# D2.2 Citizen Science Landscape Review

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**Abstract:** This deliverable presents the findings of an extensive citizen science landscape review in which 100 projects from Bulgaria, Germany, Belgium and Greece were mapped and analysed to inform pilot deployment in COMPAIR. Although recommendations are targeting local project teams that will oversee COMPAIR citizen science labs in Plovdiv, Sofia, Berlin, Flanders and Athens, the results of this deliverable may also be of interest to anyone following developments in citizen science in Europe in general and the four said countries in particular.



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# Executive summary

This review sets the context for local Citizen Science (CS) labs to be established in Athens, Berlin, Flanders, Plovdiv and Sofia, by examining a selection of projects from the national CS landscapes. In total, the research team mapped 100 projects across the four countries, collecting information, by means of desktop research, on their type, scale, engagement approach, data collection tools, and impact. Insights gleaned from the review are presented in the form of critical analysis of the identified initiatives and are distilled into a set of recommendations intended to help COMPAIR pilots deliver successful CS campaigns. In addition, this deliverable fills gaps in existing literature by providing a nuanced perspective on the state of play of CS in Bulgaria, Belgium, Germany and Greece, and it advances the state of the art of CS research by proposing a new typology of CS regimes.

**Brief summary of country samples**

The 20 initiatives reviewed for the Bulgarian sample are a mix of global initiatives, European initiatives, EU-funded projects, and activities started by local and regional stakeholders. Citizens involved in air monitoring projects usually receive prior training and guidance but it's not clear to what extent they are engaged in stages preceding data collection (e.g. problem formulation, location selection) and stages that follow it e.g. reflection, analysis, lobbying for change. Impact on individuals and policy could not be easily identified within the air cluster. And as regards technology, the project with the highest innovation potential is METER.AC, which provides a continuously updated environmental dataset as open data under CC0 license.

The German sample includes 29 initiatives. We found initiatives that originated in Germany but have since spread to other countries (the so-called 'inside-out' initiatives), and initiatives that completed the opposite journey i.e. they arrived in the country as an extension of an international project (outside-in initiatives). Many projects are initiated, funded and managed by domestic stakeholders, and then there are 'supporters' i.e. projects that support the growth of the CS community without running any CS activities themselves. Projects that monitored air pollution and traffic did offer some training and guidance to participants, but the effort was mainly oriented toward technical skills needed to successfully operate a DIY sensor. Where attempts were made to measure behavioural change, the most commonly reported impact was increased knowledge and interest in air pollution. There was little impact on policy in the air cluster, but this has been compensated for by considerable impact on technology, delivered mainly, but not exclusively, by two inside-out projects Sensor.Community and senseBox.

The Belgian sample has 31 initiatives, representing a mix of small-scale local initiatives (city-level), regional initiatives that are active only in Flanders, Brussels or Wallonia, initiatives or pilots linked to EU projects, and initiatives that don't organise any CS activities as such, but that are on a mission to support existing or would-be CS projects. The Belgian sample has the largest primary cluster comprising 12 air related and two traffic related initiatives. Here, most projects avoided a hands-off approach, preferring a deeper engagement instead. Where this happened, participants were involved in pre- and post-data collection activities that ranged from brainstorming, workshops and training, to analysis, reflection and planning. Based on evaluation results of several projects (hackAIR, iSCAPE, Ground Truth 2.0), the most common benefits to CS participants are greater awareness of and improved motivation to get involved in air issues, as well as higher propensity to engage in soft-mobility behaviour. Policy impacts were largely limited to expressions of interest on the part of local authorities to mainstream CS kits in areas of mobility and education. One exception that stands out is CurieuzeNeuzen Flanders. Among the 20000 participants were 784 schools. 80% of those that participated did so in order to use project results to improve teaching practice. Moreover 39% reported to have informed their students about air quality findings and encouraged them to use active transportation modes more often. Finally, Belgium is the only country where we saw media outlets (newspapers) participating in CS projects as dissemination partners. Case in point is De Standaard, a Flemish daily that published CS results of two projects as online maps on its website (Curieuze Neuzen in de Tuin, CurieuzenAir).

The 20-strong Greek sample includes many EU projects. In fact, EU funding is present in all fields covered by the sample, from air quality and biodiversity monitoring, to humanities and art. That said, the Greek landscape is not without domestic initiatives, with some interesting examples observed at both local and national levels. Like other countries, Greece is not impervious to international CS initiatives, whose presence is especially strong in the field of environmental and biodiversity monitoring. We found one project with the hallmarks of a ‘supporter.’ But whereas German and Belgian counterparts focus on the whole landscape, this one targets universities as a starting point for CS transformation. Engagement tactics used by air projects involved some close-knit cooperation between CS projects and stakeholders. The latter benefited from training, sometimes in the form of an online course, designed to improve their capacity not just to build sensors but also develop CS scenarios for integration into institutional structures (e.g. education curriculum) to achieve a more lasting impact. Although many CS projects worked with schools, only hackAIR provides a glimpse of behavioural change stimulated by CS, as one participating school reported increased motivation among students to use CS experience as a springboard for new activities e.g. entrepreneurship.

The analysis of country samples allowed us to reach the following broad conclusions about air monitoring projects:

- Projects that experimented with different engagement tactics found that participants who attended several co-creation and training workshops tend to stay longer (and may even become ambassadors for the project at a later stage) than those whose engagement can be described as ‘shallow’ e.g. they learn about the project from social media, they have no contact with the organisers, they only follow online instructions on how to assemble a sensor
- Projects are generally aware of different levels of participation in which citizens can act as sensors (level one), interpreters (level two), data collectors (level three), data collectors and co-creators (level four), with many offering engagement opportunities at level three or above. Very few projects try to extend this standard model by offering engagement at even higher levels, such as when the ownership of a project is transferred to local communities in whole or in part (citizens scientists as co-managers)
- In many projects, schools are a priority stakeholder and sometimes the only stakeholder-cum-participant in CS activity. This shows that health risks posed by air pollution to young children are increasingly becoming more of a concern to schools,

parents and policy makers, for whom CS is a means to understand the scale of the problem, raise awareness about the issue, and co-develop strategies to address it, for example through school streets

- Through schools CS projects have potential to engage participants from lower socioeconomic (LSE) backgrounds, but this depends on the type of school (private or public). In general, few projects make it an explicit priority to target hard-to-reach groups, and fewer still manage to demonstrate success in this area. One engagement tactics that worked well in a recently finished project in Brussels is to use local charities that focus on health and poverty issues to identify LSE groups in areas that suffer disproportionately from air pollution
- The use of online maps is by far the most common way of presenting air quality data. Sometimes projects build their own platform to display results, sometimes they use platforms of international initiatives, with Sensor.Community being the most popular example. Sometimes data is accessible via API, sometimes as raw datasets on Zenodo. On a few occasions, projects in Flanders used a media outlet to disseminate findings, with results published as map-based visualisation on a daily's website

**Recommendations**

The country analyses and the above conclusions led to several specific recommendations. Recommendations are not prescriptive and should be seen as an invitation for local teams, and some other project partners, to consider a possible course of action in the following eight areas.

***R1) CS lab ownership:*** Pilots might want to start thinking about how deeply they want participants to be engaged with the lab. In particular, do they foresee a future where management of the lab is transferred to local communities in full or in part? Depending on the ambition, different levels of participation will need to be stimulated using different tactics and tools.

***R2) Location selection:*** To get a representative coverage of air pollution and include hard-to-reach groups in the measurement network, pilots should consider placing sensors in regular locations (that give a representative coverage of a city), community locations (identified through local NGOs) and background locations (pollution-free areas like forests), at least for NO2 measurements.

***R3) Stakeholder network:*** Pilots are encouraged to expand their networks with charities that work on health, poverty, age, and gender issues, to obtain access to vulnerable groups. Other stakeholders worth considering are local newspapers and magazines that may be interested in publishing project results, and different schools with and without prior CS experience. Local media may also be interested in coverage at an earlier stage, and could be a good way of reaching a diverse set of participants, and therefore help with recruitment and awareness raising. Local radio too might be interested in day-by-day reporting of results.

***R4) Data collection at workshops:*** It's important that data collected at workshops and in other project settings complies with good qualitative-research practices. To that end, local teams should perform a risk assessment whenever a certain group is excluded and/or unable to attend; circulate background papers to participants ahead of the meeting; inform participants that the meeting will be recorded and any pictures or videos may be used for dissemination purposes; stimulate a balanced discussion free from facilitator bias; understand the risks and how to manage them whenever antagonistic groups are placed in the same room; and circulate meeting notes to participants to collect additional feedback before finalising the workshop report.

***R5) Impact:*** Three areas where COMPAIR wants to make a difference are: (sensor) technology, behavioural change, and policy making. By using electrochemical gas sensors for real-time NO2 measurements, COMPAIR goes beyond the current state of the art where simple diffusion tubes rule the day. To ensure our sensors give accurate readings, they will be calibrated with data from reference-grade, highly accurate measurement stations. The main recommendation would be to consider placing sensors in other locations, not just around schools and reference stations. This is because NO2 occurs naturally as a result of lightning and microbial activity in soils, for example. To separate this background effect from anthropogenic factors, we might want to place a few sensors in locations with no local, nearby urban NO2 sources e.g. forests, parks, car-free pedestrian areas.

COMPAIR promised to elaborate five pathways to behavioural change in its objectives. There are many models and approaches we can study, including those taken by finished European CS projects on air quality. hackAIR, for example, used a different approach to study behavioural change in Brussels and Berlin. (The Brussels study was more sophisticated as it used a control and an experimental group.) When planning a behavioural change study in COMPAIR, we'll need to decide whether all pilots should follow the same methodology or whether it should vary from city to city. If the latter, it would be important to understand how this variation may affect the generalisability of our findings and ensure that results from e.g. Plovdiv and Flanders have the same validity as results from Athens, Berlin and Sofia.

Before we can claim that COMPAIR had any influence on policy, it's important to understand what a successful policy impact might be. Is it enough to secure an expression of interest from a civil servant, or should real-life application of project results by, say, a department be the standard by which to judge success? Our review shows that success in influencing policy, at least within the air cluster, is usually limited to an expression of interest by a public body to use project results in the future. This may or may not be enough for COMPAIR. Whatever our understanding of successful policy impact is, we will have to substantiate our claims about impact through some form of evidence, such as quotes, interviews, case studies, examples of project inputs to policy processes (e.g. response to a public consultation), references to implemented policies that use project results.

***R6) Dissemination:*** The main recommendation here concerns updates to existing repositories with information about COMPAIR and other projects. Specifically, the Bulgarian team should try to have some projects from the sample published on eu-citizen.science platform, which currently has no projects for Bulgaria at all. The German partners should try to advertise COMPAIR on Burger Schaffen Wissen, the Belgian ones on Iedereen Wetenschapper and, if possible, Scivil.

***R7) 10 principles of CS:*** Only one project out of 100 acknowledged following 10 principles of European Citizen Science Association (ECSA). Many others were found to be following these guidelines in practice but not in name. Some further guidance from ECSA is in order.

In particular, it would be useful to understand three things. First, do projects need to acknowledge, via a statement of sorts, that they are following principles in part or in full, to be deemed compliant with good CS practice? Second, is there a minimum threshold (e.g. following just one, two or three principles) that projects must meet in order for their activities to be considered good CS? Third, should COMPAIR advertise, through an e-badge for example, that it proudly supports ECSA's 10 principles?

***R8) Future research:*** To the best of our knowledge, and based on a quick desktop survey, no attempts have been made to create a typology of CS regimes that would categorise CS landscapes at national level. We believe that two preconditions for this new theoretical framework have been met, namely the abundance of different modes of participation and the diversity of CS project types found in different countries. We invite pilots, experts from the advisory board, and other project partners to validate the new theoretical framework that was created on the basis of this landscape review.

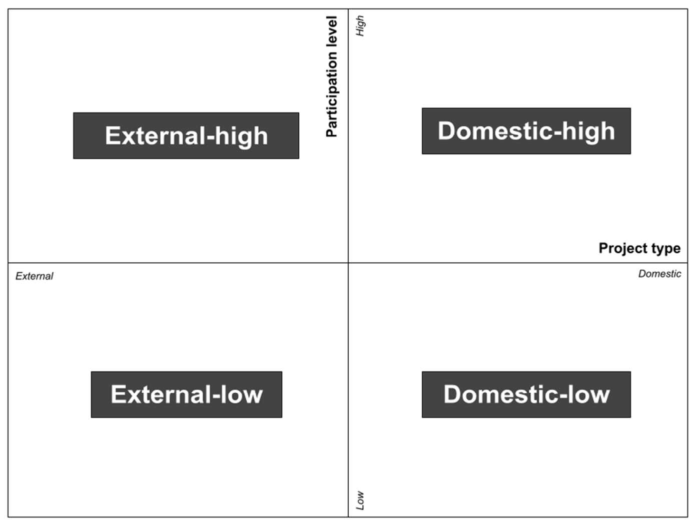


**Figure 1. The COMPAIR typology of CS regimes**

For a given country, the typology would show the distribution of projects across a range of disciplines. After mapping all initiatives according to type (external or domestic) and level of participation (low or high), the quadrant with the biggest project cluster would determine whether the national CS regime is predominantly external-low, external-high, domestic-low or domestic-high. One hypothesis that requires testing is whether regimes evolve from external-low to domestic-high—in other words from arguably a more basic landscape (dominated by external projects offering low levels of participation) to a more advanced landscape (dominated by domestic projects, including 'inside-out' initiatives,[1] offering more meaningful engagement)—under the influence of different drivers of change e.g. national policies that stimulate public participation in science, national funding for CS, technological advances, activities performed by enabling and supporting initiatives.[2] And what about external-high and domestic-low, can these be considered regimes in transition?

[1] The inside-out version of projects have really only been available in the past 20-30 years due to technological progress. Before that, most projects were domestic. So technological advances are clearly an important driver that have made inside-out initiatives possible.

[2] For an example of an 'enabler' see the Greek chapter, for 'supporter' Belgian and German ones

# Introduction

As cities prepare local Green Deals to achieve net zero emissions, it's important to focus on different co-benefits this transition may bring and not just on carbon reduction alone. Such co-benefits include health gains and climate justice for communities (e.g. school children, migrants, lower-income households) who have traditionally been more exposed to urban pollution than other demographic groups. COMPAIR is a new European initiative that helps cities make their air cleaner for all in the context of green and just transition. COMPAIR pilots a multi-pronged methodology that includes extreme CS,[3] low-cost air sensors and advanced digital tools in four geographically varied locations across Europe: Sofia and Plovdiv in Bulgaria, the region of Flanders in Belgium, Athens in Greece, and Berlin in Germany.

Established in these pilot sites will be local CS labs, each with its unique focus:[4]

- ***Bulgarian CS lab:*** create awareness of how different commuting patterns affect air quality; improve air quality around schools through new mobility measures; champion sustainable behaviour among young people
- ***Berlin CS lab:*** decrease the city's impact on climate by introducing more car-free streets; use CS data on traffic counts and air quality to model an optimal policy scenario
- ***Flemish CS lab:*** help city inhabitants avoid pollution hotspots by providing personalised recommendations based on air quality data from wearable sensors; measure traffic around schools using Telraam sensors to support the implementation of a school street scheme
- **Athens CS lab:** create a greener city by measuring and understanding the environmental impact of everyday habits e.g. wood burning, smoking, recycling, heating etc.

Local teams are currently preparing groundwork for their CS labs. This includes identifying extra stakeholders in the value network, specifying user requirements in terms of sensors and digital tools needed for CS experiments, developing an inclusive and scientifically-grounded engagement strategy, designing participation protocols and risk-mitigation strategies, and understanding the context in which their CS lab will operate. This deliverable directly supports the last task by providing a snapshot of the national CS landscape on the basis of which other tasks (e.g. stakeholder engagement) can be further improved.

For the purposes of this deliverable, the landscape is understood in terms of CS projects that took place or are still running in a given country. In this review, we tried to identify, to the extent possible, a representative sample of such initiatives for Bulgaria, Germany, Belgium and Greece. Based on a critical analysis of the country samples, we generate a list of

[3] Extreme CS represents the highest level of participation in a four-level typology developed by Muki Hacklay. In extreme CS, volunteers act not only as sensors or basic interpreters, they actively participate in problem definition, data collection and analysis. See Haklay, M. (2013). Citizen Science and Volunteered Geographic Information - overview and typology of participation. In D. Sui, S. Elwood, & M. Goodchild, Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice (pp. 105-122). Berlin: Springer.

[4] See pilot overview https://www.wecompair.eu/

recommendations that is both compelling and timely for COMPAIR CS labs while they are still laying the foundation for future activities.

Besides local teams working on CS labs, this deliverable would be of interest to people outside the consortium who are looking for new research on CS in Europe. The lack of visibility on CS in Bulgaria and, to an extent, Greece perpetuates the impression that countries in the Balkans and Southern Europe are seriously lagging behind those in the West and the North. Our research does show that CS landscapes in Germany and Belgium are more mature, but it would be wrong to assume that Bulgaria and Greece are completely new to the field - far from it. Both boast a fledgling CS landscape that is highly diverse. There are different project types (domestic, international, EU-funded) covering a variety of fields: air monitoring, water monitoring, biodiversity monitoring, social sciences, humanities, and arts, to name a few. Germany and Belgium are certainly doing better visibility-wise, as much has been written about their CS over the years. Even so, existing literature on German and Belgian CS landscapes sometimes lacks depth and critical analysis, thus failing to provide a nuanced picture of the landscape's general characteristics and distinguishing features. While our review is not perfect, we believe it helps fill some of the gaps identified for the four countries.

***Bulgaria and Greece:*** There is notable lack of sources providing information on the national CS landscape, its size, diversity and main characteristics. Many papers have been written on CS in Europe, with the most recent one being *CitizenScience in Europe*.[5] In this book chapter, the authors refer to Greece and Bulgaria, but only briefly. The landscape in Greece was summarised in just two paragraphs, whereas Bulgaria received even less page space (actually just a few sentences).

***Germany:*** The country's CS landscape is arguably one of the most advanced in Europe. Over the years, hundreds of projects have been funded by the Federal Ministry for Education and Research to involve citizens in all kinds of scientific research, from monitoring air quality to identifying invasive alien species. In 2016, a green paper was published to guide Germany's CS strategy until 2020,[6] and more recently, in 2021, a white paper was produced to steer CS until 2030.[7] There are also research papers that analyse the state of play of CS in Germany. An example is the work by Schleicher and Schmidt (2020)[8] who reviewed 127 German initiatives by examining their descriptions on the aggregation platform Bürger schaffen Wissen ("Citizens Create Knowledge).[9] While the sample is impressive, project abstracts can provide only so much information about the project. One would also need to spend some time browsing the project website and other sources, if necessary, to get a more complete understanding of what actually happened in the project and what its true impact might have been. Moreover, the authors allocated just three pages in the manuscript to the results presentation, much less than one would expect from such an extensive review.

[5] Vohland, K. et al. (2021). Citizen Science in Europe. In: The Science of Citizen Science. Springer, Cham. https://doi.org/10.1007/978-3-030-58278-4_3
[6] https://eu-citizen.science/resource/42
[7] https://www.citizen-science-weissbuch.de/
[8] Schleicher K, Schmidt C. (2020) Citizen Science in Germany as Research and Sustainability Education: Analysis of the Main Forms and Foci and Its Relation to the Sustainable Development Goals. Sustainability. 12(15):6044. https://doi.org/10.3390/su12156044
[9] https://www.buergerschaffenwissen.de/

***Belgium:*** The country too has a buoyant CS landscape. There is a CS strategy (for Flanders at least)[10] and not one but two platforms akin to Germany's Bürger schaffen Wissen. One is called Scivil,[11] another Iedereen Wetenschapper ("Everyone Scientist").[12] The latter is a national database providing information on more than 180 finished and ongoing projects. Scivil, on the other hand, is a Flemish initiative supported by the regional government that nurtures the CS ecosystem in Flanders. In 2021, Scivil published a paper on CS in Flanders.[13] It was based on a survey of almost 200 citizen scientists, who provided information on their demographic profile (age, educational level etc.), on the kind of projects they participated in, on their motivation and experiences, among others. This paper is quite useful to get a general idea about the Flemish CS from a citizen perspective. But if one is looking for a more critical analysis of engagement tactics used, and of the impacts different projects might have made not only on individuals but also policy and technology, then the reader will need to look elsewhere as the paper provides scant details in this regard. Perhaps this information is provided in a book titled 'Citizen Science. Hoe burgers de wetenschap uitdagen' ("Citizen Science. How citizens challenge science").[14] But the problem with this publication is that it's not free. One needs to fork out 30 euros to get a copy.

So the main rationale for this deliverable is to help pilot teams better understand the context in which their CS lab will operate, to address some gaps in existing literature on CS in Bulgaria, Germany, Belgium and Greece, to provide recommendations for successful CS deployment in pilot countries based on the analysis of national CS landscapes and international best practice, and to identify opportunities for future CS research.

The next chapter will introduce the methodological approach and its limitations. This will be followed by a detailed review of the four country landscapes. In conclusion, we'll briefly summarise what we have learned from these reviews, before recommending to local teams things they can do to improve their CS campaigns. Our final recommendation is an invitation to advance the state of the art of CS research by validating a new typology of CS regimes that was developed based on the deliverable's findings. Placed in the annex are 20 international case studies, half a page each, that offer an additional perspective on the fight against air pollution by CS projects in other EU countries. These case studies can be examined by pilots and indeed the wider CS consortium to understand how our project compares to others in the field.

[10] In Flanders, for example, it's incorporated into the Flemish Science Agenda
[11] https://www.scivil.be/en
[12] https://www.iedereenwetenschapper.be/
[13] Duerinckx, A., Hens, C., Kerckhoffs, S., Van Laer, J., Verstraelen, K. (2021) The citizen in Flemish citizen science: Demography, motives, and experiences. Scivil, Leuven, Belgium
[14] https://www.tijdschriftenwinkel.be/products/citizen-science

# Research design

Research design comprises two sequential work streams. The one focused on pilot initiatives received a priority and was therefore implemented first. It identified 100 CS initiatives from Bulgaria, Germany, Belgium and Greece, which were then analysed following a predefined schema. The main results of this ‘primary workstream’ are:

- Mapping tables detailing the results of the categorisation process[15]
- Pilot chapters where we critically analyse pilot samples in terms of stakeholder engagement, data and tools used, and impact achieved
- Recommendations to COMPAIR pilots based on lessons learned from the analysis

The other workstream focused on projects outside the pilot countries that also used CS to monitor urban air quality. 20 initiatives from different EU and non-EU countries, among them France, Spain, Norway, and the UK, were identified based on desk search and recommendations from COMPAIR project partners. The results of this ‘secondary workstream’ contribute to the main findings of D2.2 and include

- 20 case studies of air related initiatives from different European countries
- Recommendations to CS labs based on lessons learned from the international case studies and their relevance to COMPAIR.

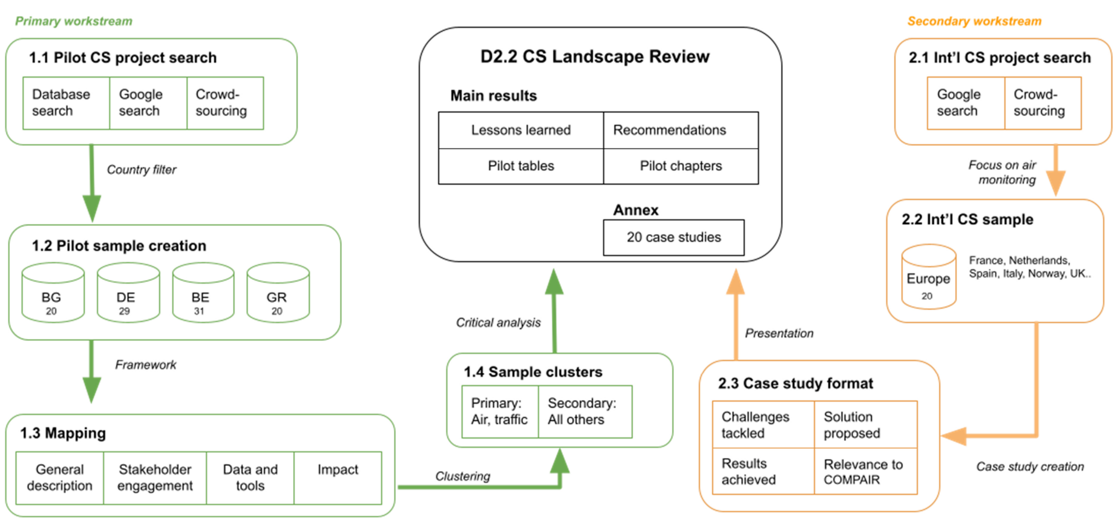


Figure 2. CS landscape review: methodological approach

**Primary workstream**

*Pilot CS project search*

To identify CS projects in Bulgaria, Germany, Belgium and Greece we conducted searches on two popular CS databases and Google, and also asked pilot teams to fill in gaps by recommending any additional projects they know that would add value to the pilot sample.

Two international platforms used for the database search are EU-Citizen.Science[16] and CitSci-X.[17] The first one is managed by the European Citizen Science Association (ECSA),

[15] https://www.wecompair.eu/results-1
[16] https://eu-citizen.science/

 

the second one by the Joint Research Centre (JRC) of the European Commission. Both have large collections of CS projects, some of which were relevant to our study - and so were subsequently added to the pilot samples - but some were not. This was especially the case with JRC's Cit-Sci-X, where we found many projects with dubious links to CS, mainly because it wasn't clear how, if at all, citizens were involved in scientific research. As regards ECSA's EU-Citizen.Science, one challenge we faced with its collection is that it has no projects from Bulgaria, which gives an impression that the CS landscape in the country is barely visible or even non-existent. Given these limitations, we had to conduct additional search on Google[18] and rely on some crowdsourcing to build more representative pilot samples.

*Pilot sample creation*
A combination of these three techniques yielded the following results
- Bulgarian sample: 20 initiatives
- German sample: 29 initiatives
- Belgian sample: 31 initiatives (predominantly Flanders and Brussels)
- Greek sample: 20 initiatives

In order to have a balanced representation of country samples, we decided to cap our pilot collection at 100. German and Belgian samples have slightly more projects because, as will be explained in the next chapters, their CS landscapes are more advanced than those in Bulgaria and Greece. The German landscape has at least 150 projects according to the national portal Bürger schaffen Wissen. The Belgian one at least 180 according to Iedereen Wetenschapper. So, at best, we managed to capture 17-20% of the CS landscape in these countries with our pilot samples.

It's more difficult to make similar estimates for Bulgaria and Greece as they don't have national CS portals akin to Bürger schaffen Wissen and Iedereen Wetenschapper. We can only gauge the scale of the CS landscape in these two countries indirectly, by estimating the point of diminishing returns reached during a scanning process. In the case of Bulgaria, we felt that 20 was pretty close to that point as each new research attempt, whether it was a Google query or call for contribution, yielded fewer original results than the previous one. In the case of Greece, 20 was a bit further away from that point as new research did yield some new results, it's just that we didn't have time to review them. Based on this distance to the point of diminishing returns, we estimate that our Bulgarian sample covers 70-80% while the Greek one 50-60% of the national CS landscape.

In building pilot samples we considered all kinds of CS initiatives: those in which citizens act as sensors (crowdsourcing), those that use citizens as basic interpreters (distributed intelligence), those that engage citizens in problem definition and data collection (participatory science), and those that go one step beyond by allowing citizens to also take part in the analysis stage (extreme citizen science).[19] Because our goal was to capture CS diversity that extends beyond levels of participation, we chose to include projects that play

[17] https://ec-jrc.github.io/citsci-explorer/
[18] Example of search techniques used: ("citizen science" OR "citizen observatory") AND ((Sofia) AND (Bulgaria)) AND ("air pollution" OR "air quality")
[19] These are the four levels of participation in CS described in Haklay (2013)

 

more of a supporting role in the national CS landscape. Such projects don't necessarily conduct any CS experiments themselves, but thanks to their presence the national CS ecosystem is able to grow and develop, with results disseminated far beyond the country's boundaries. Examples include national or regional CS aggregation portals, capacity building platforms and technical initiatives that do some or all of the following: provide curated collections of CS projects, train and advise those who want or already run a CS project, develop CS kits for use by volunteers during CS projects.

*Mapping*

The resulting sample was then categorised according to a predefined schema. The mapping covers four areas: general description, stakeholder engagement, data and tools, and impact. These were selected during an internal meeting with project partners based on relevance to COMPAIR. The mapping tables are available to view and download from the project website.[20]

***General description:*** includes the project's name, field (e.g. air monitoring), status (finished or ongoing), lead organisation, location where activities take place, scope (local, national, EU, international), description and objectives, and use of 10 principles of CS developed by ECSA.[21] During the mapping process, we tried to find out whether projects used or at least referred to ECSA's recommendations.[22] This was also a way for us to check whether different levels of participation were present in the sampled projects.

***Stakeholder engagement:*** focuses on the overall engagement approach e.g. how volunteers were recruited, engaged and retained, whether any special techniques or incentives were used to promote participation e.g. gamification, vouchers. As well as trying to find out the size of the volunteering force, we checked if any participants were from hard-to-reach groups, and if all members of the quadruple helix (civil society, research, policy, science) contributed to the project one way or another.

***Data collection and analysis:*** provides information on tools used to collect data (e.g. DIY or mobile sensors, apps, online forms) and on the type of data collected e.g. particulate matter (PM), nitrogen dioxide (NO2), animal species. Also mapped was the medium for presenting results: map, table, dashboard, paper, et cetera.

***Impact:*** the final section looks at the impact in terms of technical change (did the project improve any technical tools or processes that benefit citizen science?), behavioural change (did participants change their attitudes and behaviour as a result of the project?), and policy change (did the project have any impact on policy making?)

*Sample clusters*

Represented in country samples is a great variety of scientific fields: air quality monitoring, traffic monitoring, noise monitoring, odour monitoring, waste management, soil monitoring, seismography, vegetation monitoring, environmental monitoring, biodiversity monitoring, water quality monitoring. Several projects are from fields other than natural sciences e.g.

[20] https://www.wecompair.eu/results-1
[21] https://osf.io/xpr2n/wiki/home/
[22] https://osf.io/xpr2n/wiki/home/

arts, humanities, social sciences. To make our analysis more focused, we split each country sample into two clusters. The primary cluster includes air and traffic related projects, the secondary one all other projects. Although all projects were mapped according to the same framework, the ensuing critical analysis was applied more rigorously to the primary cluster as it's more relevant to COMPAIR.

**Secondary workstream**

The goal of this task was to identify 20 projects on air quality from other parts of Europe and to present them as brief case studies that can serve as an inspiration and a useful source of knowledge for COMPAIR CS labs and others looking to engage citizens in the monitoring of air pollution. Our research design for this workstream was much simpler. We started by running Google queries for different European countries[23] and, in parallel, asked project partners to share any relevant projects they know that would make an interesting case study. We ended up with a 20-strong international sample comprising initiatives from Ireland, Norway, UK, France, Spain and Netherlands, to name just a few countries. To standardise case studies, we followed a simple format addressing four topics: what challenges were tackled, what solution was proposed, what results were achieved, and how the case study is relevant to COMPAIR. Lessons learned from case studies have been incorporated into final recommendations and case studies themselves are available in the annex and the project website.

**Limitations of this research**

The next four chapters will present the results of the primary workstream. However, before introducing the reader to the CS landscape in Bulgaria, Germany, Belgium and Greece, it's important to address the main limitations of the research undertaken, which have a bearing on the ensuing discussion. The limitations are a result of decisions made concerning the review scope and focus, the amount of time allocated to the review, and research methods used to accomplish the task.

***Scope of the review:*** Our landscape review focused exclusively on CS projects i.e. projects that label themselves as such. A more complete review would have included institutional arrangements, funding mechanisms, strategies and regulations that promote public participation in science. Even though these milieu factors weren't addressed in D2.2, some of them will be reviewed as part of the upcoming D2.3 Policy Landscape Review due in June 2022.

***CS literature review:*** While D2.2 may seem like a perfect place to discuss CS, what this concept means and how it varies depending on context, we made no such attempt in our deliverable. For one, this would be a daunting task given that CS has no shortage of definitions. Hacklay et al. (2021)[24] provide a list of 35 definitions from all kinds of organisations, who prefer to emphasise different aspects as regards scientific work and levels of participation. We are quite happy with the definition proposed by ECSA, which sees CS as an "umbrella term that describes a variety of ways in which the public participate in

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[23] A similar search query was used as in the primary workstream e.g. ("citizen science" OR "citizen observatory") AND (Spain) AND ("air pollution" OR "air quality")

[24] Haklay, M., Dörler, D., Heigl, F., Manzoni, M., Hecker, S., Vohland, K. (2021). What Is Citizen Science? The Challenges of Definition. In: , et al. The Science of Citizen Science. Springer, Cham. https://doi.org/10.1007/978-3-030-58278-4_2

science."[25] Such a broad definition allowed us to complete mapping in less time than would have been possible if a more stringent CS criteria was used.

***Absence of evidence:*** During the mapping process, we weren't always able to find information on things that interested us e.g. project impact, stakeholder engagement, the size of the volunteering force. But just because we couldn't find something does not mean the results or activities did not happen. It goes without saying that absence of evidence is not evidence of absence. Failure to find some information on our part can be explained by the fact that we worked primarily with internet sources, so we had to make do with whatever publicly available information we could find within reasonable time. Under different circumstances, not only could we have checked more resources/documents, it would have been possible to carry out primary research too to fill in gaps left by desk work.

[25] https://ecsa.citizen-science.net/

# Bulgarian CS landscape

The Bulgarian sample includes 20 initiatives. When we started the exercise, the project team was aware that CS is relatively new to the country. The main reasons for that are i) comparatively low levels of public participation in science in the region[26] and ii) a limited number of initiatives published on international CS aggregation platforms. As regards the last point, the CitSci-X platform[27] managed by JRC lists 9 projects for Bulgaria, most of which appear to have a questionable link to CS upon closer examination. And on EU-Citizen.Science, there is no country filter for Bulgaria in the projects section, which can give an impression that the CS landscape in the country is completely barren.[28]

Below is a quick overview of the 20 Bulgarian initiatives. We found several projects in the domain of air quality monitoring and biodiversity monitoring. A few projects were from fields other than natural sciences i.e. social sciences, humanities and arts. The rest were individual instances related to the monitoring of water quality, vegetation, environment, waste, and odour pollution.

**Table 1. Bulgarian sample**

| Field | Projects | Total |
|---|---|---|
| Air quality monitoring | AirBG, HEAL Sofia, Dustcounters, IQAir Sofia, METER.AC | 5 |
| Biodiversity monitoring | Alien CSI, The Quest for the Storks, ANEMONE, RECONNECT, Gecko monitoring, PECBMS, Let's count the sparrows | 7 |
| Monitoring of water quality, vegetation, environment, waste and odour pollution | DNOSES, EdnoDarvo, GLOBE BG, Shared Compost, Watermap of Bulgaria | 5 |
| Social sciences, humanities and arts | CitizenHeritage, REFRESH, Citizens' App | 3 |

**General overview**

Our sample shows that Bulgarian CS landscape is a mix of global initiatives, European initiatives, EU-funded projects (outside-in initiatives), and activities started by local and regional stakeholders. Some of these are finished projects, some are still running. To better illustrate this diversity, we'll briefly present a couple of projects from each category. After this, we'll delve deeper into the sample by examining key themes related to stakeholder engagement, data collection, and impact, first for air related projects (primary cluster) and then all the other ones (secondary cluster).

*Global initiatives*

In this category we placed GLOBE and AirBG. Although AirBG is active nationally, the project started as part of Luftaden.info (now Sensor.Community), which originated in Germany in 2016 and has since spread to all corners of the world (there are 57 community

[26] Vohland, K. et al. (2021). Citizen Science in Europe. et al. The Science of Citizen Science. Springer, Cham. https://doi.org/10.1007/978-3-030-58278-4_3

[27] https://ec-jrc.github.io/citsci-explorer/project/

[28] The platform is sustained by a community of volunteers, who will add the country filter for Bulgaria shortly after the publication of this deliverable.

labs in 65 countries according to the website). AirBG set itself an ambitious goal when it started - to build a national network of 1000 stations across the country[29] - and that goal has almost been achieved judging by the number of deployed sensors on the AirTube map[30] where results are displayed.

GLOBE was founded in 1994 in the US to improve the understanding of the Earth system and global environment among students and the public worldwide. Currently, GLOBE has presence in 125 countries, including Bulgaria and all other pilot countries. In Bulgaria, GLOBE cooperates with eight schools, two of which are in Sofia: Anglo-American School Sofia, American College of Sofia. In total, there are 247 CS sites across Bulgaria that collectively produced 582 measurements on land cover, trees and clouds.[31]

*European initiatives*

By European initiatives we don't mean EU-funded projects (as these will be discussed next) but rather projects with a pan-European scope, such as HEAL and PECBMS. HEAL was a CS project initiated by the eponymous Health and Environment Alliance.[32] It was active in six European capitals that at the time (2019) failed to meet EU air quality standards as regards nitrogen dioxide (NO2) and particulate matter (PM). Two of them are COMPAIR pilot cities: Berlin and Sofia. In Sofia, HEAL worked with eight primary schools[33] located in different municipal districts to measure indoor and outdoor pollution (PM2.5, NO2), as well as carbon dioxide (CO2) concentration in classrooms.

PECBMS stands for the Pan-European Common Bird Monitoring Scheme, a project that was started in 2002 by the European Bird Census Council and BirdLife International. Counting birds in the field is performed by volunteers in different countries. The number of 'test sites' in Bulgaria exceeded 100 in 2021, with citizen scientists making a total of 11,430 entries that year.[34]

*EU-funded projects*

There are several EU-funded projects in the sample. The ones we're going to briefly present are DNOSES and RECONNECT. DNOSES is a finished project that stands for the Distributed Network for Odour Sensing Empowerment and Sustainability. The project used CS as one of the tools to tackle odour pollution in six pilot cities, among them Sofia. The Bulgarian pilot focused on food waste collection within Sofia Municipality. By mapping and framing the issue, the pilot tried to identify bottlenecks in the municipal system for separate collection of food waste, and ultimately improve it using new insights from CS activities.

RECONNECT too is a finished project, with CS activities performed in Bulgaria, Greece and Cyprus. The project relied on volunteer divers to identify marine species and monitor

[29] https://www.airbg.info/
[30] https://airtube.info/
[31] https://www.globe.gov/web/bulgaria-citizen-science
[32] HEAL (2019) Healthy air, healthier children. 50 schools across the EU monitor air quality. https://www.env-health.org/
[33] 26 SU "Yordan Iovkov", 75 OU "Todor Kableshkov", Telelcomunication school, and NPMG. Other schools wished to remain anonymous.
[34] https://bspb.org/monitoring/bg/results.html

changes in biodiversity over time. There were four study areas in Bulgaria, all from the Natura 2000 site Plazh Gradina - Zlatna Ribka.

*Domestic initiatives*
Found in this category are initiatives started by local stakeholders, for example METER.AC and EdnoDarvo. METER.AC is an ongoing CS initiative by Plovdiv University. It has a network of some 100 nodes across Bulgaria, covering Plovdiv, Sofia and many other cities, that measure atmospheric pressure, temperature, relative humidity, particulate matter, and background radiation. Essentially, METER.AC is a continuously updated dataset that provides open data with high spatiotemporal resolution for detailed atmospheric monitoring.

EdnoDarvo (OneTree) is currently active in Sofia, focusing primarily on vegetation monitoring. Volunteers and professionals gather information on urban trees via app. The results (e.g. type, height, thickness) are then displayed on a map embedded into the project website.

Now that we painted a general picture of the CS landscape in Bulgaria, we would like to proceed with a thematic analysis of the identified initiatives, focusing on their

- ***Engagement approach:*** how did they engage volunteers, how many of them were involved, were any of them from hard-to-reach groups, were other members of the quadruple helix involved, were any of the 10 principles of good CS followed?
- ***Data collection and analysis:*** what information did citizen scientists collect, how did they collect it, how was the information presented?
- ***Impact:*** what impact, if any, did the project have on individuals, technology, policy?

As detailed analysis per project would take too much space and time, we will just provide an overall summary per theme based on the information we were able to find during the mapping process. Interested readers can always consult the main tables for extra details.[35] Other caveats worth mentioning now are these.

First, just because we couldn't find, for example, evidence of impact, use of ECSA's 10 principles, or involvement of hard-to-reach groups for some initiatives, it doesn't mean that these results or activities were actually absent during the project. The fact that we failed to find something could simply be due to time constraints under which the research team operated, and also because of the nature of the research itself (desktop based).

Second, although our mapping covers all projects, those in the field of air monitoring (primary cluster) will be prioritised owing to their relevance to COMPAIR. By studying what they did or didn't do, how successful or unsuccessful they were in achieving impact, we hope to obtain some useful knowledge that can inform our planning and operations as regards pilot deployment and technical development. That said, there are some useful lessons to be learned from almost all projects, not only those in the primary cluster. We will try to do justice to some of them too by highlighting their achievements at the end of the chapter.

[35] https://www.wecompair.eu/results-1

**Primary cluster**

*Stakeholder engagement*

Within the air monitoring cluster, no comprehensive methodology to engage stakeholders was identified. AirBG has followed a rather hands-off approach in this regard, offering copious guidance on the website (e.g. what sensor parts to buy, how to assemble them) but little in the way of a multi-stage participatory process. HEAL was also short on details regarding their work with eight schools. The only project where we were able to find some evidence of co-creation was Dustcounters, a Greenpeace initiative in Stara Zagora, but even here, it appears, the process was limited to a brief info session followed by a workshop where volunteers learned how to assemble sensor devices.

As regards participants, it's only for Dustcounters that we were able to find the number of citizen scientists involved (n=25), while for all other projects this information either wasn't provided or can be estimated indirectly, by looking at the number of sensors deployed e.g. 824 in the case of AirBG.

Participation of hard-to-reach groups in CS activities was not openly mentioned by any of the projects. But if they were involved, the most likely candidate where this could have happened is HEAL. If some of the eight participating schools cater to children from different social classes, we can assume that pupils from lower socioeconomic backgrounds were represented in the schools' population (6400 pupils according to HEAL), and could therefore have been among participants that took part in CS activities.

For this cluster of projects, we couldn't find any evidence of the involvement of all members of the quadruple helix community in a single project. In most cases, participation can be described as being double helix i.e. involving scientists and citizens. METER.AC is the only project that appears to be thinking in quadruple helix terms, judging by its intention to provide tools and CS resources to help academia, public institutions and industry achieve Sustainable Development Goals.

Finally, based on the description of CS activities performed, all projects seem to follow at least the first of the 10 principles.[36] But the fact that acknowledgement of 10 principles was nowhere to be found suggests that projects did not frame their activities according to ECSA's guidance, or were even aware of it at the time of experiment design/implementation. This raises an important question, actually two. First, do projects need to acknowledge, via a statement of sorts, that they follow some or all of the 10 principles, to be deemed compliant with good CS practice? Second, is there a minimum threshold (e.g. following one, two or three principles) that projects must meet in order for their activities to be considered good CS? We will leave these questions open for now and will attend to them at the end of the deliverable when issuing recommendations for future action.

*Data collection and analysis*

In terms of data captured, the five projects collectively measured particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), carbon dioxide (CO2), as well as additional atmospheric

[36] Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leader and have a meaningful role in the project.

information e.g. pressure, temperature, humidity, background radiation. There is a clear tendency to opt for easy-to-use, easy-to-assemble, low-cost, do-it-yourself sensors, such as those offered by the now-defunct Lufdaten.info, with the NodeMCU open source IoT platform at the core. The measurement of NO2 and CO2 was carried out, respectively, using diffusion tubes and a special CO2 monitor. All projects except HEAL and Dustcounters present results on an online map. In the case of AirBG, this was linked to the main platform of Sensor.Community.

*Impact*

In assessing the impact of identified initiatives we were guided by three questions. Was there anything innovative about the project from a technical point of view? Did participants change their attitudes and behaviour as a result of the project? Did the project have any impact on policy making?

With regards to technical impact, it's worth mentioning two projects: Dustcounters and METER.AC. The innovative design of Dustcounter devices meant that they could be easily assembled from common hardware components. Moreover, they were created with open-source technology (Arduino), which made them affordable and easy to operate by non-professionals without technical expertise. As to METER.AC, we found their platform to be an interesting dissemination and awareness building resource. Not only because of the way it displays data (there are tables, maps, real-time footage), but also because the network data is licensed under Creative Commons CC0. It means that all the raw data, including the full history, is in the public domain and can be easily reused by third-party apps.

When it comes to impact on individuals and policy, we just one brief mention in the HEAL report that their recommendations would be of interest to parents, health professionals, patient groups, health sector, and schools, but whether some of these stakeholders changed their behaviour as a result of the project is anyone's guess. In the same report, HEAL identified local authorities, national and EU decision makers as another target audience for their recommendations, however there was no further discussion on whether these recommendations ultimately had any impact on policy immediately or over time.

**Secondary cluster**

*Highlights from other initiatives*

Among the projects worth highlighting outside the air cluster is DNOSES. It's one of the few reviewed initiatives that clearly focused on engaging members of the quadruple helix community. Participation in DNOSES extended beyond data collection; volunteers were also able to define the problem, co-design methodologies and tools that enabled them to own, share and act on their results. The results of the Sofia pilot were presented to the National Association of the Municipalities in the Republic of Bulgaria, and later circulated to 265 Bulgarian municipalities via association's bulletin.

Looking at projects that shared information on their volunteering force, initiatives with the highest number of citizen scientists are Let's count the sparrows (767), The Quest for the Storks (300), ANEMONE (158) and CitizenHeritage (23).

We noticed that many initiatives, especially in the field of biodiversity monitoring, relied on simple forms to report data (e.g. PECBMS, Let's count the sparrows, Shared compost, Watermap of Bulgaria) but there were also a few that developed a special app for that (e.g. EdnoDarvo, GLOBE, The Quest for the Storks, Citizen’s App). Although many opt for online maps as a way of presenting results, not all do. REFRESH, for example, presented results only in project reports.

Finally, the most common personal impact of CS participation appears to be increased awareness of issues and ways to tackle them. Additional potential benefits include the ability to counter the influence of fake news (ANEMONE), better mental health and strengthened social bonds (RECONNECT). The Watermap of Bulgaria has a clear focus on behavioural change but whether its activities/results helped limit the use of plastic water bottles has yet to be established.

# German CS landscape

We reviewed 29 past and ongoing CS initiatives in Germany. This represents but a small fraction of the actual CS landscape. On platforms like Burger Schaffen Wissen[37] ("Citizens Create Knowledge"), there are around 100 projects just for Berlin alone and over 150 for Germany as a whole. Our priority was to include 1) all the main ones that deal with air quality and traffic monitoring, 2) local projects that seem to be popular in the capital e.g. wildlife monitoring, 3) European or international projects with CS activities in the capital and other parts of Germany, and 4) interesting examples that don't conduct any CS activities per se, but which support the growth of Germany's CS culture and community. What initiatives made it to the landscape review can be seen in the table below.

**Table 2. German sample**

| Field | Projects | Total |
|---|---|---|
| Air quality and traffic monitoring | hackAIR, Measuring the Berlin Air, SenseBox, HEAL, BerlinAIR NO2 Atlas, Sensor.Community, PolDiv, Envirocar | 8 |
| Biodiversity monitoring | Fledermausforscher in Berlin, Stadtwild Tiere Berlin, InsktenMobil, Muckenatlas, NaturGucker, My Ocean Sampling Day, Ornitho, Tauchen für Naturschut, ArtenFinder | 9 |
| Water quality monitoring | Plastik Pirates, Citclops, FLOW, BeachExplorer | 4 |
| Environmental and atmospheric monitoring | GLOBE, Tator Gewasser, Netatmo CWS, PV2Go | 4 |
| Monitoring of odour pollution and soil quality | DNOSES, Open Soil Atlas | 2 |
| Other | Burger Schaffen Wissen, SimRa | 2 |

**General overview**

Notwithstanding its limitations, our sample provides a snapshot of the highly diverse CS landscape in Germany. We found initiatives that originated in Germany but have since spread to other countries in Europe and beyond (the so-called 'inside-out' initiatives), and initiatives that completed the opposite journey i.e. they started elsewhere but ended up running CS activities in Germany (the 'outside-in' initiatives). Although we came across several EU funded projects in various domains, our impression is that the vast majority of German initiatives are actually initiated, funded and managed by domestic actors. We were also surprised by the discovery of an interesting initiative type that provides support to CS projects but doesn't necessarily conduct any CS experiments itself. To better illustrate this diversity, we'll briefly present a couple of projects from each category, and will then delve deeper into the sample by examining key themes related to stakeholder engagement, data collection, and impact.

[37] https://www.buergerschaffenwissen.de/

*'Inside-out' initiatives*
Examples of initiatives that started in Germany and eventually spread to other countries are Sensor.Community and Plastik Pirates. Sensor.Community is a continuation of Lufdaten.info that was started by the OK Lab Stuttgart in 2016. Sensor.Community is now a global sensor network that includes 14400 devices and is active in 73 countries. Driven by the principles of CS, Open Data and transparency, Sensor.Community has launched a number of campaigns to bring sensors to every school (#Sensor2School), library (#Sensor2Library) and reference station (#Sensor@RefS).

Plastik Pirates started as a campaign to investigate plastic waste in German rivers. A few years later, the Trio-Presidency of the Council of the European Union for 2020/2021 led by Germany, Portugal and Slovenia, decided to scale up the project to all countries involved. Since then, thousands of young people have taken part as citizen scientists by collecting plastic waste and sharing data on the amount of waste found. The new sampling period will start in spring 2022.

*'Outside-in' initiatives (European, international)*
To this category belong international initiatives like HEAL and GLOBE. We first introduced HEAL in the Bulgarian chapter, because Sofia was one of six cities targeted by the project. Berlin is another. According to HEAL, the city's annual EU standard for NO2 was exceeded year after year and PM10 standards were not properly complied with since 2009. In response to that, HEAL started a CS monitoring project in 2019, with the active participation of ten schools[38] across Berlin representing approximately 4300 children.

GLOBE, as the name suggests, is a global initiative covering 125 countries that was founded in the US in 1994 to improve understanding of the Earth system and environment among students and the public worldwide. In this deliverable, GLOBE too was first introduced in the Bulgarian chapter. When comparing Bulgarian and German "arms" of the initiative, we noticed that the former had no country coordinator, whereas the latter has not only the coordinator, there is also a dedicated website (in German) and regular reporting.[39] In terms of numbers, GLOBE Germany has worked with 615 schools, 322 teachers and 7307 students, producing a total of 7034 measurements across 1992 German CS sites.[40]

*EU-funded projects*
EU-funded CS projects that had pilot activities in Germany include the likes of hackAIR and DNOSES. hackAIR positioned itself as an open technology platform for accessing information on air quality, thermal comfort and probability of forest fires in Europe. CS activities took place in Germany, Greece, Belgium and Norway. Participants in the German pilot (Berlin) actively participated in data collection (using largely the same sensors as Sensor.Community) and analysis. They helped with coding and supported other sensor users, with some eventually becoming ambassadors for the project.

[38] The names of schools were anonymised in the report, however all ten were identified as being at a busy location and covered the areas of Neukölln, Mitte, Tempelhof-Schöneberg, Steglitz-Zehlendorf, and Friedrichshain-Kreuzberg.
[39] https://www.globe.gov/web/germany/home/contact-info
[40] https://www.globe.gov/web/germany-citizen-science

Focusing on odour pollution, DNOSES built a special OdourCollect app that citizens could use to report odour nuisance, its source and intensity, with results then displayed on the OdourCollect map. Although Berlin has some markers there (actually just three), the highest number of markers is in Shermbeck. In total, there seem to be around 50 markers across the whole of Germany.

*Domestic initiatives*
Two examples from this group are Open Soil Atlas and BeachExplorer. Open Soil Atlas was started by FeldFoodForest with a dual objective: to educate the public about soil quality in Berlin and to demonstrate the relationship between healthy soil and healthy communities. A CS round that took place in 2021 involved 80 Berliners in soil measurements, who produced a total of 77 datasets with information on soil coordinates, land use, soil colour, soil profile, percentage of sand and clay, and pH test, to name just a few parameters.

BeachExplorer is an initiative of the Wadden Sea Conservation Station that has been running mostly in Northern Germany since 2012. By leveraging CS and promoting the understanding of marine nature, the project supports the federal program on biological diversity. Over 10 years that the project has been in existence, more than 4000 citizen scientists have made close to 40000 observations (though some of these are shared between Germany, Denmark and the Netherlands).

*Supporting initiatives*
As already mentioned, this category includes initiatives whose mission is to support CS culture in Germany, but which don't necessarily qualify as a CS project. Examples are Burger Schaffen Wissen ("Citizens Create Knowledge") and SenseBox. Citizens Create Knowledge is a joint project by Wissenschaft im Dialog and the Museum für Naturkunde Berlin. Its overall goal is to support CS communities by offering guidance on how to start a CS project, how to publish a CS project, how to work with volunteers to deliver best value for them, the scientific community and other local stakeholders. Citizens Create Knowledge has been running for almost ten years now (since 2013), focusing on several thematic areas e.g. CS in schools, CS in medicine and health research, CS in Berlin.

SenseBox is an ongoing initiative by the University of Münster. What started as a research project eventually evolved into a spin-off with different commercial offerings. There are now different DIY sensor toolkits for citizens (senseBox:home), schools and young researchers (senseBox:edu), and developers (senseBox:mini) - all of which can be bought online via senseBox website. According to the openSenseMap, 9551 senseBoxes are currently in use worldwide, which collectively have taken 11.2 million measurements.

The brief review above barely scratches the surface of the German CS landscape. But even with such limited scope, we hope that the reader gets an idea of how diverse the landscape is. One small discovery that we are especially excited about is the identification of the new types of initiatives not seen in Bulgaria, namely the inside-out projects and those that support others. One conclusion we can cautiously draw from this is that these initiatives are hallmarks of more mature CS landscapes that can be typically found in countries with a long history and high levels of public participation in science. Future research, whether conducted by COMPAIR or others, might want to further explore if this hypothesis has any merit. One interesting outcome of this research could be the creation of a typology of CS regimes (see recommendation eight in conclusion) and key requirements needed for their emergence e.g. level and history of public participation in science, existence of bodies or projects dealing exclusively with CS, amount of funding available for CS, total number of projects and domains covered.

**Primary cluster**

*Stakeholder engagement*

Most projects in this cluster engaged participants through online outreach and workshops, with additional support provided in the form of training material. The renowned Sensor.Community practices the self-assembly and self-installation approach. But this doesn't mean that interested volunteers are completely on their own if they want to deploy a sensor outside their home. Many local hubs organise open-access workshops for people who want to build their own sensors. Moreover, there is an international forum that provides support regarding sensor use and access to a large body of information on possible solutions to different technical problems.

Hardly any projects reflected on the pros and cons of different engagement tactics used. The only exception is hackAIR. The German pilot targeted potential citizen scientists online and through in person workshops. The team concluded that the degree of involvement was higher among users who attended the workshop and bought a sensor, than among those who were targeted by online means only (social media, newsletters, press releases). Why this was the case wasn't elaborated in the report, but perhaps the reason for that is two-fold: 1) people tend to absorb new knowledge better in a physical setting, where live demos and training activities appear more accessible and easier to understand, and 2) people tend to be more motivated to carry on with a certain task if they had to purchase something to accomplish it.

Some projects prefer to mention how many sensors are deployed instead of providing information on citizen scientists involved e.g. Sensor.Community (14388), senseBox (9551).[41] The HEAL project provided even less information on the Berlin pilot, stating only that it cooperated with 10 primary schools that represented a total of 4300 pupils. One project that stands out is, again, hackAIR. It reported information on the overall number of sensors set up (800), the number of people who attended workshops (500) and contributed to the project one way or another (3000).

Participation of hard-to-reach groups in CS activities was not explicitly mentioned by any of the projects. Potentially, they could have been involved in the HEAL project, provided that the 10 participating schools have children from lower-income families, a hard to reach group we are particularly interested in engaging in COMPAIR. Their participation could also have been enabled by senseBox and Sensor.Community owing to these projects' cooperation with primary education institutions (#Sensor2School, senseBox:edu).

hackAIR is the only project in the cluster that listed the full urban value chain among its users: citizens, local government, enterprises, scientific community and civil society organisations. The successful deployment of the quadruple helix model combined with the

[41] These are global figures.

multi-channel engagement tactics used could explain why hackAIR benefited from contributions of 3000 people over the course of the project.

Finally, as regards the 10 principles, none of the reviewed projects acknowledged ECSA's guidance openly. This doesn't necessarily mean they didn't want to follow it, it could mean they simply weren't aware of it, or didn't find it necessary to make a demonstrable link to it in project documentation. The fourth principle states that "citizen scientists may, if they wish, participate in multiple stages of the scientific process." hackAIR claims, for example, that besides data collection, volunteers got involved in coding and training. In the case of BerlinAIR NO2 Atlas, in addition to data collection, participants were able to prepare and evaluate passive samplers in the laboratory. This clearly shows that projects may actually be following some or all of the 10 principles even if these are not clearly acknowledged in project deliverables.

*Data collection and analysis*

In terms of data captured, some projects measured only particulate matter (hackAIR), some only NO2 (BerlinAIR NO2 Atlas), some a mix of both (HEAL). A few projects added to the list atmospheric conditions like temperature, humidity and pressure (senseBox), and some went so far as to measure allergen content, precipitation and UV radiation (PolDiv).

With regards to sensors used, NO2 measurements were carried out using simple measuring tubes (passive samplers) in the HEAL project. For PM measurements, most projects offered DIY kits that could be ordered online e.g. hackAIR, senseBox, Sensor.Community. The exception was HEAL which used a low-cost, but not a DIY sensor with a light scattering property. All other gases and particles required special tools e.g. electronic pollen measuring devices, pollen traps, a CO2 monitor.

Except PolDiv, all results were presented in some form, either on a map, in a report, or both. There is a clear preference to use online maps to display CS data, although in the HEAL project, the findings are summarised only in a report.

*Impact*

Two projects whose technical credentials impressed us the most are Sensor.Community and enviroCar. Sensor.Community developed a standard sensor kit (Node MCU SDS011) that has been widely used by individuals and projects around the world. The kit is made of universal components like an electronic module for WiFi communication, fine dust sensor, temperature, humidity and pressure sensor, cables, and plastic hydraulic elbows for weather protection. This means users can build a relatively light and small device at an affordable price (about 50 euros). Raw data from these sensors can be transferred to an online map where value readings of particulate matter and other parameters are displayed for the last 24 hours. While there are definitely many reasons for its success, this balance between cost-effectiveness and ease-of-use that Sensor.Community has managed to strike must be a factor in its worldwide growth over the years.

enviroCar earned plaudits from us because of its focus on open standards. The project is completely open source. All of its components are available on Github. Users can avail of the Web API to create new products and services e.g. maps, statistical analysis. Gathered data is publicly available as JSON and linked data, which means it can easily be integrated into any service that works with these standards.

With regard to behavioural change, a project that drew our attention is hackAIR, not necessarily because of the scale of its impact on individuals, but because of the effort that was made to measure it. The study in Berlin implemented a sophisticated Modular Behavioural Analysis that consisted of semi-structured interviews with hackAIR users following a predefined interview guide. While respondents did not always state a direct impact of hackAIR on their knowledge of air pollution, they did mention that working with CS tools was a stepping stone to a better engagement with the issue. Participants reported paying more attention to air pollution whenever it appeared in the news, for example. Hence, because hackAIR opened a door for them, or supported an already existing interest, they reported to have gained more knowledge on the subject by the end of the project. Respondents did not report many changes in terms of preventive behaviours e.g. avoiding going outside, keeping one's windows closed, wearing a mask. But some did carry on a pre-existing protective behaviour (self-care), such as avoiding busy roads.

When it comes to urban policy making, no project reported any significant impact in this area. hackAIR even openly acknowledged that political impact was rather limited as there were no specific activities or tools organised to evoke direct policy impact. If we shift focus to education policy, perhaps one project that we could highlight is senseBox. According to press reports, it appears that the Ministry of Education used project results to coordinate learning opportunities for students.[42]

**Secondary cluster**

*Highlights from other initiatives*

A project with a well-thought-out engagement approach is Citiclops. Although it deals with water quality, what stands out is their step-wise process to increase the level of maturity of stakeholder engagement. At low maturity, participants are surveyed to get a better sense of their motivations and needs. At high maturity, participants take ownership of results, to the point where they may even co-manage a CS lab alongside original founders. The five steps are:

1. Understanding and engaging stakeholders
2. Getting started with stakeholders
3. Developing a participatory science approach
4. Helping stakeholders to act as advisors
5. Developing co-management approaches

Citiclops did not refer to the 10 principles directly, but many of them were clearly incorporated into the project's modus operandi. In the early stages, Citclops' researchers consulted stakeholder communities as they planned, designed and started to implement the citizens' observatory. As Citclops evolved, stakeholders took a more active role, participating in the observatory's structure and management, and sometimes negotiating with Citiclops's partners to ensure their specific goals and values were represented. At full maturity, Citclops shared management between project partners and stakeholders, and in some cases transferred management completely to local communities, with observatory's managers only

[42] https://sensebox.de/en/press.html

providing advice and consultation. Presumably, this is the kind of maturity trajectory COMPAIR should be aiming at, one that starts with some basic engagement and culminates in a setup whereby local communities manage a CS lab first in cooperation with and later with minimal intervention from project partners.

One thing that stands out in the secondary cluster is immensely high participation rates (i.e. number of volunteers) among some projects. Clear leaders in this regard are biodiversity and water related projects like NaturGucker (111.395), Muckenatlas (29.000), Plastik Pirates (15.000), BeachExplorer (4099), ArtenFinder (3000), Ornitho (1300), My Ocean Sampling Day (1000).

In general, we noticed a clear tendency to use digital tools for data capture. Most projects introduced apps to collect information (on animal species, soil quality, water quality etc.), some both apps and websites (e.g. NaturGucker, BeachExplorer, ArtenFinder) and some websites only (Stadwild Tiere Berlin). It's worth pointing out that not everything can be captured digitally. In some cases, the use of 'manual' tools is often the only way to obtain required information. For instance, to collect insect samples, the InsektenMobil project used rooftop nets on cars; to collect mosquito samples, the Muckenatlas project asked participants to catch, freeze and send dead mosquitos to the lab; to collect water plastic, participants in the Plastik Pirates project used sampling nets and sieves to retrieve plastic pieces from water bodies.

As with data capture, there is a clear preference for online tools when it comes to results presentation. Most projects offer map-based visualisations of their findings. Only a couple of the reviewed initiatives use publications as the only method for dissemination (Tauchen für Naturschut, Fledermausforscher in Berlin).

With regards to technical impact, some projects demonstrate a very strong focus on open innovation. A good example would be the now familiar Citclops that developed its web portals with open principles in mind. The idea was that by using standards like OGC and SensorML, by enabling data sharing with GEOSS and by including semantic aspects and linked data, the project would be able to create really advanced means of information delivery to generate powerful insights for stakeholders.

In terms of behavioural change, projects often claim that participation in CS can lead to improved knowledge and awareness among participants, but only one project (My Ocean Sampling Day) actually made an effort to survey volunteers and share the results publicly. It found that 83% of those surveyed agreed that participation made them feel more engaged with ocean issues. Interestingly, some citizen scientists thought that My OSD app and sampling procedures were too complicated. The project addressed these complaints through personal communication with participants and by improving the usability of the app. This story is an important reminder to COMPAIR and indeed any other CS project that all protocols and tools should ideally be tested internally over several iterations before they are made available to the public. Then, when data collection starts, both pilot leads and technical teams should be on standby to react quickly to user complaints/suggestions while field activities take place. A more comprehensive survey should be launched ex-post, focusing not only on functionalities and methods, but also people's experience with CS, both positive and negative.

Another interesting project worth mentioning with regards to behavioural change is Netatmo. It's a French company that creates IoT products for consumers. Their Smart Home Weather Station (costs between 170-300 euros) has been used worldwide, while in Berlin there were at least 100 markers representing each owner that wished to display their data on a map. Netatmo doesn't stylise itself as a CS project. But many of Netatmo's customers inadvertently become citizen scientists as they collect air quality data and other atmospheric information (temperature, humidity, pressure, CO2 etc.) through their weather stations.[43] This could be an alternative route to CS for people who don't want to go through all the protocols, preferring the convenience of an informal, no-strings-attached crowdsourcing approach instead. For some consumers, products like Smart Home Weather Station could be a stepping stone to the world of CS.

Finally, when it comes to policy impact, many projects are clearly thinking about public policies and legislation they can influence through their results, while a few have already claimed some early successes. For example, data collected by Muckenatlas contributes to mosquito research and public and animal health in Germany. The project's database is open to the scientific community and political stakeholders to facilitate risk assessments and modelling as to where to expect mosquito-borne diseases in the future and how best to manage them. By collecting data on cycling accidents in Berlin, SimRa plans to influence changes in traffic signalling plans so that cycling can become safer and more attractive for city residents. In the FLOW project, the water body data collected by volunteers is incorporated into ecotoxicological and ecological studies to serve as a basis for local and regional strategies for water protection. And thanks to the Tauchen für Naturschut project, the idea of nature-conservation diving was proposed for implementation in the Mecklenburg Lake District.

[43] See for example a research analysis of Netatmo's data Fenner, D., Meier, F., Bechtel, B., Otto, M., & Scherer, D. (2017). Intra and inter 'local climate zone' variability of air temperature as observed by crowdsourced citizen weather stations in Berlin, Germany. Meteorologische Zeitschrift, 26(5), 525-547. doi:10.1127/metz/2017/0861

# Belgian CS landscape

We reviewed 31 Belgian CS initiatives, mostly from Flanders and Brussels, which makes this sample the largest of the four ones created. Even so, 31 represents only a limited share of the actual landscape, whose true scale can be estimated based on information provided by Iedereen Wetenschapper ("Everyone Scientist"), a project aggregator platform. Filtering the database by country (the whole of Belgium) and project type (both past and ongoing) yields a whopping result of just over 180 initiatives. One would need a separate project with a time horizon of several months to thoroughly analyse them all. Since this is not possible within the scope of D2.2, we took a more pragmatic approach whereby priority was given to projects in the field of air quality and traffic monitoring (primary cluster).

Of course, the Belgian CS landscape is much broader than this. It covers areas as diverse as nature, history, health, astronomy. To do justice to this diversity, as well as to be consistent with other geographic samples, we decided to include in the Belgian review projects that monitor biodiversity, water and soil quality, odour and noise pollution, as well as those with links to cosmology, social sciences, humanities and arts. The names and distribution of all 31 initiatives are provided below.

**Table 3. Belgian sample**

| Field | Projects | Total |
|---|---|---|
| Air quality and traffic monitoring | AIRbezen, iSCAPE, Curieuze Neuzen 2016, Curieuze Neuzen 2018, Leuvenair, HASSELair, Meet Mee Mechelen, hackAIR, CurieuzenAir, Luchtpijp, InfluencAir, ExpAIR, WeCount, BikeSTEM for Schools | 14 |
| Biodiversity monitoring | Snapp nature, Bugs 2 the Rescue, TrIAS, Animals Under Wheels, My Gardenlab | 5 |
| Monitoring of atmospheric conditions, water and soil quality, odour and noise pollution | Butterfly, Stiemerlab, Curieuzeneuzen in de Tuin, Omniscientis, NoiseTube | 5 |
| Social sciences, humanities and arts | SOS Antwerpen, MamaMito, Citizen's talk, CitizenHeritage | 4 |
| Other | Scivil, Iedereen Wetenschapper, AstroSounds | 3 |

**General overview**

Despite its small size, we believe the sample does provide a good snapshot of the diversity that is inherent in the Belgian CS landscape, not only in terms of themes covered, but also as regards the types of initiatives that make it up. We found small-scale local initiatives (city-level), regional initiatives that are active only in Flanders, Brussels or Wallonia, initiatives or pilots linked to EU projects (outside-in initiatives), and initiatives that don't organise any CS activities as such, but that are on a mission to support existing or would-be CS projects ('supporters' we already encountered in Germany). We're going to illustrate this diversity by briefly presenting a couple of examples of each project type. After this, we'll explore our sample in more detail by examining key themes related to stakeholder engagement, data collection, and impact.

*EU-funded projects*

Examples of EU projects with CS activities in Flanders are WeCount and Ground Truth 2.0. WeCount had a pilot in Leuven that deployed Telraam sensors to support the implementation of local mobility policies e.g. traffic calming measures, school streets, pedestrian zones. The Telraam device is essentially a combination of three things: a Raspberry Pi microcomputer, sensors and a low-resolution camera. To start counting traffic, people just had to mount the device on a window inside their home. Eventually, around 200 devices were deployed in several parts of the city, providing continuous multimodal data streams on local mobility flows.

Ground Truth 2.0 established several citizen observatories in the EU and Africa. One such observatory was set up in Mechelen. Called 'Meet Mee Mechelen', the observatory wanted to improve the dialogue between citizens and decision makers by creating a platform where they can share information on the local living environment, including air quality. Several measurement campaigns were organised by the observatory, in which around 50 citizen scientists took part. Volunteers spent several weeks collecting data by cycling around the city with sensors, producing a total of 2800 km and 280 hours of observations.

*Domestic initiatives (local)*

While there are many local examples we could mention here, the two that stand out are Curieuze Neuzen (2016) and HasselAIR. There were two editions of Curieuze Neuzen. The one in 2016 was local in scope. Its goal was to measure spatial variation of nitrogen dioxide (NO2) in Antwerp. Arguably, Curieuze Neuzen 2016 was one of the first large-scale, air quality-monitoring local CS projects that deployed thousands of sensors (n=2000) across the city: near hospitals, parks, bridges, schools, offices, public buildings and residential homes. At each location, two sampling tubes were fixed to a v-shaped panel that in turn was attached to a window frame facing the street. To ensure quality control, a similar setup was deployed at 8 reference stations located in the study area. Building on the success of the 2016 edition, University of Antwerp, together with other stakeholders, launched a follow-up campaign in 2018. But this one was on a regional scale, so we'll cover it in the next section.

Another interesting local initiative was HASSELair. It was started by the UC Leuven-Limburg university to address the lack of real-time measurements of air pollution (PM2.5, PM10) around Hasselt. Using CS as a solution, the project trained citizens to assemble static sensors for measuring air quality near their homes. In addition, dynamic measurements were taken while people moved about the city with a mobile Airbeam sensor. These were transferred from one citizen to another after 90 days.

*Domestic initiatives (regional)*

As already mentioned, Curieuze Neuzen 2018 is a follow-up to the 2016 edition, only this time activities covered the whole of Flanders, not just Antwerp. Given this scale, a much bigger CS force was needed to cover the entire region. So in the end, the project managed to recruit 20.000 volunteers who measured air quality around their homes, helping create a detailed map of air quality in urban and rural areas across Flanders. They used the same sampling tubes as in the first edition to measure NO2 concentrations caused largely by traffic. Arguably, CurieuzeNeuzen Flanders is the largest CS project on air quality ever undertaken.

*Supporting initiatives*
Projects in this category include Scivil and Iedereen Wetenschapper ("Everyone Scientist"). Strictly speaking, the two are not CS projects per se. They don't recruit volunteers, organise measurement campaigns, collect or process field data. But they do play an important role in the CS ecosystem, by nurturing it through extensive support and guidance (not funding though), and by giving visibility to past, current and future CS activities on their platforms. We first encountered this project type in Germany i.e. Burger Schaffen Wissen ("Citizens Create Knowledge"). So we were really excited to find not one but two CS 'supporters' in Flanders. Given the scale and depth of the Belgian landscape, we are making a cautious assumption that the presence of supporting initiatives like Scivil, Iedereen Wetenschapper and Burger Schaffen Wissen can be associated with a more mature CS landscape. So what exactly do Scivil and Iedereen Wetenschapper do?

Scivil is the Flemish knowledge centre for Citizen Science. It is financed by the Flemish government but does not offer funding to CS projects. However, Scivil can screen applications for funding and offer advice to CS projects on how to increase their chances of getting money from the regional government. Other than that, Scivil organises workshops and public events, develops guides and handbooks as a way of supporting the CS community and bringing CS closer to the masses. As well as working with grassroot communities, Scivil cooperates with scientists and regularly advises government agencies on when and how to use CS. Scivil does have a collection of CS projects, but it pales in comparison to that of Iedereen Wetenschapper.

Iedereen Wetenschapper provides a vast, continuously updated collection of CS projects (over 180), apparently covering the whole of Belgium, though we didn't check how many of them are from Wallonia. The overall mission of Iedereen Wetenschapper is to bring science and society closer together by i) motivating people to participate in scientific research and ii) making scientists enthusiastic about collaboration with non-experts. The platform ensures matchmaking in two ways. First, people can express interest in projects they want to join. Sometimes people can join projects right away. Other times, the platform will put interested participants in touch with relevant coordinators, who will then contact volunteers at an appropriate time. Second, project organisers can register their initiative and try to recruit volunteers by announcing when and how they can contribute. It goes without saying that Iedereen Wetenschapper would be an ideal place to announce CS experiments planned by the COMPAIR team in Flanders. So, we see Scivil more as a consulting and advisory platform and Iedereen Wetenschapper more of a database and a networking portal.

**Primary cluster**
*Stakeholder engagement*
Pretty much all projects avoided shallow engagement whereby volunteers have only guides and templates to rely on during CS activities. The only exception is InfluencAir, a finished project in Brussels that followed Sensor.Community's principle of minimal intervention. Other projects organised several training workshops prior to data collection, while some continued to involve participants in different capacities afterwards. WeCount, for example, organised several online sessions to teach participants about Telraam sensors and the installation process. The sensors were then delivered to citizen scientists who had to install them

themselves based on the workshop guidance and additional instructional materials.[44] The iSCAPE project went further than this. After data analysis and visualisation, participants were invited to another workshop to reflect on the findings, to discuss and plan next steps for their local Living Lab.

In some projects people had to pay for sensors (e.g. CurieuzenAir, Luchtpijp), while in others they were handed out for free e.g. WeCount, HASSELair. It's not clear whether charging for a sensor has any influence on the number of volunteers a project can recruit and retain. While the cost is certainly a barrier to participation, it can just as well be argued that by paying for something, people feel more compelled to participate. Looking at CurieuzenAir's experience, the fact that the project charged a minimum price of 5 euros for the NO2 tubes did not deter thousands of people from applying for the measurement kit. In fact, their measurement kits were oversubscribed once registration closed, with the project receiving 5000 applications for just 3000 kits.

Quite a few projects measured air pollution in and around schools e.g. BikeSTEM for Schools, Luchtpijp, CurieuzenAir, HASSELair, Curieuze Neuzen, AIRbezen. Some projects designed special workshops for primary and secondary school students (e.g. HASSELair), some developed special packages for schools that included lessons, films, experiments and a few exercises (e.g. Luchtpijp), some even added gamification elements in the form of a leaders board to promote competitive spirit among participating institutions e.g. AIRbezen. All this is a welcome sign that local stakeholders (teachers, parents, policy makers etc.) are becoming increasingly aware of the risks that air pollution poses to young people, and that they see CS as a potential solution that can help both measure the scale of the problem and raise awareness about it among pupils.

Assuming that schools cater to pupils from different backgrounds, certain hard-to-reach groups (e.g. children from low-income families) were most likely represented in the six projects listed above, though they themselves did not acknowledge this fact. The only projects that made an effort to target hard-to-reach groups are CurieuzenAir and WeCount. In WeCount socially vulnerable people were considered at several stages (scoping, data awareness, legacy). Nevertheless, in the Summative Pilot Report (D4.1), WeCount openly admitted that "the goal of reaching the hard-to-reach and vulnerable groups was not met."[45] In CurieuzenAir, one of the goals was to engage all members of society independent of sociocultural status, gender, age or education level. This was achieved in two ways, by including in the network of 3000 sensors, measurement locations that specifically connect to people with low interest in CS, and by reaching out to local organisations that focus on health and poverty issues. This allowed the project to reach out to vulnerable and excluded groups and invite them to take part in the project.

As regards other members of the urban value chain, the full quadruple helix was achieved, based on a list of mentioned stakeholders, by CurieuzenAir, Meet Mee Mechelen (Ground Truth 2.0) and Curieuze Neuzen Antwerp. In projects like iSCAPE, HASSELair and

[44] The online/pick-up format was adopted in lieu of the physical training because of Covid-19 restrictions.
[45] https://we-count.net/deliverables

BikeSTEM for Schools, the engagement amounted to triple helix at best, with industry often missing from the value network.

Looking at cluster's leaders when it comes to the volunteering force, projects with the highest number of citizen scientists are Curieuze Neuzen Vlaanderen (20.000), CurieuzenAir (3000), Curieuze Neuzen Antwerp (2000), BikeSTEM for Schools (1200). In other projects that reported this data, the number of volunteers was in the range of 50-300.

No project in the primary cluster made a direct reference to ECSA's 10 principles. But this doesn't mean that none of the principles were followed. At the core of iSCAPE methodology was a Living Lab approach, with a strong focus on inclusion. In hackAIR, besides data collection, users got involved in coding and training. In WeCount, citizens co-designed a Telraam platform where citizen scientists could find tools to analyse data, tools to understand the data analysis, tools to build context around data, tools to initiate a dialogue between citizens about data, and tools to initiate action based on data. All this shows that, at least in some of the projects, citizen scientists had a meaningful engagement that extended beyond data collection (principle 4). So some of the principles are being followed in practice, if not in name.

*Data collection and analysis*

Data collection tools for air quality varied depending on pollutant and exposure type measured. NO2 was measured using traditional diffusion tubes in AIRbezen, Curieuze Neuzen (both 2016 and 2018 editions) and CurieuzenAir, whereas in iSCAPE a more technical, Arduino-compatible Smart Citizen Kit was used. For particulate matter, a clear preference for Nova PM SDS011 that was popularised by Sensor.Community was observed across several projects: AIRbezen, Leuvenair, hackAIR, Luchtpijp, InfluenceAir. HASSELair, which also measured dynamic exposure, did so using a low-cost, palm-sized AirBeam sensor. In the case of traffic monitoring projects WeCount and BikeSTEM for Schools, it was a Telraam device and a simple smartphone app with GPS, respectively.

Pretty much all projects presented their findings in some written form (report, blog etc.) and provided a map-based visualisation on the website. Some used third-party platforms like Sensor.Community (InfluencAir, Luchtpijp) and Telraam (WeCount). Some provided personalised reports to citizen scientists. In WeCount, for example, there was additional analysis at the individual device level, accessible only to the device owner and the project team. Each participant received a personalised monthly report, every month. Through guided analysis of the data, the team gave participants tools for basic analysis to get a discussion going and generally to educate participants on how to interpret traffic count data. This type of analysis was low-threshold and aimed to engage a broad audience among participants. The unguided analysis was intended to allow participants inside and outside the project to interact with the data and conduct their own analyses without normative instructions or guidance from the project team.

CurieuzenAir also provided personalised reports to citizen scientists after lab results were ready, but we were more impressed by the project's collaboration with BRUZZ and De Standaard to disseminate findings. BRUZZ is a cross-platform that publishes and broadcasts news and culture programs about the Brussels Capital Region. De Standaard is a Flemish daily newspaper. Both media outlets published project findings as interactive maps on their website.[46,47] Without statistics on usage and visits it's hard to judge the true scale of this tactic's success. Nevertheless, we think collaboration with media outlets can give dissemination an extra boost that could help spread the word about project results further and faster than would have been possible if only project's internal channels were used.

*Impact*
Technical innovations that impressed us the most were those that had an impact on modelling support and open data. Apparently, data collected by Curieuze Neuzen Flanders helped test the ATMOSYS computer model[48] developed by VITO for the Flemish Environment Agency. By improving the model's predictive capabilities with CS data, the project contributed to a better estimation of the population exposure to NO2 and its effects on public health.

As regards open data, while most projects displayed their findings on a map or in reports, only Leuvenair and iSCAPE went so far as to publish their datasets on Zenodo. Leuvenair's dataset contains 42,203,945 measurements from 112 sensors (Nova Fitness SDS011) that were placed in and around the city of Leuven.[49] iSCAPE published numerous datasets with information on how sensors were developed, what data was obtained from outdoor deployment, and what data was generated during a simulation exercise.[50]

Finding evidence of behavioural change wasn't easy, mainly because relevant information often wasn't provided. We don't know if it's because projects didn't survey participants to collect this information, or if they did, chose not to publish the findings because feedback pointed to the contrary i.e. lack of impact. Another challenge when assessing personal impact was to distinguish project objectives from the actual change that may or may not have happened as a result of CS. Quite a few projects claimed laudable outcomes e.g. that they help young people to be more active (BikeSTEM for Schools), that people would be able to pick alternative routes to reduce personal exposure to black carbon (ExpAIR), that people will become more aware of the importance of air quality for a healthy environment (Curieuze Neuzen). But without a proper survey asking people whether these and other impacts have materialised, such lofty ambitions risk remaining what they are (ambitions, objectives) without amounting to anything else.

That said, a handful of projects actually made an effort to measure personal impact, with results showing a mixed outcome. Leuvenair clearly hoped that CS would elicit some activities on the part of participants after data collection. However, in its final report the project concluded that the original expectation that citizens would start working with data wasn't fulfilled.

Impact assessment by Meet Mee Mechelen was more upbeat. The project argued that its citizen observatory produced a much more detailed picture of local air quality, which was missing in the past. Since data was validated and concerns that people had about air quality

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[46] https://www.standaard.be/curieuzenair-kaart#11.2/50.8316/4.4014
[47] https://www.bruzz.be/curieuzenair#11/50.84/4.36
[48] https://vito.be/en/product/atmosys-air-quality-management-system
[49] https://zenodo.org/record/4936982#.YkbgTCgzaPq
[50] https://www.iscapeproject.eu/iscape-data/

became scientifically grounded, the topic gained traction as a shared story, motivating more people in Mechelen to get involved.

The results of Hasselt's Living Lab (iSCAPE) were equally positive. The project even shared a quote from one of the participants to support this: "Small changes in my daily pattern can have a big impact on the battle against the warming of the beautiful blue planet! Provided that a larger number of cohabitants want to participate. Every little effort counts." iSCAPE recommends providing users with continuous updates in simple, personalised ways, as general information on health or environmental benefits is usually not enough to trigger long-lasting transformative impacts.

The project whose work on behaviour change impressed us the most is hackAIR. In its evaluation, it investigated changes in beliefs, knowledge and self-reported behaviours of citizens that participated in the sensor building workshops in Brussels. An experimental design was chosen to investigate the actual change with a pre-test/post-test design, and a control group. In total, 58 participants responded to both surveys, 24 as part of the experimental group and 34 as part of the control group. Both groups were also promised an incentive: a €10 gift voucher in a popular nature-related shop or an air-purifier plant Calathea.

Evaluation results show that, as a result of CS, participants generally felt more heard by local policy makers on the issue of air quality in Brussels. Moreover, hackAIR’s tools positively influenced participants’ knowledge of air quality. People reported knowing more about what air quality is and where to find information about it, as well as its sources and impacts. hackAIR researchers found that one specific type of behaviour was positively and significantly impacted by the experiment: soft mobility. This means that the experimental group engaged more than the control group in soft mobility (e.g. walking, biking, taking public transport) instead of driving a car. Finally, researchers found that the hackAIR’s behaviour change experiment did have an effect (about 5% increase) on the general air quality profile of participants.

Moving on to policy impact, oftentimes projects did not allude to any policies they have or could influence in project materials. Those that had policy makers as a target audience did mention potential benefits for this stakeholder group. However, such benefits appeared more as a general project objective - for example, to provide interesting and useful data for policy in Flanders (BikeSTEM for Schools) - than a result of impact assessment.

Nevertheless, we found several projects that demonstrated really strong potential to influence local mobility policy (WeCount), education policy (iSCAPE) and citizen-local authority interaction (Ground Truth 2.0/Meet Mee Mechelen).

The legacy of WeCount in Leuven was secured by the city’s expressed commitment to maintain the Telraam network post-project. In fact, the local authority wanted Telraam to become a permanent asset within Leuven that can be used to support the monitoring of implementation of any past and future mobility measures e.g. school streets, green zones.

In Hasselt, the iSCAPE project initiated a discussion with the local authority regarding the use of CS sensor kits in Masters and Bachelors thesis projects that would be undertaken over the coming years with a view to addressing issues linked to city mobility and air pollution.

As part of Ground Truth 2.0, the CS observatory Meet Mee Mechelen interviewed participants, who reported that: 1) citizens gained more recognition by policy makers, 2) air quality became a much more important topic among both groups, and 3) politicians started to talk more about the issue in their campaigns. Nevertheless, although everyone kept listening to each other, some power play was observed between citizens and policymakers on different occasions. For example, city employees joining the observatory were still regarded as representatives of the policies the citizen group was fighting against. When the city offered to host the observatory's platform on the municipal website, many citizens objected to the proposal. This is an important piece of information that draws attention to potential risks and conflicts that may arise when antagonistic groups are brought together to work on hot topics like air pollution. At COMPAIR we must see to it that conflict resolution principles are well incorporated in our stakeholder strategy to ensure a meaningful and cordial environment for all.

**Secondary cluster**

*Highlights from other initiatives*

In the 'secondary' cluster, projects with the highest number of volunteers/test sites are those that monitor biodiversity and soil quality. Mijn Tuinlab ("My Gardenlab") has 40.941 garden labs across Flanders. The now familiar Curieuze Neuzen project branched out into a new area (soil monitoring), where it currently works with 4400 volunteers to help analyse soil quality and its resilience against drought. Around the same number of volunteers (4000) contribute to the Animals Under Wheels project, having made 70000 observations on dead animals since 2008. Projects in other fields either don't provide information on their volunteering force or have less than 1000 citizen scientists in their network.

Some projects follow a hands-off approach to stakeholder engagement e.g. AstroSounds, Bugs 2 the Rescue. They issue lots of tips, self-study guides and FAQs that volunteers must go through on their own if they want to learn how to proceed. But some projects offer a deeper engagement by training volunteers in-person or online, usually through workshops.

We didn't find evidence that hard-to-reach groups were actively involved in CS activities within the secondary cluster. Potentially this might have happened in projects that worked with schools (e.g. Butterfly, Bugs 2 the Rescue) provided that these institutions weren't, what one would call, elite. Snapp Nature was the only project that claimed that one of its objectives was to encourage citizens of all ages and backgrounds to become scientists. Whether and how many hard-to-reach groups participated in Snapp Nature could not be established during the review.

As regards other members of the urban value chain, several projects managed to achieve the triple helix model. An example would be the odour-related Omniscientis project that involved the 'source of nuisance' (industry, farming, wastewater plants, chemical plants etc.), citizens living in the area and authorities at various levels to address the issue of odour pollution in Wallonia. The quadruple helix was achieved by at least two projects judging by the types of stakeholders engaged. The Butterfly project has brought together Flemish schools, researchers, companies and local authorities to study weather conditions in urban and rural areas using meteorological sensors. Curieuze Neuzen in de Tuin has worked with citizens, schools, companies and municipalities to create a soil map for Flanders.

Although ECSA's 10 principles weren't openly acknowledged by any of the projects, there is indirect evidence to suggest that some of them actually were followed, if not in name. In the Butterfly project, pupils, teachers and parents were involved in different stages, from installing the weather station, to gathering and analysing data, to presenting results (principle 4). Scivil, which supports the CS community in Flanders, appears to promote ECSA's 10 principles too, if indirectly. For example, Scivil believes that through CS citizens can contribute to scientific research and projects regardless of their background knowledge, and can also initiate projects themselves (principle 1).

In the secondary cluster, data collection tools vary depending on project, from chunky Davis Vantage Pro 2 sensors (Butterfly), to more compact mobile apps (Snapp nature, Animals Under Wheels, Omniscientis, NoiseTube), to something in-between i.e. sensor kits (Bugs 2 the Rescue). In some projects there are no sensors at all. For instance, AstroSounds volunteers learn how to recognise stars by listening to their sounds, whereas in MamaMito volunteers must submit their ancestral data if they want to find relationships in the maternal line.[51]

When presenting their results, most projects opted for an online map published on the project website. One example that stands out is Curieuze Neuzen in de Tuin, which in addition to its own website also has findings displayed on De Standaard.[52] It's not the first time this Flemish daily cooperates with CS projects as a dissemination partner. Readers will remember that De Standaard recently provided a platform for CurieuzenAir to display their NO2 results.

As regards technical impact, projects that drew our attention are those that:

- Made their sensors easy to assemble: Butterfly's weather station has been developed in such a way as to allow students to easily build and place it themselves anywhere they want
- Made an effort to facilitate reuse of their tools: NoiseTube ensured that external developers can extend its mobile app in whichever way they see fit. The source code is available under GNU LGPL v2.1 licence on Gitlab
- Provided advice on how to handle data in CS projects: Scivil published a data charter to guide CS stakeholders on how to generate and store their data, as well as how to make it findable, reusable and interoperable[53]

Behavioural impact was harder to gauge because most projects provided scant information in this regard, and when they did, it was formulated more as an ambition rather than a conclusion established through some form of assessment e.g. participants will develop greater sensitivity to and awareness about the exotics problem and biological control (Bugs 2 the Rescue), people will learn how to scientifically describe someone's personality

[51] AstroSounds would correspond to level two (distributed intelligence) and MamaMito to level one (passive sensors) in the typology of participation levels developed by Haklay (2013)
[52] https://www.standaard.be/curieuzeneuzen-in-de-tuin/sponskracht
[53] https://www.scivil.be/en/book/data-charter-and-guide-citizen-science

(Citizen's talk), people will be more enthused about genealogy and CS (MamaMito). One project that actually demonstrated some influence on participants' behaviour is Curieuze Neuzen in de Tuin. Specifically, it managed to motivate people to carry on with CS activities after the initial round ended, with 3000 people registering for the follow-up campaign out of 4400 who took part in the first round.

As regards policy impact, several projects demonstrate strong potential to influence

- ***Educational policy:*** by providing a platform for STEM lessons on gardens (My Gardenlab), by providing new teaching material for STEM education that enables students to work with their own family history (MamaMito), and by supporting the biology curriculum in Flemish schools (Bugs 2 the Rescue)
- ***Urban planning:*** by broadening environmental sensing in cities, especially around under-appreciated problems like noise pollution, which don't generally get a lot of resources/attention in local administrations (NoiseTube). Environmental CS sensing projects could be used by policy makers in different ways e.g. to develop mobility plans (policy preparation), to understand if noise levels decline after certain measures have been implemented (policy evaluation)
- ***Transport policy:*** by providing information on the impact the road network is having on nature (Animals Under Wheels). For example, the highway between Leuven and Liège turned out to be extremely dangerous for wildlife because only the high-speed railway line next to it is fenced off. Animals trying to cross the highway from north to south collide with the grid between the highway and the railroad and have no choice but to go back where they came from, back over the highway.
- ***Local CS policy:*** by providing a hands-on manual for towns and cities on when and how to use CS[54]

[54] https://www.scivil.be/en/book/citizen-science-local-government

# Greek CS landscape

Our Greek sample has 20 initiatives. It includes a small primary cluster (just three air related projects) and a large presence of biodiversity related projects in the secondary one. Air pollution isn't the only pollution type that was monitored in Greece with the help of CS. We found several initiatives focusing on waste, odour, and water pollution, most of them EU-funded. As in other country samples, we found several initiatives from fields other than natural sciences (humanities and arts). One initiative is similar, in a way, to Germany's Burger Schaffen Wissen and Belgium's Scivil in that it has the hallmarks of a 'supporter' i.e. it's a project that aims to facilitate the spread of CS in Greece, targeting universities as early adopters. Finally, given Greece's susceptibility to earthquakes, we found one initiative that uniquely addresses this challenge, by working with schools to monitor seismic activity. An overview of the Greek sample is presented below.

**Table 4. Greek sample**

| Field | Projects | Total |
|---|---|---|
| Air quality monitoring | hackAIR, Cos4Cloud, URwatair | 3 |
| Biodiversity monitoring | Sharks and Rays in Greece and Cyprus, Hellenic Fauna CS Project, eBird, "Is it Alien to you...Share it!", Alientoma, Biodiversity GR, CrabWatch, iNaturalist | 8 |
| Monitoring of soil quality, environmental conditions, urban waste, water and odour pollution, and seismic activity | Scent, DNOSES, Waste4Think, GROW, GLOBE, Hackquake | 6 |
| Humanities and art | CitizenHeritage, Wreck History | 2 |
| Other | INCENTIVE | 1 |

**General overview**

Greece has no portals akin to Belgium's Iedereen Wetenschapper ("Everyone Scientists") where one can easily find a vast collection of finished or ongoing CS projects under one roof. True, international platforms like EU-Citizen.Science and Cit-Sci-X do list some projects for Greece, however information they provide is often incomplete (e.g. only five projects on EU-Citizen.Science) and, in the case of Cit-Sci-X, some of the listed projects have dubious links to Greece and CS in general, upon closer examination. The fact that no similar reviews were undertaken in the past makes estimating the size of the Greek CS landscape all the more difficult. Using a very conservative estimate, we think this sample represents a 50-60% share of the total, based on the number and quality of results that each new query yielded toward the end of horizon scanning. Basically, we found more projects than are included in the sample, but because it wasn't immediately clear whether and how these relate to CS, and because there was little time for additional reviews, we decided to cap the Greek sample at 20.

Even with this relatively small number, we believe we managed to capture some interesting characteristics of the Greek CS landscape. We noticed that many Greek CS projects are actually pilots of EU projects. In fact, EU funding is present in all fields covered by the sample, from air quality and biodiversity monitoring, to humanities and art. That said, the Greek landscape is not without domestic initiatives, with some interesting examples observed at both local and national levels. Like other countries, Greece is not impervious to international CS initiatives, whose presence is especially strong in the field of environmental and biodiversity monitoring. Finally, there is one project that resembles German and Belgian 'supporters' in that it tries to facilitate CS growth and adoption in Greece. But whereas Burger Schaffen Wissen and Scivil focus on the whole landscape, the INCENTIVE project in Greece focuses on institutions (universities) as a starting point for this transformation. Another difference is that INCENTIVE is funded by the EU. We will present INCENTIVE after describing a couple of projects from other categories. After this, we'll explore our sample in more detail by examining key themes related to stakeholder engagement, data collection, and impact.

*EU-funded projects*
Out of three projects in the primary cluster, two are European (H2020): hackAIR and Cos4Cloud. hackAIR had pilots in Berlin, Brussels and Athens where, through the Greek partner DRAXIS, hackAIR cooperated with some schools and communities of citizens that wished to be engaged in CS and use the platform for their own purposes. The Kantas School gave DRAXIS access to their two webcams that were placed in their schoolyard facing the sky. These webcams were integrated in the hackAIR platform to provide estimations of the local air pollution levels. Teachers together with students built a Home v1 hackAIR sensor, placed it in the schoolyard and were constantly checking their readings through the hackAIR platform. In total, 12 sensors were installed in Athens.

Cos4Cloud is an ongoing project with pilot activities in several cities. In Greece, the project developed a training course to help teachers use CS for environmental and sustainability education in schools. As part of the course, participants had to create educational scenarios for integrating CS in specific school-based contexts. These scenarios were essentially concrete plans on the basis of which teachers engaged students in CS, including air monitoring. In one of the schools, air monitoring emerged as a follow-up activity after reading a literary text about urban odours in 19th century Athens. A total of 34 students from two schools[55] measured air quality using the OdourCollect app.

*International projects*
There are quite a few international projects present in Greece. One of them is GLOBE that brings together 23000 schools worldwide. Students can collect data, exchange experiences and observations, and learn to understand the complex changes on earth in cooperation with peers. In Greece, the GLOBE community includes the Athens University, National Observatory of Athens, Foundation for Technological Research, Technical University of Crete, Ministry of Environment, Ministry of Culture, meteo.gr, Corallia incubator, as well as many individual professors, researchers and 33 schools from across the country.

iNaturalist is a social network of naturalists, citizen scientists and biologists with approximately 2.5 million registered users. It acts as a platform for science and conservation efforts, providing valuable open data to research projects, land managers, and public organisations, among others. iNaturalist GR is managed by the Goulandris Museum of

[55] Junior High School of Krestena, Senior High School of Metamorfosi

Natural History, and iSea, a marine NGO. As part of the initiative, some 7480 observers and 5778 identifiers have submitted and categorised thousands of species from Greece's flora and fauna.

*Domestic projects*

By domestic projects we mean projects that were initiated, managed and funded, in whole or in part, by the Greek organisations. One such example is URwatair. A consortium of two research teams and an NGO, URwatair involved citizens in the monitoring of air pollution and rainwater flooding incidents in Thessaloniki (hence the duality in the title). As regards air, the aim was to measure PM10 levels related to indoor and outdoor activities e.g. cooking, building. Measurements took place in summer, late autumn/early winter, and spring. Thanks to this, the project was able to get a fairly representative picture of the city's pollution profile. In total, over 80 measurement sessions were conducted, each lasting two weeks.

A domestic project operating on a national scale is Alientoma. The project appears to be managed by Greek researchers and has no formal structure. It aims to create a dynamic database of invasive alien species (IAS) by involving citizen scientists who can participate by submitting IAS records through the website. By sharing data on IAS with scientists and policy makers, the project helps mitigate adverse impacts of their presence e.g. economic burden, biodiversity loss, disturbance to ecosystem functioning.

*Supporting initiatives*

In this category we just have one project INCENTIVE. We placed it here because of its potential to nurture, grow and expand CS in Greece, evolving its relatively modest current landscape into a buoyant ecosystem with hundreds of projects and opportunities for experienced CS professionals as well as those new to the field. For INCENTIVE, the catalyst of this change is institutional transformation at the level of scientific institutions. In Greece, INCENTIVE is piloted by the Aristotle University of Thessaloniki (AUTh) within the H2020 framework.[56] The goal is to turn AUTh into a fully-fledged CS hub that can mobilise communities to co-produce new knowledge with high scientific and societal relevance. INCENTIVE's timeline is 2021-2024, so it's too early for any substantial results. AUTh's planned activities for this period include partnerships, education and equal participation in the areas of climate action, inequality, growth and sustainable development. Once CS activities start, citizens may participate as sensors, data collectors and data analysts. Eventually, the benefits of CS activities will transcend the boundaries of institutions involved, delivering substantial gains to all stakeholders in the quadruple helix model. INCENTIVE can be thought of as a supporter-cum-enabler, a kind of project that can help countries increase their CS maturity, acting as a first step on a transition course to a more advanced CS landscape. So, INCENTIVE's results are definitely worth following, not least to see if this hypothesis has any merit.

[56] The other three pilot institutions are Universitat Autònoma de Barcelona, University of Twente, and Vilnius Tech

**Primary cluster**

*Stakeholder engagement*

Two out of three projects in this cluster worked with school children on CS experiments. The hackAIR's pilot in Athens cooperated with Kantas School, which provided access to their webcams located in the schoolyard. Footage from these devices was sent to the hackAIR platform to estimate local air pollution levels. In addition, teachers and students built 12 SDS011 based sensors that were then placed in and around schools and continuously uploaded data to the platform.

In Cos4Cloud, the framework for working with schools was guided by a CS course titled 'Citizen Science and Environmental Education for Sustainability'. The course took the form of a webinar organised by the Environmental Education Lab of the National and Kapodistrian University of Athens, with the goal of introducing CS into the Greek school curriculum. As part of the course, participants, which included 11 teachers, developed educational scenarios that then had to be implemented during the school year. Some of these scenarios were related to air quality and subsequently implemented in two schools in Athens. Interestingly, air quality was understood in terms of odour pollution, so measurements were taken using the OdourCollect app developed by the DNOSES project. Eventually, 34 students took part in CS activities.

In the URwatair project, the focus was mainly on indoor air pollution. Concentrations of PM2.5 and PM10 were measured in different flats of the building using three low-cost sensors: Sensebox home, Dylos Logger, and AirVisual Pro. It's not entirely clear who the participants were and how they were recruited, but volunteers had to keep a diary of measurements and everyday activities like cooking and ventilation. Measurements were made in summer, late autumn/early winter. In total, 80 measurement sessions took place during the project, each lasting two weeks. At the end, participants provided feedback via questionnaire and received research findings in the form of a best-practices booklet. Basically, the document was a collection of recommendations for improving indoor air quality.

Since hackAIR and Cos4Cloud worked with school children, assuming that some of them were from a migrant background and/or low-income households, it's possible that these projects managed to engage people from hard-to-reach groups during CS experiments. This information wasn't acknowledged by projects themselves though. As regards other members of the urban value chain, based on the type of partners involved, all three projects appear to have achieved the triple helix model (as represented by government, education sector and civil society), with industry usually missing from the mix. It appears that no project in this small cluster used ECSA's 10 principles to guide their activities, even though some of them may have been followed in practice e.g. principle one: involve citizens as contributors, collaborators or a project leader in scientific endeavour that generates new knowledge.

*Data collection and analysis*

hackAIR and URwatair measured particulate matter (PM2.5, PM10). But whereas hackAIR used a DIY sensor based on SDS011 components, URwatair used three different sensors, one of which was DIY, while two others were low-cost commercial solutions: Dylos Logger and AirVisualPro. Cos4Cloud measured a different kind of air pollution: odour nuisance. This was done using the OdourCollect app where participants can report smells based on where and how they perceive them (e.g. pleasant, unpleasant), as well as the source e.g. waste, industrial activity. We couldn't find the results of Cos4Cloud experiments on their website. URwatair had a website which is now inaccessible, but fortunately the project's overall approach and findings are available on Researchgate as a slide deck. Finally, hackAIR's data is available on the main platform,[57] though it's not easy to separate CS data submitted by schools from CS submitted by other citizens.

*Impact*
While trying to assess technical impact, we found little evidence that the three projects really advanced state-of-the-art in some way. The projects used sensors by commercial providers (Dylos Logger, AirVisualPro) and, when a DIY sensor was used, the kit was too similar to an already existing solution e.g. Sensor.Community. In the case of Cos4Cloud, odour nuisance was used as a proxy for bad air quality, which was measured by an app from another EU project.

Impact-wise, projects had more success in trying to influence behavioural change, at least one of them. hackAIR, for example, motivated young people to initiate a follow-up action as a result of CS experience. Specifically, students at the Kantas School applied for funding under the Young Entrepreneurship Contest in Greece with an idea based on the hackAIR platform and its social benefits. The impact of Cos4Cloud was less significant, resulting in more interaction but not necessarily behavioural change. (The project reports that CS experiments using OdourCollect app promoted a lively discussion among students about odours in Athens and how they fit into the overall air pollution profile of the city.) The impact of URwatair was less evident still. The project had clear plans to induce behavioural change by using CS results to stress which activities have significant impact on indoor pollution (e.g. smoking indoors, ventilation during traffic congestion) and should therefore be avoided. But because now impact assessment was carried out after the exercise, we don't know how participants were affected by CS and its results, if at all.

Finally, two projects that had an impact, however weak, on policy are hackAIR and Cos4Cloud. In both cases, the impact concerns education policy and is limited to an expression of interest. In the case of hackAIR, it was an interest expressed by a school's director to include the assembly of hackAIR sensing devices in the school's curriculum. In the case of Cos4Cloud, an interest expressed by course participants (teachers, education officials) to implement developed educational scenarios as part of the school curriculum.

**Secondary cluster**
*Highlights from other projects*
What immediately stands out in this cluster is the high volume of volunteers working on biodiversity projects. Some of these are Greek chapters of international initiatives e.g. iNaturalist GR (13.258 volunteers), eBird GR (2750). Some are national initiatives that create their own space within an international platform to publish observations. For instance, Hellenic Fauna CS Project (10.124), Biodiversity GR (8977) and "Is it Alien to you...Share it!" (1403) all have a sub-platform on iNaturalist where they share results.

[57] https://platform.hackair.eu/

Given their sheer scale, it's possible that some of these projects involved people from LSE groups. In addition, projects that worked with schools e.g. Hackquake (100 schools), GLOBE (33 schools) might also have engaged students from this category. But it's only INCENTIVE that openly acknowledged targeting hard-to-reach groups as a matter of priority. In one of its reports, the project explains who exactly it aims to target: minorities, elderly, disabled and LGBTQ.

INCENTIVE and Waste4Think are two projects with a clear focus on engaging stakeholders under the quadruple helix framework. Other projects achieved double or triple helix at best. A triple helix achiever that actually impressed us is Scent, a finished project about land use. Out of 511 participants that took part in its CS activities, 62.6% were private, 16.4% public, 16.4% students, and 4.6% from the 'other' category. Even if it's just triple helix, such breakdown really helps to visualise the scale of contribution of different social groups, and this presentation style is way more convincing than a simple reference to the triple/quadruple helix concept or its different constituent parts.

This cluster is no different than the primary when it comes to ECSA's 10 principles. None of the projects acknowledged following the guidelines though some clearly did so if not in name. DNOSES said that in addition to monitoring, participants were able to define the problem, co-design methodologies and tools that enabled them to own, share and act on the results. INCENTIVE, with its strong focus on RRI, probably falls in this category too.

All projects provide some kind of guidance to aid data collection in the form of online courses, protocols, FAQs, group forums, and workshops, including physical workshops, though the latter appear to be used more frequently by projects that rely heavily on an in-person demonstration e.g. Hackquake (assembly of seismographs), Wreck History (diving).

Data collection tools vary depending on the project and field of investigation. Those that monitor biodiversity tend to use apps to capture and document species. An exception is Alientoma that provides only a website form to users. Some projects use special equipment to capture data on earthquakes (seismographs) and underwater wreck sites (diving equipment). In the case of Scent, their discovery app awards points to users whenever they find a small water creature. A gamification element is also observed in many biodiversity related projects, many of which have leaderboards that rank people according to the number of observations they submit, the number of species they find, et cetera. Gamification can be a great way to promote competitive spirit among citizen scientists. One of the risks, however, is that people may be inclined to cheat to get to the top. So, some means of verification and anti-cheating measures should be put in place to ensure a level playing field.

When it comes to results presentation, we noticed the popularity of international platforms, in particular iNaturalist, among several biodiversity related projects. It seems that iNaturalst has become to biodiversity projects what Sensor.Community has become to many air related ones i.e. a go-to dissemination platform. That said, many projects avoided third-party apps, preferring to use their own tools (websites) instead. Examples are DNOSES, Wreck History, Alientoma.

In terms of technical impact, projects that drew our attention are those that:

- Adapted international standards to suit their needs: In developing its OdourCollect app, DNOSES built on the European standard CEN 16841. Although the standard defines a strict methodology for measuring odours (e.g. only during certain times, in specific areas, by certified people), DNOSES adapted the methodology to gather real-time data on odour perception anywhere, anytime, by any citizen.
- Published their observations as open datasets: Biodiversity GR published raw datasets for the period 1992-2021 as open data for personal use, publication in the media, use in scientific studies etc.
- Improved existing services and databases: Scent extended GEOSS and Copernicus repositories through frequent updates of local monitoring of land-use changes using the Scent Toolbox.

When examining projects for behavioural change, we found many statements that appeared more as ambitions and project objectives, rather than actual impact established through some form of impact assessment e.g. people will think positively about oceans and will become sustainable ocean advocates (CrabWatch), people will obtain the mentality of waste sorting at source (Waste4Think), people will be more inclined to preserve biodiversity and wildlife (Biodiversity GR). Whether these impacts actually materialised is hard to tell. We couldn’t find any evidence in the form of surveys or interviews to substantiate these claims, except for GROW. An evaluation revealed that GROW has helped some people to learn about and test regenerative food growing techniques. In support of this, two testimonials were provided: "Through GROW I am able to combine soil moisture and soil temperature data in order to better control pests in my family’s organic olive grove, for better adaptation to climate change.” And the second one: “Taking part in the Changing Climate mission has allowed me to understand the levels of humidity across my vineyard. I was hence able to adapt the irrigation regime and closely monitor the use of water in the vineyard. Growing can be lonely, but GROW Place Greece has enabled me to connect with other GROWers, exchange know-how and take collective action at local-level."

Claims about policy impact could not be substantiated for most of the projects. Still, we will provide some examples to give an idea of what policies may be influenced, how, and by whom in the secondary cluster.

- ***Emergency planning:*** by creating a network of 100 seismographs that can help improve preparedness for and response to earthquakes (Hackquake)
- ***Marine policy:*** by establishing a scheme to record and report crab distribution, including new crab arrivals (CrabWatch)
- ***United Nations Environment Programme:*** by monitoring the occurrence and distribution of the world’s reptiles and amphibian species (iNaturalist GR)
- ***Education policy:*** by introducing new technologies and integrating urban science into school curriculum (GLOBE)
- ***Conservation policy:*** by providing bird data for habitat management, species management and habitat protection (eBird GR)

With this, we conclude our discussion of country samples. In the final chapter we will briefly recap what we’ve learned from our review and then, based on key insights and findings, will issue a mix of general and pilot-specific recommendations for COMPAIR CS labs.

 

# Conclusion

This deliverable was prepared to support local teams in Plovdiv, Sofia, Flanders, Berlin and Athens as they are getting ready to launch CS campaigns. The support is intended to provide value in two ways. Foremost, by contextualising the CS environment in which each CS lab will operate. This was achieved by mapping 100 CS initiatives (finished and ongoing, domestic and international) across a number of areas (air monitoring, traffic monitoring, soil monitoring, water monitoring, biodiversity monitoring etc.) in the four pilot countries: Bulgaria (20), Germany (29), Belgium (31), Greece (20). The limitations of research design prevented us from building bigger and better country samples that are more representative of the countries' CS landscapes. For one, we relied exclusively on desktop survey to gather data. For another, we operationalised the CS landscape only in terms of CS initiatives, without considering CS related policies and funding. Still, with our samples we believe we managed to extract some useful insights that COMPAIR can use to better plan its future activities.

Another way in which this deliverable adds value flows directly from the first one. In reviewing CS initiatives, we focused on those areas where COMPAIR is looking to make a difference i.e. stakeholder engagement, behavioural change, policy change, technical change. By critically examining what other projects did or didn't do, what their successes and underachievements have been in these areas, we tried to identify learning points that could be used to improve pilot deployment and technical development in COMPAIR. Things we have learned from the review are distilled into recommendations that we will present after a brief summary of national CS landscapes. So what can our samples tell about them?

**Bulgaria**
The Bulgarian sample provides an interesting snapshot of the CS landscape in the country. Our mapping shows that the landscape is bigger and diverse despite the limited amount of information available for Bulgaria on popular CS aggregation platforms. While many initiatives arrived in the country as an extension of an international project, there are some domestic projects initiated by local stakeholders that attest to the internal capacity to start and manage CS projects with some degree of success.

Projects that measured air pollution did so using low cost sensors that varied depending on pollutant type e.g. diffusion tubes ($NO_2$), NodeMCU based IoT sensors (PM). People who used them to make measurements did receive some prior training and guidance but it's not clear to what extent they were involved in stages preceding data collection (e.g. problem formulation, location selection) and stages that followed it e.g. reflection, analysis, lobbying for change. Not surprisingly, we couldn't find any references in projects' documentation to ECSA's 10 principles that promote deep and meaningful engagement beyond passive data collection, however it's possible that some principles were followed in practice if not in name.

Other aspects of stakeholder engagement that were equally poorly visible in the primary cluster are i) participation of hard-to-reach groups (the only exception might be HEAL as it worked with school children) and ii) involvement of all members of the quadruple helix community (the only project that clearly acknowledged the need for this model is METER.AC).

Impact in the primary cluster is confined to the field of technology. Here, it is METER.AC's approach to data sharing and Dustcounters' Arduino-based sensor that caught our attention. Impact on individuals and policy was limited to a few statements that appear more as project objectives than facts established through research.

This was also a problem in the secondary cluster, where impacts are presented more as ambitions than survey findings or concrete steps taken by, say, policy actors as a result of the project. Even if we found no attempts to measure impact, it's interesting to see what projects thought their potential benefits might be e.g. ability to counter the influence of fake news (ANEMONE), better mental health and strengthened social bonds (RECONNECT), reduced usage of plastic bottles (The Watermap of Bulgaria).

**Germany**

Initiatives included in the German review cover around a fifth of the German CS landscape. But even with such small sample we were able to uncover a great variety of initiatives: those that arrived in Germany as an extension of another (international or EU-funded) project, those that started in Germany but have since spread to other countries, those that are initiated, funded and managed by domestic stakeholders, and those that support the growth of CS community without running any CS activities themselves. The discovery of 'supporters', 'inside-out' initiatives and a high volume of domestic projects is especially encouraging as their presence can be an indicator of the country's advanced CS maturity level.

Projects that monitored air pollution and traffic did offer some training and guidance to participants, but the effort was mainly oriented toward technical skills needed to successfully operate a DIY sensor. Some projects experimented with different outreach tactics, and it appears that retention rates are better when people take part in live demos and workshops, as opposed to just being targeted online. We couldn't find any evidence of a more comprehensive engagement strategy being used, except in the secondary cluster, where one of the projects (Citiclops) developed a five-step process to turn volunteers into co-managers of a CS lab.

In both primary and secondary clusters we found projects that worked with schools to monitor air and water quality (HEAL, SenseBox, GLOBE, FLOW). Several also claim to have achieved quadruple helix in their engagement (hackAIR, Dnoses, Open Soil Atlas, Citiclops, Tator Gewasser). Even though projects do not acknowledge following ECSA's 10 principles, many did so in practice.[58] In several air related projects, participants were involved in coding and training (hackAIR), in preparing and evaluating passive samplers in the laboratory (BerlinAIR NO2 Atlas). This shows that projects may be following at least some of the principles even if there is no reference to them in project documentation.

Devices used for measuring air pollution varied depending on pollutant type. NO2 was measured the traditional way (i.e. diffusion tubes) in the HEAL project. Particulate matter was measured using DIY sensors provided by Sensor.Community and senseBox. An

[58] The only exception is Burger Schaffen Wissen (a 'supporter') that said it uses 10 principles to evaluate CS projects

exception was HEAL that used a commercial, albeit also low-cost, device with a light-scattering property, for PM measurements.

The project whose technical impact impressed us the most is Sensor.Community. Its DIY sensor sensor kit has been used by thousands of individuals and projects worldwide. For about 50 euros, people can build a compact device to measure air pollution around them, share data on a map (if they want), and become part of a global CS network. Other projects that caught our attention are those with a strong focus on open standards (enviroCar, Citiclops).

Where attempts were made to measure behavioural change (hackAIR), the most commonly reported impact was increased knowledge and interest in air pollution. The project's impact assessment did not find any evidence that CS activities triggered some preventive behaviours among participants, such as avoiding going outside, keeping one's windows closed, and wearing a mask. But some survey respondents did mention that they tried to avoid busy roads more often (protective behaviour) as a result of increased awareness about risks posed by air pollution.

Projects in both clusters managed to attract a considerable number of volunteers, though air related projects often share the number of sensors installed rather than the number of volunteers engaged e.g. Sensor.Community (14.388 sensors), senseBox (9551 sensors). Clear leaders by volume in the secondary cluster are NaturGucker (with 111395 volunteers), Muchekatlas (29000 volunteers) and Plastik Pirates (15000 volunteers). The latter started as a German project but has eventually spread to Portugal and Slovenia thanks to the endorsement of the Trio-Presidency of the Council of the EU, demonstrating that buy-in from senior policy makers can scale the project considerably within and across borders.

Finally, besides Plastik Pirates, some political interest in CS results was observed in relation to senseBox (the Ministry of Education used them to coordinate learning opportunities for students), Tauchen für Naturschut (the idea of nature-conservation diving was introduced in the Mecklenburg Lake District) and Muchenatlas (authorities have benefited from more accurate risk assessments of mosquito-borne diseases which allowed them to implement better public and animal health policies in Germany). Other projects either didn't target policy makers as a priority group or their policy impact appeared more as an ambition than something established through some form of impact assessment.

**Belgium**

Belgium has north of 180 CS initiatives. By reviewing just 31 of them we barely scratched the surface of the country's CS landscape. Even so, with our small sample we hope that we managed to capture a good mix of domestic initiatives (local and regional), EU projects with pilots in Belgium, and CS ecosystem 'supporters' i.e. domestic platforms that help others to start, manage and promote CS projects. The latter type was also found in Germany and we think it can be an indicator of the landscape's maturity level.

The Belgian sample has the largest primary cluster comprising 12 air related and two traffic related initiatives. Here, most projects avoided a hands-off approach, preferring a deeper engagement instead. Where this happened, participants were involved in pre- and post-data collection activities that ranged from brainstorming, workshops and training, to analysis, reflection and planning.

At least six projects in the primary cluster worked with schools to monitor air quality. In projects where schools are the main stakeholder, the number of participants can exceed dozens and even hundreds of institutions (181 schools in the case of AIRbezen, for example). Inclusion of schools in CS is a welcome sign that shows increased awareness of threats that air pollution poses to young people, and also the contribution that CS can make to school curriculum, in particular STEM education.

Through schools, projects have a channel by which to reach out to vulnerable and excluded groups, though very few projects actually succeeded in engaging people with a lower socioeconomic status. WeCount tried but ultimately failed. CurieuzenAir is the only success story that managed to achieve inclusivity by including special community locations in its measurement network and by working with local NGOs that deal with issues like health and poverty.

Two projects that set a record for engaging the largest ever number of citizens in air pollution monitoring (in Europe at least) are both from Belgium. We say two but actually it’s the same project (Curieuze Neuzen) that ran two campaigns, a local one in 2016 in Antwerp (2000 volunteers) and a regional one two years later across Flanders (20000 volunteers). Other projects that followed can also boast some impressive numbers e.g. CurieuzenAir (3000), BikeSTEM for Schools (1200).

We noticed little innovation in the way pollutants were measured. The SDS011 sensor popularised by Sensor.Community is clearly the preferred choice for PM measurements. For nitrogen dioxide it is still passive samplers (diffusion tubes). Only in iSCAPE, NO2 was measured through a computerised sensor, an Arduino-compatible Smart Citizen Kit.

Although sensor selection was quite standard, what really impressed us was the way in which some project results were presented. While online maps is by far the most common way of presenting results, displaying these maps on a newspaper’s website is a practice we only observed in the Belgian sample. De Standaard, a Flemish daily, provided this kind of dissemination support to two projects, Curieuze Neuzen in de Tuin and more recently to CurieuzenAir. Providing map based visualisations on websites of popular media outlets can give a significant boost to any project-level dissemination effort, allowing more people to learn about CS results.

Impact on individuals and policy is not something that can be easily identified based on project documentation. Oftentimes impacts are formulated as project objectives, with no clear evidence of how they were achieved. But sometimes projects do evaluate their work. Based on evaluation results of several projects (hackAIR, iSCAPE, Ground Truth 2.0), the most common benefits to CS participants are greater awareness of and improved motivation to get involved in air issues, as well as higher propensity to engage in soft-mobility behaviour. Policy impacts usually vary from project to project. WeCount, for example, reported a clear intention by the city of Leuven to make Telraam a permanent resource that can be drawn upon to implement, monitor and evaluate new mobility measures. iSCAPE mentioned the interest of the Hasselt authority regarding the use of CS sensor kits in higher education projects that could be undertaken in the coming years to help solve mobility and air related problems.

Potential to deliver impact is not limited to air and traffic related projects. Those in the secondary cluster also motivate people to carry on with CS activities (Curieuze Neuzen in de Tuin) and support policy making in different areas and ways e.g. by providing a platform for STEM lessons on gardens (My Gardelnab), by broadening environmental sensing in cities (NoiseTube), by providing information on the impact the road network is having on nature (Animals Under Wheels), by providing a hands-on manual for towns and cities on when and how to use CS (Scivil).

**Greece**

The Greek review is based on the mapping and analysis of 20 initiatives. Despite its modest size, the sample conveys some interesting insights on the state of play of CS in Greece. We noticed a large presence of EU projects, more than in any other pilot country, active in all fields covered by the review, from air monitoring to humanities. Also noticeable are renowned international projects with a large volunteering force in Greece reaching thousands (eBird GR) and sometimes tens of thousands of people (iNaturalist GR). Despite considerable external influence, the landscape is not without domestic projects, with some interesting examples found at local and national level, in fields ranging from air to biodiversity monitoring. We even found one project that has potential to evolve the country's CS landscape into a more mature state, by establishing a CS hub at one of the country's leading universities.

Engagement within the primary cluster involved some close-knit cooperation between CS projects and stakeholders. The latter benefited from training, sometimes in the form of an online course, designed to improve their capacity not just to build sensors but also develop CS scenarios for integration into institutional structures (e.g. education curriculum) to achieve a more lasting impact. Projects were therefore clearly thinking of pre- and post-data collection activities, often taking active steps to support their implementation. This corresponds to several ECSA's principles e.g. 1, 2, 3, 4. But like in other country samples, no explicit references to these guidelines were found in projects' documentation, which underscores yet again that projects usually follow some principles, if not in name.

While projects in the primary cluster worked with just several schools, the number was considerably higher in the secondary cluster, where Hackquake alone set up seismographs in 100 schools across the country. Between them, the two clusters managed to engage a significant number of young people. However we don't know how many of them were from vulnerable groups, and how exactly CS benefited students apart from improving awareness and interaction on issues like air pollution and earthquakes. Only hackAIR provides a glimpse of behavioural change stimulated by CS, as one participating school reported increased motivation among students to use CS experience as a springboard for new activities e.g. entrepreneurship.

We noticed that participation of industry was more often than not missing in the reviewed initiatives, with triple helix being the most common achievement. Where this was the case, projects often just referred to different stakeholder types to stress the result, and it's only Scent that went so far as to provide a detailed breakdown per group e.g. 62.6% private, 16.4% public, 16.4% students. COMPAIR and other projects would be well-advised to copy this practice as it's far more convincing than simply referring to the triple/quadruple model or its different constituent parts.

Data collection tools used for monitoring air pollution are pretty standard: a DIY sensor popularised by Sensor.Community and a couple of low-cost, commercial solutions all measuring PM2.5 and PM10. In the secondary cluster, projects that monitor biodiversity are increasingly using apps to capture data. Many domestic initiatives use international platforms as a dissemination tool. It appears that iNaturalist is now to biodiversity projects (at least in Greece) what Sensor.Community is to air related ones. Biodiversity is one area where we noticed many projects with gamification elements, such as leader boards, that aim to promote competitive spirit among participants.

Looking at technical innovations in the secondary cluster, we were fond of projects that adapted international standards to enable real-time monitoring of odour nuisance by any citizen, anytime, anywhere (DNOSES), that made time-series datasets on biodiversity available for use by citizens, researchers, media and policy makers (Biodiversity GR), and that extended GEOSS and Copernicus services to improve the monitoring of land-use changes locally (Scent). A project with tangible personal impact is GROW, whose CS activities helped participants learn and implement regenerative food growing techniques. There aren't many projects with a demonstrable impact on policy, but many are clearly thinking about policy areas they want to affect (emergency planning, marine policy, education, policy, conservation policy etc.), judging by project objectives.

Finally, Greece's landscape may not be at the same level of maturity as that of Belgium and Germany, but the emergence of enabling/supporting projects like INCENTIVE leaves one sanguine about the prospect of this transformation happening sooner rather than later. INCENTIVE aims to transform universities, starting with AUTh, into scientific hubs that would drive CS agenda by promoting science-society interfaces. If successful, INCENTIVE may help evolve Greece's CS landscape into a buoyant ecosystem with hundreds of projects and opportunities for experienced CS professionals as well as those new to the field.

**Recommendations**

The following recommendations are based on insights and observations (positive and negative) gleaned from the landscape review. They should not be treated as something prescriptive but rather as an invitation to consider a possible course of action, one that local teams may want to take after weighing all the options. Ideally, these recommendations will be discussed and debated over several iterations (within local teams, between COMPAIR partners, with stakeholders) to produce an agreed-upon set of actions that has the best fit with the needs, capacities and ambitions of each CS lab.

The recommendations cover eight areas:

1. CS lab ownership
2. Location selection
3. Value network
4. Qualitative research
5. Impact
6. Dissemination
7. ECSA’s 10 principles
8. Future research

Some of them are more generic and apply to all pilots in more or less equal measure. Some apply to certain pilots more than to others. Where this is the case, we will highlight which pilots should take action and what that action might be.

On some topics, useful recommendations can already be found in submitted project deliverables. Case in point is D7.1 Participation Risks and Compliance. It contains a good overview of different levels of participation in CS (from crowdsourcing to extreme CS), different engagement tactics for planning, data collection and legacy stages, different personal motivations that influence participation, different biases and ethical issues that can undermine project success. The above will not be covered in these recommendations so as to avoid overlap with D7.1.

*R1: CS lab ownership*

The highest level of participation described by Haklay (2013) - that is, extreme CS - involves citizens in problem definition, data collection and analysis, but obviously this is not the limit. The next level can extend citizen participation to CS lab ownership. So, at some basic level, participants will merely provide data for the lab. At more advanced levels, they will co-manage it with the founders and may even take full ownership of the lab in the long term.

One project that experimented with this approach is Citiclops. In the early stages, Citclops' researchers consulted stakeholder communities as they planned, designed and started to implement the citizen observatory. As Citclops evolved, stakeholders took a more active role, participating in the observatory's structure and management, and sometimes negotiating with Citiclops's partners to ensure their specific goals and values were represented. At full maturity, Citclops shared management between project partners and stakeholders, and in some cases transferred management completely to local communities, with observatory's managers only providing advice and consultation. Presumably, this is the kind of maturity trajectory COMPAIR should be aiming at, one that starts with some basic engagement and culminates in a setup whereby local communities manage a CS lab first in cooperation with and later with minimal intervention from project partners.

Now is a good time for pilots to start thinking about the future of their CS lab. Is the goal to turn it into a fully-fledged CS observatory during or after the project? What role should citizens play in the lab’s future? Do you plan to increase their level of participation to the point where they become co-owners, or maybe even sole owners? Depending on the ambition, different levels of participation will need to be stimulated using different tactics and tools. Ground Truth 2.0's recommendations for citizen observatories, one of which was set up in Mechelen, would be a useful resource to consider in this regard.[59]

*R2: Location selection*

Air pollution varies greatly from one place to another. The challenge for pilots is to determine where to take measurements to get a representative coverage of air quality in the city. Since COMPAIR also wants to make CS more accessible to LSE groups, our selection approach should ensure that vulnerable, hard-to-reach groups are represented in target locations. One project that had similar objectives and went to great lengths to describe its approach is CurieuzenAir.[60] In Brussels, where the project was implemented, measurements were taken in three different places.

***Regular locations:*** These are the 3000 sampling locations where NO2 sensor kits were placed. Selection process was guided by public value (i.e. how to maximise the project's societal impact) and scientific value i.e. how to ensure that the distribution of measured NO2 values is representative of the whole population, and that the impact of street-level emissions becomes apparent?

***Community locations:*** These measurement locations were meant to establish a bridge with vulnerable and hard-to-reach groups that have low propensity to participate in CS and that may not be easily targeted via online outreach. Community locations were identified through cooperation with local NGOs and their beneficiaries.

***Background locations:*** These are measurement locations that have no local, nearby urban NO2 sources e.g. forests, parks, car-free pedestrian areas. They were added to the network to separate the effect of imported pollution from natural background concentration of NO2, which can result from lightning and microbial activity in soils, for example.

Since we are going to use electromagnetic sensors to measure NO2 instead of simple diffusion tubes (one of COMPAIR's key technical innovations), we may need to add another location to the list to calibrate our sensors e.g. reference stations. But the three ones outlined above provide a good starting point for thinking about how to select places with high public and scientific value.

*R3: Stakeholder network*

D2.1 Value Network Canvas provides a good initial overview of stakeholders that pilots need to engage to deliver a successful CS campaign. In the deliverable, stakeholders are visualised as members of the quadruple helix community (government, academia, business, society) and placed in different categories based on their interest in COMPAIR: low, medium, high. A further breakdown is provided per group, which is in line with good practice followed by other CS projects e.g. Scent.[61]

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[59] Deliverable D1.13 Guidelines for Citizen Observatories and Future Recommendations, https://gt20.eu/

[60] https://curieuzenair.brussels/en/results/

[61] See the infographic at https://scent-project.eu/kifisos-river-basin-attica-greece

To further grow their networks, local teams may wish to consider some additional stakeholders that the research team deemed relevant during the landscape review, namely specific community groups, schools, and media outlets.

- Community groups: these are NGOs that can help us engage vulnerable, hard-to-reach groups, including those that may not be easily targeted online. CurieuzenAir worked with health and poverty charities. Also useful to consider would be NGOs dealing with migration, gender and age issues.
- Schools: In every sample we found CS projects where the focus was exclusively on schools or where schools were prioritised during the selection process. Since schools are a priority for COMPAIR pilots too, we would like to share the names of schools that emerged during research, hoping that local teams may see some of them, given their prior experience with CS, as potential candidates for target locations. The names will be provided separately per pilot below.
- Media outlets: One interesting finding that emerged from the Belgian review is that newspapers sometimes participate as dissemination partners in CS projects. One outlet that stands out is De Standaard, a Flemish daily, that published the results of Curieuze Neuzen in de Tuin and CurieuzenAir as maps on its website. Pilots are therefore encouraged to check which media outlets may be interested in sharing our results through their channels. Any support we might get from local newspapers/magazines would reinforce our communication efforts and help spread COMPAIR results further and faster.

In the next few paragraphs, we will share the names of schools with prior CS experience that emerged during the landscape review, and will reference some other stakeholders that may be worth adding to the value network. Potentially, they may be willing to contribute to the CS lab as data collectors, advisors or in some other capacity within the quadruple helix model.

***Bulgaria:*** Schools that worked on the GLOBE project include the Anglo-American School Sofia and the American College of Sofia. Schools that worked on the HEAL project in Sofia are 26 SU “Yordan Iovkov”, 75 OU “Todor Kableshkov”, Telecommunication school, and NPMG. A university that is worth contacting is the University of Plovdiv that is in charge of METER.AC. In addition, consider approaching Sofia Municipality under the banner of EU project clustering to increase chances of cooperation.[62,63]

***Germany:*** HEAL did not share the names of 10 participating schools, but it did say that they were from busy locations near Neukölln, Mitte, Tempelhof-Schöneberg, Steglitz-Zehlendorf, and Friedrichshain-Kreuzberg. GLOBE has a list of participating schools for the whole country (616).[64] Zooming in on Berlin, one can easily find several markers with the school's name and address. SenseBox also cooperates extensively with schools, many of which can

[62] LIFE IP CLEAN AIR (https://lifeipcleanair.eu/) is an EU funded project that aims to improve air quality in the municipalities of Sofia, Burgas, Veliko Tarnovo, Montana, Ruse, and Stara Zagora. The project will be running for two more years and is managed by Sofia Municipality. Approaching Sofia Municipality under the banner of project clustering, as opposed to project-municipality cooperation, may be a more effective way of engaging the city.
[63] It's important to keep in mind that air quality is a sensitive issue in the capital. In 2021, an NGO called Za Zemiata tried to sue Sofia authorities over harmful levels of air pollution. Some resistance among policy makers to work with citizens to tackle air pollution can therefore be expected.
[64] https://www.globe.gov/web/germany

be identified on the openSenseMap e.g. Berlin Metropolitan School.[65] Finally, an ongoing SimRa project that works with cyclists to identify dangerous hot spots, may be interested in advertising COMPAIR among its volunteers.

***Belgium:*** A useful resource to explore is AIRbezen's list of 181 schools across Flanders.[66] Although air pollution was measured using plants, not sensors, given schools' prior experience with CS, some of them may be open to new opportunities, including new methods of taking measurements. Among other projects we can recommend GLOBE Belgium, which cooperated with 19 schools.[67] The Flemish ones are based in and around Ghent, Ostend, Antwerp, Malle, Meise.

***Greece:*** We identified three schools that cooperated with CS projects to monitor air pollution: Kantas School, Senior High School of Metamorfosi, and Junior High School of Krestena. Additionally, GLOBE Greece provides a list of 13 schools from Athens that engaged students in environmental monitoring.[68]

*R4: Data collection at workshops*

Recently, pilot teams held their first co-creation workshops with stakeholders. Many more will be organised in the coming months. Just as we need to ensure validity of CS data (through calibration algorithms, sampling protocols, spatial representation etc.), so we need to ensure that information gathered at events adheres to good qualitative-research practices. The following checklist is intended to help pilots in this endeavour.

- ***Balance and risk assessment:*** Ideally, at all future workshops a perfect balance will be maintained as regards stakeholder type, age, gender, socio-economic profile. In reality, however, a strict proportional representation may never be achieved. So, while pilots should try to ensure that balance is maintained whenever possible, and that engaged stakeholders provide knowledge and opinions that are representative of or are accepted by the stakeholder community at large, it's inevitable that certain groups will be excluded from the process. Whenever this happens and a certain group is unable to participate, it's advisable to perform a risk assessment to better understand any negative consequences that may result from failing to include this stakeholder in the activity.
- ***Preparation:*** Circulate background papers and any relevant research findings from the project in an accessible format to participants ahead of the meeting to help them come prepared.
- ***Privacy:*** Let the attendees know that the meeting will be recorded and that pictures or screenshots may be used to promote the event via project dissemination channels. Moreover, attendees can cease participation and opt out of the project if they wish.
- ***Workshop activity:*** Use a workshop guide to structure the discussion. Avoid loaded questions and use probes to get additional information. Try to maintain a balanced discussion as much as possible, ensuring that everyone gets a chance to speak.

65 https://opensensemap.org/explore/5a55cd5a53bf5e00129b68a3
66 https://airbezenatschool.be/scholen/
67 https://www.globe.gov/web/belgium
68 https://www.globe.gov/web/greece/home/schools

Encourage quieter participants to share their thoughts and manage those who talk all the time.

- ***Group dynamics:*** If recent court battles in Brussels and Sofia are any indication, air pollution remains a highly contentious issue, with citizens often at loggerheads with local officials about inadequacy of measures taken to address it. Even when the two are working together as part of the same citizen observatory, conflicts and power play can emege, plaguing cooperation.[69] Thus understanding and managing group dynamics should be a key part of pilots' stakeholder engagement. Such awareness can be crucial for ensuring that planned activities run smoothly, for example by interacting with conflicting groups at different meetings rather than assembling them in one room. Part of the art of CS is to improve minority groups and make sure their interest is reflected in the overall ambition and measures intended to achieve it. That said, a good CS activity will strike a balance, as one needs support of 'big actors' (policy, industry) to get credibility and some chance of success, and inputs of minorities to get fairness and justice.
- ***Feedback:*** Circulate notes from the meeting and/or slide decks to all participants, including those who could not attend. Ask for feedback and any relevant additional information to validate conclusions. Incorporate this feedback into the final summary report, making sure that the document is properly anonymised.

*R5: Impact*

One important finding from the review is that evidence of impact was more often than not missing in project documentation. Many projects formulated their impact as a potential benefit to stakeholders in project objectives and/or recommendations. Only a few substantiated their claims through some form of impact assessment. Fewer still acknowledged that impact was minimal or less than what had been expected. All these are useful pointers for us to consider before delving into specific recommendations.

***General recommendations:*** Imagine it's 2024 and a casual visitor is browsing our website. He navigates to the impact page and sees.. what? Sentences that talk about impact in the future tense? Or claims about impact supported by quotes, surveys and case studies showing how our results helped people in real life? The answer is obvious as all projects want to demonstrate tangible impact during their lifetime. However, as our research has shown, and perhaps unsurprisingly, demonstrable impact is more an exception than the rule. To do better than most projects in our samples, we should start by operationalising our stated objectives e.g. what do we mean by behavioural change? What can be considered a good or satisfactory impact on policy? The next step is to understand how these can be influenced while COMPAIR is still running and put in place strategies to that effect allowing enough time for evaluation. Some impacts are best measured using a mixed-method survey (behavioural change) while others can be captured using more qualitative techniques e.g. case studies. Even if impact is minimal, we should still report it, explaining why this may be the case. Other projects (e.g. hackAIR, WeCount) were candid in this regard, and we should be too, not least to allow others to learn from our experience.

[69] The experience of Meet Mee Mechelen is a case in point. City employees joining the observatory were still regarded as representatives of the policies the citizen group was fighting against. When the city offered to host the observatory's platform on the municipal website, many citizens objected to the proposal.

***Behavioural change:*** COMPAIR promised to elaborate five pathways to behavioural change in its objectives. A good resource to consult on behavioural change and how to conceptualise it is hackAIR's pilot implementation and final evaluation report.[70] The document reviews different models of behavioural change (The Theory of Planned Behaviour, The Self-Efficacy Theory, The Health Belief Model, The Social Practice Theory, The Diffusion of Innovation Theory, The Five Doors Theory, The Fogg Behaviour Model) and, more importantly, explains the approach taken by the project to measure it in Brussels and Berlin.

All COMPAIR pilots, but especially those in Flanders and Berlin, should spend some time studying this deliverable to see which models are more applicable to their context. The behaviour change study in Brussels differed from the one in Berlin. Some main differences are: in Brussels, people were offered incentives (voucher, plant as a gift), they had to buy a sensor for 35 euros, and they were divided into two groups, a control group, and an experimental group. Researchers found that one specific type of behaviour was positively and significantly impacted by the experiment: soft mobility. This means that the experimental group engaged more than the control group in soft mobility (e.g. walking, biking, taking public transport) instead of driving a car.

The study in Berlin was less sophisticated. There were no control and experimental groups, and the focus was mainly on the use of project technology. Participants did not report many changes in terms of preventive behaviours e.g. avoiding going outside, keeping one's windows closed, wearing a mask. But some did carry on a pre-existing protective behaviour (self-care), such as avoiding busy roads.

When planning a behavioural change study in COMPAIR, we'll need to decide whether all pilots should follow the same methodology or whether it should vary from city to city. If the latter, it would be important to understand how this variation may affect the generalisability of our findings and ensure that results from e.g. Plovdiv and Flanders have the same validity as results from Athens, Berlin and Sofia.

***Impact on policy:*** Our review shows that success in influencing policy, at least within the primary cluster, is usually limited to an expression of interest by a public body to use project results in the future. In Leuven, the intention was to maintain the Telraam network and use it for monitoring the implementation of different mobility measures e.g. school streets, green zones (WeCount). In Athens, to include the assembly of sensing devices in a school's curriculum (hackAIR). In Hasselt, to use CS sensor kits in Masters and Bachelors thesis projects with a focus on city mobility and air pollution (iSCAPE). We just found one project in Germany where policy impact was described in the past tense. (Apparently, the Ministry of Education used senseBox results to coordinate learning opportunities for students.) But as regards urban planning, for example, no project that monitored air quality was able to demonstrate that, during its lifetime, public officials used project's CS data, either alone or in conjunction with other data sources (e.g. data from official monitoring stations), to aid policy making.

[70] https://zenodo.org/record/2531140#.YlaSL-hByPo

In view of the above, COMPAIR should think about how to conceive policy impact, is an expression of interest enough, or should real-life application be the standard by which to judge success? How to convincingly lay claim to future impact, assuming that it materialises, to get credit for it during the project? How to present real or potential impact, through quotes, interviews, case studies, examples of project inputs to policy processes (e.g. response to a public consultation), references to implemented policies that use project results, or something else?

Our research has shown that education is one area where the potential of CS to deliver impact is especially high. The upcoming policy review should therefore

- Identify all possible areas where the project can make a difference e.g. STEM education in schools, national science policy, local mobility and health policy, local Green Deal
- Operationalise the term ‘policy’: does it cover laws, regulations, plans, strategy papers, green papers, white papers? Some measures carry legal weight while others are just ambitions that set out a vision of the future
- Provide specific examples of the above (e.g. Sofia’s Green City Action Plan, Flemish Science Agenda, EU’s Zero Pollution Action Plan) and explain how COMPAIR can contribute to them
- Identify complementarities between policy measures to better demonstrate co-benefits that COMPAIR can deliver across health, education, climate, social cohesion, urban planning and other areas
- Identify opportunities for project to provide input to new policies or any existing ones that are in the process of being updated, for instance by responding to public consultations or attending policy roundtable events

***Technical impact:*** Our review has shown that deployment of passive samplers, with a subsequent lab test, is by far the most common way of measuring NO2. The downside of this approach is that it gives cumulative measurements of the average pollutant concentration over a long period of time, usually a month. The temporal resolution of these measurements is therefore very low, which renders them less apt for use cases involving e.g. school streets that require comparisons of pollutant concentration at different hours of the day. COMPAIR, by using electrochemical gas sensors for real-time NO2 measurements, goes way beyond the current state of the art where simple diffusion tubes rule the day. To ensure our sensors give accurate readings, they will be calibrated with data from reference-grade, highly accurate measurement stations. The main recommendation would be to consider placing sensors in other locations, not just around schools and reference stations. This is because NO2 occurs naturally as a result of lightning and microbial activity in soils, for example. To separate this background effect from anthropogenic factors, we might want to place a few sensors in locations with no local, nearby urban NO2 sources (e.g. forests, parks, car-free pedestrian areas), as was done in the CurieuzenAir.

Not all projects reviewed in this deliverable embraced open standards principles. But some did, serving as an inspiration for others, including COMPAIR, to follow in their footsteps. enviroCar, a traffic monitoring project in Germany, is completely open source. All of its components are available on Github. Users can avail of the Web API to create new products and services e.g. maps, statistical analysis. Gathered data is publicly available as JSON and linked data, which means it can easily be integrated into any service that works with these standards.

Citclops is another example. A finished EU project focusing on water quality, it developed web portals with open principles in mind. The idea was that by using standards like OGC and SensorML, by enabling data sharing with GEOSS and by including semantic aspects and linked data, the project would be able to create really advanced means of information delivery to generate powerful insights for stakeholders.

As regards open data, while most projects displayed their findings on a map or in reports, we found only a handful of projects that made raw datasets available to the public. So, while providing API access to CS data is important, COMPAIR might want to follow the examples of iSCAPE and Leuvenair, both of which published raw datasets as CSV files on Zenodo. Leuvenair's dataset contains 42,203,945 measurements from 112 sensors (Nova Fitness SDS011) that were placed in and around the city of Leuven.[71] iSCAPE published numerous datasets with information on how sensors were developed, what data was obtained from outdoor deployment, and what data was generated during a simulation exercise.[72]

*R6: Dissemination*

Our research identified several gaps in existing repositories that can be filled with information from this deliverable. We also identified several opportunities that can help us find volunteers and increase the visibility of project results. The following recommendations apply to Bulgaria, Germany and Belgium.

***Bulgaria:*** The local team already knows that a popular aggregation platform EU-Citizen.Science has no country filter for Bulgaria. One can therefore get an impression that the CS landscape in the country is non-existent. But as our deliverable shows, this couldn't be further from the truth. To increase visibility, the platform can be updated with some projects (e.g. those that are still running) from the mapping tables. The team managing the Bulgarian CS lab may want to contact project coordinators to alert them to the opportunity (ideally they will add entries themselves). Perhaps some of them will also be interested in joining COMPAIR's stakeholder panel.

***Germany:*** If Burger Schaffen Wissen accepts submissions from EU projects, we should try to advertise COMPAIR there.[73] Being present on the platform means people will be able to find out when they can get involved (immediately or later), if they can use an app (in our case yes), and if the project is suitable for children (yes).

***Belgium:*** The recommendation is to create a project profile on Iedereen Wetenschapper and, if possible, Scivil too. This would make it easier to find volunteers, especially during COMPAIR's Open CS round. It may be more difficult to get visibility on Scivil as they seem to publish only projects funded by the Flemish government. If that is the case, Scivil can still

[71] https://zenodo.org/record/4936982#.YkbgTCgzaPq
[72] https://www.iscapeproject.eu/iscape-data/
[73] https://www.buergerschaffenwissen.de/projekte

 

be useful in other ways. For example, there is a 'partner corner' where we may find NGOs that work with vulnerable groups.[74] Bewiging.net looks especially promising.

*R7: 10 principles of CS*

The only project in the entire review that referred to 10 principles is Burger Schaffen Wissen.[75] Many other projects seem to be following ECSA's guidance in practice but not in name. Going forward, it would be useful to understand how projects, including COMPAIR, can demonstrate compliance with good CS practice.

***Germany (ECSA):*** This recommendation is an invitation to elaborate on three things. First, do projects need to acknowledge, via a statement of sorts, that they are following principles in part or in full, to be deemed compliant with good CS practice? Second, is there a minimum threshold (e.g. following just one, two or three principles) that projects must meet in order for their activities to be considered good CS? Third, should COMPAIR advertise, through an e-badge for example, that it proudly supports ECSA's 10 principles?

***Bulgaria:*** The recommendation would be to translate ECSA's 10 principles into Bulgarian. Currently, they are available in more than 30 languages, but Bulgarian is not one of them.[76] Translating 10 principles is important but it's even more important to follow what we preach. Ideally, COMPAIR as a project will be able to put a tick next to each principle. At the very least, we should be able to demonstrate we offered meaningful engagement that extends to pre- and post-data collection activities.

*R8: Future research*

CS literature abounds with conceptual models of CS projects. They can be categorised according to levels of participation (Haklay 2013), sensor deployment (broad v slim), agency (protocol-based v full autonomy).[77] Existing models can be extended - for instance, by adding ownership of a CS lab (level five) to Haklay's typology - to capture new roles and opportunities in a constantly evolving space.

The flurry of activity in academic literature is mirrored on the ground as many countries are witnessing a real boom in CS activity. There are countries whose landscapes are fairly modest, comprising just several dozen initiatives, most of them 'external', and then there are those with a much more advanced ecosystem, characterised by a strong presence of domestic projects, 'supporters' and 'inside-out' initiatives i.e. domestic projects whose influence transcends national boundaries.

To the best of our knowledge, and based on a quick desktop survey, no attempts have been made to unite the two models to create a typology of CS regimes. We believe that two preconditions for this new theoretical framework have been met, namely the abundance of different modes of participation and the diversity of CS project types found in different

[74] https://www.scivil.be/en/partners
[75] They use it to evaluate projects that are submitted for publication on the platform, so we can expect to be judged according to this framework when we make our submission
[76] https://ecsa.citizen-science.net/documents/
[77] Oudheusden, M. V., Huyse, H., Laer, J. V., Duerinckx, A., & Soen, V. (2021). Sharing open science experiences: A conversation on citizen science . In proceedings 2021. https://doi.org/10.21428/1192f2f8.c6029b3b

countries. In the next few paragraphs we would like to sketch the basic contours of this typology, starting with its objective.

For a given country, the typology would show the distribution of projects across a range of disciplines. After mapping all initiatives according to type (external or domestic) and level of participation (low or high), the quadrant with the biggest project cluster would determine whether the national CS regime is predominantly external-low, external-high, domestic-low or domestic-high. One hypothesis that requires testing is whether regimes evolve from external-low to domestic-high—in other words from arguably a more basic landscape (dominated by external projects offering low levels of participation) to a more advanced landscape (dominated by domestic projects, including ‘inside-out’ initiatives,[78] offering more meaningful engagement)—under the influence of different drivers of change e.g. national policies that stimulate public participation in science, national funding for CS, technological advances, activities performed by enabling and supporting initiatives.[79] And what about external-high and domestic-low, can these be considered regimes in transition?

***External-low CS regime:*** Characterised by a large presence of ‘external’ or ‘outside-in’ projects (international, European, EU-funded) that offer low levels of engagement i.e. citizens act as sensors, interpreters or basic observers. Examples include eBird and iNaturalist.

***External-high CS regime:*** Similar projects dominate this landscape as in the previous regime, with the main difference being that these projects offer a more meaningful engagement to citizens i.e. citizens can help define a problem, build sensors, collect and interpret data, maybe even co-manage a CS lab. Examples include WeCount and Citiclops.

***Domestic-low CS regime:*** The landscape has considerably more domestic projects than in two previous regimes. Some of these projects may even be ‘inside-out’ initiatives with branches and/or sensor deployments in many other countries. However, most projects of this type offer only basic engagement to citizens. Examples include AstroSounds, Alientoma and Sensor.Community.

***Domestic-high CS regime:*** The fourth type is characterised by a significant presence of domestic projects, ‘supporters’ that nurture the ecosystem and ‘inside-out’ initiatives all offering deep and meaningful engagement. Examples include HASSELair and Open Soil Atlas.

[78] The inside-out version of projects have really only been available in the past 20-30 years due to technological progress. Before that, most projects were domestic. So technological advances are clearly an important driver that have made inside-out initiatives possible.
[79] For an example of an ‘enabler’ see the Greek chapter, for ‘supporter’ Belgian and German ones


**Figure 3. The COMPAIR typology of CS regimes**

To understand which of these regimes are present in a country, a significant share of CS projects would need to be mapped along the x and y axis. To get a better sense of where the regime is now compared to where it was before, finished and current projects can be mapped separately, with distributions then compared to identify possible changes over time. Another idea would be to perform two mapping exercises with a time gap of several years to see by how much the regime has changed during this period. It's possible that in some domains (e.g. biodiversity monitoring) the country's regime is domestic-low or domestic-high, while in others it is dominated by external projects with high/low levels of participation. Where this is the case, it would be interesting to understand why some domains 'outperform' others, is it due to funding, policies, societal norms, or something else? The same is also true for the typology as a whole. Future research seeking to validate the framework would need to provide possible explanations as to why the country's regime is what it is, and how to improve it to get to domestic-high (assuming it's the goal), or how others can get to this stage if domestic-high has been achieved. This deliverable lays the foundation for precisely this kind of work that we intended to complete in the future.

# Annex A: Country initiatives

**Bulgaria**

| Initiative name | Field | Status | Lead organisation in Bulgaria |
|---|---|---|---|
| AirBG | Air quality monitoring | Ongoing | AirBG |
| Alien CSI | Biodiversity monitoring | Finished | University of Forestry, Sofia |
| ANEMONE | Biodiversity monitoring | Finished | Institute of Oceanology |
| CitizenHeritage | Humanities and arts | Ongoing | Sofia University |
| Citizens' App | Social sciences | Ongoing | Grajdanite |
| DNOSES | Odour monitoring | Finished | Sofia Municipality |
| Dustcounters | Air quality monitoring | Finished | Greenpeace |
| EdnoDarvo | Vegetation monitoring | Ongoing | One Tree Foundation |
| Gecko monitoring | Biodiversity monitoring | Finished | Shumen University |
| GLOBE | Environmental monitoring | Ongoing | No country coordinator |
| HEAL Sofia | Air quality monitoring | Finished | Health and Environment Alliance |
| IQAir Sofia | Air quality monitoring | Ongoing | IQAir |
| Let's count sparrows | Biodiversity monitoring | Ongoing | Bulgarian Society for Birds Protection |
| METER.AC | Air quality monitoring | Ongoing | University of Plovdiv |
| PECBMS | Biodiversity monitoring | Ongoing | Bulgarian Society for Birds Protection |
| RECONNECT | Biodiversity monitoring | Finished | Hellenic Centre for Marine Research |
| REFRESH | Social sciences | Finished | Centre for Research and Analysis |
| Shared compost | Waste management | Ongoing | Zero Waste Sofia |
| Quest for Storks | Biodiversity monitoring | Finished | Bulgarian Society for Birds Protection |
| Watermap of BG | Water monitoring | Ongoing | Zero Waste Sofia |

### Germany

| Initiative name | Field | Status | Lead organisation in Germany |
|---|---|---|---|
| ArtenFinder | Biodiversity monitoring | Ongoing | SNB |
| BeachExplorer | Water monitoring | Ongoing | Schutzstation Wattenmeer |
| BerlinAIR NO2 Atlas | Air quality monitoring | Finished | Technical University Berlin |
| Burger Schaffen Wissen | Other | Ongoing | Wissenschaft im Dialog |
| Citclops | Water monitoring | Finished | University of Oldenburg |
| Dnoses | Odour monitoring | Finished | ECSA, University of Kassel |
| Envirocar | Traffic monitoring | Ongoing | CITRAM project |
| Fledermausforscher | Biodiversity monitoring | Finished | Leibniz-IZW |
| FLOW | Water monitoring | Ongoing | iDiv |
| GLOBE | Environmental monitoring | Ongoing | GLOBE Germany |
| HackAIR | Air quality monitoring | Finished | BUND |
| HEAL | Air quality monitoring | Finished | Health and Environment Alliance |
| InsektenMobil | Biodiversity monitoring | Finished | UFZ |
| Measuring the Berlin Air | Air quality monitoring | Finished | Futurium |
| Muckenatlas | Biodiversity monitoring | Ongoing | Leibniz-ZALF |
| MyOSD | Biodiversity monitoring | Finished | MPI |
| NaturGucker | Biodiversity monitoring | Ongoing | Naturgucker non-profit |
| Netatmo CWS | Atmospheric monitoring | Ongoing | Netatmo, a company in France |
| Open Soil Atlas | Soil monitoring | Finished | FeldFoodForest |
| Ornitho | Biodiversity monitoring | Ongoing | DDA |
| Plastik Pirates | Water monitoring | Ongoing | BMBF |
| PolDiv | Air quality monitoring | Ongoing | UFZ |
| PV2Go | Atmospheric monitoring | Ongoing | Fraunhofer ISE |
| SenseBox | Air quality monitoring | Ongoing | University of Münster |
| Sensor.Community | Air quality monitoring | Ongoing | OK Lab Stuttgart |
| SimRa | Other | Ongoing | Einstein Centre Digital Future |
| Stadtwild Tiere Berlin | Biodiversity monitoring | Ongoing | BIBS, Leibniz-IZW |
| Tator Gewasser | Environmental monitoring | Finished | Leibniz-IGB |
| Tauchen für Naturschut | Biodiversity monitoring | Ongoing | NABU |

**Belgium**

| Initiative name | Field | Status | Lead organisation in Belgium |
|---|---|---|---|
| AIRbezen | Air quality monitoring | Ongoing | University Antwerpen |
| Animals Under Wheels | Biodiversity monitoring | Ongoing | Natuurpunt |
| AstroSounds | Other natural sciences | Ongoing | KU Leuven |
| BikeSTEM for Schools | Traffic monitoring | Finished | UGents |
| Bugs 2 the Rescue | Biodiversity monitoring | Ongoing | VUB |
| Butterfly | Atmospheric monitoring | Ongoing | Gent University |
| Citizen's talk | Social sciences | Ongoing | University of Gent |
| CitizenHeritage | Humanities and arts | Ongoing | ModeMuseum Antwerp |
| CurieuzenAir | Air quality monitoring | Ongoing | Université libre de Bruxelles |
| CurieuzeNeuzen 2016 | Air quality monitoring | Finished | Ringland Academie |
| CurieuzeNeuzen 2018 | Air quality monitoring | Finished | Universiteit Antwerpen |
| Curieuzeneuzen in de Tuin | Soil monitoring | Ongoing | University Antwerpen |
| ExpAIR | Air quality monitoring | Finished | Leefmilieu Brussel |
| hackAIR | Air quality monitoring | Finished | VUB |
| HASSELair | Air quality monitoring | Finished | UCLL |
| Iedereen Wetenschapper | Other | Ongoing | Eos Science |
| InfluencAir | Air quality monitoring | Finished | Civic Lab Brussels |
| iSCAPE | Air quality monitoring | Finished | Universiteit Hassel |
| Leuvenair | Air quality monitoring | Finished | Straten Vol Leuven |
| Luchtpijp | Air quality monitoring | Ongoing | Beweging |
| MamaMito | Social sciences | Finished | Histories vzw |
| Meet Mee Mechelen | Air quality monitoring | Finished | VITO |
| My Gardenlab | Biodiversity monitoring | Ongoing | Kenniscentrum tuin+ |
| NoiseTube | Noise monitoring | Finished | VUB |
| Omniscientis | Odour monitoring | Finished | SPACEBEL S.A. |
| Scivil | Other | Ongoing | Scivil |
| Snapp nature | Biodiversity monitoring | Ongoing | Natuurpunt Studie |
| SOS Antwerpen | Social sciences | Ongoing | Histories vzw |
| Stiemerlab | Water quality monitoring | Ongoing | Hasselt University |
| TrIAS | Biodiversity monitoring | Finished | Belgian Biodiversity Platform |
| WeCount | Traffic monitoring | Finished | Transport & Mobility Leuven |

**Greece**

| Initiative name | Field | Status | Lead Organisation in Greece |
|---|---|---|---|
| "Is it Alien to you...Share it!" | Biodiversity monitoring | Finished | ELNAIS |
| Alientoma | Biodiversity monitoring | Ongoing | Individual researchers |
| Biodiversity GR | Biodiversity monitoring | Ongoing | Hellenic Biodiversity Center |
| CitizenHeritage | Humanities and arts | Ongoing | NTUA |
| Cos4Cloud | Air quality monitoring | Ongoing | Environmental Education Lab |
| CrabWatch | Biodiversity monitoring | Finished | SeaChange project |
| Dnoses | Odour monitoring | Finished | MIO-ECSDE |
| eBird GR | Biodiversity monitoring | Ongoing | Individual researchers |
| GLOBE | Environmental monitoring | Ongoing | University of Athens |
| GROW | Soil monitoring | Ongoing | Individual researchers |
| hackAIR | Air quality monitoring | Finished | DRAXIS |
| Hackquake | Seismography | Finished | OpenAIRE |
| Hellenic Fauna CS Project | Biodiversity monitoring | Ongoing | Zoological Museum |
| iNaturalist GR | Biodiversity monitoring | Ongoing | iSea |
| INCENTIVE | Other | Ongoing | AUTh |
| Scent | Water monitoring | Finished | ICCS |
| Sharks and Rays | Biodiversity monitoring | Ongoing | The MECO project |
| URwatair | Air quality monitoring | Finished | AUTh |
| Waste4Think | Waste management | Finished | NTUA |
| Wreck History | Humanities and arts | Finished | AUTh |

# Annex B: International case studies

**1. Ambassad'Air[80] (FR)**

***Challenge:*** Air quality in Rennes is average, with frequent spikes in nitrogen dioxide and fine particles (PM2.5, PM10). PM2.5 are especially dangerous as they can cross the pulmonary barrier and enter the bloodstream. Several years ago, Rennes was taken to court for breaching air pollution limits.

***Solution:*** In 2016, the City Council set up a pilot scheme to change the behaviour of inhabitants to improve air quality. The project engaged citizen volunteers to measure PM AirBeam1 and AirBeam2 sensors. The idea was that, by raising participants' awareness about air pollution, citizen scientists would then raise awareness about related issues among their contacts, essentially acting as ambassadors for clean air.

***Results:*** Many volunteers saw themselves as 'pioneers' determined to make the project known beyond the city. In total, 260 citizen scientists took measurements and helped promote the project among more than 1000 young people within and outside Rennes. 46% volunteers said that the project had given them a better understanding of air quality. 24% volunteers reported that they had adopted individual outdoor protection measures e.g. changes in breathing practices, new times and routes for physical activities. 46% of volunteers stated they had fulfilled their duty as a clean air ambassador by passing information to others to raise awareness.

***Relevance:*** The use of the ambassador approach in COMPAIR may help to educate and encourage others to adopt pro-environmental behaviour. If the approach is adopted, we would need to develop a special programme for identifying, incentivising, training and supporting community leaders that can become ambassadors for COMPAIR.

**2. Amsterdam Smart Citizens Lab[81] (NL)**

***Challenge:*** Although there are different levels of participation in citizen science, many projects often use a top-down approach whereby scientists design the research project, with citizens joining the project later on, mainly to collect data.

***Solution:*** The project introduced a bottom-up approach to organising citizen sensing for urban environmental monitoring. It is based on a community-based, participatory research model where citizens are involved in all steps of the project, from developing sensing strategy to designing community action based on results.

***Results:*** The bottom up approach led to the production of several results at each stage of the process. From start to end, these include a community platform (MeetUp) for information sharing, an Open Hardware Bootcamp for building NO2 sensors, a data collection campaign in 27 points across the city, an online map for visualising NO2 data, and a community analysis for enhanced understanding and follow-up action. The project concluded that such a bottom-up approach was challenging but successful overall.

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[80] http://www.wiki-rennes.fr/Ambassad'Air

[81] https://waag.org/en/lab/smart-citizens-lab

**Relevance:** COMPAIR would need to consider at which stage of the project it wants to engage citizens: issue mapping, sensor making, sensing, understanding, acting. While the ambition may be to engage citizens in all stages, implementing a full bottom-up approach can be challenging. To succeed, a wide cooperation involving different types of community building, professional support and facilities (online and offline) would be needed.

**3. CAPTOR (EU)[82]**

***Challenge:*** Air pollution is a serious threat responsible for 400 thousand premature deaths in Europe each year. Current top-down initiatives have helped to increase awareness among citizens about the dangers of polluted air, but despite all this effort, collective action on a large scale towards pro-green behaviour is missing.

***Solution:*** Captor implemented a bottom-up approach in Austria, Italy and Spain to demonstrate the power of Collective Awareness Platforms to foster collaboration of local communities, citizens, NGOs, and scientists. The project established a monitoring network of low-cost sensors to measure ozone pollution in affected areas and developed collaborative learning tools to stimulate solution co-creation.

***Results:*** Open ozone maps for 2017 and 2018 based on several dozen representative nodes measuring ozone concentrations. These were DIY monitoring nodes based on low-cost sensors. Citizens reported a greater sense of ownership of results thanks in no small part due to their involvement in a wide range of activities, from sensor assembly to interpretation of results.

***Relevance:*** COMPAIR would be well-advised to follow the DIY philosophy practised by CAPTOR and many other projects, as their experience shows time and time again that people who take part in hands-on training workshops are more likely to stay and use the results than people who are engaged only via online means.

**4. CITI-SENSE[83] (EU)**

***Challenge:*** Governments play a significant role when it comes to finding solutions to environmental problems, but they aren't the only stakeholder who can support this endeavour. Citizens too can help, but they need some guidance and impetus to band together to monitor and manage local environmental problems in ways that government agencies cannot.

***Solution:*** The project set up citizen observatories and created an environmental monitoring information system to empower communities to influence policy and decision-making processes. An air quality sensor network was created in Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava, Vienna and Vitoria-Gasteiz. The main elements included sensors and linking technologies, information products derived from the data and services. Atmospheric information was drawn from satellite data, yet locally specific to various European cities. Different participatory methods, data management strategies and applications were deployed to facilitate data utilisation.

[82] https://www.captor-project.eu/en/
[83] https://citi-sense.nilu.no/

***Results:*** The project established a network of 24 observatories that included 324 sensors and 400 volunteers across 9 EU cities, yielding a total of 9.4 million air quality observations. 8 observatories monitored outdoor air quality, 12 monitored indoor air quality in schools and 4 monitored personal comfort in public spaces. 400 volunteers were involved in the development of sensors, visualisation solutions and other tools used in the project. Over 1200 people downloaded and used the project's air perception app.

***Relevance:*** COMPAIR will be measuring outdoor air pollution near schools and through mobile sensors as people move about the city. However, PM is also found in all indoor environments. Indoor PM levels have potential to exceed outdoor PM levels. COMPAIR would be well advised to follow CITI-SENSE in this regard and measure indoor pollution as well.

**5. Citi-Sense-MOB[84] (NO)**

***Challenge:*** Existing policies in Oslo aim to sustain air pollution levels within acceptable limits. However, currently the coverage from static networks is insufficient. There is a need for new data to enable the municipality to design and implement reduction strategies for different scenarios e.g. sudden spikes in pollution, long-term planning.

***Solution:*** Citi-Sense-MOB developed a Citizen Observatory Toolbox to obtain volunteered geographic information from the public. Data was collected in different ways: via mobile device (e.g. pictures), via sensors measuring pollution, noise, humidity and temperature, via physiological responses e.g. headache, dizziness sneezing. As well as providing information to the public on environmental conditions, citizen science data was meant to support compliance checking and contribute to an improved development and implementation of environmental policies and strategies with respect to ambient air quality.

***Results:*** Citi-Sense-MOB provided information at high spatial-temporal scales related to citizen activity by performing real-time monitoring at the street level. Urban-scale air quality mapping served as useful input to local authorities, enabling them to visualise and manage air pollution
to a much finer degree than was possible before. By seeing a complete and high fidelity geospatial map of air pollution, authorities were able to implement better measures in areas where they were needed the most.

***Relevance:*** Citizen science projects have different levels of participation, which typically influence the kind of data that participants generate. Physiological responses to air pollution are rarely provided in citizen science projects, in the EU at least. Arguably, this has a lot to do with privacy and data protection. But assuming that GDPR compliance is assured, such information can improve the understanding of how air pollution is perceived by different people and in different circumstances.

**6. ClairCity[85] (EU)**

***Challenge:*** Decision makers operate in an increasingly complex policy environment shaped by a multitude of forces: globalisation, decentralisation, climate change, air quality and other

[84] https://www.nilu.com/publication/27511/
[85] http://www.claircity.eu

environmental concerns. As well as dealing with these challenges, decision makers must secure extensive public support in order to achieve net zero and decarbonisation objectives.

***Solution:*** ClairCity engaged citizens in Amsterdam, Aveiro, Bristol, Genoa, Ljubljana and Sosnowiec to promote inclusive policy making in the context of green transition. The project established a baseline of behaviours in each pilot location and explored policy and governance landscapes to understand how this impacts on citizens behaviours. Citizens were engaged in co-creation activities and used advanced modelling to understand what happens to air quality and carbon emissions when their suggestions are incorporated into decision making. Feedback was then provided to policy makers, citizens and influential organisations to improve carbon emissions and air quality in participating cities and regions.

***Results:*** The baseline examination showed that there are various strategies to promote ambitious air quality and carbon policies, varying from supporting an active and independent role of citizens, stressing equality aspects of these policies to promoting them indirectly as a co-benefit of other policies. In all cities, air quality policies were motivated by stressing their health benefits. The project identified some gaps in cities between the willingness of citizens to change their own behaviours and the policy ambitions formulated in the city, which suggests that awareness creation and dialogue with citizens are needed in order to close these gaps.

***Relevance:*** ClairCity's policy analysis provides a useful spectrum of co-benefits for citizens linked to air quality and decarbonisation strategies: active living, equality, better health. These should be explored in COMPAIR's own policy review (D2.3) to see whether and how they manifest in the policy landscape of Bulgaria, Germany, Flanders and Greece. ClairCity's modelling process and outputs is also something worth exploring in the early stages of designing COMPAIR's simulation dashboard.

**7. CLAIRO[86] (CZ)**

***Challenge:*** The Ostrava region has one of the worst air pollution levels in the country due to high concentration of industry, including ArcelorMittal, the biggest smelting facility in the Czech Republic. Not surprising, 93% inhabitants are not happy with the air they breathe.

***Solution:*** Scientists from Ostrava's Technical University established a living lab that uses sensors to track concentrations of particulate matter (airborne dust), ozone and nitrogen oxides. The sensors will operate for eight years (starting from 2019) without the need for a complex laboratory analysis. One of the objectives is to understand what plant species are more resistant to pollution and can capture more airborne dust in the long term, and to plant these species over the course of the project.

***Results:*** Based on data collected from ongoing measurements, combined with meteorological data, scientists have created models of how current vegetation and the proposed new plantings capture and absorb pollutants from the air. In April 2021, a total of 442 new trees, 1867 shrubs and bushes, and 14700 square metres of lawns and grassy areas were planted based on initial project results. In addition, methodological guidelines, a practical manual for urban greenery plantings, and a database of plant species with a proven

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[86] https://clairo.ostrava.cz/about-project/

effect on reducing air pollution were prepared to support authorities in choosing the most appropriate species for high-emissions locations.

***Relevance:*** The planting strategy can be considered alongside other measures to improve air quality in urban environments. Potentially it can be included in COMPAIR recommendations to reinforce other measures like car-free streets or school streets.

**8. CleanAir@Schools[87] (EU)**

***Challenges:*** Air pollution poses a threat to children's health. It can damage their growth and leave them with lasting health problems. Children are especially exposed to bad air quality during school runs and while at school.

***Solution:*** The joint initiative by the European Network of Heads of Environmental Protection Agencies used citizen science campaigns to better understand children's exposure to a key air pollutant, nitrogen dioxide (NO2), in the school environment across Europe (Estonia, Ireland, Italy, Malta, the Netherlands, Slovakia, Spain, Scotland). Using simple low-cost devices, the kids measured nitrogen dioxide levels around their schools, with at least two sampling points at each school. The schools monitored the effects of road transport emissions in two situations: low traffic and high traffic. One measurement tube was placed near the school's main road, another one in a less polluted area e.g. school's backyard.

***Results:*** Children at participating schools in eight countries learnt about air pollution and health effects, while both pupils and their parents saw how road transport affects air quality. Measurement results are presented in the online viewer that has a map and dynamic tables. Furthermore, each participating region tells its own CleanAir@School 'story', based on the pupils', teachers' and local authorities' experience with this citizen science project.

***Relevance:*** The measurement framework is in line with COMPAIR's approach to measure NO2 in different locations to separate pollutant's natural concentration from human-induced factors. A storytelling approach is something COMPAIR pilots might want to consider when presenting their case studies.

**9. DIAMS[88] (FR)**

***Challenge:*** Marseille generally has good air quality. However, as the city becomes more popular with tourists, air quality can suffer when many cruise ships line the port to drop off and pick up passengers. In addition, the build of nitrogen dioxide and other chemicals has been observed as a result of growing traffic.

***Solution:*** The Aix-Marseille-Provence Metropolis and its partners created a platform for exchanging data on air quality and digital services allowing everyone (political decision makers, experts, citizens, civil society, economic actors etc.) to engage in the development of coordinated action plans at all territorial levels. The data is collected by means of low-cost sensor devices, and various micro and mobile stations.

[87] https://discomap.eea.europa.eu/cleanair/
[88] https://www.airdiams.eu/

***Results:*** 2000 mobile sensors were handed out to different users: citizens, associations, municipalities. Data from 'citizen' sensors was combined with data from 50 micro stations and 200 mobile stations placed on vehicles, to build a pollution profile of the territory. Data visualisations provided on the platform are intended to help citizens adapt/change their behaviour based on pollution distribution in the area, while policy makers can use it for environmental performance management, or to develop climate and/or sustainable mobility plans.

***Relevance:*** With all the micro and mobile stations added to the mix, 2250 measurement devices represent quite a dense network of air quality nodes comparable to that of CurieuzeNeuzen Antwerp (2000) and Curieuzen Air Brussels (3000). Arguably, this is how many sensors are needed to build a representative pollution profile of a city with 0.5-1 million inhabitants. The question for COMAIR is will it be able to deploy so many sensors in each pilot city? If not, how would this affect the representativeness of air pollution coverage?

**10. DivAirCity[89] (EU)**

***Challenge:*** Covid-19 shed light on the relationship between air-polluted areas and health and well-being of their inhabitants. The pandemic also revealed social inequalities in cities. The nexus between air pollution, diversity, social inequalities and cities is a challenge that needs immediate action.

***Solution:*** DivAirCity proposes a new urban paradigm by valuing human diversity as an important resource for driving transition toward culture-driven, green and carbon-neutral smart cities. The project will leverage citizen science and creativity to help cities achieve green and just transition. Pilot cities are Aarhus, Bucharest, Castellon, Orvieto, Potsdam.

***Results:*** DivAirCity started in 2021 so there are no substantive results as yet. By the end of the project, however, DivAirCity aims to create 5 Permanent Living Labs, 1 Diversity and Inclusion green city index, 5 Smart Cities Climate contracts, 1 Community of Practice, 5 air pollution mitigation services, and 1 EU protocol for decarbonization diagnosis.

***Relevance:*** CivAirCity and COMPAIR have a lot in common. CivAirCity's inclusive approach is of particular interest as it can help COMPAIR to better identify, engage and manage people from vulnerable hard-to-reach communities.

**11. HOPE[90] (FI)**

***Challenge:*** The Helsinki air quality monitoring network provides accurate measurements from the locations of fixed monitoring stations in the region but the network currently consists of eleven monitoring locations spread over a wide and diverse area of the four municipalities. Thus there is a lack of high-resolution data on urban micro-environments, which makes it difficult to develop interventions that people can apply to help reduce air pollution locally.

***Solution:*** A two-pronged approach that will provide comprehensive, real-time, reliable air-quality data using cost-effective technology (technical level), and a greater citizen participation and inclusion (social level). The project established a feedback loop between

[89] https://divaircity.eu
[90] https://ilmanlaatu.eu/

high-resolution hyperlocal air quality monitoring and actions of individuals and communities through co-design and participatory budget planning.

***Results:*** Six crowdsourced air quality measuring campaigns were organised in which 100 volunteers carried a mobile sensor to capture PM2.5 and PM10. A web page with graphs and heat maps was created to show volunteers exposure to pollution based on gathered information. To ensure an accurate picture of the city's air profile, portable sensors were complemented by a network of static, state-of-the-art monitors, with new installations planned in the three districts. The project developed some user apps. One is a tool for recommending green routes with the least pollution and traffic noise. Another is a CO2 footprint calculator. As regards policy making, people were able to vote on air quality improving interventions to be implemented in their districts.

***Relevance:*** HOPE's outputs and ambitions are very much similar to COMPAIR's. An interesting outcome we haven't considered before is a proposal for new installations of reference stations in places with high pollution concentration, determined based on citizen science data. Also, when COMPAIR organises ideathons at the end of the project, HOPE's experience with participatory budgeting can be considered to recommend air quality interventions in pilot cities.

**12. Hollandse Luchten[91] (NL)**

***Challenge:*** Traditionally, air quality is measured by official measuring stations of parties such as the National Institute for Public Health and the Environment (RIVM) and the GGD. These measuring stations provide accurate but location-specific data. However, air quality can vary greatly per location and time. Because there are relatively few monitoring stations, the air quality in many locations is either estimated via calculations and predictions or not measured where it is important e.g. school or football club located near a busy road.

***Solution:*** A citizen sensing approach that uses cheap and accessible open-source sensors to map air quality across the region. Volunteers are supported by experts who will help analyse results to create a shared picture of air pollution. This helps lay the foundation for a discussion among regional stakeholders about the causes of air pollution and possible solutions. The project is carried out on behalf of the regional government with the support of research, industry, civil society and other organisations.

***Result:*** Measurements started in the IJmond region, but are now also made in the North Sea Canal area. Most sensors measure particulate matter (PM2.5, PM10), while a few also measure nitrogen oxide and ozone. The results are displayed on a public platform Hollandse Luchten website.[92] Each sensor has a unique number, allowing participants to track its performance. The map also shows data from the official, national air monitoring network of the RIVM.

***Relevance:*** Hollandse Luchten demonstrates a very strong collaboration among members of the quadruple helix community, which is an important ingredient for long-term sustainability. On a technical side, the project's approach to data visualisation is in line with

[91] https://hollandse-luchten.org/
[92] https://hollandse-luchten.org/kaart/

what COMPAIR wants to achieve, namely display citizen science data alongside other data sources to provide a picture of the city's air pollution profile that is as complete as possible.

**13. iSPEX (NL)[93]**

***Challenge:*** Aerosols are small particles that can penetrate lungs and therefore affect people's health. But they also constitute the largest unknown factor within the current understanding of climate change.

***Solution:*** iSPEX developed an add-on for the camera, activated through an app, that measures the spectrum and linear polarisation of sunlight scattered by a mix of molecules and aerosols in the sky. In 2013, 8000 iSPEX add-ons were distributed to participants across the Netherlands. Measurements took in the entire country on a cloud-free day.

***Results:*** 6007 measurements were submitted to the database from the national measurement day, with two subsequent campaigns yielding 1546 and 2444 observations. Maps derived from iSPEX are in agreement with results derived from satellite imagery and ground-based precision photometry. These maps show structures at scales of kilometres that are typical for urban air pollution, indicating the potential of iSPEX to provide information about aerosol properties at locations and at times that are not covered by current monitoring efforts. In 2015, iSPEX branched out into other EU countries: Greece, Spain and the UK.

***Relevance:*** iSPEX is a good example of an inside-out project that started in the Netherlands and has since spread to other countries. Among factors contributing to this success are high quality results, contribution to scientific research, large number of participants, awards, funding, extensive cooperation with stakeholders, and good media coverage. It might be useful to study inside-out projects like iSPEX and Sensor.Community in more detail to better understand their 'success ingredients'.

**14. Love Lambeth Air[94] (UK)**

***Challenges:*** In 2013, in the Lambeth borough of London, UK, air pollution contributed to 400 emergency admissions for lung disease and 351 emergency admissions for heart disease. Moreover, there were just three static monitoring stations across the borough.

***Solution:*** Every month for a six month period the diffusion tubes were changed and sent to the lab for analysis. At the start of the citizen science project there was a workshop to explain how a diffusion tube worked and a demonstration of how to change the tube each month. There was another workshop six months later to discuss the monitoring results (you can read more about this feedback event here). During the feedback event, there was a discussion on ways to help improve air quality and reduce personal exposure and explore steps for further action.

***Results:*** The project provided local people with the materials and support required to collect measurements for nitrogen dioxide across Lambeth. This was the first exercise of its kind and sought to create a more granular picture of air quality in areas not previously monitored.The findings were made available on the Community Maps website.

[93] http://ispex.nl/en/

[94] https://mappingforchange.org.uk/projects/love-lambeth-air/

***Relevance:*** The project demonstrates the importance of organising different workshops during the project (e.g. to explain how the technology works, to gather participant feedback after data collection), of selecting locations where pollutants were not previously monitored, and of presenting results in some visual form (e.g. map) online.

**15. Lufta er for alle![95] (NO)**

***Challenge:*** The period between mid-March to mid-April is the high season for particulate matter pollution in Norway. NILU, a research institute, has been monitoring air pollution in Oslo and other cities. This has been done with complex stationary measuring stations that are highly accurate but cover only some parts of the city.

***Solution:*** A joint initiative by the Asthma and Allergy Association, Oslo Municipality and the Extra Foundation, Lufta er for alle! ("The air is for everyone!") launched a measurement campaign to help researchers get data on airborne dust from many more places at greater spatial and temporal resolution. The project was aimed specifically at school children as they are especially vulnerable to pollution peaks in spring.

***Results:*** 30 schools participated in citizen science, producing over 300 measurements. Students cast themselves as junior environmental researchers who reported air pollution based on perception of air quality. As participants, they learned about the health effects of air pollution and were able to discuss results with other schools via interactive online map. In addition, the results stimulated a discussion among policy makers, scientists, teachers and charities about how to improve air quality in and around schools.

***Relevance:*** The project shows that even very young children (fourth grade students) can become citizen scientists. But it also shows that when targeting people at a very young age the level of sophistication of the measurement approach drops down significantly. In the case of Lufta er for alle! measurements were based on perception and reported on a sheet of paper attached to a tree. In terms of engagement, calling students junior environmental researchers might be an effective way of motivating them to take part.

**16. NO2 NO Grazie[96] (IT)**

***Challenge:*** Every year in Italy, over 70000 people die prematurely due to poor air quality, mostly in the Po Valley and in the major Italian cities. Almost 15000 of these deaths are attributable to citizens' exposure to nitrogen dioxide (NO2).

***Solution:*** A citizen science campaign targeting three large urban areas: Rome, Milan and Naples. Volunteers measured NO2 using passive samplers, simple tubes that collect the gaseous pollutant through absorption. Collected results were then analysed in the lab and calibrated with data from reference stations, to estimate the impact of exposure of NO2 concentrations on population.

***Result:*** For about a month, 2000 citizens took part in the measurement campaign, placing nearly 300 diffusion tubes in different locations, many of them near schools. The maps of

[95] https://luftaforalle.nilu.no/

[96] https://www.cittadiniperlaria.org/no2-no-grazie-2020/

NO2 concentrations produced at the end of the study show alarming results in all three cities, with NO2 levels exceeding the legal threshold. Results were closely examined by the scientific committee composed of experts from universities and one health agency, to identify risks to citizens, especially children, and recommend the best course of action to policy makers.

***Relevance:*** NO2 NO Grazie is one of many citizen science projects that measured NO2 using diffusion tubes, demonstrating yet again that this method represents the current state of the art of NO2 monitoring. At the same time, this shows a need for more innovative approaches that, for example, use electromagnetic sensors to provide real-time information on NO2 concentrations, which is what COMPAIR plans to do.

**17. Onze Lucht[97] (NL)**

***Challenge:*** Northern Netherlands generally has good air. But more and more people want to know just how clean is the air they breathe. This information is especially apt for people living near the southern ring road in Groningen, people with asthma, members of a local football club, and residents in close proximity to an industrial estate.

***Solution:*** A citizen science project managed by the University of Groningen covering the region of Northern Netherlands. Participation is not free, but because of a government subsidy, volunteers only need to pay 25 euros instead of 50, to get the sensor and start measuring air pollution. Onze Lucht uses the same equipment as Sensor.Community and has a lot of online guidance for participants.

***Result:*** At least 650 volunteers took part in the first campaign in 2020. While there is plenty of guidance online, workshops were held in different libraries across the region to teach people how to assemble and manage DIY sensors. There is now an online map with coloured nodes representing PM sensors installed by citizen scientists. And an online dashboard for different cities in the region showing up-to-date information on PM2.5 and PM10, among others. Each sensor has a colour scheme (green, yellow, red, black) denoting different threat levels associated with particulate matter.

***Relevance:*** Onze Lucht demonstrates a growing trend that started with Cureuze Neuzen Flanders toward air pollution measurement on a regional scale. But perhaps the project's most interesting aspect is the use of a government subsidy to reduce the cost of a DIY sensor for participants. Such financial support not only encourages people to take part, but also makes acceptance of citizen science results more likely by policy makers, while also contributing to the growth of the citizen science landscape in the long term.

**18. SensHagen[98] (NL)**

***Challenge:*** The climate is changing. Extreme weather events are becoming more frequent and more severe. This has major consequences for society. Measures to tackle them usually come from the government, but citizens too can play a role.

[97] https://onzelucht.nl/

[98] https://senshagen-zwolle.opendata.arcgis.com/

***Solution:*** A bottom-up initiative by and for residents of Zwolle that provides insight into climate change. Residents have a sensor in their garden that measures temperature and air quality. This data is forwarded to research institutes RIVM and the KNMI for analysis. The project currently uses two types of sensors: a weather station for measuring temperature, precipitation and wind (speed), and an RIVM sensor for measuring air quality.

***Results:*** After several years of measurements, a good picture of the local climate in the area has been created. Data collected by citizens offers more granular information on local air quality and wider environmental conditions, which is used by the municipality to make more accurate decisions and implement better policies to make the city more resilient to climate change. There is a dashboard displaying PM10, PM2.5 and other environmental data.

***Relevance:*** SensHagen is a good example of a citizen science project that receives a lot of support from the city, with the latter even using results to implement better policies and strategies e.g. Slimme Samenleving (Smart Society programme), Klimaatadaptatie (Climate Adaptation programme). This suggests that the take up of results by a municipality is directly proportional to its involvement in the project. In COMPAIR, cities should be invited to become a stakeholder as early as possible. Approaching them in the final stages to present results is unlikely to yield significant impact in terms of adoption.

**19. Smart Citizen[99] (Int'l)**

***Challenge:*** In the past years, multiple research projects have explored the potential of low-cost environmental sensors for urban air pollution monitoring. However, each project has taken its own independent and in many cases, fully or partially closed approach.

***Solution:*** Smart Citizen built a distributed sensor platform that allows citizens to collect environmental data from around the world. Anyone can check in real time the air pollution levels, noise levels and complementary data such as light, temperature, humidity or barometric pressure. Since sensors are modular and open source, they can be expanded to add extra sensing capabilities e.g. water pollution, soil pollution. The sensor kit costs just over USD 100.

***Results:*** Currently, there are more than 3000 sensor kits collecting data in Europe, North America, South America, Africa, Australia, and Asia. Smart Citizen has helped local communities to build noise and air quality maps to raise awareness about these issues. Smart Citizen outputs have also helped governments to foster citizen engagement, and researchers to better understand the relationship between people, environment, and technology. Additionally, the use of open source components and APIs means that developers can easily use data from the platform to create new services and apps.

***Relevance:*** Smart Citizen as is a spin-off of the finished EU project Making Sense[100] that was in operation between 2015 and 2017. It's also a great example of an 'inside-out initiative' that started locally (or in a few cities) and has eventually spread to many countries internationally. Successful deployment of the quadruple helix model, adherence to the open source philosophy, copious training and guidance on how to assemble, operate and maintain

[99] https://smartcitizen.me
[100] http://making-sense.eu/about/

sensors, a distributed platform for data visualisation, as well as the affordability of sensor kits, all are factors that probably have contributed to the initiative's success over the years.

**20. xAire[101] (ES)**

***Challenge:*** In 2017, the annual concentrations of NO2 in Barcelona captured by the two existing traffic automatic monitoring stations were above the WHO and European Commission limit values. This noncompliance with air quality recommendations was systematically reported for several years. Moreover, around 1000 new cases of childhood asthma are reported in the city each year.

***Solution:*** With the support of the Barcelona Education Consortium (Consorci d'Educació de Barcelona) a broad partnership was established to launch the xAire project with more than 1650 participants, 10 professional research scientists, 36 teachers, 4 non-scientific organisations and 18 primary public schools distributed evenly among the city. After a training session, the schools organised mixed groups of 4–5 people with parents and children and placed up to 800 passive diffusion tube NO2 samplers following identical protocol and resulting in 725 valid data points.

***Results:*** The air quality map generated by xAire provides a useful tool for estimating current exposures to NO2 in Barcelona. It used an increased number of measurement sites compared to previous models with samplers distributed by professional scientists, and an updated set of concentration levels. The results help determine how many asthma cases can be attributed to NO2.

***Relevance:*** Citizen science can stimulate a useful discussion among local stakeholders about environmental health issues. If COMPAIR pilots collect enough high-resolution data on NO2 levels, it may be possible to carry out an accurate exposure assessment to NO2 and estimate how many childhood asthma cases could be prevented each year.

[101] http://www.ub.edu/opensystems/projectes/3205/