CitiMeasure

Using citizen measurements to create smart, sustainable, and inclusive cities

CitiMeasure - using citizen measurements to create smart, sustainable, and inclusive cities

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Acronyms

CC	Creative Commons
CGD	Citizen Generated Data
CS	Citizen Science
CSISTA	Citizen Science Impact StoryTelling Approach
DG	Directorate General
DG ENVI	DG Environment
EC	European Commission
ECSA	European Citizen Science Association
EEA	European Environment Agency
EIF	European Interoperability Framework
EPA	Environmental Protection Agency
EU	European Union
FAIR	Findability, accessibility, interoperability, and reusability
GDPR	General Data Protection Regulation
IPR	Intellectual Property Rights
JRC	Joint Research Centre
MICS	Measuring Impact of Citizen Science
PSI	Public Sector Information
QA/QC	Quality Assurance/Quality Control
R&I	Research and Innovation
RIVM	Dutch National Institute for Public Health and the Environment
SWD	Staff Working Document
SDGs	Sustainable Development Goals
TPB	Theory of Planned Behaviour
WG	Working Group
WHO	World Health Organization

1 Executive Summary

CitiMeasure aims to develop three instruments to tackle challenges of citizen science initiatives related to data comparability and interoperability, digital inclusion and behaviour and policy change. At the end of the project, the tested tools, guidelines, and a repository of best practices will be available in an online European Knowledge Centre. This deliverable includes a review of relevant literature regarding these three challenges to identify and connect to theoretical conceptualisations of the concepts, as well as an overview of 164 EU citizen initiatives involving citizens collecting data for sustainability purposes in urban areas. The main contributions of this report are:

- Advance understanding about the state of the art of citizen science in the European Union (EU).
- Shed light on key scholarly discussions, concepts and examples related to the three main identified challenges.
- Identify key aspects and hints that can be later applied for the development of the instruments by the CitiMeasure working groups. These working groups will be formed by cities, experts, and other key citizen science stakeholders.
- Form the foundation for other core tasks and activities within the CitiMeasure project across a range of Work Packages.

2 Introduction

2.1 ABOUT CITIMEASURE

Citizen measurement (or citizen science) initiatives contribute to a sustainable transition in European cities. By using an array of tools and instruments, citizens can play a role in measurement and monitoring of indicators on air quality, temperature, soil moisture, biodiversity, or risk management, among other environmental areas. Citizen measurement initiatives also can foster communications and interactions among stakeholders and contribute to the democratisation of science and policy.
The CitiMeasure project (2021-2023) aims to bring together the experiences and expertise of European cities, organisations and networks in implementing citizen science initiatives (in the form of guidelines, toolbox, web-platform, Apps, etc.). The project builds upon the lessons learned from the Dutch City Deal Working Groups, a network of stakeholders working on the broader area of smart cities, which includes the topic of citizen measurement initiatives. The City Deal has been working closely with the Dutch Ministry of Interior and Kingdom Relations for over a year. CitiMeasure builds upon these experiences and will use those to develop and pilot three 'instruments' namely:

1. An instrument that allows the outputs of different city measurement initiatives to be compared.
2. An instrument that safeguards the digital inclusivity of city measurement initiatives (maximising the opportunities for participation of interested individuals and communities).
3. An instrument that connects information to behaviour change and policy.

There is a 4th (Strategy and Oversight) working group that focuses on providing strategic direction and ensuring cohesion of activities across the three Instrument Sub-Groups, and the project in general.

CitiMeasure will also raise awareness of the importance of citizen measurement initiatives and capitalise on the results and tools of similar citizen science projects by creating an online European Knowledge Centre with a repository of good practices.

2.2 PURPOSE OF THIS REPORT

The main purpose of this report is to capture the landscape of citizen science initiatives in the European Union, especially regarding data interoperability, digital inclusion, policy, and behavioural change. This landscape review focuses on the EU experience, its institutions and processes related to the field of citizen science. Through review of seminal publications, survey, and interviews with network stakeholders, cities, public institutions and experts, a picture of the current European landscape of citizen science initiatives was created that will inform the design of three instruments and support local measurement initiatives by citizens and local authorities across Europe.

2.3 STRUCTURE OF THE REPORT

This report is divided into four main parts. Sections 3 and 4 provide background information about this review, and about the concept of citizen science. Section 5 describes the methodological approach of this review and its limitations. Section 6 showcases the findings of the review, including the analysis of the literature review and the inventory of citizen science initiatives. Finally, section 7 includes concluding remarks.

3 The future of citizen science is bright

According to the yearly mapping report on *European Union Research and Innovation* (EU R&I) *for and with cities*, today, 75% of EU citizens live in cities (European Commission, 2021). This is projected to increase to almost 85% by 2050. Not only cities host most present and future populations, but they have become key hubs for solving global challenges such as climate change. In doing that, cities often face barriers such as the lack of data to design effective policies and monitor their implementation, as well as limited participation of key stakeholders in decision-making processes.

Citizens and citizen platforms are coming into play in the governance of cities through their involvement in citizen science initiatives. Citizen science has thus the potential to advance a paradigm shift towards more smart, inclusive, and sustainable cities by contributing to evidence-based policies and changing behaviours. Citizen science initiatives not only address the barriers cities face but bring benefits such as science learning, environmental awareness-raising, and enhanced social interactions. In addition, citizen science initiatives are especially effective at the local and national level, due to the availability of organisational structures that can support these initiatives (Haklay, 2015).

The digitalisation of our societies is an unstoppable trend that can help citizens to participate in public life which is essential for the health of our 21st century democracies. However, it also brings challenges related to the access to these technologies as well as the necessary skills for their use (Vasiliades et al., 2021). The ongoing digital transformation has put the focus on data, more specifically, citizen-generated data and its effect on new roles and relationships between citizens and local governments. Citizen-Generated Data (CGD) can be defined as "data that people or their organisations produce to directly monitor, demand or drive change on issues that affect them. It is actively given by citizens, and a complement to datasets collected by governments or international institutions" (Ponti & Craglia, 2020, p.7). A more appropriate framing is to consider CGD as 'complementary' to data generated by governments or international institutions, as opposed to an 'alternative', because these data sources are often most useful when combined.

Recently, there has been a boost in the number of citizen science initiatives in Europe, as well as in research on this topic. The value of highly efficient and low-cost data collection, the impact of these initiatives on social innovation, and the appearance of new digital technologies are different reasons that may explain this increase, which is expected to come along with more influence in decision-making processes at the local level (Gharesifard, 2020; Ponti & Craglia, 2020; Vohland et al, 2021).

The European Commission, in different Directorate-Generals (DGs) and policies, but mainly through the work of the Joint Research Centre (JRC), has long been interested in understanding the role of citizens as catalysers of innovation in science and policymaking (Figueiredo et al, 2016; Gordienko, 2013). The European Commission published a staff working document identifying three main challenging areas for citizen science initiatives to reach their full potential (European Commission, 2020). These include comparing data collected by different initiatives, involving a diverse and representative group of people, and measuring the impact of these initiatives at both individual and societal level. Multiple efforts by the scientific, the governmental and civil society communities are aimed at solving these challenges. This working document also includes key recommendations for environmental policy uptake of citizen science initiatives, as well as the creation of common data quality and interoperability standards. Regarding the policy uptake, the document identified favouring factors such as governmental support, high public involvement, and scientific rigour – including appropriate assessments and monitoring.

While citizens and local governments are key stakeholders in citizen science, Environmental Protection Agencies (EPAs) have also had a rich contribution, especially for harnessing the potential of citizen science data (Rubio-Iglesias et al., 2020). Environmental Protection Agencies are giving more and more attention to citizen science, with a special mention to the work of the Dutch, Finish, and Irish agencies. The EPA Network has created an interest group on citizen science which is working on sharing practical examples of citizen science projects, infrastructure, tools, and networks.

3.1 LANDSCAPE REVIEWS: PAST AND PRESENT EFFORTS

There have been two major efforts to map citizen science initiatives in Europe. Hecker et al., 2018 provided the first large-scale online explorative survey of European citizen science which was conducted in 2016. Two years later, the JRC published a landmark report including an inventory of 503 citizen science projects relevant for environmental policy – 49 of which were reviewed in depth - and assessed how these projects contribute to the Sustainable Development Goals (SDGs). The Table below summarises the key details of the two landscape reviews, as well as a third landscape review, with a more limited scope, that was conducted by the WeObserve project.

	Year	Source	Project/thematic scope	Number of answers	Availability of raw data
Hecker et al	2016	Survey and desk research	Broad scope	174	Upon request
JRC	2018	Survey and desk research	Environment related topics, especially focused on biodiversity	503	Open access
WeObserve	2020	Desk research, workshops, interviews	Citizen observatories/environment related topics	Circa. 20	Retrievable from reports and interactive map

Table 1: Comparison of landscape reviews from 2016, 2018 and 2020

The JRC report identified challenges for making citizen-science policy relevant in relation to scientific excellence, citizen engagement and policy uptake (Bio Innovation Service, 2018). Its findings have been confirmed with similar results and identified challenges by later landscape reviews (Vohland et al, 2021). In addition, there are specific landscape reviews at country-level that can help complete the picture at EU level, mostly in Western Europe, for instance, France (Houllier & Merilhou-Goudard, 2016), Germany, and Austria (Pettibone et al. 2017). There are also reports in Southern European countries such as Spain (Serrano et al. 2017) and Portugal (Tiago et al. 2017) and some in Central and Eastern European countries, such as Latvia (Prūse and Dātava 2017) and the Czech Republic (Duží et al. 2019).

Citizen science projects have for a long time predominantly taken place in Western Europe, especially in the UK, Germany, and Austria. Southern and Eastern European countries remain underrepresented in most studies, although countries such as Spain have experienced a boom of these initiatives in the past years (Vohland et al, 2021). The geographical imbalance in the European citizen science landscape might be partly explained because citizen science lacks a clear definition, and many initiatives remain invisible or hidden (Manzoni et al.,2021). On the other hand, the concept is overall less known and implemented (at least with the title 'citizen science') in Eastern Europe.

Traditionally, studies on citizen science initiatives have focused on biodiversity and conservation – for a long time most were these types of initiatives (Bonney et al., 2009; Turbé et al., 2019). Similarly, other landscape reviews have signalled this thematic area as predominant in the field of citizen science (Rathnayake et al., 2020). The term citizen science is quite accepted in the biodiversity field which can explain a certain bias towards finding initiatives working on this topic as they are easier to find. In addition, many of the surveys on citizen science reach people working on this topic. Moreover, air quality is an important topic from the perspective of both the environment and human health. The increasing number of initiatives focusing on air quality might cause a paradigm shift in the way air pollution is measured and monitored, i.e., by using low-cost sensors (EEA, 2019). Initiatives such as CurieuzenNeuzen are being widely researched and replicated (Van Brussel & Huyse, 2019). Other themes such water quality, monitoring plastic and noise pollution are also becoming more and more relevant.

While previous landscape reviews have focused on a wider range of topics related to citizen science, this review follows a narrower approach by looking at those themes more relevant to the development of the three CitiMeasure instruments, namely data comparability and interoperability, digital inclusion, and policy impact and behaviour change:

- **Comparability and interoperability.** Data can be gathered by multiple stakeholders (e.g., researchers, businesses, public administrations, or by citizens via citizen science initiatives), and at different levels (local, regional, national, etc.). Therefore, data comparability and interoperability are essential for exploring the full potential of citizen science initiatives. This is a challenge because guidance and frameworks that would allow greater comparability are missing.
- **Addressing the digital divide**. There is a digital divide in citizen science, i.e., there are differences in motivation, physical access to technology, digital skills, and usage patterns. Enhancing the digital inclusion of citizen science initiatives is thus key for their legitimacy and representativeness.
- **Changing behaviours and impacting policies**. Citizen science can underpin environmental policies, support policymaking, and prompt behavioural change. However, there are many barriers for the use of citizen science data for behaviour and policy change. More efforts thus need to be addressed at breaching this gap, supporting fit-for-purpose approaches as well as appropriately measuring these impacts.

In conclusion, this landscape review includes EU citizen science initiatives with thematic relevance that have an environment and urban focus with some degree of use of digital technologies.

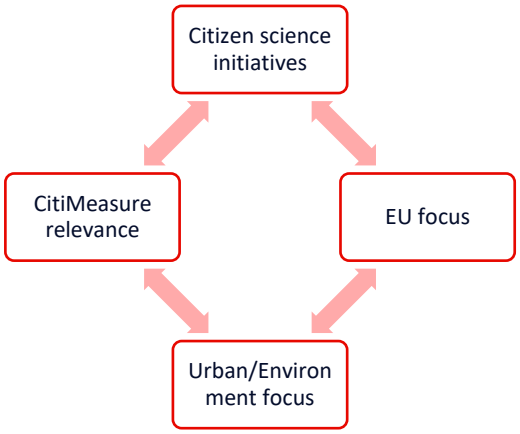

Figure 1: Scope of this landscape review

4 Citizen science as a concept

The term citizen science was first coined in the literature in 1989. The practice of citizen science, however, started back in the 18th century mainly focusing on the observation of nature. Since then, there have been many efforts to classify and define citizen science and the discussion is still ongoing (Gharesifard, 2020). The lack of a common definition has resulted in a variety of approaches and conceptual frameworks that make doing a comprehensive landscape review a challenging task. Moreover, practices that would classify as citizen science remain invisible or hidden based on cultural, social, political or language differences (Vohland et al, 2021).

Vohland et al (2021) included in their book 34 definitions of citizen science and divided them amongst three different approaches to citizen science: descriptive, instrumental, and normative. In a meta-analysis of citizen science literature, Kullenberg & Kasperowski (2016) clustered citizen science according to three main higher purposes: citizen science as a method, as public engagement with science and policy, and as civic mobilisation. These categories were adapted and further described by Gharesifard (2020) based on other sources. A summary of these descriptions is provided in Table 2.

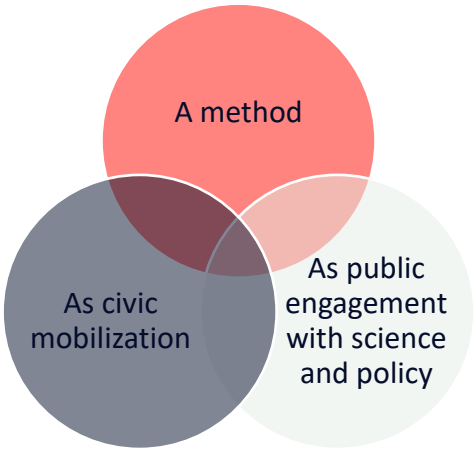

Figure 2: Three approaches to citizen science identified by Kullenberg (2016) and adapted by Gharesifard (2020).

The following Table includes definitions of the term citizen science based on the approaches:

As a method	"The collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists" (Oxford English Dictionary, 2014)
	the systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on a primarily vocational basis" (OpenScientist blog, 2011)
As public engagement	a science which assists the needs and concerns of citizens ... [and] at the same time [is] a form of science developed and enacted by citizens themselves" (Irwin, 1995, p. xi)
As civic mobilization	The higher aim of these social movements is to gain legal or political influence in matters of concern through joint action, evidence gathering, and awareness-raising.

Table 2: Definitions of citizen science according to three main approaches

The field of Citizen Science (CS) overlaps with the field of Open Science (also known as Open Research) in two main aspects: the value of the transparency and 'open' access to the results and process of research, and the participation of volunteers in research. While open science contributes with data

infrastructure to the field of citizen science, the latter contributes with research with societal relevance (see Figure 3). Concepts such as open innovation, responsible research, and innovation, or public engagement, also overlap with these fields which sometimes leads to terminological confusion when classifying an initiative under the umbrella of citizen science.

In practice, this has had implications in the citizen science ecosystem. The European Commission has mainstreamed citizen engagement in its research agenda through the Horizon Europe programme as it is now a criterion for evaluating proposals. On the other hand, the JRC is changing its approach towards citizen science by following a more systemic approach and exploring the concept in the context of open research, digital governance, artificial intelligence, data-driven innovation, and public sector modernisation.

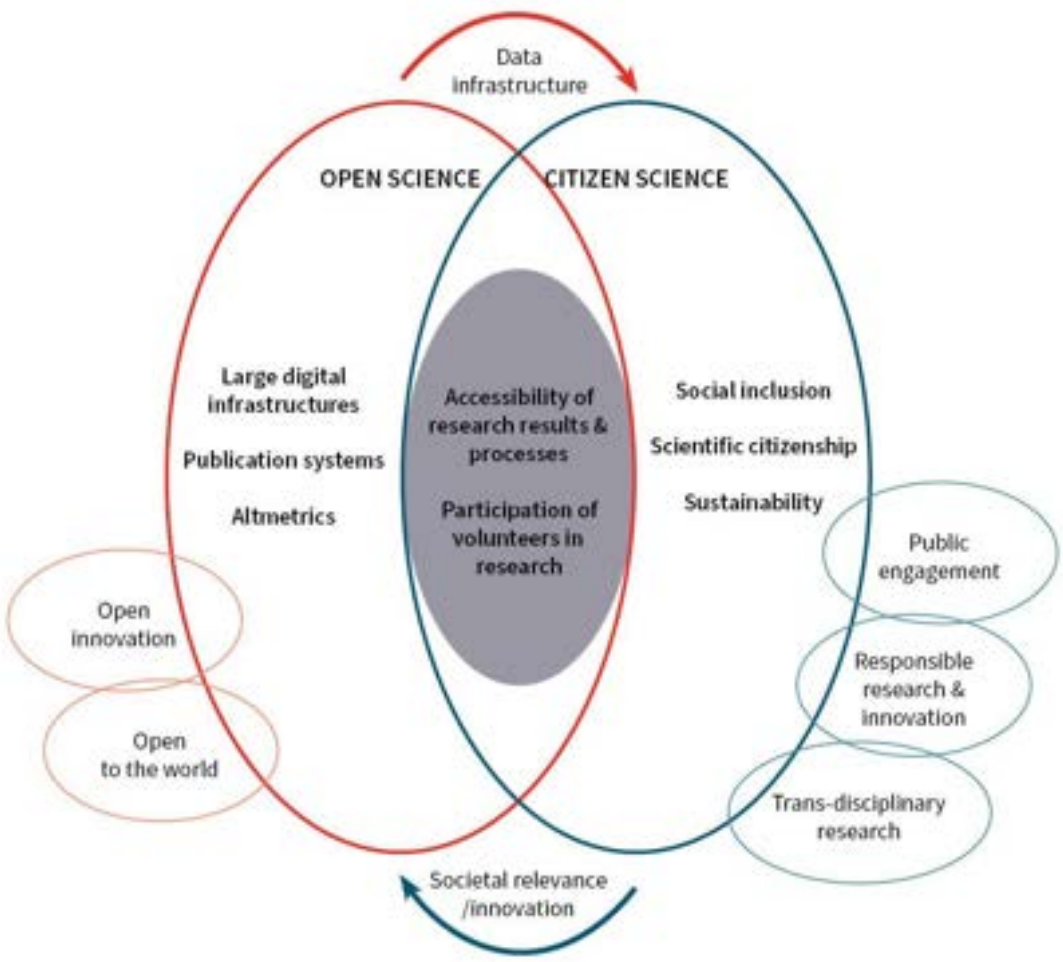

Figure 3: Open Science and Citizen Science, adapted from When et al;(2020).

5 Methodology

The landscape review is built on primary and secondary sources of information. The secondary information was collected using a desk research approach that consisted of both a review of literature related to the focus of the CitiMeasure working groups, as well as literature, datasets, and online resources that helped create a repository of citizen science initiatives. The insights from the desk research were complemented with primary data from an online survey and 8 semi-structured interviews with key stakeholders. A triangulation approach was used to analyse the findings of the desk research, the online survey, and the interviews.

5.1 DESK RESEARCH

The desk research consists of two distinct elements; (1) review of literature related to the topic of the WGs using keywords, and (2) review of literature and online search to find relevant Citizen Science projects. The first element was a non-exhaustive literature review. The search in Google Scholar followed key words such as: policy AND citizen science, citizen science AND behaviour change, citizen science AND data comparability, citizen science AND digital inclusion, and digital divide AND citizen science. The second part of the desk research included reviewing public websites and datasets and revising literature where different citizen science projects were mentioned or analysed. Other resources, including grey literature such as policy documents, were included in the review. Additional resources were identified by the CitiMeasure team based on their expertise and participation in citizen science projects. The inputs gathered as part of drafting this publication were used to identify four case studies (Deliverable 1.2), citizen science initiatives (Deliverable 1.1, Section 6.2), and key stakeholders through a stakeholder mapping (Deliverable 1.3).

5.1.1 Inventory

This landscape review builds upon previous efforts to create inventories of citizen science projects, especially the work done by the JRC in 2018 for two main reasons: it is the most comprehensive database in terms of environmental topics, and the raw data is easily accessible. The inventory of citizen science projects relevant for CitiMeasure thus follows a similar structure:

Name of input	Type of input	General description
ID	Identification Number	A unique number was given to each initiative
Source	JRC EEA European Commission City Deal Survey ECSA Proposal Desk research Ibercivis UIA WeObserve Interview H2020 Others	Identify the main source where the project has been identified.
Name		Name of the project/activity
Lead Organization		Name of the lead partner

Geographic Scope	Global European National Sub-national City	Identify the scale of implementation
Start Date		Add date
End Date		Add date
Status	Ongoing Finalized Unknown	Status of the project, sometimes unclear.
Thematic Focus		See Table 4
Decision	Exclusion/Inclusion	Mutually exclusive
Criteria for inclusion		See Table 5
Criteria for exclusion		See Table 5
Link		Link of the project
Contact details		Contact details of the project coordinator

Table 3: Structure of the inventory, adapted from JRC 2018

The geographic scope refers to the spatial scale at which the project is implemented. This landscape review simplified the categories used in the JRC data set. European is used instead of Macro-regional. Subnational is used as generic category for projects for which the geographic scale is not known (i.e., regional, or city, or neighbourhood). Regional projects were thus included in the Sub-national category, and neighbourhood projects were absorbed in the 'City' category.

The categories for the thematic focus used in this review are based on the categories applied in the JRC inventory to facilitate comparison. Initially, the JRC categories were adapted based on the environmental fields in the environmental impact assessment under the Better Regulation Agenda, they include Air quality; Biodiversity, nature, and landscapes; Climate; Land; Noise; Sustainable consumption and production; Waste; Water; Efficient use of resources; Transport and energy use; Animal welfare; Environmental risks; Environmental health and Cross-cutting. The CitiMeasure inventory applied the following categories:

Thematic category	Rationale
Air quality	JRC
Biodiversity, nature, and landscapes	JRC
Cross-cutting	JRC
Environmental health	JRC
Environmental litigation	New category
Land use and soil moisture	Modified from JRC: Instead of the category Land, we have used land use and soil moisture.
Noise	JRC
Plastics	New category
Resilience and adaptation	Modified from JRC: We have used Resilience and adaptation instead of environmental risks.
Resources, consumption, production, and others	Modified from JRC: We have mixed Sustainable consumption and production, energy, waste, and efficient use of resources.
Temperature	Modified from JRC: Instead of the category Climate, we have used Temperature.
Water	JRC

Table 4: Categories of this landscape review and their rationale

Following the narrower scope of this inventory (see Figure 1), we did not include all the entries included in the JRC data set. Firstly, we selected projects from the JRC dataset based on four themes (air quality, noise, temperature, and soil moisture) to align with the thematic focus of the Dutch City Deal working group on data comparability. Following the urban focus of CitiMeasure, we expanded this initial selection to those projects directly or indirectly impacting SDG 11. As a result, 192 out of 503 initiatives were identified following these criteria. Multiple additional sources have been used to identify more citizen science initiatives including:

1. 2021 European Environmental Agency (EEA) report on air quality
2. 2020 European Commission communication on citizen science best practices
3. ECSA website
4. CitiMeasure Project Proposal
5. Dutch City Deal inventory
6. WeObserve landscape review
7. Citizen Science Office of the city of Barcelona
8. CORDIS database[1]
9. Ibercivis database
10. Urban Innovative Actions (UIA)[2]

Finally, more initiatives were identified through the online survey and through random online searches with key words such as *citizen science projects*. The total number of identified initiatives in this landscape review is 400. Some of these databases are overlapping, and thus several projects appeared repeatedly under different sources. Whenever there was a duplication, we prioritised the JRC inventory as the main source, followed by the CORDIS database and other official projects databases. For instance, if a project appeared in the Weobserve review and the JRC inventory, we deleted the former and left the entry of the JRC. If a project appeared as part of the desk research, but also in the ECSA website, we deleted the former and left the ECSA record.

From the list of identified projects (400), we followed an Inclusion/Exclusion criterion to narrow down the inventory to those projects that can benefit CitiMeasure working groups the most (see Table 6). Regarding the geographic scope, this landscape review specially focuses on initiatives with a strong urban focus or implemented at city scale. It thus excludes international initiatives (including initiatives in the United Kingdom). Regarding the thematic focus, we have followed the categories of the JRC but focusing on those topics that are more relevant in an urban context. We have thus excluded projects that focused on wildlife, coasts and marine environments, astronomy, etc. We have also included projects which were relevant for the development of the CitiMeasure instruments, or which were considered as flagship initiatives, e.g., by the European Commission.

Due to the conceptual differences, there were some initiatives included in the JRC and the CORDIS databases that were discarded. For instance, organisations (that were not initiatives per se), initiatives that focused on citizen engagement, open science, or responsible R&I, but lacked a citizen science angle, i.e., only had an awareness raising focus or the data was collected through official institutions without involving citizens. We have also eventually discarded projects if the website/trustworthy information could not be found. Throughout the desk research process, we did not include many

[1] H2020 projects appearing after searching "Citizen science" from the 1st of January of 2018 as the data collection of the JRC inventory finished on the 6th of February of 2018.

[2] Urban Innovative Actions (UIA) is an Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Based on article 8 of ERDF, the Initiative has a total ERDF budget of EUR 372 million for 2014-2020.

projects we came across based on these criteria, so the number of total initiatives (400) could have been higher.

Inclusion Criteria	Exclusion Criteria
Geographic scope: urban/city	Geographic scope: Global, UK
Thematic focus: urban and environment focus	Lack of strong urban focus (astronomy, wildlife monitoring, etc.)
Relevance for CitiMeasure WGs, flagship initiatives or relevant projects mentioned in the proposal	Lack of citizen science angle

Table 5: Inclusion and Exclusion criteria

5.2 ONLINE SURVEY

An online survey to Eurocities members has been designed to identify and understand which citizens' initiatives have been developed and implemented in the European Union. The online survey was partly informed by the structure of the inventory developed by the Joint Research Centre in 2018 (see Annex 2). There was a total number of 11 responses.

5.3 INTERVIEWS

A series of in-depth interviews with key stakeholders were conducted to deepen the understanding of the current situation, structures, processes, and legal elements of citizen science initiatives as well as validating assumptions. For that, three different interview protocols were developed:

- Interview protocol for 5 EU city representatives (see Annex 4). The aim of this protocol is to gather information about the advantages and disadvantages European cities face when designing or implementing citizen science initiatives. It also investigates the local experiences in relation to the scope of CitiMeasure's working groups. Different European cities indicated their availability for an interview in the Expression of Interest form. We organised five instead of four interviews with the intention to keep geographical balance. They include the city of Barcelona (Spain), the city of Helsinki (Finland), the city of Amersfoort (the Netherlands), the city of Debrecen (Hungary) and the city of Dublin (Ireland). Special attention was given to Eastern European experiences and approaches to balance their lower representation in the interviews.

- Interview protocol for citizen science initiative representatives (see Annex 3). The experiences from other citizen measurement initiatives are extremely valuable to understand the structures and processes needed for a successful implementation. We reached out to the following initiatives: MeetMeMechelen, D-NOSES and CurieuzeNeuzen, from which we got a positive answer from the latter two. CurieuzeNeuzen is widely accepted as a success case, and its approach is replicated and has become a reference in the field. We chose to interview D-NOSES given their innovative approach to digital inclusion, which is an aspect that remains poorly addressed in citizen science initiatives. Unfortunately, due to the impossibility to align our calendars in September we had to eventually drop this interview.

- Interview protocol with 2 ecosystem stakeholders (see Annex 5). The Joint Research Centre and the European Citizen Science Association (ECSA) are two of the most knowledgeable organisations regarding citizen science initiatives. Based on their experience in these

organisations, we reached out to two experts from the Joint Research Centre and the Citizen Science Lab of Leiden University with prior experience on ECSA for an interview.

Type of stakeholder	Name of stakeholder	Total Number
Ecosystem stakeholders	Joint Research Centre	2
	Leiden University, Citizen Science Lab	
EU cities	Barcelona	5
	Amersfoort	
	Dublin	
	Debrecen	
	Helsinki	
Citizen science initiatives	CurieuzeNeuzen	1

Table 6: Number of interviews by type of stakeholder

The analysis of these interviews has also been used for the development of the stakeholder mapping (Deliverable 1.3) and the case studies (Deliverable 1.2).

5.4 LIMITATIONS OF THIS LANDSCAPE REVIEW

Thematic: This landscape review focuses on environment and urban related citizen science initiatives (see section 3.1). Even though the thematic categories used in the CitiMeasure inventory are based on the JRC repository, there might be some inconsistencies due to different interpretations of the concepts, or with the Dutch City Deal approach. This might have resulted in a higher number of citizen science initiatives on air quality and biodiversity in the CitiMeasure inventory. In addition, this review might have excluded initiatives from the JRC inventory by design that are still relevant, but which do not fall under our search categories. For example, in relation to Water, there are some initiatives including beach cleanings which have not been included based on their international nature, or that they were not necessarily focusing on urban areas. Further efforts also need to be made to disentangle the Cross-cutting and the Resources, consumption, production, and others categories in useful sub-categories.

Geographic scale: Indicating the geographic scale of citizen science initiatives is a difficult task because it might change depending on the criteria followed: funder's geographic scale, pilot's scale, lead organization's scale, etc. This attribution is often based on a subjective interpretation of the scale of the project.

Sources and language: The inventory build upon the most relevant sources to identify citizen science initiatives; it has also reviewed key literature in the topics of the future CitiMeasure instruments. However, the approach followed, and the literature review were not comprehensive. These limitations are due to language barriers, the blurriness of the concept of citizen science and time restrictions. There are anecdotal references to bottom-up initiatives, including initiatives from the Netherlands (through the City Deal) and from the Eurocities network.

6 Summary of insights from the desk research and interviews

The CitiMeasure's approach is a call for action to capitalise on the multiple efforts undertaken in the field of citizen science by developing tools based on best practices that can help improve data comparability, foster digital inclusion, and support policy uptake and behavioural change. This section includes a combination of insights from the desk research on the topics of CitiMeasure's working groups, interviews with EU cities, experts on citizen science, and citizen science initiatives. The results from the triangulation of insights from these sources are presented in two sub-sections. 6.1 introduces the summary of concepts related to the topic of the three working groups, and 6.2 showcases the landscape of citizen science initiatives in the European Union.

6.1 INSIGHTS RELATED TO THE TOPIC OF THE CITIMEASURE WORKING GROUPS

6.1.1 From information to change behaviour and policy

There are many recognised benefits of citizen science initiatives regarding their contribution to behavioural and policy change (European Commission, 2020). The capitalisation of these results is, however, limited. A comprehensive and objective overview of the impact of citizen science initiatives, including change in behaviour and influence on existing policy and decision-making processes, is not yet readily available and further research is needed to understand values and social impacts of citizen science (Rathnayake et al., 2020).

Kieslinger et al., 2017 presented an elaborated framework for evaluating the impact of citizen science which outlines three main dimensions: scientific advancement, citizen engagement, and socio-ecological and economic impact. The project MICS (Measuring Impact of Citizen Science) (2021) provided a systematic review of the literature about impact assessment methods for citizen science initiatives, including impact pathways and elements for the development of tools. This effort that included a systematic review of 77 publications on impacts of citizen science, provides a number of guiding principles for measuring the impacts of citizen science. Wehn et al., 2021 suggested the Citizen Science Impact StoryTelling Approach (CSISTA) as a tool to understand or communicate the policy impact of citizen science initiatives. Nevertheless, scales and specific tools for measuring various impacts of citizen science are still lacking. Targeted tools and shared impact evaluation frameworks to measure and evaluate specific outputs, outcomes and impacts of citizen science projects are thus urgently needed (Schade et al., 2021).

The CitiMeasure project aims to create an instrument to connect information generated by citizen science initiatives to behaviour and policy change, while supporting the best way to use the data collected in citizen science initiatives to stimulate these changes. However, these relate to two different domains of impact of citizen science (When et al, 2021). While policy is related to the governance domain, behaviour is to the social domain. This distinction is also evident in the literature. Schade et al., 2021 have developed an impact framework that articulates six pathways through which citizen science projects can create environmental change. These pathways have an impact on practices at individual, collective and institutional level. The authors distinguish these two areas i.e., behavioural change, evidence for policy, among others (see Table 7).

Impact Pathways	What is changing in relation to policy?
Environmental management	Institutional practice
Evidence for policy	
Community action	Collective practice
Social network championing	
Political advocacy	Individual practice
Behaviour change	

Table 7: Impact pathways and relation to policy of citizen science initiatives based on Schade et al (2021)

Therefore, the summary of the insights from the desk research are organised and discussed separately in sections 6.1.1 and 6.1.2.

6.1.1.1 Change in knowledge, attitude, behaviour

Citizen science initiatives influence behaviour at both individual and societal level. This is especially relevant in fields such as climate change as it is a 'wicked problem', too big to solve by changing only our individual behaviour. Participants in citizen science initiatives are especially responsive whenever the initiative is linked to a concerning local problem, i.e., air pollution or health-related issues, alo whenever they can monitor the impact of changing their behaviour and the technology or devices used are made easily accessible and user-friendly (European Commission, 2020; Bio Innovation Service, 2018).

Figure 4: Poster of a campaign against plastics in Barcelona

By engaging in citizen science initiatives, participants improve their science literacy, gain knowledge and skills, rethink their attitudes, and share networks with communities of interests which result in raising awareness and lead to behavioural change (Gordienko, 2013; Hecker et al, 2018; Bio Innovation Service, 2018; European Commission, 2020; San Llorente Capdevila et al., 2020; Vasiliades et al., 2021; Vohland et al, 2021).

This growing awareness also leads to new stewardships and civic actions in the environmental field (Hecker et al, 2018; San Llorente Capdevila et al., 2020), as well as to build social capital (Van Brussel & Huyse, 2019). Figure 4 showcases a poster of the campaign against plastics "La Barceloneta diu plastic 0!" in Barcelona. The campaign started after the implementation of a citizen science project in the beach of La Barceloneta (Barcelona), which resulted in this awareness raising campaign.

Social psychology theories have long established a link between change in behaviour and change in knowledge and attitude. For example, the Theory of Planned Behaviour (TPB) that helps understand actions that are thought about and 'planned for', suggests that attitudes (which are made up of beliefs) are closely related to behaviour, while evidence from other research has also suggested that knowledge and attitudes are linked (Zwickle & Jones, 2018). However, an increase in knowledge does not necessarily lead to changes in behaviour. It is thus important that these changes in behaviour remain even after the intervention or initiative is over (Abrahamse & Matthies, 2012). Trust plays a

key role in both the motivation to participate in citizen science initiatives and the uptake of climate friendly behaviours. People often trust environmental groups and scientists regarding their engagement in mitigation and adaptation behaviours (Cologna & Siegrist, 2020; Topal et al., 2020).

Behavioural change is thus a key expected outcome of citizen science initiatives, but more research is needed to determine the key factors contributing to this outcome as it is difficult to measure (Hecker et al, 2018; Vohland et al, 2021). A more holistic approach to project evaluation which considers the impact on scientific knowledge and both individual and societal level is needed so the depth of the changes in participants' behaviour can be better understood (Hecker et al, 2018). The systematic review of the MICS project includes a review of approaches for assessing environmental attitudes, knowledge, and behaviour (When, et al., 2021).

Figure 5: Conceptual framework of behavioural change followed in this review

The following table summarises their work regarding the main definitions and identified tools/conceptualisations.

Concept	Definition	Tools/conceptualizations
Environmental attitude	Cruz & Mantana (2020, p. 2) termed the concept "*a hierarchical attitude system that connects and organizes more specific attitudes about a range of environmental topics*".	**Ecology Scale** from Maloney and Ward (1973) Schultz's **three-dimensional Scale** (2001) **New Ecological Paradigm (NEP)** model (Dunlap & Catton, 1979; Dunlap et al, 2000). The most comprehensive tool currently available in the field is the **Environmental Attitudes Inventory** (EAI) (Milfont & Duckitt, 2010).
Environmental behaviour	While environmental attitudes are closely linked to behaviour, pro-environmental attitudes do not necessarily lead to corresponding behaviours, so they have to be assessed separately. Assessment of behaviour is often done through observation in the field; laboratory observation; or most commonly, self-reporting. Environmental behaviour is multidimensional and interdimensional.	The **General Ecological Behavior Scale - 50'** (Kaiser, 2020) was identified by MICS as the most comprehensive, used and flexible tool in the context of citizen science.
Environmental knowledge	Frick et al (2004) specified key dimensions for environmental knowledge: system knowledge (e.g., understand the basic structural and functional characteristics of an ecosystem); action-related knowledge (e.g., understand	Braun and Dierkes (2019) developed a framework, which was later adapted in a similar study by Liefländer et al. (2015).

	solutions for environmental issues); and effectiveness knowledge (e.g., understand the benefit of sustainable actions).	An alternative scale is the Assessment of Sustainability Knowledge (ASK) (Zwickle and Jones, 2018).

Table 8: Tools and definitions of three key conceptual elements, based on MICS 2.7

Regardless of the existence of tools and methods to measure behaviour change, citizen science initiatives tend to design their own approaches based on their existing aims, expertise, and resources with the risk of being rather anecdotal in their approaches. Figure 6 presents an example of how CurieuzeNeuzen Vlaanderen monitored change in behaviour of participants.

CurieuzeNeuzen and behaviour change

CurieuzeNeuzen Vlaanderen monitored behavioural changes in terms of choice of transport mode in three groups of people. These included the 20 000 participants in the air quality measurement campaign, the approximately 33 000 people who expressed interest in participating but were not selected and a reference group of 1 000 citizens not involved in the project. Interestingly, most people involved and interested in the initiative indicated that they now use their cars less, while those not involved in the initiative had not changed their behaviour.

There is also the issue of how behaviour change is measured. In this case, it was people self-reporting who used their cars less. There are shortcomings in this approach given that if the people were interested in the project, they know that using their car is considered 'bad behaviour' so they would not want to admit to it. As a result, there is consistent inaccuracy of self-reporting behaviour change. It is also not possible to establish causality given the existence of other environmental factors when choosing your transport mode i.e., technology available, fuel price, pandemics, or other crises. Future research could focus on the long-term effects on participants of this kind of project (Van Brussel & Huyse, 2019).

CurieuzeNeuzen is currently being replicated in the city of Brussels through the CurieuzenAir project. They will choose a control group between the participants who will get a questionnaire with different questions in relation to their environment-related behaviour, attitude, and knowledge at different stages of the project (EEA, 2019).

Figure 6: Monitoring behavioural change in the CurieuzeNeuzen project and its replications

6.1.1.2 Change in policy and decision-making processes

The potential of citizen science to contribute to better policies at the global, European, national, regional, and local level is generally accepted. Citizen science can support the monitoring of environmental changes and indicators towards policy targets, it can also inform policies, assist decision-making, and exert policy pressure (Rubio-Iglesias et al., 2020; Sauermann et al., 2020; (Krabbenhoft & Kashian, 2020). The European Commission (2020) identified multiple obstacles for policy impact of citizen science such as long timescales of these initiatives, as well as the number of resources needed, resistance from public authorities, difficulty in identifying relevant policy strategies, tensions across different governance levels (local/national/EU), or even reluctance of citizen scientists to work with governments and vice versa.

While in the previous sub-section, several tools to measure behavioural change have been included, the impact of citizen science on the policymaking process is a field on its own. The relevance to policy can often be indirect and linkages may need to be made at different scales (Gordienko, 2013). It thus remains extremely difficult to measure impact and many times it is a rather anecdotal process. As a result, there is an increasing need to understand the key factors that promote policy impact in citizen science initiatives (Turbe et al., 2019) as well as the need for their appropriate assessment (Hinckson

et al., 2017). Schade et al (2021) propose a more comprehensive approach to the intersections between policymaking and citizen science by distinguishing between policies (content formulation), politics (processes and instruments) and polity (institutions and other actors). This distinction is relevant to understand the complexity of how citizen science initiatives can influence the policymaking process.

Figure 7: Conceptual framework of the policymaking process followed in this review

Politics matter. Although many citizen science initiatives choose to remain politically neutral, politicians and political actors are still key stakeholders. The electoral cycle (often every 4 years) together with competing interests of political actors, influence the policy uptake of citizen science initiatives. On the one hand, politicians and political parties might be interested in promoting an initiative for political gains. On the other hand, conflicting political interests, or lack of political will and transparency, can create barriers for citizen science initiatives (Manzoni et al., 2021). This is related with the Pandora's box dilemma, as described by one of the members of the CitiMeasure Policy Working Group. There are environmental policy topics that remain uncovered or unregulated by policies and this is in the interest of politicians holding the decision-making power. For instance, monitoring noise where there is a culture of bars and economic dependence on tourism might be unattractive for many local administrations.

Regarding **polity**, there are structures and processes that must be considered for the impact of citizen science initiatives on policy. The governance of citizen science is often siloed which makes influencing policies more difficult. The citizen science office of the city of Barcelona remains almost an exception, and many cities still do not include citizen science in their structures. Additionally, cities may hold legal responsibilities and face legal barriers when it comes to their direct involvement in citizen science initiatives. New structures and processes such as policy committees may emerge because of citizen science initiatives. In addition, changes in structures and procedures may result from other parallel and overlapping fields e.g., Open Science and Responsible Research and Innovation, which can strengthen the uptake of citizen science and foster its impact on decision and policy making processes (Schade et al., 2021).

Citizen science can contribute to each step of the **policy** process: Problem definition (identification of new environmental issues or formulation of new hypothesis about known issues); Policy formation (definition of the structure of the policy); Policy implementation and monitoring (putting into effect policies or describing their implementation); Compliance assurance (measures to promote, monitor, and enforce compliance with existing environmental regulation, such as through awareness raising, inspections, fines, and warnings); Policy evaluation (assessing the outcomes of policy interventions) (Turbe et al;, 2019).

In a study, the JRC aimed to develop policy recommendations on better integration of citizen science in the different phases of the environmental policy cycle, in particular for monitoring, reporting and regulatory compliance (Bio Innovation Service, 2018). In their inventory, the policy relevance of the initiatives was identified by classifying the initiatives according to the following categories: problem definition, early-warning, policy implementation or monitoring, policy evaluation, compliance assurance, or no clear policy link (Bio Innovation Service, 2018). The study also identified three key

dimensions of citizen science (citizen scientist, scientific, socio-economic) and how they interact with the policy process to generate impact and improve policy relevance (see Figure 7).

Figure 8: Citizen science and the policy process (Bio Innovation Service, 2018)

Globally, citizen science initiatives are contributing to research, SDGs monitoring and their accountability (Fraisl et al., 2020). At European level, citizen science keeps gaining importance in the field of environmental policy, especially regarding data. The European Green Deal has provided a framework for more initiatives to flourish. Beyond the biodiversity strategy for 2030, citizen science initiatives can contribute to monitoring the achievement of the goals of policies such as the zero-pollution ambition, the circular economy action plan, the climate neutrality objective, the farm to fork strategy and the Climate Pact. The European Union's research agenda has also been through a big transition towards the new funding programme Horizon Europe. Citizen engagement has been mainstreamed in its calls and it is currently a criterion for evaluating proposals. Although citizen science is not necessarily explicitly mentioned, it is seen as a keyway of engaging in both science and the co-design of policy solutions. Anecdotally, citizen science was promoted to fight pollution at the 2021 European Green Week. At a micro level, citizen science initiatives such as SamenMeten have reported an impact on traditional media, and some politicians used the data gathered in the project for policy design; the data of the initiative HushApp was used for the design of the Urban Quiet and Recreational Areas for Short-Term Stays Berlin Plan (Ponti & Craglia, 2020).

The working group on behaviour and policy change will need to address the nuances between these two connected but different topics. The potential of citizen science initiatives to influence behaviour of individuals needs to be better understood, and clear and targeted communication is key in this regard. The instrument might address some of the limitations in measuring the impact of citizen science initiatives on behavioural change, or it may focus on how to use of citizen-generated data to change attitudes, enhance knowledge, or influence individual behaviours. From the policy change perspective, the working group might focus on how cities or other relevant citizen science stakeholders can use citizen generated data to influence policies. For that, it will be key to test different ways to measure the impact or develop best practices regarding how cities and other decision-making power entities can better use the outputs of citizen science projects.

6.1.2 Digital inclusion

Although digitalisation is bringing a revival in citizen science, its speed has come with new challenges. On the one hand, citizen science initiatives face issues such as data protection and privacy and need to guarantee that there are democratic safeguards in place to protect citizen scientists and the data they share. On the other hand, the openness, inclusivity, and representativeness in citizen science initiatives are important for their legitimacy and credibility (Stepankova et al., 2020; Paleco et al., 2021).
Engaging communities that have been historically excluded from participating in scientific research is still a challenge in citizen science. Greater inclusion can improve the quality of the research and result in engaging systemically underrepresented communities in scientific research. Citizen science can also facilitate the inclusion of diverse societal perspectives in decision-making and create more inclusive and participatory socio-scientific-policy ecosystems (European Commission, 2020).

One possible angle to study and understand the topic of digital inclusion is through the opposite lens of digital divide. The digital divide commonly refers to the gap between those individuals and communities that have access to new forms of information technology and those that do not (van Dijk, 2006; Stepankova et al.,2020). Although the concept remains highly contested, a more recent definition describes the digital divide as a division between people who have access to and use of digital media and those who do not (Van Dijk, 2019). Even though there is generally a lack of concrete evidence about the demographics of citizen science initiatives, the work of Stepankova et al., (2020), Paleco et al (2021) and (Vasiliades et al., 2021) show that participants in European citizen science projects are typically white, have a high level of education and belong to the middle and upper socio-economic classes. Many of them have been involved in similar activities before. Except for projects that specifically targeted students and youth, middle-aged and older age groups often participate more in citizen science projects. The gender distribution of the participants depends largely on the topic of the project, but the gender distribution is fairly evenly (Vasiliades et al., 2021). Further research could thus focus on gender from an intersectional approach.

The sudden rise of the term digital divide at the beginning of the century put the focus on the new types of inequality in an information society. Contemporary research on the digital divide often focuses on a descriptive nature of this concept rather than on the explanation about why these differences exist (Van Dijk, 2006; Van Dijk, 2019). Van Dijk (2006, 2019) described four successive kinds of access in the appropriation of digital technology:

Figure 9: The conceptual framework of digital inclusion followed in this review

- Motivation to use technology. Social, cultural, mental, or psychological factors affect the motivation of people to access and use digital technologies. Notwithstanding, it is hard to find people 'in or out' but rather intermittent users.

- Physical and material access. The research on physical and material access, mainly access to computers and ICT infrastructure and the Internet, has long been based on demographical categories such as income, education, age, sex, and ethnicity. In this regard, there are differences both intranational and between developing and developed countries.

• Digital skills. These are mainly instrumental or operational skills that become a barrier for digital inclusion once the motivation and access is guaranteed. Many digital skills are highly dependent on the socioeconomic status.

• Usage skills. This refers to the usage time and frequency, the number and diversity of usage application, broadband or narrowband use, and active or creative use. In general, all social and cultural differences are reflected in computer and Internet use.

The increasing digitalisation - together with the effects of the COVID-19 pandemic yet to be fully considered-, as well as the access to electronic devices has been an opportunity to expand citizen science initiatives in Europe. Digital connectivity is considered a social right in the EU (Stepankova et al., 2020) and the Declaration on Digital Rights (2018) stresses the need for interoperability, inclusion, full representation, and participation, all of which are relevant for the success of citizen science initiatives. The European Citizen Science Association has a working group on Empowerment, inclusiveness & equity[3] that has gathered a list of resources on the topic.

However, there are remaining challenges for a true digital inclusion and more efforts could be made towards ending the digital divide in citizen science. From a geographic perspective, countries such as Greece remain at the bottom among the EU member states regarding the digital divide (Stepankova et al., 2020). Vulnerable groups are still extremely difficult to reach. Inequalities related to differences in skills and usage will thus become more and more strategically important in a network society (Deursen & Van Dijk, 2014), and access remains a barrier for inclusion (Vasiliades et al., 2021). There are new approaches to the digital divide which go beyond access, or as other authors refer as Second Level Divide or Deepening Divide, towards a wider understanding of social, psychological, and cultural backgrounds explaining this divide (Deursen & Van Dijk, 2014; Stepankova et al., 2020). The lack of participation of certain groups in citizen science should not be assumed as lack of interest but as limitations in the outreach.

CurieuzenAir and digital inclusion

This initiative organized a three-week recruitment process in which they collaborated with local newspapers in Brussels, they also launched a social media campaign and a website in three main languages (French, Dutch and English). The aim was to target everyone and have a diverse group of participants. The Flemish speaking community knew the CurieuzenNeuzen initiative so special efforts were put in reaching out to French speakers.

To reach more vulnerable communities, they followed an innovative approach by collaborating with a local NGO. This process started before the main recruitment to build trust with these communities. The NGO Bral used different ways to engage and raise awareness on air quality. They organized air quality walks that were followed by individual calls, air quality monitoring devices were installed in public places such as medical homes as well as in key stores in the neighbourhoods.

Figure 10: Digital inclusion in CurieuzenAir

The involvement of key stakeholders such as NGOs and civic centres that have a closer relationship with citizens is important. Improved access channels are needed to link the digitalisation potential with those from diverse, non-traditional, and excluded backgrounds. The channels and software used should be targeted and user-friendly. Moreover, real inclusion in citizen science initiatives is more likely to occur whenever participants believe they have an impact through their participation, when

[3] Link to website: https://ecsa.citizen-science.net/working-groups/empowerment-inclusiveness-equity/

issues are framed around their values, or when they focus on local and tangible concerns (Vohland et al., 2021).

The project CitiMeasure aims to create an instrument that enhances the digital inclusion in citizen science initiatives. This review has focused on understanding different aspects related to tackling the digital divide as conceptualized in the literature. Digital and usage skills remain key obstacles for digital inclusion, and more efforts should be put in understanding how these barriers apply in the context of EU citizen science initiatives.

6.1.3 Data comparability and interoperability

Data can be gathered by multiple stakeholders (e.g., researchers, businesses, public administrations, or by citizens via citizen science initiatives), and at different levels (local, regional, national, etc.). Therefore, data comparability and interoperability are essential for exploring the full potential of citizen science initiatives. This is a challenge because guidance and frameworks that would allow greater comparability are missing (Hecker et al., 2018).

The European Commission is currently evaluating the ISA² programme and the European Interoperability Framework (EIF) to present a reinforced public sector interoperability policy in 2021. The EC is also aiming to connect the European Interoperability Framework (EIF) with Smart Cities and Communities (EIF4SCC). In terms of environment-related topics, the INSPIRE Directive established an infrastructure for spatial information to support environmental policies, and activities. The EC has also recently launched a new innovative action to create a Common European Green Deal data space to provide more accessible and exploitable environmental observation data in support of the European Green Deal priority actions. On the other hand, the Joint Research Centre is supporting data sharing for a green and digital transition, and the commitment of Member States on the Declaration on A Green and Digital Transformation of the EU.

The European Interoperability Framework identifies four layers of interoperability barriers with the aim of connecting public administrations, businesses, and citizens.

- Technical interoperability: Exchanging data between two existing systems.
- Organisational interoperability: Exchanging data between public administrations with compatible internal procedures for data sharing.
- Semantic interoperability: Exchanging data in the right format and overcome differences in terminology.
- Legal interoperability: Exchanging data between two systems whose legal frameworks fit together.

Figure 11: The conceptual framework on data interoperability followed in this review

A fifth layer on cultural interoperability is being considered regarding the existing cultural differences across different regions in the European Union.

A measure to help address the challenge of data interoperability could be the development of citizen science data and metadata standards which provide a standardised format for sharing meta-data

between citizen science-projects, which will make both sharing of data and evaluation of data quality more accessible (Kullenberg & Kasperowski, 2016). Also, the use of technologies aligned with regulatory requirements (Hecker et al., 2018). From the perspective of cities and local governments, data is often gathered by local and regional institutions with expertise. National Statistics Offices and National Mapping Agencies are also key to develop common data standards that remove some of the technical barriers for the use of data. Coordination and cooperation with these stakeholders are thus essential for data comparability.

With the purpose of working towards the creation of common data standards, a Data & Meta Data Working Group[4] chaired by the Citizen Science Association (2015) was created; and the Open Geospatial Consortium (2016) adopted a Citizen Science Domain Working Group in 2016. The former initially designed a metadata standard for describing key facets of citizen science projects to help existing project repositories exchange records. As a result, they created PPSR Core, a set of global, transdisciplinary data and metadata standards for Public Participation in Scientific Research (Citizen Science). This standard includes:

- Project Metadata Model or (PMM)
- Dataset Metadata Model, (DMM)
- Observation Data Model (ODM)

These standards are united, supported, and underlined by a common framework, the Common Data Model (CDM).

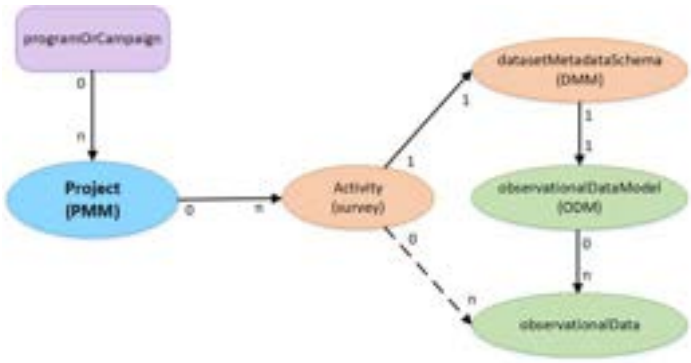

Figure 12: The Public Participation in Scientific Research Core Standard, retrieved from REF

The latest version of the PPSR-Core can be found as part of the Geneva Declaration, emerging from the 2018 European Citizen Science Conference. CitSci2019 lead to a (work in progress) PPSR Core Git repository[5] for hosting the standard. In addition, SWE4CitizenScience, is a common data model that once implemented and deployed will support data interoperability between almost all types of crowdsourcing projects.

There are some advances regarding data interoperability on air quality initiatives. Firstly, regarding the legal framework, the EU Ambient Air Quality Directive (EU, 2008) states that samplers can, if used and located correctly, meet the formal data quality criteria: 'A Member State may use any other method which it can demonstrate gives results equivalent to any of the methods' (vii). In addition, the European Committee for Standardization is leading on the calibration of sensor systems (EEA, 2019).

Moreover, citizen science can play a role in the open science movement as open data and standards promote data interoperability and scientific impact (Turbe et al, 2019). Access to data should be wider,

[4] Link to page: https://citizenscience.org/get-involved/working-groups/data-and-metadata-working-group/
[5] Link to page: https://github.com/citizen-science-association/ppsr-core

and preferably open source, but important questions about data ownership, privacy, and Intellectual Property Rights (IPR) often arise. Sometimes citizen science projects do not want to share the collected data. On the other hand, volunteers are often poorly informed about their intellectual property rights (Gordienko, 2013). The ethical questions regarding re-using citizens' data, or the lack of democratic safeguards for individual citizens in relation to government, private organisations, or businesses, need to be considered (Figueredo et al., 2016), especially due to the more active role of citizens as sensors themselves. This has created some tensions between the right of citizens to keep the data, and the interest of data platforms to standardise the data, in initiatives such as 'Botellon no me deja dormir' (Ponti & Craglia, 2020).

Data quality is another topic closely linked to the topic of data interoperability, especially when the alignment with monitoring requirements and regulatory standards is necessary (Hecker et al., 2018). Many research organisations and decision-makers do not trust citizen-generated data (Bonney et al., 2009; Bio Innovation Service, 2018; Turbe et al, 2019; Rubio-Iglesias et al., 2020). Data quality is thus key for policy and scientific uptake (European Commission, 2020). Generally, projects with higher number of data records, open access conditions and scientific endorsement result in more peer-reviewed publications (Bio Innovation Service, 2018). Data collection protocols also play a key role to ensure data quality in citizen science initiatives. In addition, policymakers have advocated the notion of fitness for purpose to consider the value of data for a particular policy question (Ponti & Craglia, 2020).

Citizen science initiatives often face the dilemma of balancing data quality with an inclusive and sustained engagement of citizen scientists (Hecker et al., 2018; Turbe et al, 2019). The goal is to ensure data quality by following scientific standards in data collection and management, without making it too difficult for individuals to participate or without excluding already marginalised communities with less knowledge, skills, or access to digital technologies. Some even argue that citizen generated data may not need to comply with established quality conventions but rather good enough standards for operational use. In addition, not every project collects interoperable data, i.e., the project D-Noses did not define its data standards (Ponti & Craglia, 2020).

Consistent with the European Citizen Science Association's Principle 9, citizen science programmes are evaluated for their scientific output, data considerations, participant experience and wider societal or policy impact. The concern over data quality has diminished following the appearance of statistical methods that improve large and imperfect datasets, as well as the calibration and validation of low-cost sensors (Hecker et al.,2018; European Commission, 2020). Further developments in data collection, data integration, data sharing, data validation processes and interoperability among other technical features are needed.

The European Commission (2020) provided some solutions to overcome the data quality gap by including quality guidance, smart project design, tools, and training in citizen science initiatives. Public administrations must identify and strengthen their skills and expertise to identify specific public needs and communicate them clearly so citizen science initiatives can be designed with them in mind (Figueredo et al., 2016) and citizen science initiatives should adhere to scientific standards in research design, data standardisation and database management (Bio Innovation Service, 2018). However, this is challenging for small organisations that normally run these types of projects, and support for information management and operationalisation of data portals is needed (Haklay, 2015). In its staff working document (2020), the European Commission has the following recommendations to promote data quality and interoperability standards and sharing tools:

- Promote the application of data management and sharing principles (e.g., FAIR data principles, etc.).
- Encourage open access policies and the use of standard open data licences (e.g., creative commons licences such as CC-BY or CC0) where feasible.
- Communicate transparently on the methodologies used. This could be supported by a terminology or framework that maps methodologies and approaches against specific policy goals.
- Apply and document data management and QA/QC methodologies and procedures.
- Promote or adhere to relevant standards of good practice and legal frameworks in science.
- Provide training and resources on data management, QA/QC methodologies and how to connect with relevant expertise such as law clinics. Regarding European standards on Open Data and PSI Directive, INSPIRE and the GDPR.
- Share knowledge on issues related to data donation, privacy-preserving technologies, and decentralised data governance.

The working group on comparability aims to create an instrument that allows the data generated in citizen science initiatives to be compared and used by different stakeholders. The future instrument can enhance comparability of citizen science initiatives through the creation of a community and common standards. It can also strengthen governance of bottom-up initiatives by improving knowledge sharing and the collection of data and its analytics through improved comparability.

6.2 LANDSCAPE OF EU CITIZEN SCIENCE INITIATIVES

This landscape review builds upon numerous resources and previous efforts, especially the work of the JRC (2018) on mapping citizen science initiatives in the European Union. This report includes an overview of 164 initiatives focusing on their geographic scale and thematic focus. Table 9 summarises the number of initiatives of this inventory and their main source. Initially 400 initiatives were identified. After following an Inclusion/Exclusion criterion explained in Section 5, 236 initiatives were excluded.

Source	Included	Grand Total
JRC	49	192
H2020	34	98
City Deal	23	23
Desk research	12	21
ECSA	17	17
UIA	11	14
WeObserve	2	13
Survey	7	10
BCN Citizen Science Office	2	5
EEA	2	2
Proposal	2	2
European Commission	1	1
Ibercivis	1	1
Interview	1	1
Grand Total	**164**	**400**

Table 9: Number of included initiatives and the main source

6.2.1 Geographic scale

This review focuses on initiatives with an urban focus thus being implemented in cities or at local level. Table 10 includes the exact number of EU citizen science initiatives included in the CitiMeasure inventory by their geographic scale (from city to global level). Notwithstanding, the results of aggregating the data of this inventory based on the geographic scale can be misleading. For instance, the inclusion of initiatives under the category Global can be explained because of their relevance for the CitiMeasure project (and despite their presence in third countries or being described as international). Most of the initiatives are EU initiatives, and many of these initiatives are implemented at city level or are relevant for the challenges addressed by CitiMeasure. The number in the sub-national category is high as it includes regional projects and other initiatives with an unclear geographic scope. As discussed in the methodology, the existing categories have been adapted from the ones used in the JRC inventory; 33 out of 164 initiatives could be categorized as implemented at city level.

Geographic scale	Number of initiatives
Global	5
EU	57
National	25
Sub-national	44
City	33
Grand Total	**164**

Table 10: Number of initiatives by geographic scale

6.2.2 Thematic focus

Together with the interviews and the desk research, and align with the literature, this landscape review revealed emerging topics and discussions in the field of citizen science relevant for the CitiMeasure project.

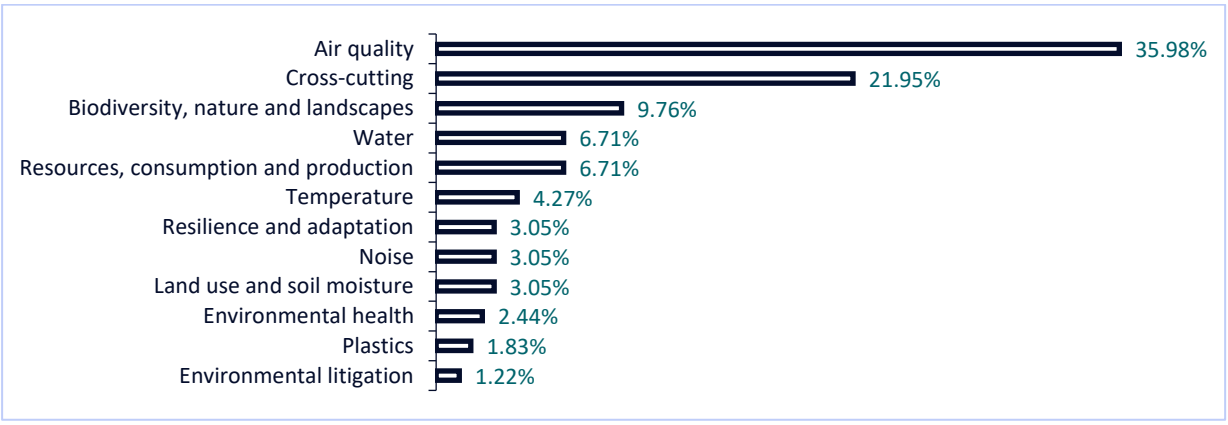

Figure 13: EU citizen science initiatives in the CitiMeasure inventory by thematic focus

Air quality

Air quality remains one of the most important environmental issues worldwide. The EC launched an open public consultation in 2021[6] on the revision of EU rules on ambient air quality. This revision aims to align the EU air quality standards more closely with the new recommendations of the World Health Organization (WHO) to strengthen provisions on air quality monitoring, modelling and plans to help local authorities achieve clean air. So far, the WHO has established a health-based guideline for long term exposure to fine particulate matter of 10 µg/m^3. The EU has set an annual limit value for fine particulate matter of 25 µg/m^3 under policies to deliver clean air in Europe, such as the Directive 2008/50/EC. Moreover, the European Environment Agency has recently published a European City Air Quality viewer[7] .

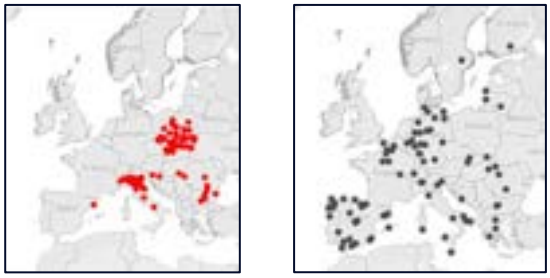

Figure 14: EU cities with poor air quality (on the left) and EU cities with no shared data on air quality (on the right).

This dashboard showcases EU cities with poor air quality (marked in red); four cities from Poland, Croatia and Italy respectively were classified under the category very poor (see Figure 14). However, many cities do not appear in this dataset either because they do not have urban or suburban air quality monitoring stations, the urban and/or suburban air quality monitoring stations in the city have not reported data covering 75% of the days in the year or the city is not included in the database of cities established under the European Commission's Urban Audit (marked in black)

The topic of air quality has thus been gaining more and more policy and social relevance in the field of citizen science, a total of 59 initiatives have been identified in this landscape review. The existence of strong communities of practice such as Sensor.Community and success stories such as CurieuzeNeuzen favour this tendency.

The City Deal has a working group working on comparability that has mapped initiatives in the Netherlands working on air quality measurements. The Dutch National Institute for Public Health and the Environment (RIVM) is a reference in Europe regarding data comparability, and it integrates citizens science data into its databases. Initiatives such as Measure Together (or Samen Meten in Dutch) are leveraging a huge community of citizens using sensors on air quality. They have developed a data infrastructure in collaboration with other initiatives such as Sensor.Community that has been later used in other projects, i.e., Sniffer bike (or Snuffelfiets in Dutch), or Dutch Skies (Hollandse Luchten inEnglish). Participating citizens in Sniffer bike measure three types of particulate matter while cycling. Also, location, (average) speed, battery voltage, temperature, humidity, road conditions and organic gases. On the other hand, Dutch Skies involves citizens in measuring air quality in their environment in the Province of North Holland.

[6] The public consultation is available in the following link: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12677-Revision-of-EU-Ambient-Air-Quality-legislation/public-consultation_en

[7] Link to dashboard: https://www.eea.europa.eu/themes/air/urban-air-quality/european-city-air-quality-viewer

At European level, the JRC included initiatives such as CurieuzeNeuzen, CAPTOR or ClairCity. CuriezeNeuzen used sensors (tubes) built by citizens to measure air quality from their homes. The project CAPTOR installs and maintain a network of low-costs sensors for Ozone measurement and ClairCity engaged European citizens to better understand their environmental behaviours in their local contexts. Also, the JRC inventory included D-NOSES in the air quality category, although from the perspective of odours in cities.

Other relevant projects using sensors are the H2020 project WeCount which follows participatory citizen science methods to co-create and use innovative low cost, automated, road traffic counting sensors (i.e., Telraam) or an UIA project, Healthy Outdoor Premises for Everyone (HOPE). While these two are being implemented in cities, there are also other projects which are cross-border such as Transf'air.

In conclusion, although many citizen science initiatives involve citizens through the direct use of sensors, there is a diverse group of projects measuring air quality in the EU with different approaches and focus (type of particles measured, types of sensors, geographic scope, etc). Many European cities are implementing policies to reduce air pollution, and citizen science presents both an opportunity and a challenge in the field of air quality. On the one hand, it can complement official measurements with low-cost data sensors. However, these processes must be inclusive, and the data gathered should be comparable with official data measurements so the results can be used in policymaking processes.

Cross-cutting

Cross-cutting initiatives are relevant for CitiMeasure as the nature of this project is also multi- and cross-disciplinary. There are two main types of cross-cutting projects that have been included in this landscape review: those that tackle several topics at the same time (i.e., energy and climate change), and those that tackle the topic of citizen science as an overarching topic.

Regarding the latter, there are initiatives such as CS-Track that seek to broaden the knowledge about the impact of citizen science activities. In addition, WeObserve tackled challenges of citizen observatories, MICS aims to develop metrics and instruments to evaluate citizen-science impacts on the environment and society and TRANSFORM seeks to design, test, and disseminate three sound co-creation methodological frameworks (including citizen science) within the Smart Specialisation Strategies of different pilots It will thus be important to connect with these projects for the development of the European Knowledge Centre to make sure that the CitiMeasure's Knowledge Centre is complementary to other existing portals sharing knowledge, best practices, etc.

Other topics

Monitoring **biodiversity** remains an important topic in the field of citizen science, and the expertise and lessons learnt in this community are numerous. For instance, the EU-funded OptimCS project will build a workflow to maximise the information that citizen scientists contribute to collective knowledge of biodiversity. Biodiversity is also related to other topics such as light and air pollution, nature-based solutions in cities, green areas, food security, etc. For stakeholders working on biodiversity in the Eurocities network, predictability, data collection and the existence of layered data coming from various sources remain challenges.

The topic of **water** quality is also relevant in the citizen science field. While many projects focus on water quality such as The Clean Water Experiment in the city of Amsterdam, citizen science initiatives are focusing more and more on **resilience and adaptation** such as the management of floods. For instance, the project ScoreWater focuses on enhancing the resilience of cities against climate change

and urbanization by enabling a water smart society. On the other hand, a recent study (Smid et a., 2019) analysed the frequency of heatwaves in European capitals. Citizen science initiatives focusing on measuring **temperature** can thus become very relevant, especially when tackling heat islands (see initiative CoolWalks BCN). In addition, MeetjeStad is a project where residents have measured their own environment and have examined the perceived consequences of climate change in the city of Amersfoort.

Further efforts are needed to disentangle the **Resources, Consumption and Production** category regarding sub-categories such as waste, energy, or circular economy. For instance, this report has already separated the category dealing with plastics which is an environmental concern that is gaining more and more importance, also in the field of citizen science. While there are many initiatives in Europe on **plastic pollution**, these often relate to pollution in aquatic environments, i.e., Paddlesurfing for Science in the city of Barcelona. Further research thus needs to be addressed to understand how to best capture the landscape on initiatives tackling plastic.

The issue of **health** has been popular in citizen science for a while. There are more and more initiatives focusing on health-related issues, a trend that started even before the covid-19 crisis. The boom in apps that track health related issues is also favouring this trend. Although public health is not necessarily related to environmental concerns, there are obvious links between the two. The CitieS-Health project aims to put citizens' concerns at the heart of research agenda on environmental epidemiology. It explores how the pollution in their living environment is affecting its citizens' health. In that line, the Irish EPA is now developing an Air Quality and Health index.

Noise pollution is the second most common environment-related global complain. Eurocities Noise WG identified different ways in which data collection in initiatives engaging citizens is relevant: to predict increase in night-time noise in areas (i.e., following lower noise during recent lockdowns), to develop quiet walking paths for citizens, or to model the best flight paths for aircraft to reduce noise as much as possible.

Emerging topics: the potential of citizen science for environmental litigation

The contribution of citizen science to environmental litigation is under researched. The burden of proof in environmental litigation as well as monitoring compliance are challenges that might be addressed though citizen science projects. Recently, the Sensing for Justice (SensJus) project was launched to research the potential of grassroots-driven environmental monitoring, i.e., citizen science, as a source of evidence in environmental justice litigation, and as a tool for environmental mediation in extra-judicial settings. Environment-related data has also been highly valued in other fields with projects such as Horizon 2020 Research and Innovation project enviroLENS: Copernicus for environmental law enforcement.

The channels for enforcing an environmental legal framework vary amongst Members States. At European level, however, the European Commission has the obligation to identify possible infringements of EU law based on its own investigations or following complaints from citizens, businesses, or other stakeholders. In the webinar Europe Calling "One Rule for All? Infringements of EU environmental laws"[8] a representative from DG ENVI shared that DG ENVI remains the DG with most open infringement procedures in the European Commission, i.e., 451 open infringement procedures in 2020, most were infringements in Spain (30) and Greece (29). Regarding sectors, procedures were open in sectors such as waste, water, air, and nature.

[8] Available online: https://sven-giegold.de/en/europe-calling-infringement-eu-environmental-law/

The potential of citizen science initiatives to monitor the implementation (or not) of EU legislation, as well as international agreements (Aarhus Convention) remains to be fully explored. Recently, there was a political agreement on the Aarhus Regulation welcoming increased public scrutiny of EU acts related to the environment (2021)[9]. The agreed amendment will improve the possibilities for civil society to request that EU institutions review their acts with the aim to ensure better environmental protection and more effective climate action which is very relevant in the context of citizen science.

[9] Link to document online: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3610

7 Concluding remarks

Citizen science can contribute to the environmental governance and monitoring of cities by fostering community building and citizens' involvement in environment-related topics and providing greater access to citizens to decision-making processes. It has also proven useful to influence municipal policies as well as to support policy implementation (SDGs). More generally, citizen science initiatives are a great tool to raise awareness and change behaviours of citizens and can contribute to the governance of data by democratising information flows, covering gaps of official data collection, and creating new paths for environmental litigation. In addition, tackling systemic issues such as climate change sometimes require following trial and error approaches, and citizen science initiatives provide experimentation spaces or testbeds. However, there are common challenges or barriers to citizen science.

This landscape review sheds light on key horizontal challenges that citizen science initiatives face: data comparability and interoperability, digital inclusion and behaviour and policy change. For that, it includes a review of relevant literature on these challenges, as well as their conceptual implications. The following table attempts to summarise key concepts and considerations of these challenges.

	Policy	**Behavioural change**	**Digital inclusion**	**Data interoperability**
Main conceptual building blocks	Polity, politics, and policy (the policy cycle)	Attitudes, knowledge, and behaviour	Motivation, access, digital skills, and usage	Technical, organizational, semantic, and legal
Key considerations	How to involve public administrations and influence the policy-making processes remains the million-dollar question in citizen science. Best practices include communication and scientific excellence.	The existence of many methodologies in the literature still needs to be simplified for their actual implementation.	Improving digital skills and usage practices is key for the legitimacy of citizen science.	The creation of common data standards such as the PPRS CORE is key for data interoperability.

Table 11: Summary of insights per challenge

The collaboration between different stakeholders, i.e., local public administrations and citizen scientists requires learning about different ways of working to keep citizens actively engaged throughout the implementation of a project or initiative. Lack of trust remains a big barrier and it exists both ways. Moreover, there are political barriers such as corruption, and top-down and authoritative approaches to governance; also, the lack of political will and siloed governance can constrain the involvement of public authorities in citizen science initiatives. There are also legal barriers to citizen science such as laws and regulations on issues from policy design, participation, to data protection or IPR, as well as economic barriers such as the lack of funding, or its short-termism. The covid-19 crisis has affected all facets of human activity and the effects of this crisis on citizen science are yet to be determined. Projects such as CitiMeasure aim to enhance the societal impact and policy uptake of citizen science initiatives by creating hands-on instruments.

The most vulnerable and most affected by environmental issues in Europe remain silent, and again, there is a lot of work ahead regarding the digital inclusion of these voices in citizen science. The

instruments of CitiMeasure aim to develop core principles or elements that can be then applied in different European contexts. Finally, there are technical barriers for the development of a richer ecosystem of urban-related citizen science initiatives. Among others, the concerns over the data quality and interoperability, or the lack of expertise within citizen science stakeholders. The instruments developed by the CitiMeasure project will tackle these barriers.

This report includes an inventory of 164 citizen science initiatives. The three main challenges described in this landscape review are horizontal, it is thus difficult to classify citizen science initiatives based on the challenge they address as many of them face issues regarding policy uptake, digital inclusion, or data comparability at the same time. However, the report does include examples and best practices in relation to these challenges. This knowledge will help shaping the instruments in the CitiMeasure working groups. Although this inventory is not comprehensive due to the methodological limitations, its analysis reveals that citizen science initiatives can further expand both thematically and geographically. Thematically, most initiatives have a focus on biodiversity and air quality where rich levels of expertise already exist. The full potential of citizen science in other environment- related areas is yet to be explored. Geographically, more efforts should aim to understand the real situation of citizen science in Southern and Eastern Europe.

The project will also develop a European Knowledge Centre which aims to strengthen the citizen science community by making it more accessible, including diverse voices, enhancing communication, and providing instruments, guidelines, and tools to raise its impacts at all levels.

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Annex 1 EU citizen science initiatives

Name	Geographic scale	Status	Thematic focus
100 &CIA for Victoria Gasteiz	City	Finalized	Biodiversity, nature and landscapes
ACTION	European	Unknown	Cross-cutting
AIR BREAK- Co-producing healthy clean commuting air spots in town	City	Ongoing	Air quality
AIRbezen Oost-Vlaanderen	Sub-national	Unknown	Air quality
AirClean School (Environmental agencies)	European	Finalized	Air quality
AiREAS	Sub-national	Ongoing	Air quality
AIR-HERITAGE	Sub-national	Ongoing	Air quality
Amai!	Sub-national	Finalized	Cross-cutting
Antwerp Circular South	City	Finalized	Resources, consumption and production
Apeldoorn in Data	Sub-national	Ongoing	Air quality
APPLAUSE	City	Finalized	Resources, consumption and production
Aqua	National	Finalized	Water
ARCS (ARenas for Cooperation through citizen science)	National	Ongoing	Cross-cutting
Arnhems Peil	Sub-national	Ongoing	Air quality
Bee projects in Copenhagen	Sub-national	Finalized	Biodiversity, nature and landscapes
BEES	European	Unknown	Cross-cutting
Biochar	National	Unknown	Temperature
Biodivercities	European	Ongoing	Biodiversity, nature and landscapes
Bioenergy Villages (BioVill) – Increasing the Market Uptake of Sustainable Bioenergy	European	Finalized	Resources, consumption and production
BlueSCities	European	Unknown	Water
Bodegraven-Reeuwijk	Sub-national	Ongoing	Air quality
Boeren en Buren	Sub-national	Ongoing	Air quality
Breathe Brno	City	Ongoing	Air quality
Brenta-Bacchiglione citizens' observatory	National	Ongoing	Resilience and adaptation
Build your own noise annoyance function	Sub-national	Ongoing	Noise
CAPTOR	European	Finalized	Air quality
C-CASCADES	European	Finalized	Temperature
Cetalingua	Global	Unknown	Cross-cutting
CitieS-Health	European	Finalized	Environmental health
CITI-SENSE	European	Finalized	Air quality
CitiSense MOB	City	Finalized	Air quality

Citizen sensing	Sub-national	Unknown	Cross-cutting
CLAiR-CITY	City	Finalized	Air quality
CLAIRO project	Sub-national	Ongoing	Air quality
Cluana Urban Nature	City	Ongoing	Biodiversity, nature and landscapes
CoAct	European	Unknown	Cross-cutting
COBWEB	European	Finalized	Land use and soil moisture
COESO	European	Unknown	Cross-cutting
Coping & Resilience	Sub-national	Ongoing	Air quality
COS4CLOUD	European	Ongoing	Biodiversity, nature and landscapes
CROWD4SDG	European	Unknown	Resilience and adaptation
Crowdwater	European	Ongoing	Water
CS Garrotxa	Sub-national	Ongoing	Air quality
CS- SDG	National	Finalized	Cross-cutting
CS Track	European	Unknown	Cross-cutting
CSI-COP	European	Unknown	Cross-cutting
CurieuzenAir	City	Unknown	Air quality
CurieuzeNeuzen	City	Finalized	Air quality
CurieuzeNeuzen In De Tuin	Sub-national	Unknown	Land use and soil moisture
DECIDO	European	Ongoing	Cross-cutting
Delft Measures Rain	City	Unknown	Water
DIAMS project (Aix Marseille Provence)	Sub-national	Ongoing	Air quality
Die Igel sind los!	National	Unknown	Biodiversity, nature and landscapes
DITOs	European	Finalized	Cross-cutting
DivAirCity	European	Unknown	Air quality
D-NOSES	European	Unknown	Air quality
Ecología a pié de barrio	City	Ongoing	Cross-cutting
ECSAnVis	European	Unknown	Cross-cutting
EnviroCitizen	European	Unknown	Cross-cutting
ENVRI PLUS	European	Unknown	Cross-cutting
ESAIRE	Sub-national	Finalized	Air quality
EU-Citizen.Science	European	Unknown	Cross-cutting
FLAMENCO	Sub-national	Finalized	Cross-cutting
FLOODUP	National	Finalized	Water
FoodSmartphone	European	Finalized	Resources, consumption and production
Forschung begreifen	National	Unknown	Cross-cutting
GBG_AS2C - Blue, Green & Grey_Adapting Schools to Climate Change	City	Ongoing	Resilience and adaptation
Gelderse Valei	Sub-national	Ongoing	Air quality
Generation Solar	National	Ongoing	Resources, consumption and production
GRACE	European	Unknown	Cross-cutting

Ground Truth 2.0	European	Unknown	Biodiversity, nature and landscapes
GROW	European	Finalized	Land use and soil moisture
hackAIR	European	Finalized	Air quality
Hollandse Luchten	Sub-national	Ongoing	Air quality
HOOP	National	Ongoing	Resources, consumption and production
HOPE	Sub-national	Ongoing	Air quality
Hush City	European	Finalized	Noise
ICARUS	European	Finalized	Air quality
Improve My City	City	Ongoing	Cross-cutting
InfluenceAir	City	Finalized	Air quality
INNOAIR	City	Ongoing	Air quality
InSPIRES	National	Unknown	Environmental health
ISABEL	European	Unknown	Resources, consumption and production
iSCAPE Improving the Smart Control of Air Pollution in Europe	European	Finalized	Air quality
iSpex	European	Finalized	Air quality
Jaarrond tuintelling	National	Unknown	Biodiversity, nature and landscapes
Jarokelo	National	Ongoing	Cross-cutting
JoinUs4Health	European	Unknown	Environmental health
Land Conservation Program of Vitoria-Gasteiz	City	Ongoing	Land use and soil moisture
Lansingerland	Sub-national	Ongoing	Air quality
Lichens in Barcelona	City	Ongoing	Biodiversity, nature and landscapes
LIFE AskREACH LIFE16 GIE/DE/000738	European	Unknown	Environmental health
Life+Respira	City	Finalized	Temperature
Lucht voor Leidschemdam Voorburg	Sub-national	Ongoing	Air quality
Luftdata	National	Unknown	Air quality
Maaspoort Meet	Sub-national	Ongoing	Air quality
Meet Je Stad!	City	Unknown	Temperature
MICS	European	Ongoing	Cross-cutting
miniMET	National	Unknown	Temperature
MosquitoAlert	National	Unknown	Biodiversity, nature and landscapes
Mückenatlas	National	Unknown	Biodiversity, nature and landscapes
MySense	Sub-national	Ongoing	Air quality
Netzwerk Natur - Wiener Arten- und Lebensraumschutzprogramm	City	Finalized	Biodiversity, nature and landscapes
NEWSERA	European	Ongoing	Cross-cutting
NO2 No Grazie	Sub-national	Ongoing	Air quality
NOCMOC	National	Unknown	Cross-cutting
Noise Tube	National	Unknown	Noise

NoisePlanet	Global	Unknown	Noise
OASIS	City	Ongoing	Resilience and adaptation
Objective 1000 @JardinMassart	City	Ongoing	Biodiversity, nature and landscapes
Onze Lucht	Sub-national	Ongoing	Air quality
OptimCS	European	Unknown	Biodiversity, nature and landscapes
Paddlesurfing for Science	Sub-national	Ongoing	Plastics
ParCos	European	Unknown	Cross-cutting
Participatory Lab- Laboratory of Spatial, Urban and Environmental Participatory Planning for Climate Change Adaptation	National	Unknown	Cross-cutting
Passer by Researcher	City	Ongoing	Resources, consumption and production
Plastic Spotter	City	Ongoing	Plastics
REINFORCE	European	Ongoing	Cross-cutting
RESILIO - Resilience nEtwork of Smart Innovative cLImate-adapative rOoftops	City	Ongoing	Resilience and adaptation
Samen Duurzaam Zeist	Sub-national	Ongoing	Air quality
Samen houtrook meten	Sub-national	Ongoing	Air quality
Samen Luchtkwaliteit Meten in Zuid-Holland'	Sub-national	Ongoing	Air quality
Samen Meten Zuid-Holland	Sub-national	Ongoing	Air quality
Samenmeten	National	Ongoing	Air quality
Scapeler	Sub-national	Ongoing	Air quality
Scent	European	Finalized	Land use and soil moisture
Sci4all	European	Unknown	Cross-cutting
Scorewater EU	City	Unknown	Water
SeaChange	European	Unknown	Water
See it? Say it!	National	Unknown	Environmental litigation
Senshagen	Sub-national	Ongoing	Air quality
SensJus	European	Ongoing	Environmental litigation
Sensor.Community	European	Ongoing	Air quality
Skywarn	National	Unknown	Temperature
Smart Citizen	Global	Unknown	Resources, consumption and production
Smart emission portal	City	Finalized	Air quality
Smurbs (ERA-PLANET)	European	Finalized	Cross-cutting
Snuffelfiets	Sub-national	Ongoing	Air quality
SoundMap	City	Ongoing	Noise
Stadslab Luchtkwaliteit	Sub-national	Ongoing	Air quality
StadtWildTiere Berlin	City	Unknown	Biodiversity, nature and landscapes
STEP CHANGE	European	Unknown	Cross-cutting
Sympnia	City	Ongoing	Air quality
The Clean Water Experiment	City	Unknown	Water

The Food Waste Experiment	National	Finalized	Resources, consumption and production
The Freshness of Water	Sub-national	Finalized	Water
TIME4CS	European	Ongoing	Cross-cutting
TransfAIR	European	Ongoing	Air quality
TRANSFORM	European	Ongoing	Cross-cutting
Urban AirQ	Sub-national	Ongoing	Air quality
Urwatair	City	Finalized	Air quality
Vigilantes del aire	National	Finalized	Air quality
Vigilantes del cierzo	Sub-national	Finalized	Air quality
Vliet Clean (s)Up - Microplastics	Sub-national	Unknown	Plastics
Waddinxveen	Sub-national	Ongoing	Air quality
Waste4Think	European	Unknown	Resources, consumption and production
WeCount	European	Ongoing	Air quality
WeObserve	European	Unknown	Cross-cutting
WeSenseIt	Sub-national	Unknown	Water
WOW-NL	Global	Unknown	Temperature
YOUCOUNT	European	Unknown	Cross-cutting
Zuidplas	Sub-national	Ongoing	Air quality

Annex 2 Online Survey Form

CitiMeasure_Online Survey on Citizen Science Initiatives

CitiMeasure is launching this survey to identify and understand which citizen science initiatives related to citizen measurement have been developed and implemented in Europe.

Background

There has been an increase in the number of citizen science and local measurement initiatives that use sensors to collectdata on a range of sustainability topics (e.g., air and noise pollution, mobility patterns, ground moisture levels, etc.) in Europe. However, there are certain risks and challenges related to such measurement initiatives involving sensors, data, and digital tools. Their technological and participative nature risks over- or underrepresentation of groups of people. Moreover, there is astandardisation challenge to leverage the potential of aggregated data from local projects over Europe. Experience has also shown that it can be challenging to translate collected data into meaningful insights, and hence,inform policy and behavioural change that leads to more sustainable cities.

Over the first quarter of 2021, Eurocities has developed a project for DG REFORM, the Directorate-General responsible for structural reform support that helps EU member states to design and implement reforms as part of their efforts to support sustainable growth. It is a 2-year project called CitiMeasure (derived from Citizen Measurement) and aims to support safe and effective local data collection by citizens to create smart,sustainable, and inclusive cities.

The purpose of this survey is to **analyse the current landscape** of these initiatives in Europe. We would also like to **support the knowledge exchange among cities** through sharing good practices and inspire policy changes in cities in relation to citizen measurement initiatives. This survey will thus provide valuable inputs from cities to feed directly into the CitiMeasure project.

Why should you participate in this survey?

This is a unique opportunity for cities to exchange information on their local citizen measurement initiatives. The results of this survey will be published as a part of a public project report. Questions regarding this survey can be sent to the Project Officer, Irene Vivas Lalinde (irene.vivas-lalinde@eurocities.eu (mailto:irene.vivas-lalinde@eurocities.eu)).

How will we use your city responses to the survey?

All information you share with us will be treated with confidentiality. Only the EUROCITIES team will have access to the detailed data and will analyse it into a report which will include an inventory of

2021

initiatives.

All personal information you share with us will be treated with confidentiality and incompliance with the General Data Protection Regulation (GDPR, EU 2016/679).

1. Name of the citizen science initiative (including local citizen measurement projects)

2. Lead organization

3. Geographic Scope

- ○ Global
- ○ Macro-regional/European
- ○ National
- ○ Sub-national
- ○ City
- ○ Neighborhood
- ○ Other

4. Start Date

Format: M/d/yyyy

5. End date

Format: M/d/yyyy

6. If your initiative is ongoing, please indicate an approximate end date (only the year)

7. Which of the following topics are relevant for the objectives, activities, or results generated by your initiative?

- [ ] Comparability of data
- [ ] Digital Inclusion
- [ ] Behavioural change and municipal policy

8. Thematic focus

- [ ] Air Quality
- [ ] Soil Moisture
- [ ] Temperature
- [ ] Noise pollution
- [ ] Water
- [ ]

Other

9. Link to the project website

10. Name of the Project Coordinator or contact person

11. E-mail address of the Project Coordinator or contact person

12. Any further information that you would like to provide about your initiative

13. I hereby confirm that EUROCITIES can use my personal information with regards to the implementation of the CitiMeasure project.

- ◯ Yes
- ◯ No

Annex 3 List of interview questions for EU citizen science initiatives

Interview Protocol with EU citizen initiatives

Date of interview:

Location & event of interview: Online

Link to informed consent form: Link

Interviewer

Name of interviewer:	
Name of the observer:	
Organisation of interviewer:	

Welcome & introduction

Background on CitiMeasure / focus of WP1 on the landscape review of citizen science initiatives in Europe

Purpose of the interview:

- To obtain insights into the ecosystem for citizen science initiatives in the EU related to the topic of CitiMeasure WGs.
- From these interviews and other activities, CitiMeasure will create an updated landscape report with identified gaps to deepen the understanding of the current situation and validate assumptions.

IMPORTANT

- Send in advance CitiMeasure Informed Consent sheet & get signature

Demographic information

Interviewee:	
Gender:	
Interviewee organisation:	
Job title/function:	

Questions:

1. In your view, what are the most significant contributions of [name of the initiative] to theory and practice of citizen science?
2. What type of obstacles did this initiative face during the design and implementation phases?
3. How did this initiative ensure interoperability and comparability of their data? What were the best practices?
4. How did this initiative better ensure digital inclusion? What were the best practices?

5. How did this initiative measure its effect on knowledge, attitudes, and behaviour change? What went well, what went wrong?
6. How did this initiative facilitate its policy uptake regarding air quality in Antwerp, Flanders, and Belgium? Any EU policy influenced? What went well, what went wrong?
7. In the context of your initiative, how can we best ensure the balance between data privacy and consent mechanisms with open data and data democratization?

*Please share with us any leads, documents, or links with more information on this

8. We are planning to develop a European Knowledge Centre by the end of this project, which should be the main functionalities/aspects? Any lessons learnt from the project?
9. In your view, which are the key institutions regarding environmental data collection in Europe?
10. In your view, which are they key citizen science initiatives on air quality in Europe at the moment?

Closing

Explanation of the next steps

- All results from interviews & workshop will be analysed.
- CitiMeasure will produce the CS landscape report.
- Involvement in CitiMeasure

Those are all the questions that we wanted to ask. Thank you for your time!

Annex 4 List of interview questions for EU city representatives

Interview Protocol with EU cities

Date of interview:

Location & event of interview: Online

Link to informed consent form: Link

Interviewer

Name of interviewer:	
Name of the observer:	
Organisation of interviewer:	

Welcome & introduction

Background on CitiMeasure / focus of WP1 on the landscape review of citizen science initiatives in Europe

Purpose of the interview:

- To obtain insights into the ecosystem for citizen science initiatives in the EU related to the topic of CitiMeasure WGs.
- From these interviews and other activities, CitiMeasure will create an updated landscape report with identified gaps to deepen the understanding of the current situation and validate assumptions.

IMPORTANT

- Send in advance CitiMeasure Informed Consent sheet & get signature

Demographic information

Interviewee:	
Gender:	
Interviewee organisation:	
Job title/function:	

Questions:

1. In your view, what are the advantages of citizen science initiatives for the city of [x]?
2. In your view, hat type of obstacles does your city face regarding the design or implementation of citizen science initiatives?

   Prompts:

   - Legal

- Social (lack of engagement)
- Political (government discourages, does not support…)
- Financial (not enough funds available)
- Methodological

3. What is the current citizen science landscape in your city? Are there any ongoing initiatives? In which topics are they focusing?
4. In your view, how can citizen science initiatives better ensure interoperability and comparability of their data? Does your city have any experience with this regard that you can share with us?
5. In your view, how can citizen science initiatives better ensure digital inclusion? Does your city have any experience with this regard that you can share with us?
6. In your view, how can citizen science initiatives maximize their effect on knowledge, attitudes, and behaviour change? Does your city have any experience with this regard that you can share with us?
7. In your view, how can citizen science initiatives maximize their policy uptake? Does your city have any experience with this regard that you can share with us?

*Please share with us any leads, documents, or links with more information on this

8. We are planning to develop a European Knowledge Centre by the end of this project, which should be the main functionalities/aspects?
9. In the context of citizen science initiatives, how can we best ensure the balance between data privacy and consent mechanisms with open data and data democratization

Closing

Explanation of the next steps

- All results from interviews & workshop will be analysed.
- CitiMeasure will produce the CS landscape report.
- Involvement in CitiMeasure

Those are all the questions that we wanted to ask. Thank you for your time

Annex 5 List of interview questions for ecosystem stakeholders

Interview Protocol with Ecosystem Stakeholders

Date of interview:

Location & event of interview: Online

Link to informed consent form: Link

Interviewer

Name of interviewer:	
Name of the observer:	
Organisation of interviewer:	

Welcome & introduction

Background on CitiMeasure / focus of WP1 on the landscape review of citizen science initiatives in Europe

Purpose of the interview:

- To obtain insights into the ecosystem for citizen science initiatives in the EU related to the topic of CitiMeasure WGs.
- From these interviews and other activities, CitiMeasure will create an updated landscape report with identified gaps to deepen the understanding of the current situation and validate assumptions.

IMPORTANT

- Send in advance CitiMeasure Informed Consent sheet & get signature

Demographic information

Interviewee:	
Gender:	
Interviewee organisation:	

Job title/function:	

Questions:

1. Has there been any major changes in the citizen science landscape after the JRC publication on the inventory of citizen science activities in terms of data interoperability, digital inclusion and/or policy uptake? Please share with us any leads, documents, or links with more information on this.
2. So far, biodiversity has been a key thematic focus in many citizen science initiatives, which are the current "key themes" in the citizen science landscape? (Biodiversity, health, air quality, etc.)

Prompts:

- Environmental Justice

3. In what ways, if any, is the Joint Research Centre supporting the quest for improving the interoperability of citizen science data?
4. Which tools, guidelines or practices exist for improving the comparability of citizens' environmental monitoring programmes?

Prompts:

- Common standards
- Communities of practice

5. How can we minimize the existing digital divide in the context of citizen science initiatives?
6. Do you know about any best digital inclusion policies or practices in citizen science activities? If yes, what are these?
7. What are the main EU institutes collecting environment related data?
8. In your view, what is the best way to measure impact of citizen science initiatives on policy and decision making?
9. In your view, what is the best way to measure impact of citizen science initiatives on knowledge, attitudes, and behaviour change?
10. In your experience, which are they leading cities/initiatives in the field of citizen science?

11. We are planning to develop a European Knowledge Centre by the end of this project, which should be the main functionalities/aspects?
12. In the context of citizen science initiatives, how can we best ensure the balance between data privacy and consent mechanisms with open data and data democratization?

Closing

Explanation of the next steps

- All results from interviews & workshop will be analysed.
- CitiMeasure will produce the CS landscape report.
- Involvement in CitiMeasure

Those are all the questions that we wanted to ask. Thank you for your time!