity/features/arfoundation

DEVA concludes our discussion of technical tools. Missing in the present review is DEV-D. This fourth dashboard (DEV-D) is an important result but one that was produced too close to the deadline of this deliverable, hence its exclusion at this stage. But disappointed readers should rest assured: DEV-D will make it to the final exploitation plan that we will prepare next year.

Now that we mentioned this caveat, it's time to present various communication and dissemination tactics that will be deployed in the coming months to improve exploitation. We call it CD4E, i.e. Communication & Dissemination for Exploitation.

7. Platforms and pilot channels

Communication, dissemination and exploitation are included in one overarching strategy for a reason. If we want our results to be used (exploitation), we need to share them with and make them discoverable by relevant target audiences. This can be achieved in many different ways, including by sending emails/newsletters with links to results, by inviting people (via emails, newsletters, word of mouth etc.) to attend events where results will be showcased, by promoting results at events - our own or someone else's (panel, keynote, presentation, booth, networking), by regularly tweeting and blogging about results, by participating in cluster events (e.g. European Citizen Science Collaboration Group), by leveraging cluster's dissemination capacity (e.g. Citizen Science Lighthouse newsletter), by publishing research papers, guidance documents for actors on impactful usage, and so on. These are all elements of communication and dissemination but they play an important role in making exploitation and - by extension - sustainability more likely.

Dissemination platforms

The CD4E efforts mentioned above need to be carried out regularly to be effective. However, there are some channels that are less demanding in terms of effort but are not necessarily less effective in terms of audience reach. Third party platforms are a case in point. They are less demanding than blogging for example, which needs to happen weekly or a few times a month. But they do provide a valuable antenna for dissemination, and generally we only need to publish once (e.g. add a project description with main results) on any given platform to start attracting interest with minimal future effort. COMPAIR is already featured/mentioned on several platforms:

- Samen voor Zuivere Lucht[62]
- CitiMeasure[63]
- EU-Citizen.Science[64]
- MOOC on Open Science by University of Konstanz (forthcoming)

Additional platforms to consider include:

- ***UN World Environment Situation Room Citizen Science Portal***[65] has two sections where COMPAIR can be featured. One is called Citizen Science Project Inventories (ideal

[62] https://samenvoorzuiverelucht.eu/en/inspiratie/handy-tools-compair-project
[63] https://citimeasure.eu/comparability-tool/
[64] https://eu-citizen.science/project/379
[65] https://wesr.unep.org/article/citizen-science-and-private-data

for a general project description), another is about Pollution (ideal for showcasing our digital tools).

- ***Horizon Results Platform***[66] is managed by the European Commission and only accepts important results.[67] To get an idea of what we can publish, we checked what others before us shared on this platform. We found policy briefs, data sets, computer models, platforms, hardware, publications, and websites. We can use HRP to promote technical results (apps, data) and policy-related results (policy briefs), and also to look for investment, loans, financial expertise or support with business planning for results that partners would like to bring to market
- ***CitiesHealth Toolkit***[68] is collecting stories of successful citizen engagement. By stories they mean "tools or methods that show how to develop citizen science in an engaging way and put citizens' concerns at the heart of the process." Given this focus, the toolkit provides a relevant channel for sharing lessons from stakeholder engagement activities in COMPAIR pilots, especially their work with lower socioeconomic groups
- ***Zenodo*** can be used to sustain internal deliverables like policy briefs, case studies and infographics which will not appear on Cordis after the project

Learning platforms

Another effective CD4E channel is an online course. We promised one as part of D8.5 COMPAIR Citizen Science Lab with MOOC due August 2024. The course is a one-off investment that should deliver high return on investment in terms of reach. Based on past experience with MOOCs, we expect that a well-designed COMPAIR course will continue attracting users well after the project has ended without any marketing effort.[69]

To be an effective vehicle for exploitation, the course must be published on a platform that is optimal in some sense. Optimal for us means that:

- The platform must have a name i.e. be known as a learning platform instead of simply being a video hosting service like YouTube;
- The platform offers easy, Moodle-like features that students expect to see in a course e.g. forum, quiz, certificate;
- The platform must have a low barrier to entry for non-institutional creators without an international clout.[70] Whilst it would be nice to publish a course on Coursera or edX, COMPAIR does not qualify to partner with these platforms due to its low profile;
- The course must be cost effective, ideally free to make and most definitely free to use.

Below we review several options against the listed requirements (Table 1).

[66] Horizon Results Platform

[67] As stated on HRP, "outcomes or announcements of consortia meetings, conferences or other events" are not considered to be important and therefore are not in the scope of HRP

[68] https://citizensciencetoolkit.eu/add-your-story/

[69] Some of the COMPAIR partners created an online course for a finished project PoliVisu. The course was published back in 2020 and still receives 3-5 new registrations per month with no promotion whatsoever.

[70] It would be nice to publish a course on edX or Coursera, but they only work with top-class organisations, so out of reach for COMPAIR. We need a platform with low-entry partner requirements

Table 1. Comparison of some MOOC platforms

Platforms	Popularity	Learning features	Entry	Cost	Access
Future Learn	High	Video lectures, quizzes, forums	High	30-50K	Free
EdEra	Low	Videos, quizzes	Low	~30K	Free
UNITAIR	Medium	Narrated videos, text	Low	50-80K	Free
OLC	Medium	Videos, forums, quizzes, pdfs	Low	Free	Free
Alison	Low	Voice recording, images, quizzes	Low	Free	Free
eu | academy	Medium	Videos, forums, quizzes, reports	High	N/A	Free
data.europa.eu	Low	Videos, quizzes, slides, pdf	High	N/A	Free
Udemy	High	Videos, quizzes, pdfs	Low	Free	Free

The most popular platforms are Future Learn and Udemy. However, Future Learn only partners with renowned institutions and is cost-prohibitive. Udemy is better in this regard as anyone can publish a course - even individuals - at no cost. One small issue with Udemy is that courses that are free for students to take - and our course would need to be free - are capped at 2 hours of video content. So, if we wanted to offer a longer course, it would need to be provided as a paid course, which is not desirable for an EU project.

Two platforms linked to the EU are EU Academy and data.europa.eu. They seem to be a natural place for us to host the MOOC in full (EU Academy) or in part e.g. just the modules on citizen science data (data.europa.eu). However, the platforms have high barriers to entry as they only publish content approved by the Publications Office and associated Units/agencies of the European Union. Moreover, in terms of visibility and reach the two are less appealing than some other, more accessible alternatives. For instance, data.europa.eu has only 9 courses in the entire collection.

EdEra hosts an online course by Auroral, an EU project.[71] EdEra is an interesting choice for Auroral Academy because courses on EdEra are mostly about Ukraine or are in the Ukrainian language. As such, it is little known outside the Ukrainian community. What's more, publishing on EdEra isn't cheap. A course similar to Aurural Academy would cost around EUR 30,000.

A basic course on UNITAIR would cost almost as much. Alison is free but less popular. This leaves us with OLC (Open Learn Create). Courses can be published by anyone, even projects and individuals. They are free to create and free to take. Thanks to the association with Open University, OLC is relatively popular in the MOOC community. The platform itself has more than 100,000 registered users.[72] All in all, OLC appears to be the most viable, cost effective option. This conclusion is a recommendation, not a final verdict. Which platform or platforms to go for is a decision that will be made in the early 2024. It may be OLC or some alternative platform that will prove its worth upon closer examination.

[71] https://auroral.eu/#/academy
[72] https://www.open.edu/openlearncreate/local/ocwaboutpage/about.php

Pilot channels

The final set of measures in the CD4E toolkit concerns pilots' upscaling efforts. These are thoroughly documented in D5.4 Open Round Report and D5.5 Co-Innovation Report which are being prepared in parallel with D8.4. To avoid duplication, we are not going to repeat everything that is mentioned there. Interested readers are encouraged to consult these deliverables to learn about pilot results, their past, ongoing and future campaigns. What we want to do next is provide a high-level overview of activities that COMPAIR pilots have planned for the final year of the project as these measures have a direct bearing on exploitation, especially within societal and policy-oriented tracks. Also, by mentioning pilots' plans here we are doing justice to our integrated CDE strategy which weaves together multiple pathways to sustainability to have a greater chance of success.

Table 2 documents pilots' measures aimed at facilitating exploitation across four areas:

- ***Mobile measurements*** of outdoor air pollution carried out by volunteers on the move
- ***Static measurements*** of outdoor air pollution captured outside one's home or school
- ***Apps and dashboards*** (PMD, CO2 Calculator, DEVA, DEV-D)
- ***Stakeholder engagement*** involving different social groups

These measures provide a foundation for local exploitation activities during and after the project.

Table 2. Pilot measures

Mobile measurements	**Static measurements**	**Apps and dashboards**	**Stakeholder engagement**
Berlin: Work with cycling charities to increase the number of volunteers to 50 ***Flanders:*** Engage students from primary and secondary schools to teach them how to measure air quality on a bike. This is done as part of the Interreg Joaquin educational package	***Athens:*** Engage members of the Friendship Club to compare air quality in the neighbourhoods of Neos Kosmos and Kipseli ***Berlin:*** Work with an urban charity Changing Cities to measure air quality in Kiezblocks, low-traffic neighbourhoods to implement a parking ban ***Flanders:*** Work with local partners in Herzele on the extension of the schoolstreet and a new winter campaign ***Plovdiv:*** Continue collaboration with the Dimitar Talev primary school and a new school nearby that	***Athens:*** Introduce volunteers to the CO2 Calculator to show how they can support capital's progress toward reaching the 2030 Climate Resilience Strategy ***Flanders:*** Gather ideas from secondary school students in Herzele based on their experience with PMD Foster competition among schools or groups to boost the number of recorded bicycle trips visualised in DEV-D Hand out DEVA and DEV-D to 100 students from Herzele and Ghent so they can start recording their trips to and from school	***Athens:*** Extend cooperation to municipal medical centre in the districts of Kipseli and Neos Kosmos, and to groups involved in the Synathina platform ***Berlin:*** Work with local advocacy groups to recruit volunteers from neighbourhood management areas, places inhabited by minorities and marginalised communities ***Flanders:*** Use digital communication channels and traditional mail (posted letters) to target a mix of participants and identify local champions who can advocate in their community to ensure COMPAIR work carries

	showed interest ***Sofia:*** Partner with AirBG, the first sensor.community DIY network in Bulgaria, to recruit more volunteers	Run local workshops in Leuven, one of 100 climate neutral cities, to show how climate neutrality can be supported through the use of the CO2 Calculator ***Sofia:*** Organise a datathon in partnership with the Data Science Society of Bulgaria to present results and PMD visualisations to the Sofia City Council Organise workshops with local residents to show how the CO2 Calculator can help them understand their footprint and what they can do to reduce it	on ***Plovdiv:*** Bring together schools and policy makers to collaborate on the implementation of the first ever school street in the city ***Sofia:*** Partner with Roma minority organisations to recruit volunteers from this difficult to reach vulnerable community

These measures are not plucked out of thin air but represent real plans of action that local teams want to implement while the project is running. In fact, the measures are included in the upcoming public round that is due to start at the end of 2023 in the pilot cities. Some or all of the planned activities might continue post-project. An update on that will be provided in the final exploitation plan.

8. Conclusion

COMPAIR has one more year to go as an EU project managed by a 15-strong international consortium. As we get closer to the finishing line (October 2024), questions about results and what will happen to them become front and centre in sustainability discussions. We hope that this deliverable has demonstrated that far from being a cause for concern, the project's sustainability potential is strong and sound, ensured by:

- A diverse set of outputs and results comprising apps, dashboards, data, processes, publications, local citizen science labs with stakeholders, etc.;
- A resilient exploitation framework that allows for different uses of our results by a variety of stakeholders, which in turn ensures that the overall success does not depend on any one track/pathway; and
- A multi-pronged communication and dissemination strategy that leverages, among other things, third-party platforms, learning resources and pilot channels to sustain the use of results by partners and stakeholders, in pilots and new contexts, well after the project has ended.

So as not to lull partners into thinking that everything is perfect, below we present areas for improvement in our digital tools identified through market analysis, literature review, and internal research conducted in preparation for D8.4.

PMD is already on par with many leading dashboards, however its full potential is still untapped. We recommend changing the underlying air quality index to EU's, adding several calls to action and filtering options for active/inactive sensors, providing more opportunities for users to engage with sensors and their owners (e.g. follow a station, see all stations), and specifying conditions for the use of data served through the platform.

In the exploitation survey, a critical remark about the CO2 calculator had to do with its weak link to citizen science. One way to strengthen it would be to improve the calculator's ability to promote behavioural change. This would require supplementing the calculator's current role of statistics provision with elements of environmental psychology, such as pledges, gamification, and goal setting. The calculator's exploitation can be further improved by adding an FAQ on basic energy concepts (e.g. relationship between consumption and emissions) and by placing it in an institutional setting where students can use it as part of sustainability studies.

The main take-away from the user testing carried out at the workshop in Sofia is that DEVA in its current version is too complex for non-experts. Product owners are aware of that and are working hard on improvements that would make DEVA more accessible and easier to use/navigate. The added value of this deliverable is two-fold. First, it uncovered, based on the landscape review, that our only "competitor" (another solutions provide offering a similar app) is a sister EU project GreenSCENT. Second, and more worryingly, we learned that our competitors, many of whom launched their apps before or at the same time as COMPAIR, didn't survive very long despite showing early signs of market traction. We need to understand why this happened to avoid a similar fate. Maybe citizens get bored with AR apps for air quality very quickly and so the most viable exploitation option for DEVA is not the social track but the innovation track i.e. integration with Unity, as suggested by product owners. These two questions/considerations will be guiding our exploitation strategy for DEVA in the months to come.

In addition to these recommendations, we need to work on the following in the coming months.

- ***Financing:*** identify revenue models and costs for results that are conducive to commercial exploitation (business canvas).
- ***Pilot-level scalability:*** define which local activities conducted during the project will carry over to the post-funding period, also which results will be used, by whom, and for what purpose.
- ***Dissemination to 100+ cities mission:*** explore opportunities to share COMPAIR results with this group as its members are actively looking for solutions to engage with stakeholders to show how carbon neutrality can be achieved by 2030. Pilot results and lessons will be key here.
- ***MOOC collab:*** check whether other projects are interested in co-designing an online course as joint effort can potentially lead to more lasting outcomes. Interested projects may also suggest more suitable MOOC platforms.

We conclude the deliverable by returning to where we started: the exploitation framework. Table 3 below adds specifics to what may seem like a highly conceptual construct. Listed is a variety of measures that partners can/will take to exploit and scale the results across the five categories. The table will serve as a point of reference for future discussions on sustainability, with contents regularly updated and refined as results and new opportunities emerge.

Table 3. Results exploitation matrix

Results	Exploitation and route to scale				
	Social	**Policy**	**Technical**	**Scientific**	**Commercial**
Apps / Dashboards	***PMD:*** Add call to action to become a volunteer ***DEVA/D:*** run competitions for schools ***CO2:*** integrate into school's sustainability studies	***PMD:*** Offer to Flemish cities through VMM ***CO2:*** use in ideathons to simulate and stimulate city-wide action towards net zero	***DEVA:*** Use as an AR framework for Unity	Publish journal articles detailing the architecture and outputs ***PMD:*** update air quality index ***CO2:*** explain the methodology and energy concepts	***PMD:*** Display sensor ads on a map
Sensor Devices	Continued use by citizen scientists Interest from new groups and locations	Continued use in pilot cities to support existing measures (e.g school street, bus route) and new ones	Further develop in another project (TRL increase)	Publish journal articles showing how devices were used in a CS project	Agree on revenue sharing if sales come from PMD
Data	Offer to journalists, media outlets and think tanks	Calibrate to address shortcomings inherent in low cost sensors	Add a licence to regulate use of data served via apps	Provide real-time and historic data for use in research work	Offer a consultancy service to help others make sense of data
Processes	N/A	N/A	Improve calibration by adding new sources (e.g. space data) and tools e.g. AI, ML	Describe calibration approach and data manager in a journal article	Provide calibration service for a fee
Written & other	Capture testimonials from volunteers and share on social media	Publish policy briefs on how calibrated CS data can support environmental decision making in cities	Create or respond to challenges at hackathons	Publish journal articles based on project results	If the free course proves to be popular, consider publishing a paid one in the future