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COMMISSION STAFF WORKING DOCUMENT

Best Practices in Citizen Science for Environmental Monitoring

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Executive summary

The volume of environmental knowledge generated by citizen science initiatives across the EU offers a unique opportunity to help deliver on the European Green Deal and other EU (and global) priorities, and to involve the public in EU policy-making. This document summarises the opportunities for and benefits of using citizen science for environmental monitoring, highlights good practices and lessons learnt, and identifies the obstacles holding back its broader uptake. On that basis, it puts forward recommendations and possible actions to facilitate and enhance the use of citizen science in environmental monitoring.

Citizen science can be defined as the non-professional involvement of volunteers in the scientific process, commonly in data collection, but also in other phases, such as quality assurance, data analysis and interpretation, problem definition and the dissemination of results. This document does not cover their participation in opinion polls or personal data on participants and their views.

Citizen science is a powerful tool for public engagement and empowerment in policy-making and for raising awareness of environmental issues and policies. By promoting people's involvement in EU policies, the recommendations in this document contribute directly to the European Commission's policies on open, transparent and participatory decision-making, such as 'a new push for European democracy' (one of its six headline ambitions¹), better regulation², e-government³ and open data⁴ (the digital single market), and the EU's implementation of the Aarhus Convention⁵.

Equally important, the environmental knowledge generated in citizen science initiatives will be needed to deliver on our ambitions, strategies and plans under the European Green Deal. In particular, citizen science could offer a valuable source of complementary information for the biodiversity strategy for 2030, the zero pollution ambition, the new circular economy action plan, the climate neutrality objective and the 'farm to fork' strategy on sustainable food.

The examples in Annex I illustrate that EU and Member State authorities are already using citizen science data for environmental monitoring in several policy areas. Citizen science already contributes to monitoring the implementation of EU environmental legislation and progress on international commitments such as the United Nations sustainable development goals (SDGs).

In some environmental areas, such as biodiversity, authorities depend on citizen science for observations of indicator species such as butterflies (under the EU pollinators initiative⁶) and birds⁷. Official monitoring alone could never give us (at reasonable cost) the number of observations and geographical and temporal coverage currently provided by thousands of volunteers and required for the above purposes. Examples of good practice are also demonstrating the added value of citizen science in monitoring and policy-making in the areas of air pollution and waste/litter.

There is significant potential for public authorities to make more use of this valuable source of information and for citizen science initiatives to have a greater impact on policy. A growing number

¹ https://ec.europa.eu/info/strategy_en

² https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en

³ <https://ec.europa.eu/digital-single-market/en/european-egovernment-action-plan-2016-2020>

⁴ <https://ec.europa.eu/digital-single-market/en/open-data>

⁵ [The United Nations Economic Commission for Europe \(UNECE\) Convention on access to information, public participation in decision-making and access to justice in environmental matters \(adopted on 25 June 1998\)](#).

⁶ COM/2018/395 final; http://ec.europa.eu/environment/nature/conservation/species/pollinators/index_en.htm

⁷ https://ec.europa.eu/eurostat/web/products-datasets/product?code=sdg_15_60

of initiatives are generating significant amounts of valuable data and knowledge in a range of environmental domains. The wide availability of mobile internet, dedicated apps, portable sensors and other devices is facilitating the participation of large numbers of volunteers and the near real-time publication of results. The findings (e.g. on pollution) are attracting public interest and the attention of the media, and people are demanding that local politicians take action.

However, obstacles such as data quality issues and the complexity of data requirements seem to be holding back a wider use of this potentially policy-relevant information. The recommendations in this document aim to address those obstacles.

The need for complementary data was identified in the Commission's 2017 fitness check of reporting and monitoring of EU environment policy^{8,9}. That review concluded that tapping into new sources of data, including data collected by members of the public, could help improve and streamline reporting, and make it more reliable, thereby strengthening the evidence base for environment policy. The companion plan setting out ways of streamlining environmental reporting¹⁰ called for more specific action to promote the wider use of citizen science and, in particular, the development of guidelines and disseminating best practices (see action 8 – box below). Boosting public involvement will help build the environmental knowledge that EU policy-makers need (e.g. indicators for monitoring progress on the SDGs and the biodiversity objectives).

Action 8: Promote the wider use of citizen science to complement environmental reporting¹⁰

Another promising source for complementary information and data on environmental issues is citizen science. This offers another way to collect environmental data that is cost-effective and is useful in providing early warnings about environmental trends and specific problems. At the same time, it increases awareness and empowers people. However, despite an increasing amount of citizen science data and activities, in practice citizen science data are not (yet) used widely for official environmental monitoring (especially as for some areas the data is not on par with scientifically more elaborate monitoring equipment) and reporting. Nonetheless, it can trigger official reporting and action, for example if citizens report problems with a local landfill, and complement it.

The Commission will continue promoting citizen science activities through EU research and innovation programmes. This includes developing technologies that allow citizens to contribute (e.g. to monitor air quality), promoting coordination between existing actions at regional, European and international level and encouraging as well as disseminating best practices.

This document has been prepared on the basis of a 2018 study, *Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices*¹¹. The study assesses the impact and policy applications of citizen science by providing an inventory of 503 environmental citizen science initiatives of EU policy relevance and in-depth analysis of 45 selected initiatives¹². It also identifies the challenges and obstacles involved.

⁸ http://ec.europa.eu/environment/legal/reporting/fc_overview_en.htm

⁹ COM(2017) 230 final; <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017SC0230&from=EN>

¹⁰ *Actions to streamline environmental reporting* (COM(2017) 312); http://ec.europa.eu/environment/legal/reporting/pdf/action_plan_env_issues.pdf

¹¹ Published 7 December 2018;

<https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

¹² <https://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004>

In addition, this document builds on feedback from consultations with stakeholders (representatives of citizen science networks, citizen science initiative leaders, researchers/academics, public authorities in Member States, including environment protection agencies (EPAs), etc.).

Analysis of the challenges, opportunities and examples of good practice has led to the development of recommendations for promoting wider use of citizen science in environmental monitoring and reporting (see Chapter 5). The recommendations are clustered around four main areas of intervention to support the policy-making cycle:

1. match-making between knowledge needs for environment policy and citizen science activities;
2. promoting awareness, recognition and trust;
3. promoting standards for data quality and interoperability, and sharing tools; and
4. supporting coordination, cooperation and resources for policy impact.

In each area, we put forward concrete recommendations and possible future actions for the various actors in the field (public authorities, citizen science networks and communities, and researchers/academics).

The possible actions (see also Annex II) include:

for EU and Member State authorities:

- supporting citizen science initiatives in environment policy priority areas under the Green Deal and related strategies and ambitions, including on pollution (e.g. air, water, plastic, noise), biodiversity, climate change, the circular economy and sustainable food;
- promoting the availability of citizen science data on existing or new open platforms and ensuring that official reporting mechanisms can accept and integrate these data; and
- reviewing and communicating relevant data quality requirements and methodologies in close cooperation with EPAs, statistical offices, etc.

for citizen science communities and associations:

- communicating transparently on methodologies used and adhering to good practice;
- fostering strategic partnerships when and where possible;
- creating an online knowledge base of citizen science initiatives across Europe, including tools and resources; and
- promoting the coordination of citizen science initiatives at EU/national/regional levels.

for all relevant stakeholders:

- engaging in co-creation activities to scope out needs, capabilities and capacities, so as to implement successful and impactful environmental monitoring activities.

The recommendations and possible actions aim to harness the potential of citizen-generated data and to link them more closely to environmental monitoring and policy-making.

Notably, citizen science is not only about collecting data and generating useful knowledge (which is the focus of this document) – it is also a powerful tool for raising awareness of environmental issues and policies, and involving and empowering the public. Initiatives' sustainability depends on these other outcomes being actively fostered, so that citizen science is rewarding for volunteers and other

participants. EU institutions and Member State authorities should recognise the importance of community-building, social empowerment and science education in citizen science.

As a next step, these best practices will be promoted among European citizen science communities and stakeholders such as EU policy-makers, environmental authorities in Member States, citizen science networks and academia/research organisations.

This document sets out recommendations and potential actions to enhance the uptake of citizen science for environmental monitoring. The Commission will work to ensure a coordinated approach in the implementation of the recommendations across the EU.

1. INTRODUCTION AND POLICY BACKGROUND

Growing numbers of private individuals worldwide are collecting and reporting scientific information and observations about their surroundings. They are participating in thousands of citizen science initiatives that can produce valuable data about the environment and a rich set of other benefits (e.g. awareness-raising and empowerment), enabling communication, trust-building and behavioural change. However, in spite of their massive potential, the acknowledgement and use of these data by policy-makers and their uptake in monitoring and implementation remain limited.

The best practices in this document aim to demonstrate how citizen science and policy-making can be of mutual benefit, to strengthen the link between them and to facilitate and enhance the use of citizen science in the EU's environment policy-making. Building on a study of the European environmental citizen science landscape, past experience and ongoing projects and initiatives, we will identify the opportunities and challenges of citizen science in EU environment policy and highlight good practice and lessons learnt. We present a series of recommendations for specific actions to improve the uptake of citizen science in environment policy. Particular attention is given to the uptake and use of citizen-generated data as a complementary, value-adding element in monitoring and reporting; other relevant areas of environment policy are considered to a limited extent. The resulting enhanced environmental monitoring might serve different purposes, such as policy development, official environmental reporting and the formulation of environment policy indicators.

The recommendations in Chapter 5 and Annex II constitute tools and a basis for further reflection for the key actors in citizen science and environmental monitoring, including:

- EU authorities – policy-makers in EU institutions (e.g. the Commission) and other EU bodies (e.g. the European Environment Agency (EEA));
- public authorities in the Member States – national, regional and local governmental bodies, including environmental protection agencies (EPAs) and statistical offices;
- citizen science associations and networks (including civil society organisations (CSOs) and other partners) – formal organisations, usually national or regional networks promoting citizen science (see Table 1 in Section 1.3 for examples);
- citizen science communities – groups of people leading or participating in citizen science initiatives. These can be informal, grassroots groups of volunteers or organised groups taking part in projects (possibly including professionals leading or advising the initiative); and
- researchers – researchers in academia and in other research organisations.

Since citizen science is by nature based on cooperation, most of the actions do not address a single group of stakeholders, but rather target partnerships involving practitioners, researchers and public authorities across different levels of administration. The stakeholders have been consulted on several occasions¹³ and their valuable input and feedback have contributed to the development of this document and the recommendations in particular.

¹³ e.g. COST workshop (Ispra, 22 November 2018), H2020 Doing It Together Science (DITOs) event (Brussels, 3 April 2019), Environmental Governance and Compliance Forum (Brussels, 14 May 2019), EPA Network — Interest Group on Citizen Science (Zurich, 23 May 2019), DG ENV citizen science stakeholder meeting (Brussels, 10 October 2019), (written) Eionet consultation (October 2019 and February 2020).

1.1. What is citizen science?

Citizen science can be defined as the non-professional involvement of volunteers in the scientific process, commonly in data collection, but also in other phases, such as quality assurance, data analysis and interpretation, problem definition and the dissemination of results¹⁴. Other definitions exist and are under debate in the scientific community¹⁵. The level of expertise or qualifications required of the volunteers depends on the nature of the initiative. For activities such as reporting litter, none are required. Under other initiatives (e.g. FreshWater Watch¹⁶), volunteers may receive instruction or training. For initiatives in highly specialised areas (e.g. identifying lichen species), volunteers may need specific knowledge (not necessarily from professional training) in order to be able to make observations.

Citizen science entails participation by members of the public in rigorous scientific processes and measurements; this document does not cover their participation in opinion polls or personal data on participants and their views.

While citizen science is growing and attracting increasing attention from the scientific community, governments and the media, it is not a new concept in itself. It stems from a long and varied history of public participation in scientific research. For instance, participants in Austria's Phenowatch¹⁷ network have been recording observations on plant and animal lifecycle events (such as the appearance of flowers or migratory animals) at fixed locations in Austria since the mid-1800s. Similarly, volunteers in many local and national bird monitoring schemes and networks of weather and ocean monitors have been collecting data for decades (e.g. for the UK Breeding Bird Survey¹⁸, Vigie-Nature in France¹⁹, Rainfall Observers²⁰ in Scotland, the US National Weather Service programme for storm-spotters²¹).

Citizen science is well developed in the environmental domain, where it offers a unique opportunity to expand the knowledge base by mobilising lay and local knowledge, and to promote public awareness and involvement. In particular, it has been recognised that citizen science plays a critical role in advancing knowledge on biodiversity, by monitoring trends in the occurrence, distribution and status of species. The vast volume of data that can be collected in a cost-efficient manner by such a large number of volunteers dwarfs the capacity for professional monitoring. This is especially true for biodiversity monitoring over a wide area (e.g. the European continent) or timespan (e.g. several decades).

There are many different types of environmental citizen science initiatives. According to a recent study²², the majority are 'contributory', i.e. designed by academics/research organisations, but entailing the collection of monitoring data by volunteers. However, initiatives with greater public involvement in the scientific process have recently been on the rise, i.e. 'collaborative' projects (designed by researchers, with volunteers contributing data, refining project design, analysing data

¹⁴ Science Communication Unit, University of the West of England, Bristol (2013). *Environmental citizen science*, 'Science for environment policy' in-depth report for DG ENV (December 2013); <http://ec.europa.eu/science-environment-policy>

¹⁵ Auerbach *et al.*, *The problem with delineating narrow criteria for citizen science*, PNAS 30 July 2019, 116 (31) 15336-15337; <https://www.pnas.org/content/116/31/15336>

¹⁶ <https://freshwaterwatch.thewaterhub.org/>

¹⁷ <http://www.phenowatch.at/>

¹⁸ <https://www.bto.org/our-science/projects/bbs>

¹⁹ <http://www.vigienature.fr/fr>

²⁰ <https://envscot-esportal.org.uk/rainfallobs/>

²¹ <https://www.weather.gov/skywarn/>

²² Bio Innovation Service (2018), *Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices*, final report for DG ENV; <https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

and/or disseminating findings) and ‘co-created’ initiatives (volunteers and researchers work together throughout).

The value of citizen science has been widely recognised in the literature and on the ground. Here, we are focusing on its policy value, but its scientific and societal value are equally important (see also figure 1, below):

- **policy value** – citizen science can contribute to various phases of the policy-making cycle, by:
 - identifying problems or issues, by making valuable, systematic observations and bringing public concerns (with supporting scientific evidence) to the attention of decision-makers;
 - helping in the formulation of policy, e.g. by contributing to the development of policy options and assessing their potential impacts. Citizen science can facilitate the inclusion of diverse societal perspectives in decision-making;
 - increasing societal support to policy (‘ownership’), by involving people in decision-making and thereby improving understanding of environmental issues, stewardship and public decisions;
 - helping government agencies and other organisations to implement policies that are meaningful to society, following their legitimisation and public endorsement (see above);
 - helping to evaluate the impacts of policy decisions through scientific observations and investigations on the ground, thereby contributing to a climate of openness and trust and bringing forward the best practices of transparent, rigorous scientific research; and
 - supporting the monitoring of policy implementation and compliance by contributing to data collection, co-designing measurement methodologies and drawing authorities’ attention to emerging issues.

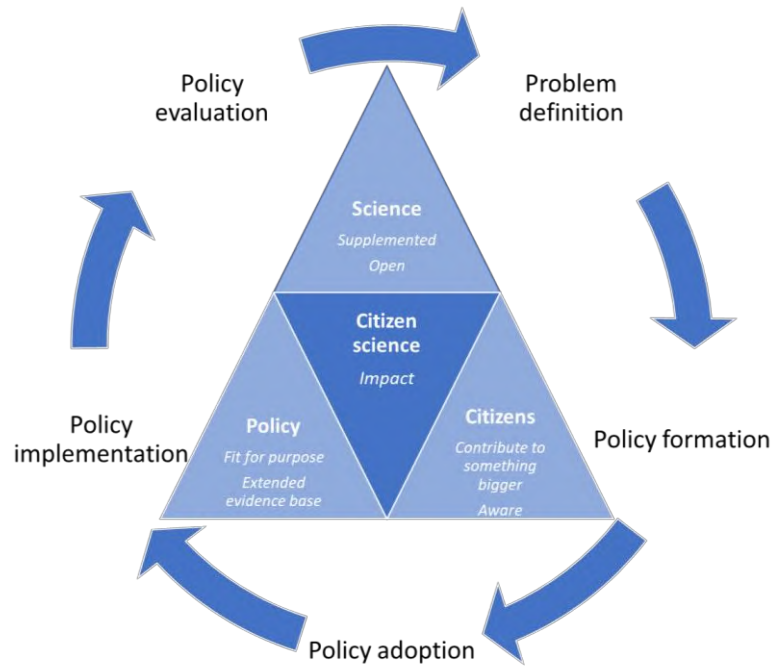


Figure 1: Three main pillars of citizen science in the policy cycle: scientific excellence, citizen engagement and policy-relevance²³

- **scientific value** – policy decisions increasingly rely on the best available scientific evidence, but this does not necessarily come only from peer-reviewed academic publications. Citizen science can complement or even improve on conventional science in many ways (see Section 2.3 **Error! Reference source not found.**). One of its primary benefits is the collection of data that would otherwise be unavailable, e.g. because of their temporal or local granularity and detail, vast time/spatial coverage, and sheer volume, etc. (see examples in Chapter 3). Key parameters for the scientific value of citizen science data are:
 - fitness for purpose;
 - documentation of quality;
 - precision;
 - spatial and temporal resolution;
 - robustness; and
 - long-term access and re-usability.

Access to and the inclusion of lay, local and traditional knowledge are equally important;

- **societal value** – citizen science initiatives empower people to draw attention to local issues, provide the evidence base to call for, propose or co-create solutions (e.g. noise abatement) and contribute to increased participation and sustained involvement. Initiatives and their outcomes can also help to:
 - raise awareness of environmental issues;
 - support life-long learning²⁴; and

²³ <https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

- prompt behavioural change — especially in relation to issues that are not immediately visible (e.g. air pollution near schools or radiation from radon and longer-term health effects).

1.2. Environmental reporting and monitoring

In the EU, information on the environment is in many cases first collected locally. Monitoring air pollution, the state of nature and biodiversity, water quality, etc. involves measuring what is happening on the ground. EU legislation requires Member States to report specific monitoring data to the Commission or the EEA. The Commission uses these data to monitor the application of EU legislation and progress on policy objectives²⁵.

The 2017 fitness check of reporting and monitoring of EU environment policy assessed the efficiency of this regulatory monitoring. It concluded that tapping into new sources of data, including data collected by the public, could help simplify and streamline reporting, and make it more reliable, thereby strengthening the evidence base for environment policy. The companion plan setting out ways of streamlining environmental reporting then called for more specific action on citizen science (see below).

The EU's efforts to increase transparency for the public, improve the evidence base for implementing EU policy and simplify reporting (thus reducing administrative burden) are further reflected in Regulation (EU) 2019/1010 on the alignment of reporting obligations in the field of legislation related to the environment²⁶, which amended several sectoral acts.

Data collected via biodiversity monitoring schemes involving individuals or networks of volunteers have been used in the context of official environmental monitoring and reporting for many years. For example, Member States have used observations from volunteers and conservation groups at national or international level (e.g. Birdlife²⁷) for official reporting under Article 12 of the Birds Directive²⁸ and Article 17 of the Habitats Directive²⁹. Several biodiversity indicators used to measure progress towards the targets in the EU's biodiversity strategy and the Aichi targets³⁰ in the 2011-2020 strategic plan for biodiversity (i.e. the streamlined European biodiversity indicators (SEBIs)³¹) rely heavily on observations by volunteers. These indicators have been used, *inter alia*, for the EU's sixth report to the Convention on Biological Diversity³². Citizen science is also used for the calculation of national biodiversity indicators (e.g. Sweden's bird monitoring³³).

Developed by the EEA and operational since 2002, Reportnet³⁴ is the current IT infrastructure supporting environmental data and information flows linked to obligatory reporting, not only to the EEA but also to the Commission and other regional and international organisations, e.g. the UN Economic Commission for Europe (UNECE). While it has no specific functionality to deal with

²⁴ e.g. <https://www.ri-tools.eu/-/citizen-inquiry-synthesising-science-and-inquiry-learning>

²⁵ It is important to distinguish between the monitoring of the environment and the monitoring of the implementation of environment-related policy. The former concerns the status of the environment and possible changes (e.g. improvement of bathing water quality); the latter concentrates on the application of agreed rules or guidelines (e.g. the reduction of plastic packaging).

²⁶ [OJ L 170, 25.6.2019, p. 115.](https://eur-lex.europa.eu/eli/oj/l/2019/170/20190625/0001/01/html)

²⁷ <http://www.birdlife.org/>

²⁸ https://ec.europa.eu/environment/nature/knowledge/rep_birds/index_en.htm

²⁹ https://ec.europa.eu/environment/nature/knowledge/rep_habitats/index_en.htm

³⁰ <https://www.cbd.int/sp/targets/>

³¹ <https://biodiversity.europa.eu/topics/sebi-indicators>

³² <https://chm.cbd.int/pdf/documents/nationalReport6/243509/1>

³³ <http://www.fageltaxering.lu.se/english>

³⁴ <https://www.eionet.europa.eu/reportnet>

citizen science data, Reportnet has been used to host data reported by civil society organisations (CSOs). Under the action plan to streamline environmental reporting, the EEA is currently updating Reportnet to enable the full use of new IT tools and standardised practices and procedures. Reportnet 3.0³⁵ will facilitate the use of complementary information sources (in particular Copernicus³⁶ and citizen science) for EU environment policy purposes, supporting reporting streams from citizen science associations and CSOs where required under submission agreements³⁷.

1.3. Citizen science in the EU and in EU environment policy

Citizen science is already supported or recognised under a number of EU policies and programmes. For instance, EU-funded research programmes have included action to promote and support it in various thematic domains and throughout the research and innovation (R&I) process:

- Under the 7th (2007-2013) framework programme for R&I (FP7), the Commission funded several projects involving citizen science, including Societize, an initiative to promote and support citizen science. Another important example is the ‘citizens’ observatories’³⁸ and their second generation, which is funded under the ‘Earth observation’ topic in Horizon 2020 (successor to FP7) societal challenge 5 (climate action, environment, resource efficiency and raw materials). The observatories are community-based environmental monitoring and information systems, e.g. on air pollution, flooding, drought or water quality. They enable the public to help observe the environment, e.g. through innovative Earth observation apps. In these areas, various aspects of the observatories’ activity are targeted besides those relating to monitoring, e.g. the co-design of experiments and protocols, and ‘ground-truthing’ (verification and/or validation) of datasets.
- The Horizon 2020 ‘science with and for society’ sub-programme aims to build effective cooperation between science and society, foster the recruitment of new talent for science and couple scientific excellence with social awareness and responsibility. With a budget of almost €500 million, it has funded actions that bring societal actors together in R&I, improve gender equality, promote open access and open data, support ethics and integrity, take due and proportionate precautions in R&I and improve knowledge on science communication. The 2018-2020 work programme puts particular emphasis on encouraging regional institutions and research funding/performing organisations to open up to society, strengthening the territorial dimension of the cross-cutting ‘responsible R&I’ priority and supporting citizen science through coordination and support actions, research and projects involving ‘hands-on’ citizen science activities across all areas of science³⁹.
- ‘Responsible R&I’ encourages societal actors to work together throughout the R&I process to align R&I and its outcomes more closely with the values, needs and expectations of society. As of January 2020, over 2,600 projects had been identified as taking such an approach (which includes citizen science) across all parts of Horizon 2020.
- Horizon 2020 also funds citizen science under its ICT programme, in particular through collective awareness platforms for sustainable and social innovation (CAPS)⁴⁰, including crowd/citizen-sensing initiatives such as the ‘making sense’ project⁴¹. Following similar endeavours under FP7⁴², the programme supports the creation of online platforms to raise

³⁵ <https://www.eionet.europa.eu/reportnet/reportnet-3.0>

³⁶ <https://www.copernicus.eu>

³⁷ <https://www.eionet.europa.eu/reportnet/docs/business-vision.pdf>

³⁸ <https://ec.europa.eu/easme/en/news/have-you-heard-about-concept-citizens-observatories>

³⁹ https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-swfs_en.pdf

⁴⁰ <https://ec.europa.eu/digital-single-market/en/collective-awareness>

⁴¹ <http://making-sense.eu/wp-content/uploads/2018/01/Citizen-Sensing-A-Toolkit.pdf>

⁴² <https://ec.europa.eu/digital-single-market/en/programme-and-projects/caps-projects-fp7>

awareness of sustainability problems and to put in place collective, cooperative solutions, by enabling people to share knowledge, make better-informed decisions as consumers, nudge collective environment-savvy behavioural change and establish more participatory democratic processes.

- Citizen science will become even more prominent under the Horizon 2020 successor programme, Horizon Europe, which will promote citizen science (as part of open science), responsible R&I and the involvement of members of the public and end-users in co-design and co-creation across the programme. In addition, impact pathway 6 on ‘strengthening the uptake of innovation in society’ (one of nine ‘key impact pathways’) starts with projects in which members of the public and end-users co-create R&I content, and a section under ‘reforming and enhancing the European R&I system’ focuses on citizen science. Overall, a high level of citizen science implementation can be expected in the missions⁴³, clusters and other parts of the programme.
- The Horizon Europe proposal also includes an ‘environmental observation’ area of intervention in cluster 6 (‘food, bio-economy, natural resources, agriculture and environment’), with citizens’ observatories seen as one of the sources of information.

With these programmes, the Commission has confirmed the important role of citizen science in contributing to knowledge creation and trust between science and society, and to (digital) social innovation, which involves developing solutions that meet social needs through an open, participatory, bottom-up and co-creative approach.

The Commission also recognised the role of citizen science in opening up and improving EU research through the European open science agenda (adopted in 2016) and the European open science cloud⁴⁴. An Open Science Policy Platform 2018 discussion paper on citizen science⁴⁵ included recommendations in its integrated advice to the Commission⁴⁶.

Public involvement is crucial for the effective delivery of EU funding for environmental goals, which is why citizen science can be included in projects supported by cohesion policy programmes. For instance, several projects under the ‘urban innovative actions’ initiative involve elements of citizen monitoring. The Air-Heritage project in Portici (Italy) is testing an innovative way of monitoring air quality and integrating it with ordinary institutional monitoring. People will contribute directly to monitoring through mobile personal exposure analysers, forming a crowd-sensing social network that will feed into a new air-quality policy decision support system for the city⁴⁷.

In EU environment policy, citizen science contributes to the implementation of the 7th environment action programme (EAP), in particular in the context of Article 3 of the EAP Decision, which requires ‘[p]ublic authorities at all levels [to] work with businesses and social partners, civil society and individual citizens’⁴⁸. Its 5th priority objective (on the improvement of knowledge and evidence base for EU environment policy) recognises the value of citizen science initiatives and calls for the strengthening of the science/policy interface and public involvement, including the accessibility of data for citizens and the contributions of citizen science.

⁴³ <https://op.europa.eu/s/nG7h>

⁴⁴ <https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud>

⁴⁵ https://ec.europa.eu/research/openscience/pdf/citizen_science_recomendations.pdf#view=fit&pagemode=none

⁴⁶ https://ec.europa.eu/research/openscience/pdf/integrated_advice_opspp_recommendations.pdf#view=fit&pagemode=none

⁴⁷ <https://www.uia-initiative.eu/en/uia-cities/portici>

⁴⁸ 7th EAP; <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN>

The significant knowledge dimension of citizen science holds great potential for further uptake in current and future environmental programmes and projects. Some examples that reflect this potential are set out in Chapter 3.

Several Commission environment policy documents call for specific action on citizen science:

- the **action plan on nature, people and the economy**⁴⁹ provides for targeted support for citizen science initiatives to promote the development and use of alternative information sources on status and trends in protected sites and biodiversity in the EU. The aim is to improve knowledge (e.g. through enhanced monitoring) and public online access to the data needed for implementing the Birds and Habitats Directives;
- in the **actions to streamline environmental reporting**⁵⁰, action 8 is ‘promote the wider use of citizen science to complement environmental reporting’. It calls for stepwise actions leading to the development of guidelines in 2019, and hence forms the basis of this document;
- in the **action plan on environmental compliance and governance**⁵¹, action 7 focuses on improving how Member States deal with public complaints, and proposes that good practice in citizen science be shared as a way to facilitate people’s submissions to public authorities⁵²; and
- the **EU pollinators initiative**⁵³ (to stop the decline of insect pollinators) sees citizen science devising cost-effective, standardised monitoring, raising awareness and involving society in the conservation of pollinators.

Member States, regions, public organisations, universities and interest groups are also supporting citizen science, e.g. by setting up networks, centres of expertise and strategies (see Table 1).

An overview of national and regional strategies and platforms in the EU is currently being compiled as part of action CAA15212 (‘citizen science action to promote creativity, scientific literacy and innovation throughout Europe’) under the ‘cooperation in science and technology in Europe’ (COST) programme⁵⁴.

Table 1: Examples of citizen science networks and centres of expertise

Country	Network	Reference
AT	Citizen Science Network Austria	https://www.citizen-science.at/
AT	Centre for Citizen Science, Austria	https://www.zentrumfuercitizenscience.at/
BE	Flemish Knowledge Centre for Citizen Science (Scivil)	https://www.scivil.be/en
DE	German Citizen Science Network	https://www.buergerschaftenwissen.de
IT	Italian SNPA Citizen Science Group	https://www.snpambiente.it
DK	Danish Citizen Science Network	https://citizenscience.dk

⁴⁹ COM(2017) 198 final; http://ec.europa.eu/environment/nature/legislation/fitness_check/action_plan/communication_en.pdf and SWD(2017) 139 final; http://ec.europa.eu/environment/nature/legislation/fitness_check/action_plan/factsheets_en.pdf

⁵⁰ COM(2017) 312 final; http://ec.europa.eu/environment/legal/reporting/pdf/action_plan_env_issues.pdf and http://ec.europa.eu/environment/legal/reporting/fc_actions_en.htm

⁵¹ COM(2018) 10 final; http://ec.europa.eu/environment/legal/compliance_en.htm

⁵² In May 2019, the Environmental Compliance and Governance Forum approved in principle a vademecum on complaint handling and citizen engagement, which refers to citizen science.

⁵³ COM/2018/395final; http://ec.europa.eu/environment/nature/conservation/species/pollinators/index_en.htm

⁵⁴ <https://cs-eu.net/about> (this work is part of working group 3 on improving the society/science policy interface).

SE	Swedish Citizen Science Network	https://medborgarforskning.se
European	European Citizen Science Association (ECSA)	https://ecsa.citizen-science.net/
European	European Network of Heads of Environmental Protection Agencies – interest group on citizen science	http://epanet.pbe.eea.europa.eu/

1.4. Citizen science at international level and outside the EU

The work of the Citizen Science Global Partnership and the European Citizen Science Association (ECSA) ensures that citizen science is promoted and exhaustively discussed in relation to the SDGs⁵⁵. Particular attention is paid to ways in which volunteer-generated data could contribute to the SDG indicator framework. Following the participation of citizen science delegations in the third and fourth (2018 and 2019) meetings of the UN Science-Policy-Business Forum on the Environment⁵⁶, these potential contributions have clearly been recognised^{57,58}.

On the basis of early reflections in 2017⁵⁹, several initiatives have recently been launched to carry out the work that is needed; this includes:

- helping the citizen science community see how it can contribute to the SDG framework⁶⁰;
- support for data management⁶¹; and
- a focus on citizen science contributions relating to Earth observation data and tools⁶².

In addition, there are particular efforts targeting single indicators, e.g. those relating to vector-borne diseases⁶³.

These ongoing, fast evolving international developments are evidence of the greater recognition of the value and potential of citizen science, e.g. its contribution to data gathering, data-collection methodologies, indicator development and assessment. In the SDG context, these activities not only address environment policy, but also have societal and economic effects. This holistic approach to sustainable development worldwide should also be considered when addressing citizen science issues in a European context.

Examples of networks and the integration of citizen science into policies at international (global) level:

- Citizen Science Global Partnership⁶⁴; and
- Citizen Cyberlab⁶⁵ (Switzerland, UN-linked).

Examples of citizen science institutions, associations and networks, and policy uptake of citizen science outside the EU:

- UK Environmental Observation Framework – working group on citizen science⁶⁶;

⁵⁵ <http://citizenscienceglobal.org/projects.html#his>

⁵⁶ e.g. <https://citizenscience.org.au/2019/02/11/citizen-science-on-the-world-stage-at-unea4-in-nairobi/>

⁵⁷ <http://web.unep.org/environmentassembly/major-groups-and-stakeholder-science-and-technology>

⁵⁸ <http://web.unep.org/environmentassembly/science-and-technology-major-group>

⁵⁹ <https://mediamanager.sei.org/documents/Publications/SEI-2017-PB-citizen-science-sdgs.pdf>

⁶⁰ <http://citizenscienceglobal.org/projects.html#his>

⁶¹ <http://www.codata.org/task-groups/citizen-science-for-the-sustainable-development-goals>

⁶² <https://www.weobserve.eu/weobserve-cop4-sdgs/>

⁶³ <http://citizenscienceglobal.org/projects.html#mos>

⁶⁴ <http://citizenscienceglobal.org/>

⁶⁵ <http://citizencyberlab.org/>

- Citizen Science Center Zurich⁶⁷;
- Participatory Science Academy, Switzerland⁶⁸;
- US Citizen Science Association (CSA)⁶⁹;
- US Environmental Protection Agency (EPA), which has published several strategic documents on citizen science, including *A vision for citizen science at EPA* and a *Handbook for citizen science quality assurance and documentation*⁷⁰;
- US Federal Community of Practice on Crowdsourcing and Citizen Science (CCS)⁷¹;
- Australian Citizen Science Association (ACSA)⁷²;
- the governments of New South Wales and Queensland (Australia) each have a strategy on citizen science^{73,74};
- Citizen Science Asia⁷⁵; and
- African Citizen Science Association⁷⁶.

⁶⁶ <http://www.ukeof.org.uk/our-work/citizen-science>

⁶⁷ <https://citizenscience.ch>

⁶⁸ <https://www.pwa.uzh.ch/en.html>

⁶⁹ <https://www.citizenscience.org/>

⁷⁰ <https://www.epa.gov/citizen-science>

⁷¹ <https://www.citizenscience.gov/>

⁷² <https://citizenscience.org.au/>

⁷³ <https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Research/Citizen-science/oeh-citizen-science-strategy-2016-2018-150859.pdf>

⁷⁴ <https://www.chiefscientist.qld.gov.au/strategy-priorities/queensland-citizen-science-strategy>

⁷⁵ <https://www.facebook.com/CitSciAsia>

⁷⁶ <https://techmoran.com/2017/12/07/usi-africa-to-host-the-first-african-citizen-science-association/>

2. USING CITIZEN SCIENCE FOR ENVIRONMENTAL MONITORING AND REPORTING – OPPORTUNITIES, CHALLENGES AND POTENTIAL BENEFITS

Citizen science is not a new concept, especially in the environmental domain. However, ICT developments in the past decade and growing calls for public involvement and transparent policy-making have created new opportunities and fuelled rapid change in approaches and practices. The citizen science community has not only grown, but also become more organised (nationally and internationally). This has attracted increasing interest, including from public authorities at all levels, who themselves are trying to make policy processes more accountable to citizens and more knowledge-based. The Commission's ambitions under the Green Deal can be expected to increase the need to tap into sources of information that can complement the knowledge base for environment policy development and monitoring. Below we highlight the new opportunities relating to environmental monitoring and reporting, set out the challenges and single out potential benefits in terms of stronger links between citizen science activities and EU environment policy.

2.1. New opportunities

The digital revolution has given us new tools for sharing, collecting and processing large volumes of information. These include the ubiquitous presence of (broadband) internet, the easy availability of mobile tools (such as dedicated apps and smart devices) and big data analytics.

In addition, the rise of social media makes it easier to promote and encourage participation in citizen science initiatives among interested communities (and beyond). Participatory approaches to societal issues easily attract mass attention on social media.

The abundance of scientific information, education and awareness-raising activities (fairs, youth camps, museum events, TV programmes, etc.) helps to build science literacy, trust and recognition among the general public. Citizen science initiatives can both benefit from and contribute to science education, and can raise environmental awareness, which in turn can lead to behavioural change.

Many citizen science communities are already active across the EU, often with a local or regional action radius. In some cases, committed volunteers work with professional researchers when designing projects and/or processing data. In some, CSOs provide coordination and support. In others, governmental authorities are directly involved, with a view to improving their own communication with the public and public services. Knowledge exchange is enabled via regional, national and international associations.

The public expects governments to make transparent, evidence-based policies and decisions. In response, EU policy-makers and institutions are adopting increasingly open, transparent and participatory decision-making processes, as reflected in initiatives such as the Union of Democratic Change⁷⁷, 'better regulation'⁷⁸, 'e-government'⁷⁹ and 'open data'⁸⁰ (the digital single market) and the EU's implementation of the Aarhus Convention in the area of access of justice in environmental matters⁸¹, etc. This also applies to the SDGs, which offer opportunities for citizen science at several stages: setting national and subnational targets and metrics, monitoring progress and taking action^{82,83}.

⁷⁷ <https://www.parlementairemonitor.nl/9353000/d/political%20guidelines%20-%20juncker%20commission.pdf>

⁷⁸ https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en

⁷⁹ <https://ec.europa.eu/digital-single-market/en/european-egovernment-action-plan-2016-2020>

⁸⁰ <https://ec.europa.eu/digital-single-market/en/open-data>

⁸¹ <https://ec.europa.eu/environment/aarhus/>

⁸² <https://mediamanager.sei.org/documents/Publications/SEI-2017-PB-citizen-science-sdgs.pdf>

⁸³ <https://www.nature.com/articles/s41893-019-0390-3>

The public sector is influenced by similar drivers. In the context of ‘better regulation’⁸⁴ and a renewed interest in artificial intelligence (AI)⁸⁵, there is a relentless push to innovate in public services, engage more with the public, make use of emerging technologies and establish pan-European data spaces⁸⁶.

Citizen science activities offer an under-used, cost-efficient additional source of knowledge and feedback in the monitoring of the environment and the implementation of environment policies. This includes non-traditional data sources, analytical capacities, opportunities for engaging with citizens and possibilities for knowledge exchange (learning). With the environmental ambitions under the Green Deal, public authorities will be even more driven to tap into citizen science initiatives, communities and outputs, to expand their knowledge base in key areas such as biodiversity, pollution, circular economy, climate change and sustainable food.

In the EU’s R&I policy programmes, open science, open innovation, and responsible R&I are all explicit drivers of public involvement, manifesting variously as citizen science, user-led innovation and ‘quadruple helix’ approaches⁸⁷ to knowledge-gathering and innovation. Increasingly, research funding/performing organisations and regional/local authorities are recognising these approaches, which could in turn open up new opportunities for environmental monitoring based on citizen science.

2.2. Challenges and obstacles

The uptake of citizen science in policy-making is still limited. While some initiatives have been massively successful in supporting environmental action, at both EU and Member State levels (e.g. e-Bird for conservation planning, the European bird index for biodiversity and agricultural policies), the evidence⁸⁸ points to a gap between the policy relevance and policy uptake.

Obstacles relating to design and organisation:

- ✦ **long timescales and resources needed** – connecting knowledge needs for policy-making and implementation and creating a network of interest for environmental monitoring is a long process that requires sustained motivation and resources at the right levels of administration (local, regional, national and international). Some initiatives suffer from inadequate funding, in particular for the continuation of activities and maintenance of the community. This is a key challenge in achieving policy linkages, since many policy-relevant initiatives need medium/long-term effort to operate over an appropriate timescale. For example, the collection of data for monitoring indicators requires systematic design and long time-series to be rigorous and useful; this can be expensive⁸⁹. At the same time, there is a lack of mechanisms for incorporating potentially useful short-term (maybe even one-off) environmental monitoring activities into institutionalised processes;
- ✦ **resistance from public authorities** – policy-makers are not always convinced of the added value of citizen science. Obstacles include doubts as to data quality (see also below), reluctance to embrace change in traditional working methods, and incumbent ownership and responsibilities in

⁸⁴ https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en

⁸⁵ <https://ec.europa.eu/digital-single-market/en/artificial-intelligence>

⁸⁶ <https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy>

⁸⁷ A process-based approach to innovation that emphasises the interactions of four different types of societal actors: government, civil society, academia and industry.

⁸⁸ *Citizen science for environmental policy — development of an EU-wide inventory and analysis of selected practices*, published 7 December 2018;

<https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

⁸⁹ For example, the cost of each of the UK headline biodiversity indicators that rely on citizen science data has been estimated at around £100,000 a year (Roy, H.E. *et al.*, *Understanding citizen science and environmental monitoring*, final report on behalf of UK EOF, NERC Centre for Ecology and Hydrology).

reporting processes. Also, an initiative has to stand out in order to reach policy-makers and insufficient visibility can be an issue;

- ✘ **difficulty in identifying relevant policy strategies and linkages** – in a dynamic policy landscape, it can be difficult for leaders of initiatives to identify relevant policy priorities. Moreover, policy linkages are typically complex and an initiative's policy relevance is often indirect;
- ✘ **barriers to the involvement of the scientific community** – potentially, academic researchers and research organisations could support all phases of citizen science initiatives, e.g. to help ensure data quality. However, such involvement is not always easy to secure, and the lack of rewards and incentives in the academic world to engage in such work and lack of guidance or even awareness in the scientific community of how to do so, means that it is not necessarily easy for researchers/academics to engage with initiatives in a constructive and co-creative manner;
- ✘ **lack of transparency, feedback and acknowledgement** – it is often difficult for organisers of initiatives to ascertain whether their work is used and, if so, by whom and how. However, it is usually key for citizen scientists that their contributions are valued and acknowledged. The voluntary nature of the work may also give rise to a need for clarification, e.g. as regards data ownership, insurance-related matters, intellectual property rights and restrictions on access to and the use of potentially personal (or other sensitive) data, some of which might be required in order to provide adequate feedback and reassure the communities and institutional actors in question;
- ✘ **overall protocol and language complexity** – the linkages to policy are often complex and inefficient, and can make excessive use of technical or specialised jargon. This can make the policy relevance difficult to communicate and impair its use as a lever for encouraging engagement. Similarly, high scientific data standards and complex monitoring protocols in relation to some projects can affect the accessibility and attractiveness of the activity, especially if scientifically elaborate monitoring equipment is required. The clarity of the issue to be addressed, i.e. the aim of the activity, is another important factor;
- ✘ **mobilising participants** – with an increasing number of initiatives calling for volunteers, those with a policy linkage need to stand out and appeal to the most appropriate target groups in order to mobilise a sufficient number of participants. On the one hand, this is a coordination challenge (e.g. to avoid 'reinventing the wheel' or addressing issues with little impact). On the other hand, people may be more motivated to act on issues that are obvious and of immediate concern (e.g. rubbish on the street, noise) than on less visible issues (e.g. health risks from radon);
- ✘ **sustaining engagement** – once the novelty has worn off, it can be difficult to keep citizen scientists motivated over the long term (although not all initiatives have a long-term objective) or to attract replacements ('monitoring fatigue'). Another obstacle to sustaining engagement arises when the connection between the source of a problem and its impact is not clear (e.g. because they do not occur in the same place). This can make it difficult for people to relate to the issue and thus to maintain motivation;
- ✘ **lack of guidance** – a lack of guidance on how to organise citizen science activities can be an issue, as can academic involvement with and support for CSOs that develop activities. All actors need to be prepared to take different supporting roles and share responsibilities in order to exploit the opportunities of citizen science for environmental monitoring and reporting;
- ✘ **risk of disguised lobbying / biased data / conflicts of interest** – a 2015 *Nature* editorial highlighted the risk of results being distorted by citizen scientists' personal motivation⁹⁰.

⁹⁰ <https://www.nature.com/news/rise-of-the-citizen-scientist-1.18192>

However, in a joint response⁹¹, three networks stressed that statistical testing and good design are used to identify and minimise bias in citizen science outcomes, and that much is done to uphold research integrity and promulgate best practice. In any case, the risk of bias calls for full transparency on methodology and data quality assurance;

- ✦ **governance across different levels (local/national/EU)** – upscaling or integrating a successful local initiative to EU-wide level can open up opportunities for use in policy implementation, but it can be difficult to establish the additional layer(s) of coordination/governance. In addition to the organisational aspects, priorities may differ between regions and between local and national/pan-European levels (e.g. due to differences in demography, political environment, social ecosystem, climatic and environmental conditions, etc.). However, in some cases overarching issues (and solutions) only surface at wider geographical levels. Challenges of governance can also arise when a successful approach is ‘exported’ from one local context to another (‘spreading’). Cultural differences and language barriers must also be taken into account;
- ✦ **missing overview** – it remains difficult to retain an up-to-date overview of activities, issues and unused potential. While activities with wider geographical coverage are often highly visible and produce recent information (as proven by an EU-wide study on initiatives relating to environment policy⁹²), it is difficult to get an overview of local and regional activities. This creates challenges, because solutions cannot be easily identified and transferred to other regions or municipalities in need; and
- ✦ **possible reluctance to work with governmental institutions** – in some cases, practitioners of grassroots citizen science (i.e. activities carried out primarily in response to community needs) might be reluctant to work closely with the government. Without such cooperation (especially where activities were initiated due to distrust in governmental decision-making), it is difficult to have the results recognised by policy-makers. The community (or its members) might want their data and knowledge to be used for better decision-making, while maintaining their independence.

Data-related challenges/obstacles:

- ✦ **data quality** – policy-makers often do not trust citizen science data. It is difficult to establish the right balance between ensuring sufficient data quality and not deterring potential participants. Quality assurance requires attention even before an initiative begins, e.g. through the availability and use of good quality guidance, smart project design (co-creation with researchers from academia/research organisations) and training for citizen scientists and project managers. Data quality assurance and validation are crucial if citizen-generated data are to complement data from more traditional sources. Good documentation and communication on quality assurance are key in reassuring potential data users. This also applies where quality concerns are based on prejudice rather than real shortcomings;
- ✦ **risk of inconsistency in information acquisition and processing, and thus overall quality** – academic data are produced according to a tradition of rigorous accountability, quality control and peer review. Complementing them with non-academic data creates new challenges and new support tools are required to ensure the requisite overall quality. It is important to know the ‘pedigree’ of data (i.e. to have a standardised description of the mode of production and the anticipated use), in order to ensure consistency when processing and communicating scientific information. It is also difficult to grasp the weight of evidence in citizen science data and the degree of underlying uncertainty;

⁹¹ <https://ecsa.citizen-science.net/blog/citizen-science-community-responds-nature-editorial>

⁹² Published 7 December 2018;

<https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

- ✘ **achieving appropriate data scalability** – it is difficult to provide data that, if relevant in terms of spatial and temporal scale, can reach all required administrative levels (from local to EU-wide and *vice versa*), given the cultural diversity and different opportunities to engage with local and regional stakeholders across Member States. Many local projects do not achieve sufficient geographical coverage to be relevant for EU monitoring purposes (e.g. where national coverage is needed);
- ✘ **data heterogeneity / integration of citizen science data with other public (or private) information** – currently, many citizen science initiatives determine their own data structures (due to a lack of common standards and collection methods) and remain fragmented as a result. There can also be differences/issues in definitions and the time/spatial resolution of variables. This is due to the local nature of many initiatives and often a lack of a standard-based coordinating structure at higher levels. Mismatches (in terms of structure, definitions and/or resolutions) between datasets and *vis-à-vis* policy-makers' data needs can deter public authorities' use of (even good-quality) data;
- ✘ **different data policies and data management principles** – research has identified a need for guidance and training on the importance of data licences, clear data access and use conditions^{93,94}. This is because data management practices vary widely across citizen science activities and limited use is made of common standard licence schemes providing a clear indication of data ownership and conditions for re-use. It is also unclear whether current standards cover the most important cases of intended re-use;
- ✘ **data protection and handling of sensitive information** – citizen science (and other) communities are still coming to terms with the implications of the General Data Protection Regulation (GDPR)⁹⁵. Issues related to the application of the GDPR such as how to obtain valid consent, the identification of data controllers in decentralised initiatives and the anonymisation of data may bring challenges to citizen science activities. Beyond the scope of the GDPR, the handling of certain types of sensitive information (e.g. on vulnerable species, nesting of rare birds, etc.) also requires further consideration;
- ✘ **balance/representativeness of data** – depending on the arrangements for the activity in question, the demography of participants might be unbalanced. Typically, the result is that data may be biased depending on access to territory, participants' knowledge, population density, educational or economic background, etc. It is still difficult to describe clearly and track potential and actual bias in participation and outcomes, but this is important when interpreting the knowledge generated and considering its use for decision-making;
- ✘ **embracing innovation at different rates** – due partly to the fast development and wide accessibility of technology, many approaches, tools and platforms provide data that are potentially useful for environment-related policy-making. This poses challenges of data integration and can quickly lead to a plethora of sources producing incompatible data. The nature of citizen science initiatives means that some embrace innovation faster than similar official processes. The data may be better, but it may be difficult to integrate them into established data flows. Cooperative approaches could help the public sector to stay 'ahead of the game'⁹⁶; and
- ✘ **lack of data traceability** – impact assessment and feedback on scientific and other applications are hampered by a lack of established data traceability methods. It remains difficult to tell:

⁹³ JRC, [Survey report: data management in citizen science projects](#)

⁹⁴ First Monday article '[Scientific data from and for the citizen](#)'

⁹⁵ Regulation (EU) 2016/679; https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en

⁹⁶ AQ example: [Joint statement on new opportunities for air quality sensing — lower-cost sensors for public authorities and citizen science initiatives](#)

- whether/when data have been taken on board;
- how they have been used for knowledge creation and decision-making; and
- from whom they originate.

2.3. Expected benefits

- ✓ **improved knowledge base** – citizen science can generate new data, uncover new issues and add (upwards or downwards) scalability to existing data. In particular, the data can complement existing (government-led) monitoring schemes, with a potential for gap-filling through increased data volume with greater time/spatial coverage and/or higher resolution. A review of best practice suggests that, where a business model for sustained financing is embedded in the governance process, citizen science may represent a long-term data resource;
- ✓ **more accountable, informed open society** – citizen science leads to a better-informed public and more transparent data. People can see how the data to which they have contributed are used for decision-making and science. In the best cases, they can be involved in the decision-making process. Citizen science raises awareness of environmental issues and can lead to behavioural change, through improved science literacy and information-sharing in networks and communities of interest (e.g. the transfer of species knowledge, where volunteers ‘teach’ other volunteers about particular species). It also helps to establish working relationships, distribute responsibilities and build trust between stakeholders;
- ✓ **timely reaction and pro-active approaches** – citizen science makes it possible to identify and solve problems more quickly. It is particularly useful for detecting rare events (e.g. pests, pathogens, invasive species and diseases). The use of mobile sensors and other devices in combination with online data platforms enables the near real-time availability, processing and visualisation of measurements and observations. This can also speed up the detection of changes/trends in environmental indicators (shorter time-lag than with ‘conventional’ reporting);
- ✓ **fit-for-purpose use and re-use** – citizen science widens the evidence base for policy-making, by providing new or complementary evidence at the right scale. In particular, it can help bring local problems (e.g. river pollution⁹⁷) to light. While its use might differ from local to international contexts, contributions can suit several purposes, i.e. be relevant at various administrative levels and to various institutions. For instance, some initiatives generate data of a geographical granularity and timescale (and quality) fit for EU-wide official indicators (e.g. bird monitoring);
- ✓ **societal relevance of policy measures** – by improving our understanding of people’s needs and expectations, citizen science can ensure that policies are more socially relevant. It contributes to the dialogue between policy-makers and society (uptake and use in relation to policy);
- ✓ **more inclusive and participatory socio-scientific-policy ecosystems** – citizen science can help establish a direct connection between real-life actions and policies, and it can open up participation to different stakeholder groups. It can raise policy-makers’ and stakeholders’ awareness of certain environmental issues (e.g. identify new problems) and provide starting points for further investigation, including evidence and established partnerships. It can shift research agendas towards more practical and relevant questions, e.g. in the case of nature conservation;
- ✓ **better value for money** – arguably, citizen science can provide better value for money than traditional scientific methods^{98,99,100}. In particular, it allows for the densification of observation

⁹⁷ <https://freshwaterwatch.thewaterhub.org/>

⁹⁸ See, for example, Wilson, E. *et al.* (2018), *A review of the biological recording infrastructure in Scotland by the Scottish Biodiversity Information Forum: Enabling Scotland to be a global leader for biodiversity* (Scottish Biodiversity Information Forum commissioned report no 1), which claims that investment in the biological recording infrastructure

networks at lower cost and provides decision-makers with low-cost, high-granularity and timely information, thus helping to innovate public services. At the same time, it also adds value to deliberation, life-long learning, environmental awareness and (possibly) behavioural change. However, its cost-effectiveness compared with other options should not be taken for granted (citizen science can entail costs not associated with other forms of science);

- ✓ **empowering people** – policy-relevant citizen science rewards volunteers primarily by enabling them to increase their awareness and contribute to something of general importance. They can be empowered through their involvement in solving local problems and can sometimes be the force behind regulatory change. This is particularly important for vulnerable groups in society, who may have a low perception of their agency: by contributing with their actions to the improvement of their conditions, perceived self-efficacy will increase, and the likelihood of exclusion will decrease¹⁰¹.
- ✓ **creation of networks and partnerships** – citizen science may create new communities of interest and improve social connections and the sense of belonging. Most initiatives bring together actors and communities who would never cooperate otherwise. Thereby, they help to establish new paradigms of communication — with or without the use of new technologies; and
- ✓ **making evidence-based policy-making more open and transparent** – citizen science often goes hand in hand with open data access and data-sharing policies, and brings about more responsible, fairer and more accessible research and policy-making.

offers an impressive cost-benefit ratio (conservative estimates indicate that every £1 invested underpins £10-23.50 of economic value), which is only possible due *inter alia* to the scale of volunteer participation and the depth of expertise and rich knowledge about the ecology, occurrence and status of species;

<https://nbn.org.uk/wp-content/uploads/2018/11/SBIF-Review-Final-Report-and-Recommendations.pdf>

⁹⁹ In France, annual savings of € 1–4 million have been estimated as a result of the citizen science biodiversity monitoring programme of the National Museum for Natural History (Levrel H., Fontaine B., Henry P., Jiguet F., Julillard R., Kerbiriou C, and Couvet D. (2010). ‘Balancing state and volunteer investment in biodiversity monitoring for the implementation of CBD indicators: a French example’, *Ecological Economics* 69, no. 7: 1580–6). In the United States, analysis of 238 citizen science biodiversity projects around the world estimated that the in-kind contributions of 1.3-2.3 million volunteers had an economic value of up to \$2.5 billion per year (Theobald E.J., Ettinger A.K., Burgess H.K., DeBey L.B., Schmidt N.R., Froehlich H.E., Wagner C. *et al.* 2015. ‘Global change and local solutions: tapping the unrealised potential of citizen science for biodiversity research’, *Biological Conservation* 181: 236–44).

¹⁰⁰ A cost-benefit analysis also turned out favourable, for instance, for the surveillance of invasive disease-carrying mosquitoes in Spain through citizen science (Mosquito Alert); see John R.B. Palmer *et al.*, ‘Citizen science provides a reliable and scalable tool to track disease-carrying mosquitoes’, *Nature Communications*, 8.916 (DOI: 10.1038/s41467-017-00914-9).

¹⁰¹ DellaValle, Nives, and Siddharth Sareen. "Nudging and boosting for equity? Towards a behavioural economics of energy justice." *Energy Research & Social Science* 68 (2020): 101589.

3. CURRENT AND POTENTIAL USES OF CITIZEN SCIENCE FOR ENVIRONMENTAL MONITORING

Data and knowledge from ongoing and past citizen science initiatives have had an impact in various areas of environment policy and legislation. In some cases (e.g. bird and butterfly observations), citizen science has provided data on a scale or with a granularity that would not be available otherwise and that have become an essential basis for policy implementation. In other cases, volunteers have helped to reveal problems (e.g. air pollution in rural areas, illegal dumping sites) not adequately covered by existing monitoring networks.

The examples below illustrate the valuable contribution of citizen science to environmental monitoring, reporting and policy-making in various areas. Further details and references are available in Annex I. A more comprehensive inventory (available online¹⁰²) has been analysed in *Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices*¹⁰³.

Biodiversity monitoring is one of the longer-standing areas of citizen science involvement. Observations collected by millions of volunteers across Europe, in some cases over decades, have been fed into detailed species maps. Such coverage and granularity could not be achieved through official monitoring alone, and have provided essential input for policy-makers. Examples of this include:

- the pan-European common bird monitoring scheme (PECBMS)¹⁰⁴, which collects bird observations from a network of volunteers. The PECBMS common farmland bird index and EU common bird index are recognised indicators for biodiversity monitoring in Europe and have been used:
 - to assess Member States' rural development plans;
 - for monitoring the EU biodiversity strategy to 2020 and progress on the SDGs; and
 - in the common agricultural policy (CAP) monitoring and evaluation framework;
- the European butterfly monitoring scheme¹⁰⁵, under which thousands of volunteers in around 20 countries collect data that are used to calculate the European butterfly indicator for grassland species, which covers 17 species of butterfly. The indicator is important for assessing progress under the EU's biodiversity strategy, reporting to the Convention on Biological Diversity and assessing progress on the SDGs. The EU-funded 'assessing butterflies in Europe' (ABLE) project¹⁰⁶ is currently extending the scheme to southern and eastern Europe. In 2020, an additional EU-funded action, initiated by the European Parliament, will further strengthen the butterfly monitoring scheme. With a budget of €5 million, the action will also support implementation of EU-wide monitoring schemes for bees, hoverflies and moths, and citizen science will play an essential role in monitoring these other insect pollinators. All these activities come under the EU pollinators initiative, which aims to establish a common EU pollinator monitoring scheme;
- the 'invasive alien species Europe'¹⁰⁷ app, an interesting EU-level example of a new top-down (EU-institution) approach, where a policy need was recognised following the publication of

¹⁰² <http://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004>

¹⁰³ Published 7 December 2018: <https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

¹⁰⁴ <https://pecbms.info/>

¹⁰⁵ <https://butterfly-monitoring.net/>

¹⁰⁶ <https://butterfly-monitoring.net/able>

¹⁰⁷ <http://digitalearthlab.jrc.ec.europa.eu/app/invasive-alien-species-europe>

implementing regulations in 2016, 2017 and 2019. In particular, the requirement for EU-wide monitoring of invasive alien species of Union concern led several countries to consider involving citizen scientists through mobile apps. In close consultation with stakeholders, arrangements were proposed for EU-wide data collection, validation and sharing. The Commission's Joint Research Centre (JRC) developed the dedicated app, whereby people can record field observations (including pictures, locations and other details) that, after validation, are fed into the European alien species information network (EASIN)¹⁰⁸. The data supplement Member State authorities' official surveillance on the distribution of invasive alien species, thus facilitating the adoption of effective prevention, early detection and control measures, and reducing ecological and economic damage;

- *Artportalen*¹⁰⁹ (Sweden's species observation system), which is a freely accessible reporting system and data repository. *Artportalen* is financed by Sweden's EPA and represents the most comprehensive database on Swedish biodiversity, with over 60 million observations from citizen science monitoring programmes and research projects. The data are used routinely by all government authorities, agencies and many environmental consultancies to monitor biodiversity, invasive species and changes in species distribution. For instance, they form the basis of the Swedish 'red list' of threatened species. Other European countries with similar biodiversity portals include:
 - Estonia¹¹⁰, which has a portal for data on protected and invasive alien species;
 - Norway¹¹¹, where citizen science accounts for over 67% of observations of species occurrences; and
 - the Netherlands¹¹², which has a portal for registering observations of flora and fauna; and
- Germany's *Mückenatlas* ('mosquito atlas'), which was launched in 2012 to support research on mosquito monitoring and has become one of the few reliable data sources on mosquitoes and their distribution. Based on people's observations, the *Mückenatlas* collects basic data on the time/spatial distribution and ecology of mosquito species in Germany. This is particularly important given the paucity of knowledge on mosquitoes' phenology, regional occurrence, habitats, ecological requirements and vector competence and capacity. The *Mückenatlas* has received over 150,000 specimens of the 50 known mosquito species occurring in Germany, all of which have been identified and recorded in a national database. The Federal Ministry of Food and Agriculture uses the results to understand the possible spread of mosquito-borne diseases and to design management strategies.

The **waste and litter** (in particular, plastic) accumulating in Europe's seas and rivers, and along its coasts, pose a growing threat to the marine/riverine environment. On land, illegal dumping pollutes natural areas and other public spaces. Members of the public can play a major role in collecting data and information to help authorities manage and prevent litter, fill data gaps and raise public awareness. Examples of citizen science activities and programmes in this domain across the world include:

- Marine Litter Watch¹¹³, coordinated by the EEA since 2014, under which local groups (NGOs, civil society initiatives) record information on litter collected during clean-up and

¹⁰⁸ EASIN is the designated information system facilitating the implementation of EU Regulation 1143/2014 on invasive alien species;

<https://easin.jrc.ec.europa.eu/easin>

¹⁰⁹ <https://www.artportalen.se/>

¹¹⁰ http://loodus.keskkonnainfo.ee/lva_kaart/

¹¹¹ <https://artskart.artsdatabanken.no/>

¹¹² www.telmee.nl

monitoring operations. The data are collected using a mobile app that sends observations to a central database with a real-time viewer. The project has helped improve the evidence base for monitoring progress on the main objective of the Marine Strategy Framework Directive – ‘good environmental status’ of Europe’s seas by 2020 – in particular as regards marine litter (descriptor 10). It also contributes to the evidence base for the strategy on plastics and the recent Single-Use Plastics (SUPs) Directive, e.g. by identifying the 10 types of litter most commonly found on beaches. Other important EU policy links are the circular economy package waste reduction targets for 2020 (30% headline reduction for top 10 items found on beaches) and the EU-wide 2020 quantitative headline reduction target under the 7th EAP; and

- Zero Waste Scotland’s ‘dumb dumpers’ project¹¹⁴, which illustrates the potential for citizen science to map and report fly-tipping, in liaison with Member State authorities. A one-stop shop set up in 2004 to help individuals report incidences of illegal waste disposal (e.g. old tyres) has helped in the development and evaluation of better, more focused policy to address this issue, which (according to a 2010 estimate) costs Scottish local authorities about £11 million a year.

Water quality: surface water and wetlands provide habitats for many living species, and other important ecosystem services (e.g. water provision, carbon capture and storage). However, only 40% of Europe’s surface water bodies are in good ecological status¹¹⁵. Although (chemical) water pollution is often less visible than litter, members of the public can help to monitor water quality; examples include:

- FreshWater Watch¹¹⁶, which was launched in 2012 to support water-quality testing using various tools (e.g. a dedicated app in several languages, data storage on a secured open access data platform, online learning material, etc.). The initiative provides phosphate, nitrate, algal bloom and turbidity data that complement regulatory monitoring. As a global initiative, FreshWater Watch informs policy-making in various parts of the world, e.g. Indonesia, China, the UK and Brazil; specific examples include the following:
 - the UK Environment Agency used FreshWater Watch records as an early warning system for pollution incidents that were likely to lead to non-compliance with standards under the Water Framework Directive; and
 - together with WWF Zambia and Earthwatch Europe, Zambia’s Water Resources Management Authority adopted this approach in 2018 to meet ministerial and local objectives to improve catchment management and national reporting.

Air pollution is a critical threat to public health, estimated as causing hundreds of thousands of premature deaths across the EU. While EU regulations lay down strict arrangements for the measurement of ambient air quality using standardised reference methods, there is growing interest in the use of inexpensive sensors to increase the spatial resolution of monitoring at a lower cost, with many citizen science initiatives already launched, including by public agencies¹¹⁷. The quality of the sensor measurements still calls for careful interpretation and use of the results. Examples of activities in this area include:

- the work of the Dutch National Institute for Public Health and the Environment (RIVM) in collating and publishing air pollution (PM10, PM2.5, NO₂) data collected by volunteers

¹¹³ <https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch>

¹¹⁴ <https://www.zerowastescotland.org.uk/DumbDumpers>

¹¹⁵ EEA report on *The European environment — state and outlook 2020*; <https://www.eea.europa.eu/soer-2020>

¹¹⁶ <https://freshwaterwatch.thewaterhub.org>

¹¹⁷ EEA Report No 19/2019 Assessing air quality through citizen science: <https://www.eea.europa.eu/publications/assessing-air-quality-through-citizen-science>

(e.g. in the framework of the *Sensor.Community* citizen science initiative¹¹⁸), and sharing the results as open data on its *Samen meten*¹¹⁹ ('measuring together') portal. Initial results show that low-cost sensors can be a valuable addition to traditional air-quality monitoring. RIVM is testing ways to correct and calibrate the data for use in official monitoring, and Dutch officials are already using the data for experimental modelling¹²⁰;

- *CurieuzeNeuzen Vlaanderen* ('nosey parkers', Flanders)¹²¹, an initiative under which 20,000 people measured the air quality near their homes in May 2018. The aim was to compile a detailed map of air quality across Flanders (Belgium), both in cities and in the countryside, building on a similar initiative in Antwerp in 2016 (2,000 participants). The large-scale dataset also served to validate atmospheric chemical transport models used by the Flemish Environment Agency (VMM) to estimate air-quality levels. Participants were asked to install a simple, standardised measurement device on a street-facing window of their house, apartment or building. Two passive samplers (Palmes diffusion tubes) determined the mean concentration in the ambient air of nitrogen dioxide (NO₂), an important indicator for traffic pollution, over 1 month (May 2018). The samplers were attached to a V-shaped window panel (as commonly used for 'for sale' signs) in order to standardise the measurement apparatus and publicise the initiative. The data were quality-controlled and calibrated with NO₂ measurements at reference VMM monitoring stations. The 2016 and (especially) 2018 campaigns had real societal, scientific and policy impacts, triggering political debate around air quality at all levels of government. Crucially, the initiative has catalysed and contributed to growing concern about traffic-related air pollution, confirming its high variability from street to street, not only in cities but also in rural areas, and highlighting personal responsibility. It has led to other similar initiatives across Europe, such as the pan-European CleanAir@School initiative¹²², run by the European Network of Environmental Protection Agencies and coordinated by the EEA, which aims to raise awareness of air quality around schools; and
- the Horizon 2020 D-NOSES project¹²³, which tackles odour pollution by empowering people to drive change in their community by means of tools to map and measure the problem, and to work towards solutions with key stakeholders. In local studies in 10 countries in Europe and elsewhere, people report odour pollution using the OdourCollect app. The real-time observations are validated by experts, correlated with industrial processes and fed into local solutions co-designed with stakeholders, thus engaging the public in local decision-making. Also, all relevant data and information are gathered, mapped and made available via the International Odour Observatory, which has generated a map of communities affected by odour pollution and a global map of odour regulations. The project will also produce a green paper and a strategic roadmap for governance in odour pollution, which will form a basis for future regulations.

Environmental noise is also a major problem, with at least 20% of the EU population living in areas where it is considered harmful to health¹²⁴. More people will be affected as a result of urban spread and increased mobility demands. Several initiatives have been launched to involve the public in mapping noise pollution (e.g. by recording sound levels) to inform local authorities. The accuracy of

¹¹⁸ Sensor.Community promotes and facilitates the building and use of low-cost sensors for air pollution (in particular, fine particles PM10 and PM2.5) and its open sharing and visualisation. Thousands of citizens all over the world have bought and assembled a sensor and Sensor.Community visualises the measurements on maps.

¹¹⁹ samenmeten.rivm.nl

¹²⁰ <https://samenmeten.rivm.nl/uurkaart/>

¹²¹ <https://curieuzeneuzen.be/>

¹²² <https://www.eea.europa.eu/themes/air/cleanair-at-school>

¹²³ <https://dnoses.eu/>

¹²⁴ EEA report on *The European environment — state and outlook 2020*; <https://www.eea.europa.eu/soer-2020>

the measurements depends on the technology used, weather conditions and other factors that deserve careful consideration. One example is:

- the Hush City app¹²⁵, which uses a novel mixed methodology to identify, assess and plan urban ‘everyday quiet areas’ — small peaceful spots at walking distance from the places we work and live. Whereas traditional plans of quiet areas in agglomerations generally include huge parks and green areas identified according to acoustic criteria, Hush City’s inventor argues that people’s preferences should also be a factor, in line with the ‘soundscape’ approach¹²⁶. She also argues that ‘everyday quiet areas’ should be identified and protected, as required by the Environmental Noise Directive (2002/49/EC). The app was set up as a tool enabling people to identify and evaluate such areas. Its design targets parts of the Directive, using a citizen science approach. The results of a successful pilot in Berlin (in cooperation with the Berlin Senate) were fed into the Berlin noise action plan (2018-2023). Several other cities, in Europe and elsewhere, have started to use the app for local policy development.

Flood risk is another area in which citizen science can make a contribution, by helping to alert communities of floods in real time (early warning and mitigation). Examples of local flood warning schemes involving community groups include:

- a citizens’ observatory in the Brenta-Bacchiglione catchment (Italy) to support the flood risk management plan for the Eastern Alps hydrographic district. Funded by the Italian Ministry of Environmental and Protection of the Territory and the Seas (MATTM), the project provides useful data for the implementation of the Floods Directive, in line with the Water Framework Directive. The plan is to supplement the monitoring network with traditional and innovative low-cost sensors in order to improve the accuracy and reliability of early warning systems. The project is expected to improve emergency protocols and reduce response times, involving members of the public across more than 100 municipalities in the region.

Plant protection products (pesticides) represent a major pressure on the environment (in particular biodiversity and water) and human health. However, the quality of data on the impacts is still inadequate. Currently, Member States report annual data on pesticide sales and on their actual use (on selected crops) every 5 years; both datasets tend to be incomplete and unharmonised. There is currently no EU-wide initiative to collect data on the presence of pesticides in the environment. However:

- the EU-funded INSIGNIA project¹²⁷ aims to develop a protocol for a monitoring programme whereby beekeepers will collect pollen samples from honeybee colonies in order to analyse pesticide residues and botanic origin. Once rolled out, the protocol will enable the generation of high-quality data on pesticide presence in the environment across the EU. It will be implemented on the ground from late 2020 by a preparatory action initiated by the European Parliament, with an EU-funded budget of €3 million.

The above examples are not exhaustive and many other initiatives are contributing to environmental monitoring, e.g. in the areas of climate change adaptation, environmental compliance, etc.

¹²⁵ <http://www.opensourcesoundscapes.org/>

¹²⁶ ISO 12913-1 2014.

¹²⁷ <https://www.insignia-bee.eu/>

4. POLICY UPTAKE OF CITIZEN SCIENCE – KEY FINDINGS

We can draw various lessons from the inventory and analysis of citizen science initiatives:

- **citizen science can underpin environment policy** – the examples in Chapter 3 and analysis of the inventory show that citizen science is already making an essential contribution to environment policy, most prominently in the area of nature and biodiversity monitoring. Initiatives have been developed in all environmental fields and offer significant potential for uptake in environment policy-making and implementation, beyond monitoring and occasional reporting. There is also scope for more targeted initiatives, contributing to the study of environmental processes, and behavioural studies;
- **monitoring SDGs** – environmental citizen science could contribute to the knowledge base for SDG monitoring and implementation, but its coverage of the 17 SDGs is currently uneven. Its best direct contribution has been on marine and terrestrial nature conservation (SDGs 14 and 15). In contrast, it has made limited direct contributions on food and sustainable agriculture (SDG 2), sustainable water management (SDG 6) and sustainable consumption and production (SDG 12). More bottom-up forms of citizen science, such as civic and DIY engineering initiatives, could contribute to a range of SDGs. In-depth analysis of selected initiatives shows that their governance is a key factor determining how much they contribute to the SDGs. EU-funded and government-led projects contribute to a wider range of SDGs than other policy-relevant initiatives, perhaps because the former are more closely linked to policy processes: at least 60% of the Horizon 2020 budget is expected to fund sustainable development, so the topics and selection criteria for research projects tend to reflect the SDG objectives. Similar priorities are likely to apply for national governments;
- **government support favours policy uptake** – the uptake of citizen science in environment policy seems to be determined by a combination of the initiatives' governance and intrinsic characteristics. Government support (not only in the funding stages, but also through active participation in project design) appears to be a key factor for the successful uptake of project results in policy-making. Also, government involvement broadens the policy relevance of initiatives and guarantees the long-term availability of the data. However, government-led projects tend to attract fewer participants than those led by CSOs or other actors.
- **facilitating public involvement promotes policy uptake** – a key challenge for citizen science initiatives is to balance the data quality required for research and policy use, on the one hand, with the need to sustain volunteer engagement. The easier it is for people to get involved (in terms of skills, effort, support and feedback), the more likely it is that the initiative will be used in policy-making;
- **scientific rigour encourages policy use** – projects supported by academic institutions and those that have high scientific standards and wide geographical coverage are more likely to be used in various phases of the policy cycle. Good scientific data validation and quality assurance procedures are key, but end-users' perception of the data often remains biased and seems to be one of the main barriers to uptake. Furthermore, various restrictions still apply, whether in the form of outright data access restrictions or through insufficient operationalisation of data licensing and downloading procedures;
- **NGOs are key actors** – NGOs are the most prominent leaders of environmental citizen science activities and often key partners in initiatives led by others. They often support academic institutions on networking, communication, dissemination and community-building. They may be well positioned to understand and articulate specific knowledge needs for environment policy, whether at local level or more widely. There are many examples of

successful partnerships with EPAs, such as the Riverfly partnership¹²⁸ and the Air Quality project in schools in Ireland under the GLOBE programme¹²⁹. However, they often encounter organisational challenges, in particular as regards:

- access to information;
 - funding; and
 - establishing solid working relationships with academic institutions;
- **policy uptake rests on the availability of sustainable business models** – although dedicated one-off initiatives may have major policy impacts, establishing policy linkages is typically a lengthy process. Moreover, end-users will not commit to using the data for policy unless they can be sure of a predictable flow of data. This means that the sustainability of the data infrastructure and management are as important as the life expectancy of the project and the volunteer community. Policy-relevant initiatives are based on a range of business models, but citizen science (albeit sometimes apparently more cost-effective than traditional science) is never cheap. Sustainable funding is key to its medium/long-term survival. The private sector may be an under-exploited source of finance, especially as private capital investment in nature conservation and environmental initiatives in general has grown steadily over the past decade;
- **various citizen science approaches can support policy-making** – environmental citizen science features a wide range of approaches in relation to volunteers, science and policy. While these seem to coalesce around a distinct set of scientific methods and similar approaches to training, data validation, data management and accessibility, it would be difficult to identify a standard approach in relation to members of the public. Rather, it would probably be more appropriate to compile a portfolio of best practices that can be tailored to individual initiatives, e.g. on the basis of target audience, aims and technical requirements. It is important to match the requirements for science and public involvement with the right type of initiative and form of participation.

Some initiatives address the policy issues from the design stages (including government support, links with policy-makers, co-creation), while others compile large amounts of data with broad time/spatial coverage that provide policy-makers with an evidence base that can be used to focus on a range of questions. One advantage of the latter option are the cost savings that can be generated from re-purposing data to serve multiple objectives; and

- **citizen science can contribute to geospatial intelligence** for environmental monitoring applications – the data can be used to validate and calibrate data for Earth observation (e.g. Copernicus) with lower cost and greater frequency, e.g. as regards land cover, forests, biodiversity, phenology, marine environment and disaster response. Activities can range from online image interpretation to *in situ*, field-based data collection. The potential benefits of using people's observations to complement geospatial and Earth observation include cost savings, gap-filling data, calibration and validation, and time/spatial frequency. Combining human reasoning with machine learning and other AI techniques can extend scientific knowledge, as already proven in areas such as deforestation, agricultural production and light pollution.

¹²⁸ <http://www.riverflies.org>

¹²⁹ <https://www.globe.gov/web/ireland>

5. RECOMMENDATIONS

From analysis of the good practices and challenges summarised above, it is clear that there remains scope for citizen science to contribute more to environment policy-making and implementation. In this chapter, we set out recommendations on the basis of our findings, as confirmed and complemented by feedback from stakeholders¹³⁰.

The recommendations cover a range of potential actions targeting relevant stakeholders and relating to:

- the connection with policy and science;
- awareness, recognition and trust;
- the quality and openness of data and methodologies; and
- coordination, cooperation and resources for policy impact.

The actions are summarised below under each recommendation, and described in more detail in Annex II, which also provides a short description of the stakeholder groups to which they relate.

5.1. Match-making between knowledge needs for environment policy and citizen science activities

The scientific knowledge produced by citizen science initiatives that could be useful for environment policy monitoring is not yet widely known and should be disseminated more actively. At the same time, citizen science communities would benefit from greater awareness of the policy issues that they could help to address, thereby enhancing policy impact and sustaining relevance.

The first set of recommendations aims to bridge these gaps by promoting the establishment of a knowledge base of citizen science initiatives and environmental data portals. It is also proposed that the maintenance, spread and upscaling of successful citizen science activities be promoted in the priority areas of the European Green Deal.

Recommendation 1: Pool information on citizen science initiatives, tools and resources to enhance visibility and exchange
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Information-sharing could promote synergies, help identify gaps and avoid overlaps and duplication between initiatives. Citizen science associations could play a key role by developing and maintaining an online portal, including a central catalogue of activities. This would help to connect communities and activities and make them more visible. It could be used to share training modules, tools and resources, make them easier to find and facilitate exchange. It could include material describing pathways to consolidate, spread and upscale monitoring schemes, and information on funding options for different stages of initiatives (funding roadmap). This would help initiative leaders to plan resource/funding needs and consider alternative sources of funding.

¹³⁰ Stakeholders consulted include citizen science project coordinators, practitioners, network coordinators, national government representatives involved in citizen science (including EPAs), scientists, citizen science consultants, etc. Results from an early consultation have been published in a dedicated report:

<https://ec.europa.eu/jrc/en/publication/citizens-science-and-environmental-monitoring>

Recommendation 2: Support the creation, extension and/or upscaling of pan-European citizen science initiatives in priority areas under the Green Deal

Citizen science could be a cost-effective way to complement environmental reporting in the priority areas of the Green Deal, but it also requires investment. Ensuring the launch, upscaling and long-term sustainability of relevant initiatives could enhance policy impact.

Action under this recommendation could involve the following:

- EU and Member State authorities could provide funding and support through targeted actions to contribute to the knowledge base needed to deliver on climate and environmental goals, in particular the ambitious Green Deal objectives. For instance, volunteer-based monitoring schemes contributing to the 2030 biodiversity strategy could be supported further and new initiatives incubated, in particular in relation to the EU pollinators initiative;
- initiatives to fight environmental (e.g. air, water, noise, plastic) pollution could be identified and supported as part of the zero pollution ambition; further investigation of methodologies and approaches (e.g. those using low-cost sensors) is needed in this area; and
- exploring the potential of citizen science (e.g. through pilot projects) in the context of the chemicals strategy, the circular economy action plan, the climate ambition and the ‘farm to fork’ strategy, and in other (emerging) areas that are relevant to EU and global policy frameworks (e.g. Paris Agreement, SDGs).

It would be recommendable that funding options are clearly communicated and made available for **different stages** of initiatives (i.e. not only the pilot phase), – as well as for capacity-building and impact assessment. To assess and demonstrate initiatives’ contribution to environmental priorities, it could be made mandatory to evaluate their impact, including policy and societal impacts. Also, successful technical solutions and methodologies could be disseminated and exploited for re-use, thus offering EU-wide solutions.

Recommendation 3: Promote suitable reporting mechanisms, guidelines and methodologies to facilitate the use of citizen science data and information in environmental reporting

EU and Member State authorities could support the establishment or upgrade of open data portals and platforms where citizen science initiatives and public authorities can publish, preserve and curate monitoring data and information, as part of a European data space for the environment¹³¹.

In order to support and promote the uptake of relevant citizen science data collected according to agreed methodologies, EU and Member State authorities should ensure that reporting mechanisms, platforms (e.g. Reportnet 3.0) and related guidelines can accept and integrate the data. For data to meet the relevant standards and be integrated more easily with data from other sources, it is recommended that public authorities review and communicate quality requirements and collection methodologies. To facilitate the use of innovative methods and technologies, they may consider decoupling the quality requirements (under the policy) from the measurement procedure used to deliver the required quality.

It is suggested that public authorities engage with the relevant stakeholders to co-develop the raw monitoring data-capturing methodologies and quality assurance and control (QA/QC) mechanisms

¹³¹ See [draft](#) orientations document for the [future digital Europe programme](#).

required for specific environmental policies and monitoring processes, where these are not yet available.

5.2. Promoting awareness, recognition and trust

The second set of recommendations focuses on raising awareness of the value of citizen science in environmental monitoring, in particular in public institutions. It also addresses the need to acknowledge contributions by giving them adequate visibility and credit, while ensuring data traceability throughout the policy cycle. It is important to foster trust and credibility, especially where there are doubts as to the quality and scientific standards of the methodologies used.

Recommendation 4: Give visibility and recognition to citizen science outcomes

In order to give visibility and recognition to citizen science, public authorities at EU level and in Member States and researchers in academia and research organisations should explicitly acknowledge the contributions they use in reports or articles. This will also increase transparency and could help to sustain the involvement of citizen scientists. Similarly, authorities could provide citizen science communities with feedback on the use of their data for policy decisions. This could be complemented with the use of communication tools such as newsletters, e-mail lists and social media groups.

Acknowledging and referencing contributions may require the development and use of rigorous methodologies to ensure data traceability throughout the policy cycle and in reporting, analysis and communications (e.g. by using persistent identifiers).

To highlight and reward inspiring examples of citizen science, consideration could be given to an annual EU citizen science award and events, competitions, challenges, European Capital(s) of Science and Innovation initiatives etc.

Recommendation 5: Raise awareness of citizen science for environmental monitoring and promote it within public institutions

Action under this recommendation could involve:

- Promoting citizen science champions in research organisation and public authorities – this would help raise awareness, identify opportunities, facilitate cooperation, publicise and improve the uptake of citizen science; and
- developing strategies or frameworks for environmental citizen science in the Member States – this would highlight its value and use, and raise the visibility of initiatives.

5.3. Promoting data quality and interoperability standards and sharing tools

Decision-makers should have access to the best available scientific data. The data used to support policy- and decision-making should be open and trustworthy, withstand interrogation and be scientifically robust. This applies to citizen science as much as any other monitoring.

The most commonly reported barrier to academics'/research organisations' and decision-makers' use of citizen science data and knowledge relates to their openness and perceived lack of quality. Although these concerns have receded as statistical methods for dealing with large, imperfect datasets have improved, there is a need to ensure (and document) the application of data standards and good practice in data management, in order to facilitate interoperability and integration with data from other sources. Also, policy uptake and impact could be enhanced if initiatives took greater account of public

sector data requirements (e.g. under INSPIRE¹³², the Open Data and Public Sector Information (PSI) Directive¹³³, recommendations on open access¹³⁴, etc.). There is also a need to address concerns on personal data protection, intellectual property rights, security and related issues. Guidance and training specifically targeting citizen science practitioners and relevant stakeholders would help raise awareness of these matters and promote trust.

Recommendation 6 recognises the ongoing work in this area¹³⁵ and the big differences between sectors (e.g. biodiversity *vis-à-vis* air quality).

Recommendation 6: Promote the adoption, effective use and transparency of data management and sharing principles, methodologies and quality assurance/control in citizen science initiatives

Action under this recommendation could involve the following:

- in order to assess whether citizen science data are fit for purpose and fully understand their limitations (e.g. uncertainties, potential biases), EU and Member State authorities could promote the application of data management and sharing principles (e.g. FAIR¹³⁶ data principles, etc.). They could encourage open access¹³⁷ policies and the use of standard open data licences (e.g. creative commons licences¹³⁸ such as CC-BY or CC0) where feasible;
- citizen science communities could encourage the use of their monitoring outcomes by communicating transparently on the methodologies used (e.g. how they identify and minimise bias, how they ensure that contributors have the necessary expertise, etc.). This could be supported by a terminology or framework that maps methodologies and approaches against specific policy goals. Also, they should apply and document data management and QA/QC methodologies and procedures. Networks' and communities' promotion of and adherence to relevant standards of good practice and legal frameworks in science and the transparency of methodologies would also help dispel doubts as to their impartiality and improve trust;
- associations and networks could promote the importance of these issues and provide training and resources on data management and QA/QC methodologies, in particular to support the use of European standards, recommendations and good practice (e.g. from the Open Data and PSI Directive, INSPIRE and the GDPR). They could also offer guidance on handling sensitive information and help to establish and connect to facilities and groups with relevant expertise (such as law clinics) that can help citizen scientists; and
- all stakeholders could share research and knowledge on areas of particular concern, such as data donation, privacy-preserving technologies and decentralised data governance. This work could build on more general initiatives to highlight needs and ensure consistent application of emerging practices.

¹³² <https://inspire.ec.europa.eu/>

¹³³ Directive (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information;

<https://ec.europa.eu/digital-single-market/en/european-legislation-reuse-public-sector-information>

¹³⁴ Commission Recommendation (EU) 2018/790 of 25 April 2018 on access to and preservation of scientific information.

¹³⁵ e.g. ECSA working group, COST action on citizen science, CitSic.org platform).

¹³⁶ i.e. findability, accessibility, interoperability and reusability. For more information on FAIR data management plan, see: https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-data-mgt_en.pdf

¹³⁷ e.g. continue and use the Horizon 2020 model of open access to data and publications by default, but maintain the possibility to opt out.

¹³⁸ <https://creativecommons.org/use-remix/cc-licenses/>

Recommendation 7: Support the creation of citizen science capacities, reach out to the next generation of citizen scientists and promote the uptake of innovative technologies and approaches

Action under this recommendation could involve the following:

- public authorities in Member States could consider setting up centres of excellence to help provide training, technical/legal support for citizen science practitioners and reach out to local communities and schools. This could include promoting training in digital skills as well. They could also promote and support activities in primary and secondary schools, to increase awareness and engagement, and to raise the citizen scientists of the future;
- in order to foster innovation and citizen science communities' uptake of new technological approaches, technology and tools could be shared and released as open access, so that they can be re-used in other environmental areas or in the context of other initiatives; and
- citizen science networks could be involved in investigating and assessing the impact of emerging technological and methodological approaches (AI, Earth observation, big data analytics) on citizen science for environmental monitoring, so as to facilitate its transfer to and uptake by the communities.

5.4. Supporting coordination and cooperation for policy impact

A strategic choice of partners and coordination in networks can increase the likelihood of policy uptake. Therefore, cooperative approaches are encouraged among stakeholders to communicate needs and co-create/co-design activities and methodologies.

Recommendation 8: Seek and promote cooperative approaches and strategic partnerships, enhancing engagement, the societal impact of citizen science initiatives and uptake in environmental monitoring and policy-making

Action under this recommendation could involve the following:

- all potential stakeholders should try to nurture policy links by using co-creation strategies at the start and at all stages of their initiatives. As a strategic choice of partners may enhance trust in initiatives and their impact, initiative leaders should consider partnering with research organisations/academics, NGOs, civil society organisations and social movements, public authorities in Member States (including EPAs and statistical offices), community champions, schools and youth organisations, media companies, the maker community and the private sector.

While authorities in Member States should consider existing or potential initiatives for partnership, they should be aware of, and counter, possible perceptions of surveillance;

- citizen science networks could facilitate partner identification by offering networking opportunities. They could also organise regular events for citizen science groups and policy-makers, possibly focused on specific topics (e.g. field visits), thus helping to align citizen science activities and policy/data needs, and promote their achievements and potential among policy-makers.

Recommendation 9: Improve EU/national/regional coordination among citizen science initiatives

In order to promote synergies, identify gaps and avoid overlaps and duplication among environmental initiatives, there is a need for coordination and more exchange of information and tools, in Member States and at EU level, and also across thematic areas. Citizen science networks could play a key role by promoting the coordination of activities. Public authorities in Member States, CSOs, researchers in academia/research organisations and private partners could support networks by partnering with them or providing resources.

6. CONCLUSIONS AND NEXT STEPS

As we have seen, citizen science has proven its potential to contribute to environmental monitoring and reporting (e.g. in the field of biodiversity) and to policy-making (e.g. on plastic litter). Helped by increasingly available tools and technologies (e.g. mobile apps, portable sensors, open source tools for data processing and visualisation), initiatives are generating valuable data and knowledge in a whole range of environmental domains. However, the uptake of such data for official monitoring purposes remains limited.

Meanwhile, the ambitious climate and environmental objectives under the European Green Deal reinforce the need for monitoring data and knowledge on biodiversity, pollution, circularity/waste, climate change, sustainable food, etc., to steer, implement and evaluate policy. The EU policy framework on digitalisation and environmental data encourages the uptake of new, non-conventional data sources.

To better link the under-used data from citizen science to EU environmental monitoring, the recommendations in this document identify a number of possible actions in four key areas:

1. match-making between knowledge needs for environment policy and citizen science activities;
2. promoting awareness, recognition and trust;
3. promoting standards for data quality and interoperability, and sharing tools; and
4. supporting coordination, cooperation and resources for policy impact.

The suggested actions include:

for public authorities at EU level and in Member States:

- supporting initiatives in priority areas under the Green Deal and related strategies and ambitions, including pollution (e.g. air, water, plastic, noise), biodiversity, climate change, the circular economy and sustainable food;
- promoting the availability of citizen science data on existing or new open platforms and ensuring that official reporting mechanisms can accept and integrate the data; and
- reviewing and communicating relevant data quality requirements and methodologies;

for citizen science communities and associations:

- communicating transparently on methodologies used and adhering to good practice;
- fostering strategic partnerships when and where possible;
- creating an online knowledge base of citizen science initiatives across Europe, including tools and resources; and
- promoting the coordination of citizen science initiatives at EU/national/regional levels.

for all relevant stakeholders:

- engaging in co-creation activities with one another, to scope out needs, capabilities and capacities, so as to implement successful and impactful environmental monitoring activities.

The recommendations and possible actions aim to harness the potential of citizens-generated data, through the sharing of good practice, coordination instruments, partnerships and technological support. They address the key actors involved: EU and Member State authorities, citizen science networks and communities, initiative leaders (and participants) and academics/research organisations.

Notably, citizen science is not only about collecting data or generating knowledge. It has other important and valuable impacts, such as awareness-raising on environmental issues and policies, and public involvement and empowerment. It thus chimes with the spirit of the Aarhus Convention and the Commission's policies on access to information and public participation in environmental decision-making. The sustainability of initiatives depends on the active fostering of these other outcomes, so that citizen science is rewarding for volunteers and other participants alike. EU institutions and public authorities in Member States should therefore recognise the importance of citizen science in building communities, empowering people and improving scientific literacy.

As a next step, these best practices will be promoted and supported within European citizen science communities and among stakeholders such as EU policy-makers, environmental authorities in the Member States, citizen science networks and academia/research organisations.

The Commission will work to ensure coordination in the implementation of the recommendations across the EU.

ANNEX I: EXAMPLES OF CITIZEN SCIENCE INITIATIVES

The examples below show that public authorities at EU level and in Member States are already using citizen science data for environmental monitoring, reporting and policy making in various policy areas.

More examples of citizen science initiatives that have had a direct impact on environmental monitoring or policy-making are available in *Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices*¹³⁹ and the accompanying data set¹⁴⁰.

Initiative:	Pan-European common bird monitoring scheme (PECBMS)
Policy area:	Biodiversity conservation
Policy impact:	<p>The PECBMS common bird index is a recognised indicator for biodiversity monitoring in Europe. It covers 168 European species, including 39 common farmland bird species and 34 forest bird species. It is used to assess progress towards the headline target of the EU biodiversity strategy to 2020, on the streamlined European biodiversity indicators (SEBI) ‘abundance and distribution of selected species’ (EEA) and on the SDGs (indicators ‘env_bio2’ and ‘env_bio3’, Eurostat).</p> <p>The farmland bird index is used in the CAP common monitoring and evaluation framework and is a part of the agri-environmental indicators set.</p> <p>The indices show significant downward trends, in particular for farmland birds.</p>
Relevant stages of policy-making:	Problem definition / policy evaluation / compliance assurance
Organisation/tools:	A central coordination unit (based at the Czech Society for Ornithology) communicates with national coordinators (local NGOs or other institutions). Bird-counting in the field is done by volunteers. PECBMS coordinators process the data with dedicated data management and control tools, and a tool for calculating supranational indices and trends.
Geographical scope:	EU (minus Croatia and Malta), Norway, Switzerland
Temporal scope:	1990-present
Resources:	<p>PECBMS is a partnership involving the European Bird Census Council (EBCC), the Royal Society for the Protection of Birds, BirdLife International, Statistics Netherlands and several national ornithological associations. Since 2006, it has received funding from the Commission for the calculation of the indices.</p> <p>Budget of €100,000 per year.</p>

¹³⁹ Bio Innovation Service (2018), *Citizen science for environmental policy: development of an EU-wide inventory and analysis of selected practices*, final report for DG ENV;
<https://publications.europa.eu/en/publication-detail/-/publication/842b73e3-fc30-11e8-a96d-01aa75ed71a1/language-en>

¹⁴⁰ European Commission, Directorate-General for Environment; European Commission, Joint Research Centre; Bio Innovation Service (2018): An inventory of citizen science activities for environmental policies. European Commission, Joint Research Centre (JRC) [Dataset] PID: <http://data.europa.eu/89h/jrc-citsci-10004>;
<http://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004>

Initiative:	Pan-European common bird monitoring scheme (PECBMS)
	Staff of 2-5 (and 12,000 volunteers).
Quality control:	Yes
Outcomes:	<p>Scientific publications.</p> <p>Bird indices have been used by EU institutions in policy evaluations and integrated environmental assessments such as EEA reports on the state of the environment in Europe. The datasets have also been used by the Organisation for Economic Cooperation and Development, the UN Environment Programme and the Secretariat of the Convention on Biological Diversity, and in the WWF 'living planet' index.</p>
Reference:	<p>https://pecbms.info/</p> <p>https://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species-8/assessment</p>
Additional info:	<p>The Eurobird portal is a related and complementary EBCC initiative, aiming 'to establish a European data repository based on aggregated data from online bird recording portals from across Europe', in order to describe large-scale time/spatial patterns of bird distribution (seasonal distributional changes, migratory patterns, phenology) and their changes over time, and to improve the value of online data-gathering portals.</p> <p>http://www.eurobirdportal.org/</p>

Initiative:	European butterfly monitoring scheme (eBMS)
Policy area:	Biodiversity conservation
Policy impact:	Data covering 17 species are collected by thousands of volunteers in around 20 countries in Europe (including 15 EU Member States) and used to calculate the European grassland butterfly index. Together with the common bird index, the butterfly index is used to monitor progress towards the headline target of the EU biodiversity strategy to 2020. It is used for the streamlined European biodiversity indicators (SEBI) ‘abundance and distribution of selected species’ (EEA) and monitoring progress on the SDGs (sdg_15_61). As birds and grassland butterflies are the only species groups for which harmonised European monitoring data are available, this indicator is important for assessing the status and trends of Europe’s biodiversity, wider environment and the impacts of agriculture on the environment. The EU-funded ‘assessing butterflies in Europe’ (ABLE) project, launched in 2019, aims to extend this monitoring scheme to southern and eastern Europe to provide more representative assessments of the impacts of EU policies, including the biodiversity strategy and the CAP. The data will also contribute to the assessment of the health of Europe’s pollinators as part of the EU pollinators initiative.
Relevant stages of policy-making:	Problem definition / policy evaluation / compliance assurance
Organisation/tools:	The eBMS is a joint initiative of Butterfly Conservation Europe, the Centre for Ecology & Hydrology and the ABLE project. The sampling method is based on ‘butterfly transect counts’. eBMS provides volunteers and country/regional networks with methodological support, e.g. via the Manual for butterfly transect counts . The index is based on the fieldwork of thousands of trained professional and volunteer recorders, counting butterflies on more than 6,200 transects across the EU under standardised conditions. National coordinators collect the data and perform the first quality control. In 2017, transect walks were made over more than 55,880 km, more than 90% of them by volunteers, monitoring each transect an average of 15 times a year (Van Swaay <i>et al.</i> , 2017 ¹⁴¹). While the majority of BMS have their own database to collect data and organise their volunteers, eBMS launched http://butterfly-monitoring.net/ as a central online system for collecting butterfly data. This tool will provide a starting point for countries to introduce a new scheme.
Geographical scope:	Belgium, Estonia, Finland, France, Germany, Ireland, Latvia, Lithuania, Luxembourg, Romania, Slovenia, Spain, Sweden, Netherlands and UK
Temporal scope:	1990-present
Resources:	ABLE project: €800,000 over 2 years. https://butterfly-monitoring.net/able

¹⁴¹ [https://butterfly-monitoring.net/sites/default/files/Publications/Technical%20report%20EU%20Grassland%20indicator%201990-2017%20June%202019%20v4%20\(3\).pdf](https://butterfly-monitoring.net/sites/default/files/Publications/Technical%20report%20EU%20Grassland%20indicator%201990-2017%20June%202019%20v4%20(3).pdf)

Initiative:	European butterfly monitoring scheme (eBMS)
Quality control:	Yes
Outcomes:	National and EU species indices for policy monitoring (see above). Scientific publications.
Reference:	http://www.bc-europe.eu/ http://butterfly-monitoring.net/ https://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species-8/assessment

Initiative:	<i>Artportalen</i>
Policy area:	Biodiversity, nature
Policy impact:	<i>Artportalen</i> data are the primary biodiversity data used to support planning and management decisions in Sweden, e.g. for nature reserves. The data are used routinely by all government authorities, agencies and many environmental consultancies (which have developed their own interfaces to enable rapid searching of the <i>Artportalen</i> data). The data are used to monitor biodiversity, invasive species and changes in species distribution, and form the key tool in the creation of the Swedish ‘red list’.
Relevant stages of policy-making:	Problem definition / policy implementation / policy evaluation
Organisation/tools:	Freely accessible reporting system and data repository with an easy interface and minimum data requirements for reports (taxon, reporter, date, and location), in which anyone can report species observations and attributes (e.g. number, activity and observation method). Checklists enable the reporting of species absences (zero-observations). Projects can tailor reporting fields to specific requirements. Key figures: 200,000 unique returning visitors per year, >800 environmental officers with special data access rights, 6 million new observations per year.
Geographical scope:	Sweden
Temporal scope:	2000-present <i>Artportalen</i> has been in operation since 2000, but the database stores and presents earlier historical data.
Resources:	The Swedish EPA provides approx. €570,000 for administration and basic running costs and €380,000 for new development. The Swedish University of Agricultural Sciences (SLU) hosts the platform, contributes funding, pays for specific functionalities and supports the taxonomy and information databases from which <i>Artportalen</i> harvests some data.
Quality control:	Data are validated through a combination of in-built algorithms that compare observations with county catalogues or expert-produced data rules that signal outliers to the reporter and external expert validators. The openness of the system guarantees that reporting errors are quickly identified by peers (8,000 unique visitors per day).
Outcomes:	With over 73 million observations, the monitoring data are used for official purposes for biodiversity and land-planning purposes (via the country councils own integrated Artsök GIS system, invasive species, changes in species distributions) and form the basis of the Swedish ‘red list’.
Reference:	https://www.artportalen.se/ https://artportalen.desk.com/customer/en/portal/articles/2874151-who-uses-data-from-artportalen

Initiative:	<i>Mückenatlas</i> (mosquito atlas)
Policy area:	Biodiversity (species distribution), climate, health
Policy impact:	<i>Mückenatlas</i> has become the main tool for monitoring mosquitoes in Germany. The Federal Ministry of Food and Agriculture uses the results to keep track of mosquito occurrence and distribution in Germany and to monitor changes (e.g. as caused by the effects of climate change). This knowledge is used, for example, to understand the possible spreading of (native or invasive) mosquito vectors and mosquito-borne diseases.
Relevant stages of policy-making:	Monitoring / awareness-raising / education
Organisation/tools:	The initiative is based on / consists of: <ul style="list-style-type: none"> • basic information on the main web page (recruiting collectors); • a form to complete when submitting samples (mosquitoes) by post; • manual expert identification, curation of the sample and composition of individualised replies using a set of templates; and • publication via online maps and storage in a mosquito database
Geographical scope:	Germany
Temporal scope:	Since 2012 (ongoing)
Resources:	The project is supported by the German Federal Ministry of Food and Agriculture and run in cooperation with the Leibniz Centre for Agricultural Landscape Research (ZALF) and the <i>Friedrich-Loeffler-Institut</i> (German Federal Research Institute for Animal Health).
Quality control:	Expert validation of every sample received.
Outcomes:	24,720 contributions (letter with at least one mosquito) received (status 28 November 2019).
Reference:	Individual feedback to each collector (including information about collected species and its behaviour at the time of collection).

Initiative:	Invasive alien species in Europe
Policy area:	Regulation on invasive alien species Biodiversity strategy — invasive alien species Marine Strategy Framework Directive (MSFD) — non-indigenous species Water Framework Directive — alien species
Policy impact:	The ‘invasive alien species in Europe’ app feeds its data into the European Alien Species Information Network (EASIN (the official information system facilitating the implementation of Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species; see also Commission Implementing Regulations (EU) 2016/1141 , 2017/1263 and 2019/1262 , i.e. lists of invasive alien species of Union concern.
Relevant stages of policy-making:	Problem definition / early warning / monitoring / awareness-raising
Organisation/tools:	Dedicated mobile app (one of the EASIN data partners) with adaptations to suit Member States’ needs (including local species); use open to anybody; responsible authorities and academia/research organisations are main stakeholders; data management within the JRC; details about data validation below.
Geographical scope:	EU
Temporal scope:	2015-present
Resources:	H2020 support, first MyGEOSS project (2015-2016) then JRC institutional budget.
Quality control:	User manual and use of standards in the app, automated image recognition and expert validation (2020: EASIN team and EASIN editorial board).
Outcomes:	Collected data are fed into policy-making/implementation; data contributions to the scientific knowledge base used for policy-making; http://alien.jrc.ec.europa.eu/SpeciesMapper
Reference:	https://easin.jrc.ec.europa.eu/easin http://digitalearthlab.jrc.ec.europa.eu/app/invasive-alien-species-europe http://data.jrc.ec.europa.eu/dataset/jrc-citsci-cs-jrc-ias

Initiative:	Marine LitterWatch
Policy area:	Waste Marine strategy Sustainable consumption and production Water
Policy impact:	<p>Improved evidence base for monitoring progress on the main Marine Strategy Framework Directive's objective of 'good environmental status' of Europe's seas by 2020, in particular for 'descriptor 10' (marine litter).</p> <p>Contribution to the evidence base for the EU strategy on plastics and in particular the Single-Use Plastics Directive. MLW helps determine single-use plastics abundance and trends on European beaches.</p> <p>Other important EU policy links are the circular economy package waste reduction targets for 2020 (30% headline reduction for top 10 items found on beaches) and the EU-wide quantitative headline reduction target by 2020 under the 7th EAP.</p> <p>A 2017 JRC technical report on <i>Top marine beach litter items in Europe</i>¹⁴² concluded that 'NGOs are the main actors in the field of marine litter monitoring, and their reports are a major source of information regarding beach litter in Europe. This reflects the huge interest of the general public in the topic and provides valuable data through the framework of clean-up events and multiannual survey work'.</p> <p>In a document on common indicators on pollution and marine litter¹⁴³, UNEP/MAP indicates that, for the beach litter indicator, '[m]ost beach marine litter surveys are organised by NGOs with a focus on cleaning (...) More work has also to be done on informing volunteer groups about the necessity to submit standardised research data for statistical purposes' and '[b]ased on UN Environment Guidelines (Cheshire <i>et al.</i>, 2009), any long-term marine litter assessment programme will require a specific and focused effort to recruit and train field staff and volunteers'.</p>
Relevant stages of policy-making:	Problem definition / awareness-raising
Organisation/tools:	MLW mobile app for uniform data collection. Locally organised citizen groups (NGOs, civil society initiatives). Central database with real-time online data viewer. Monitoring events build on MSFD guidelines for monitoring litter.
Geographical scope:	Pan-European (coastal areas, but also lakes and riverine data).
Temporal scope:	2014-present
Resources:	EEA support of ~ €70,000/year (data-hosting, development of application, workshop) including EEA and European topic centre staff,

¹⁴²

http://publications.jrc.ec.europa.eu/repository/bitstream/JRC108181/technical_report_top_marine_litter_items_eur_2924_9_en_pdf.pdf

¹⁴³ https://www.medqsr.org/sites/default/files/inline-files/17wg444_5_eng.pdf_0.pdf

Initiative:	Marine LitterWatch
	<p>etc.</p> <p>35-40 actively contributing communities (in IT, GR, DK, SI, NL, UK, SE, PT, IE, ES, etc.)</p>
Quality control:	<p>Users (communities) are responsible for data quality. EEA is assisting communities with annual QA/QC, to make data more reliable. In the EEA database, entries will be distinguished from other monitoring data.</p>
Outcomes:	<p>2018 report on items most commonly found on European beaches.</p> <p>Status June 2020: 2,930 clean-up and community beach events performed following MSFD guidelines, almost 1,4 million items collected.</p>
Reference:	<p>https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch</p>

Project:	Dumb dumpers
Policy area:	Waste, environmental compliance
Policy impact:	Drives policy development and focused action in order to improve environmental performance through the tyre supply chain; https://sectors.sepa.org.uk/tyre-sector-plan/
Relevant stages of policy-making:	Understanding of the spatial and temporal distribution of illegally disposed waste focuses policy, drives action and evaluates effectiveness of action.
Organisation/tools:	Zero Waste Scotland and SEPA
Geographical scope:	Scotland
Time series:	2014 to 2018
Resources:	Resources involved in solving around 140 calls per month, i.e. about 9 hours per month (depending on the type, amount and location of tipped waste). The analysis for use in the sector plan was about 2 weeks' work.
Quality control:	Part of 'dumb dumpers' action
Outcomes:	Illegal waste removed (= positive feedback to volunteers) and policy focused and evaluated (= positive for EPA)
Reference:	https://www.zerowastescotland.org.uk/DumbDumpers

Initiative:	FreshWater Watch
Policy area:	Water Framework Directive — nutrients, habitat assessment Nitrates Directive Urban Waste Water Treatment Directive SDG 6.3
Policy impact:	Phosphate, nitrate, algal bloom and turbidity data are available to data centres in data download format and on shared data platforms. Data are highly complementary to regulatory monitoring and used in several cases for environment policy (see, for example, Hadj-Hammou <i>et al.</i> , 2017; Castilla <i>et al.</i> 2015).
Relevant stages of policy-making:	Problem definition / early warning / monitoring / awareness-raising
Organisation/tools:	Simple water chemistry / ecological observations / optical water quality testing approach; dedicated mobile app in multiple languages, including direct feedback to users and data storage on secured open access platform; online learning platform and data visualisation. Options for custom translations and the addition of supplementary variables to suit member's needs.
Geographical scope:	Global
Temporal scope:	2012-present
Resources:	HSBC water programme. Used in H2020 GroundTruth 2.0, MONOCLE and MICS projects. Supporting agency monitoring in Africa and Asia, and river trusts in EU and the Americas.
Quality control:	<ol style="list-style-type: none"> 1. user-based — user training by video and in person, with learning validated by a quiz before data can be uploaded; 2. user-based — anomalies in uploaded data identified and returned to user for confirmation; 3. data aggregator — percentage of samples repeated, percentage of samples compared to lab tests; 4. Earthwatch — quality control of uploaded data; 5. Earthwatch — quality control of method and kit reagents
Outcomes:	Over 22,000 samples collected to date from 40 countries — the equivalent of 30,000 hours of research. Data contribute to the scientific knowledge base used for policy-making, including over 20 peer-reviewed publications.

Initiative:	FreshWater Watch
Reference:	<p data-bbox="480 199 959 232">https://freshwaterwatch.thewaterhub.org</p> <p data-bbox="480 239 1299 306">https://earthwatch.org.uk/get-involved/projects-activities/freshwater-watch</p> <p data-bbox="480 313 804 347">https://freshwaterlinks.org/</p> <p data-bbox="480 353 1361 461">Hadj-Hammou, J. <i>et al.</i> (2017). <i>Getting the full picture: assessing the complementarity of citizen science and agency monitoring data</i>, PloS one 12.12 (2017): e0188507.</p> <p data-bbox="480 472 1361 618">Castilla E. P., Cunha D. G. F., Lee F. W. F., Loiselle S., Ho K. C., Hall C. (2015). <i>Quantification of phytoplankton bloom dynamics by citizen scientists in urban and peri-urban environments</i>, Environmental Monitoring and Assessment 187 (art. 690).</p>

Initiative:	<i>Samen meten</i> initiative
Policy area:	Air pollution / air quality
Policy impact:	<p>The Dutch Institute for Public Health and the Environment (RIVM) has been experimenting with low-cost sensors, particularly NO₂ and PM10/PM2.5 sensors, and related citizen science activities over the last few years. The Dutch innovation programme for environmental monitoring involves the development of a knowledge portal (samenmeten.nl) and sensor data portal (samenmeten.rivm.nl), new calibration approaches for sensors, and modelling and assimilation techniques for incorporating these uncertain sensor data into air pollution models. The <i>samen meten</i> results show that low-cost sensors can be a valuable addition to traditional air-quality monitoring. The air-quality measurements by volunteers in this initiative, combined with the official measurements, provide a much more (spatially) detailed overview of air quality than the (much fewer) official measuring stations alone. Official authorities use the data for experimental modelling¹⁴⁴.</p> <p>Research continues in order to establish more robust calibration methods, while ongoing work is aimed at improving understanding of the public's needs for air-quality information to optimise the use of low-cost sensors.</p>
Relevant stages of policy-making:	Problem definition / early warning / monitoring / awareness-raising
Organisation/tools:	<p>Volunteers buy and assemble low-cost sensors for fine particles (PM10 and PM2.5) according to instructions on platforms from partners such as <i>Sensor.Community</i>. <i>Sensor.Community</i> and similar organisations promote their use for citizen science and often provide maps (and IT support tools) to visualise the results.</p> <p>RIVM collates and publishes official and volunteers' data and shares the results as open data on its <i>samen meten</i> citizen science portal; https://samenmeten.rivm.nl</p>
Geographical scope:	<i>Samen meten</i> covers the Netherlands. <i>Sensor.Community</i> , an important source of citizen science data for this initiative, had more than 9,000 PM sensors across the world, but mostly in Europe (400 in the Netherlands, over 800 in Belgium, around 700 in Bulgaria) ¹⁴⁵ .
Temporal scope:	Since the public launch (6 December 2017), the number of sensors has steadily increased.
Resources:	Difficult to measure, as it is part of a larger innovation programme, with activities grouped together.
Quality control:	As the incoming raw data collected through the low-cost sensors produce erroneous values in some cases (e.g. high air humidity), RIVM is testing ways to correct and calibrate the data to make them useful for monitoring.

¹⁴⁴ <https://samenmeten.rivm.nl/uurkaart/>

¹⁴⁵ https://www.madavi.de/sensor/active_sensors.php

Initiative:	<i>Samen meten</i> initiative
Outcomes:	Although <i>samen meten</i> data are not yet used for official air-quality monitoring purposes, they have already shown their usefulness in early detection and near real-time mapping of the cross-border influx of air pollution ¹⁴⁶ . Authorities are using the data for experimental modelling.
Reference:	samenmeten.rivm.nl https://sensor.community/

¹⁴⁶ Wesseling, J.; de Ruiter, H.; Blokhuis, C.; Drukker, D.; Weijers, E.; Volten, H.; Vonk, J.; Gast, L.; Voogt, M.; Zandveld, P.; van Ratingen, S.; Tielemans, E. ‘Development and implementation of a platform for public Information on Air Quality, Sensor Measurements, and Citizen Science. *Atmosphere* 2019, *10*, 445; <https://doi.org/10.3390/atmos10080445>

Initiative:	<i>CurieuzeNeuzen</i>
Policy area:	<p>Air pollution / air quality</p> <p>Odour pollution</p> <p>Climate change</p> <p>SDGs, including SDG 3 (good health and well-being) and SDG 11 (sustainable cities and communities)</p>
Policy impact:	<p>The project aimed to map air quality accurately, with volunteers' cooperation, by installing a simple, standardised measurement device on a street-facing window of their house, apartment or building. Two passive samplers (Palmes diffusion tubes) determined the mean concentration of nitrogen dioxide (NO₂) in the ambient air over 1 month. The data were quality-controlled and calibrated with NO₂ measurements at reference monitoring stations operated by the Flemish Environment Agency (VMM).</p> <p>Two measurement campaigns have been carried out so far:</p> <ul style="list-style-type: none"> – Antwerp (2016) – 2,000 locations measured; and – the region of Flanders (2018) – 20,000 locations. <p>An initial assessment showed that the project had most policy impact in terms of procedural change (acceptance and use of citizen-generated air-quality data), agenda-setting and discursive change:</p> <ul style="list-style-type: none"> • the procedural change relates especially to broader recognition at different levels of the state-of-the-art air-quality model, which was validated and improved through the project. The VMM uses this model as a standard tool for NO₂ reporting and policy development, and it is used as a reference in multiple policy documents. Hence, through model improvement, the volunteer-based data have directly contributed to policy improvement. <i>CurieuzeNeuzen</i> also influenced the Flemish government's air-quality action plan, which now includes measures for the whole of Flanders instead of only one zone in Antwerp; • comparison of the model with volunteer-based data revealed that the quality of official traffic data (used as input to the model) was not sufficient to produce reliable air-quality simulations. Hence the lack of proper traffic data limits the predictive capacity of the official air-quality NO₂ model. In response, the Flemish government asked its Mobility Department to improve street-level mobility data; • in a national court case brought by Greenpeace, the judges agreed that Flanders should change the procedure for air-quality reporting to the EU. Reports should not be restricted to data from the sparse network of reference stations, but should also include detailed spatial maps produced by the improved NO₂ air-quality model. This ruling might have repercussions beyond Belgium, if it acts as a precedent, possibly

Initiative:	<i>CurieuzeNeuzen</i>
	<p>changing official air-quality reporting in all Member States;</p> <ul style="list-style-type: none"> • the EEA has promoted <i>CurieuzeNeuzen</i> as good practice for citizen science initiatives on air quality¹⁴⁷. Two recent Commission calls have cited the project as an example of good practice; • in the context of agenda-setting, <i>CurieuzeNeuzen</i> has been referred to multiple times in political debates at all levels of government in Flanders: <ul style="list-style-type: none"> ○ at regional level, it triggered debates about existing policies, although no directly attributable changes were recorded; ○ at municipal level, it triggered many political debates about air quality in neighbourhoods and streets. In some cases, this resulted in further measurements or changes to mobility arrangements. The VMM visited around 80% of all Flemish municipalities in the aftermath of the project and found that relevant staff and councillors had improved their knowledge on air quality significantly, largely thanks to the project; • the project has clearly contributed to the growing recognition of the problem of traffic-related air pollution in Flanders, especially through NO₂. Air quality has become a hot topic in both print and audiovisual media. The debate has shifted from air quality as a problem in only two or three cities to the recognition that it can vary strongly from street to street, and that many villages also have problem streets.

¹⁴⁷ EEA Report No 19/2019 Assessing Air Quality through Citizen Science: <https://www.eea.europa.eu/publications/assessing-air-quality-through-citizen-science>

Initiative:	Distributed network for odour-sensing, empowerment and sustainability (D-NOSES)
Policy area:	<p>Odour Pollution</p> <p>Air pollution / air quality</p> <p>Climate change</p> <p>SDGs, including SDG 3 (good health and well-being) and SDG 11 (sustainable cities and communities)</p>
Policy impact:	<p>Odour pollution is under-regulated in many countries (except Germany and the Netherlands, for example), despite being the second cause of environmental complaints after noise (accounting for around 30% of complaints globally). The future D2.2 of the D-NOSES project will explain the national regulatory frameworks for odour pollution in Europe and beyond. Where regulations exist, they are not often coherent or even scientifically sound. In addition, competence on odour pollution differs from country to country. For example, in Spain, municipalities can issue ordinances to regulate odour pollution, while in Portugal regulations first have to be adopted at national level. In December 2016, Poland encouraged the Council of the EU to start working on an appropriate legislative proposal (Information from the Polish delegation, ENV 772. 15267/16).</p> <p>D-NOSES aims to create scientific references and replicability guidelines as a basis for new regulatory frameworks to foster a more sustainable and healthy environment for currently unprotected communities suffering from odour pollution. The project has already produced a policy brief, which is currently being ‘localised’ to the local languages and countries in the D-NOSES consortium as a part of its advocacy strategy. By the end of the project (March 2021), two policy documents will have been produced:</p> <ul style="list-style-type: none"> • a green paper on odour pollution; and • a strategic roadmap for governance in odour pollution.
Relevant stages of policy-making:	Problem definition / early warning / monitoring / awareness-raising / advocacy / public participation in local decision-making

Initiative:	Distributed network for odour-sensing, empowerment and sustainability (D-NOSES)
Organisation/tools:	<p>Dedicated mobile app and specific mapping tools (with a worldwide map); open to anybody to use; main stakeholders: the public at large, authorities, odour-emitting activities and academia/research organisations.</p> <p>The OdourCollect App is a free citizen science app for co-creating collaborative odour maps. It empowers communities affected by odour pollution to report the issue. Real-time odour observations, obtained for the first time from the point of view of the receptor, are validated by odour experts and correlated with industrial processes, with the ultimate aim of co-designing local solutions with ‘quadruple helix’ stakeholders, engaging people in local decision-making.</p> <p>The International Odour Observatory has been designed to open and generate information and data in relation to odour pollution. It has been created to help anyone involved in causing or addressing odour pollution, including individuals and communities, policy-makers and regulators, researchers and industries. It includes information on odour issues, regulations, research, data collection methods and potential mitigation measures or solutions. Although odour pollution is a major source of environmental complaints (30% on average), very little is known about it and its extent. By bringing together all the information in one place, we can begin to build a picture of how big a concern odour pollution is and how we can tackle it at local, national and global levels.</p> <p>The network has already generated a map of communities affected by odour pollution, and a global map of odour regulations.</p>
Geographical scope:	<ul style="list-style-type: none"> • global, through the mapping tools (literally putting odour pollution on the map worldwide) and through the final project results (informing new regulations); • national, in Europe and elsewhere, with a specific emphasis on the partner countries (Austria, Bulgaria, Chile, Germany, Greece, Italy, Spain, Portugal, UK) and beyond; • local, through the pilot case study interventions to tackle odour pollution in affected communities in the partner countries, plus some other countries/pilot sites that have been added (e.g. in Uganda and another case study in Lisbon, Portugal).
Temporal scope:	<p>April 2018 — March 2021</p> <p>At its inception, the project produced a sustainability plan to be able to continue with the proposed objectives and exploitation of results through the project coordinator’s creation of the SME Science for Change.</p>
Resources:	<p>H2020 support (project number 789315).</p> <p>EU contribution: €3.1 million</p>
Quality control:	<p>Data validation by odour experts.</p>
Outcomes:	<p>International Odour Observatory, green paper on odour pollution, scientific and policy guidelines, strategic roadmap for governance in odour pollution to introduce the issue into the policy agenda and help promote sustainability and governance through community action.</p>

Initiative:	Distributed network for odour-sensing, empowerment and sustainability (D-NOSES)
Reference:	https://dnoses.eu/ https://cordis.europa.eu/project/rcn/217646/factsheet/en https://odourcollect.eu/ https://odourobbservatory.org/ https://dnoses.communitymaps.org.uk/welcome

Initiative:	Hush City App
Policy area:	Noise Quiet areas and human health (spotting and monitoring quiet areas), especially set up in the context of the Noise Directive (2002/49/EC).
Policy impact:	So far on local level, for example: <ul style="list-style-type: none"> • the Berlin Senate has used the results from the Hush City app in the context of the 2018-2023 Berlin noise action plan; and • the City of Limerick (2020 European Green Leaf City) uses Hush City in 2020 in the context of its noise action plan. A public announcement was made when Limerick received the Green Leaf Award.
Relevant stages of policy-making:	Monitoring / problem definition / awareness-raising / implementation
Organisation/tools:	The quiet areas crowdsourced with the app (available free on Android and Apple devices) are open access and available online via the Hush City map .
Geographical scope:	The app focuses on the local level, closely related to urban planning. Launched in 2017 in the context of a pilot study in Berlin, Hush City has scaled up to international level and is now used in many cities around the world, including in Africa, Asia and South America.
Temporal scope:	2017-present (looking for sustainability of the infrastructure and the community)
Resources:	Hush City has been developed and implemented by the following projects: <ul style="list-style-type: none"> • ‘Beyond the noise: open source soundscapes’ (2016-2018), funded by the IPODI-Marie Curie fellowship — people programme (TU Berlin / IPODI grant agreement no. 600209); and • ‘Hush City mobile lab’ (2018-2020), funded by the HEAD-Genuit Foundation [research grant P-17/08-W].
Quality control:	<ul style="list-style-type: none"> • questionnaire developed in 2016, following procedures adopted in previous soundscape and quiet areas studies; • audio data are sampled at 44.100 Hz, with 16 bit resolution. The maximum length of the audio file is 30 seconds; • pictures are collected at a maximum resolution of 6 MP and 24-bit colour; • sound-pressure levels are calculated as numerical scale values and A-weighted (i.e. 45 dB(A)). L_{eq} (equivalent continuous sound level), L_{min} (minimum sound level) and L_{max} (maximum sound level) are also calculated and displayed. NoiseTube’s app libraries have been consulted to select the most appropriate formulae for sound-pressure level calculation; • these formulae have been double-checked by a team of acoustic advisors involved in the project.
Outcomes:	Hush City map Berlin 2018-2023 noise action plan Limerick noise action plan (expected 2020)

Initiative:	Hush City App
Reference:	<p>http://www.opensourcesoundscapes.org/hush-city/</p> <p>Radicchi, A. (accepted and forthcoming). ‘15 people-centered recommendations for the design, build and use of mobile apps for soundscape research and public space studies. Lessons learnt from the Hush City project’ in Skarlatidou, A., Haklay, M. (eds), <i>Geographical citizen science design: no-one left behind</i>, UCL Press.</p> <p>Dunbavin, P., Radicchi, A. (2018). ‘The Hush City project and its relevance to planning policy’, <i>Acoustic Bulletin</i>, 43(5), pp. 34-40. ISSN: 0308-437X.</p> <p>Radicchi, A. (2017). ‘The Hush City app: a new mobile application to crowdsource and assess “everyday quiet areas” in cities’, <i>Invisible places: sound, urbanism and the sense of place</i> (proceedings of the Invisible Places conference, São Miguel, Azores), pp. 511-528. E-ISBN: 978-989-746- 129-3.</p> <p>A full list of scientific publications is available here.</p> <p>International press coverage is available here.</p>

Initiative:	Brenta-Bacchiglione citizens' observatory
Policy area:	Water Soil Floods Disaster management River basin strategies
Policy impact:	<p>This project aims to set up a citizens' observatory on water for the Brenta-Bacchiglione catchment, supporting authorities by acquiring useful data for the implementation of the Floods Directive (2007/60/EC) and specific measures under the flood-risk management plan for the Eastern Alps hydrographic district (PGRA).</p> <p>As this is seen as a strategy for involving the public in the wider policy processes of environmental management, it incorporates the principles of the Water Framework Directive (2000/60/EC) in acquiring an environmental dataset for improving knowledge on water quality.</p>
Relevant stages of policy-making:	Awareness-raising / active public involvement in water management policy / flood-risk reduction through non-structural measures / qualitative and quantitative environmental monitoring.
Organisation/tools:	<p>The observatory will be supported by the following tools and methodologies:</p> <ul style="list-style-type: none"> • new sensors for environmental monitoring, including traditional, innovative and low-cost sensors and remote control systems; • supporting technologies that will: <ul style="list-style-type: none"> ○ acquire, store and integrate heterogeneous environmental datasets from different sources (sensor data, flood and meteorological forecasts, satellite data, social media, reports from mobile devices, images, video, GIS data, etc.); ○ run hydrological and hydraulic modelling chains in order to provide early warnings and flood forecasts; ○ provide 'static' and real-time risk maps; ○ provide an easy and clear system of access to and visualisation of previously stored and elaborated data; ○ provide the authorities in charge of disaster management with decisional and operative support during flood events; and ○ simplify communication between members of the public and authorities on environmental monitoring and flood-risk management; • campaigns for educational purposes and for collecting environmental datasets.
Geographical scope:	Brenta-Bacchiglione unit of management (UOM ITN003)
Temporal scope:	2019 (September) — present
Resources:	Budget of ~ €5 million (data-hosting, development of application, volunteers' activities) from MATTM.

Initiative:	Brenta-Bacchiglione citizens' observatory
Quality control:	<p>Users (communities) and an external data provider are responsible for the quality of environmental data acquired by the supporting technologies. The system will automatically validate the data, filtering them outside a confidence interval, as well as outliers. In addition, it will apply various data assimilation techniques to improve the accuracy of the predictions. Consideration could be given to other mechanisms to control the quality of the crowdsourced data:</p> <ul style="list-style-type: none"> • contextual conditions (the expertise level of the crowd); • credibility (the volunteer group); and • users' performance. <p>Finally, educational campaigns and feedback mechanisms will assist communities with QA/QC.</p>
Outcomes:	<p>The project has only recently started, so these are expected outcomes:</p> <ul style="list-style-type: none"> • improvement of the sensor network, by installing new traditional sensors and new social, low-cost physical sensors; • enhancing the accuracy and reliability of early warning systems by incorporating crowdsourced streamflow observations in the flood forecasting model, alongside measurements from traditional networks; • improvement of emergency protocols and response time in the event of flooding; • active public involvement (at least 100 municipalities and 1.5 million individuals); • improvement of knowledge about the territory, greater awareness of vulnerability and fragility, and behavioural change with respect to emergency situations. <p>The estimated annual benefit, in terms of damage avoided (in the event of full implementation) is €137 million.</p>
Reference:	<p>The official web page, which will include all the information, is currently work in progress. In the meantime, useful information can be found at http://www.alpiorientali.it/ and https://www.cowm.eu/</p> <p>Ferri, M., Wehn, U., Anema, K., Fritz, S., See, L., 'The value of citizen science for flood-risk reduction: cost-benefit analysis of a citizen observatory in the Brenta-Bacchiglione catchment', <i>Hydrology and earth system sciences</i>, forthcoming.</p> <p>Mazzoleni, M., Verlaan, M., Alfonso, L., Monego, M., Norbiato, D., Ferri, M. and Solomatine, D. P.: 'Can assimilation of crowdsourced data in hydrological modelling improve flood prediction?', <i>Hydrology and earth system sciences</i>, 21(2), 839–861, doi:10.5194/hess-21-839-2017, 2017a.</p> <p>Mazzoleni, M., Cortes Arevalo, V. J., Wehn, U., Alfonso, L., Norbiato, D., Monego, M., Ferri, M. and Solomatine, D. P., 'Towards assimilation of crowdsourced observations for different levels of citizen engagement: the flood event of 2013 in the Bacchiglione catchment', <i>Hydrology and earth system sciences discussions</i>, 1–40, doi:10.5194/hess-2017-59, 2017b.</p>

ANNEX II: RECOMMENDATIONS AND ACTIONS

The recommendations in Chapter 5 cover a range of potential actions, which we describe in more detail here. The recommendations are set out according to the same four areas of intervention.

Each of the proposed actions relates to specific (groups of) key actors in citizen science and environmental monitoring from among the following:

- EU authorities – policy-makers in the EU institutions (e.g. the Commission) and other EU bodies (e.g. the EEA);
- public authorities in the Member States – national, regional and local governmental bodies, including EPAs and statistical offices;
- citizen science associations and networks (including CSOs and other partners) – formal organisations (usually national or regional citizen science networks), such as those listed in Table 1 in Section 1.3;
- citizen science communities – groups of people leading or participating in initiatives. These can be informal, grassroots groups of volunteers, or groups organised in projects and potentially including professionals leading or advising the initiative; and
- researchers in academia and other research organisations.

1. MATCH-MAKING BETWEEN KNOWLEDGE NEEDS FOR ENVIRONMENT POLICY AND CITIZEN SCIENCE ACTIVITIES

Recommendation 1: Pool information on citizen science initiatives, tools and resources to enhance visibility and exchange

Action 1.1: (Citizen science associations) Set up an online information portal on citizen science, including a knowledge base on initiatives across Europe, topics covered, tools and resources

Citizen science associations could facilitate and coordinate the development and maintenance of a central information portal on citizen science, which would enhance cooperation, coordination and the exchange of useful tools, best practices and other information among citizen science initiatives. It would also raise the profile of initiatives, e.g. among public authorities. Sharing tools and information on a one-stop platform could help achieve economies of scale and secure the best possible return from investment. The EU-funded EU-Citizen.Science project¹⁴⁸ is working in this direction and, together with ECSA, could become such a central reference point in the EU.

The portal could include:

- a catalogue of initiatives, possibly broken down by theme or geographical scope, which could leverage existing ones and give visibility to grassroots, community-led activities. It could be set up so that communities can register themselves, raising their profile *vis-à-vis* other stakeholders. It could help to connect different communities and activities, fostering cross-fertilisation and joint effort. The benefits and added value of being registered in the catalogue should be clearly communicated to citizen science communities;

¹⁴⁸ <http://eu-citizen.science/>

- an overview of citizen science strategies and frameworks in Member States, in organisations, at international level, etc. Public institutions may use this as a platform to communicate areas in which there are knowledge needs that could be addressed by citizen science communities;
- information on training modules, tools, best practices and resources. Citizen science initiatives could be encouraged to release and share resources as open access — including open source software, technology and tools, as appropriate. Other citizen science communities would be able to access and re-use the resources, and they would be free to branch out, develop and deploy their own tailor-made solutions where appropriate and relevant for them;
- information on funding options, e.g. a funding roadmap indicating options at different stages of an initiative. Public authorities at all levels could contribute by clearly communicating their funding options. This could encourage initiative leaders to take account, in their planning, of resource/funding needs at different stages of the initiative (for measuring impact, communicating results, project continuation/upscaling, etc.) and consider alternatives to institutional/governmental sources of funding, for instance crowd-funding, small grants for specific aspects of the initiative, or partnerships with an NGO or a company (e.g. media, SMEs);
- support materials on ways to consolidate, spread and upscale (successful) citizen science monitoring schemes. These could include twinning with larger-scale, consolidated initiatives to exchange good practices;
- information on key national/regional environmental targets, and current monitoring and evaluation gaps/needs, as identified by public authorities. This could help identify key areas for the development of new citizen science programmes. Coordination at national/regional level could enhance cooperation between local initiatives and avoid duplication of effort; and
- platforms and networks will be considered more attractive if they offer interesting networking opportunities and peer-to-peer interaction.

Recommendation 2: Support the creation, extension and/or upscaling of pan-European citizen science initiatives in priority areas under the Green Deal

Action 2.1: (EU authorities and public authorities in Member States) Increase support for citizen science in areas where it could fill knowledge gaps relating to the priorities under the Green Deal

This support could consist of funding for, or partnering with, monitoring schemes involving members of the public, where relevant to scale up the schemes or extend their time/spatial coverage and/or scope. Where needed, the development and uptake of new initiatives and pilot projects could be promoted and/or funded. A cost-benefit analysis could help to verify whether citizen science is a faster and cheaper way of gathering data of sufficiently good quality.

For initiatives that (could) contribute to policy priorities (e.g. monitoring indicators), support and financing options should be considered across the different stages of the initiative (i.e. not stopping after the pilot phase), e.g. to extend and/or upscale successful initiatives or keep them going before they become self-sustained (‘bridge funding’). This could involve making provision for operational funding for citizen science across (environmental) policy programmes, not only in the context of R&I funding. Upscaling successful initiatives to

countries or regions that do not yet embrace citizen science approaches may require specific support or mechanisms, including:

- lower thresholds for participation;
- disseminating and exploiting the technical solutions and methodologies already working in one country to other countries for free re-use and deployment; and
- offering a cross-EU solution that could then be adapted to meet different countries' needs.

There may also be a need to support further capacity-building for citizen science for environmental monitoring in particular areas, not only within citizen science communities (e.g. NGOs, civil organisations) but also in public administrations and the scientific community in general. Also, consideration should be given to support for measuring and communicating the social and/or policy impact of initiatives. Therefore, it would be advisable to make funding subject to impact evaluation requirements and accompanied by appropriate guidance and criteria. Demonstrating the success of initiatives in advancing scientific research, social engagement and policy uses is important when it comes to promoting the value of developing, funding and (where applicable) sustaining such activities.

Supporting initiatives would be particularly relevant in the context of:

- the biodiversity strategy for 2030: – in biodiversity, the benefits of citizen science (e.g. for birds, plants and butterflies) have been clear for decades and there is scope to do more. For instance, as a contribution to the EU pollinators' initiative, specific programmes could be promoted to stop the decline of insect pollinators and engage people in their conservation;
- the zero-pollution ambition, circular economy action plan and chemicals strategy – the fields of air pollution, noise, water quality, litter/plastic pollution and the potential impact (exposure) of pollution on human health are already the focus of a number of initiatives, with some success stories that could be extended. The performance of some of the low-cost sensors used (e.g. for air quality) is still a matter of concern, especially in relation to official monitoring. Methodologies for using these sensors with reference measurements to improve, validate or calibrate existing models merit further investigation. In addition, pilot projects could explore the potential of other initiatives, e.g. in the field of resource efficiency;
- the climate ambition and the 'farm to fork' strategy – citizen science initiatives could be explored in areas where knowledge gaps exist, e.g. crop monitoring. Further linkages could also be explored in related areas, e.g. biodiversity monitoring, which is relevant for climate change (impact, adaptation) and sustainable food production (e.g. pollinators); and
- in addition to the Green Deal priorities, citizen science could fill data gaps in other areas relevant to European and global policy frameworks (the SDGs and other international commitments), or on other emerging issues, where pilot projects could produce solutions.

Recommendation 3: Promote suitable reporting mechanisms, guidelines and methodologies to facilitate the use of citizen science data and information in environmental reporting

This recommendation could be underpinned by the following specific action:

Action 3.1: (EU authorities and public authorities in Member States) Promote the availability of citizen science data on existing or new open platforms and ensure that official reporting mechanisms can accept and integrate these data

There is a clear need to facilitate the discovery and wider availability of curated, well-documented citizen science data that can be relevant and used systematically in the context of environmental monitoring and reporting. In some policy areas, existing open data platforms could be used or upgraded to include and integrate citizen science data. In other areas, new data portals may be needed, based *inter alia* on an open access approach.

EU authorities and public authorities in Member States, in partnership with NGOs and where feasible with academia/research organisations, could provide support (e.g. financial resources, infrastructure) for the establishment or upgrading of such open data portals and platforms¹⁴⁹, on which initiatives can publish data and information that are relevant to environmental monitoring. The portals and platforms could facilitate data integration and visualisation capabilities, highlight knowledge/data needs for policy, give guidance, make tools and methods available and foster sustained public participation with appropriate feedback. Consideration should be given to adopting standard data quality management and procedures, including clear licensing statements (preferably standard open data licences) and compliance with data privacy law. Underpinning these platforms, data-hosting facilities and repositories could be provided at the relevant administrative level to support the long-term preservation and curation of data in the most efficient manner.

Following existing practice in some Member States, public authorities (EPAs, statistical offices, meteorological offices, etc.) could also use these platforms to publish their own (open) datasets. This could help in the calibration, comparison and quality control of citizen science monitoring data and provide a common entry point for all relevant environmental monitoring data on specific topics, regardless of their origin. The platforms could thus become a component of a European data space for the environment¹⁵⁰, with unified access to quality-controlled and quality-assured monitoring data for both public authorities and citizen scientists, with clear indication of origin and suited to specific (policy) needs.

In order to enable/facilitate the uptake in reporting contexts of relevant data on these open portals and platforms, EU authorities and public authorities in Member States should ensure that existing reporting mechanisms and platforms (e.g. Reportnet) can accept and integrate the data. The data should be previously curated by citizen science communities and be collected according to agreed methodologies. A review or update of the reporting workflows may be necessary, in order to give reporters a clear overview of the reporting process and all actors involved.

Action 3.2: (Public authorities at EU level and in Member States) Review and communicate relevant data-quality requirements and methodologies.

¹⁴⁹ There are already existing good examples such as Artportalen in Sweden (<https://www.artportalen.se/>) or Samen meten in the Netherlands (<https://samenmeten.rivm.nl/>).

¹⁵⁰ See [draft](#) orientations document for the [future Digital Europe Programme](#).

In areas where citizen science has clearly demonstrated its added value, public authorities at EU level and in Member States (including, where relevant, statistical offices and EPAs) should review and communicate relevant data-quality requirements and associated data-collection methodologies so as to enable the use of citizen science data that meet quality standards in official monitoring or reporting data flows. The methodologies to be used may vary depending on the policy goals being addressed and the policy-making phase or process (i.e. problem definition, monitoring, etc.). They should include activities, analysis and testing approaches to identify and minimise bias. The data should then be organised in such a way that they can easily complement other data, in particular existing monitoring and reporting data in the policy area. This could be ensured by using data specifications and models set out in existing monitoring and reporting guidelines. Handbooks and templates¹⁵¹ tailored to specific domains of environmental monitoring (e.g. soil, air, water, biodiversity) conveying expectations for quality assurance and documentation could be provided to help citizen science organisations, scientists, and other stakeholders involved in those activities, document the quality of their data properly for the purposes of official monitoring or reporting.

Authorities should ensure that the use and reporting of volunteers' contributions are not prohibited under the policy, the legislation or the policy-specific monitoring and reporting guidelines¹⁵², but are provided for or even encouraged as a means to complement and improve the evidence base. To facilitate this process and enable faster adaptation with novel scientific and technological approaches, public authorities at the appropriate level may also consider decoupling the quality requirements (typically within a policy area) from the measurement procedure used to deliver the required quality (typically outside the policy area) in the context of environmental monitoring.

Action 3.3: (Public authorities) Co-develop raw monitoring data-capturing methodologies and quality assurance/control mechanisms

Public authorities at the appropriate administrative level (e.g. EPAs and statistical offices) could engage with citizen science initiatives in a stepwise process to co-develop raw monitoring data-capturing methodologies, QA/QC mechanisms and, in general, standards and tools as required for specific environmental policies and monitoring processes, where these are appropriate and not yet available. This process would thus benefit from the expertise from the citizen science community in the relevant area (e.g. through data validation mechanisms), enhancing the future uptake of citizen science data in specific policy processes. Citizen science associations/networks and academia/research organisations could contribute to and facilitate this co-development process.

2. PROMOTING AWARENESS, RECOGNITION AND TRUST

Recommendation 4: Give visibility and recognition to citizen science outcomes

This recommendation could be underpinned by the following specific actions:

Action 4.1: (Public authorities at EU level and in Member States; academia/research organisations) Give explicit credit and feedback when using citizen science contributions

¹⁵¹ A good example is the [Handbook for citizen science quality assurance and documentation](https://www.epa.gov/citizen-science/quality-assurance-handbook-and-guidance-documents-citizen-science-projects) produced by the US Environmental Protection Agency;

<https://www.epa.gov/citizen-science/quality-assurance-handbook-and-guidance-documents-citizen-science-projects>

¹⁵² European policy on farm and agricultural birds already implements this good practice.

When using citizen science data in their reports, data/policy portals and policy papers, public authorities at EU level and in Member States, and academia/research organisations should give explicit acknowledgement. This would raise awareness of the scientific achievements and the role of public contributions, increase transparency and encourage citizen scientists to maintain their involvement. Examples of this exist, e.g. on air quality¹⁵³ and biodiversity¹⁵⁴, but opportunities are being missed in other areas of environment policy, by authorities at all levels. Public authorities at EU level and in Member States could also provide feedback to citizen science communities about policy decisions on particular environmental issues. Channels for such feedback could include institutional news feeds, contributions to citizen science newsletters, dedicated e-mail lists and social media groups, possibly in partnership with citizen science networks or associations. This is especially effective in maintaining interest and active participation.

Acknowledging and referencing citizen science contributions requires open and traceable data and data quality. It may require public authorities to develop a rigorous methodology for the use of citizen science along the policy cycle so as to improve data traceability, and to establish good practices in reporting its use. This could be done by including persistent identifiers, e.g. digital object identifiers (DOIs), in citizen science datasets. The identifiers could then be referenced when using the data, thus facilitating its traceability when used in reporting, analysis, communications and policy decisions. This would show the owners of the datasets when their data have been used and in what context, and ultimately enable feedback to participants and contribute to impact assessment.

Action 4.2: (EU authorities and public authorities in Member States; citizen science networks) Highlight and reward inspiring examples of citizen science

Beyond collections of good practice and analysis of outcomes, authorities could highlight and reward inspiring examples of citizen science, e.g. through the launch of an annual EU award or other relevant instruments such as events, competitions, prizes and challenges.

A European Capital(s) of Science and Innovation initiative could be considered to engage and share knowledge and passion for science and innovation by mingling scientists and innovators with citizens, society and key innovation ecosystem actors across Europe. It would open up science to Europeans in the concerned city, region or country, and strengthens collaboration among diverse innovation ecosystem actors, including citizens' networks and partnerships.

Recommendation 5: Raise awareness of citizen science for environmental monitoring and promote it within public institutions

This recommendation could be underpinned by the following specific actions:

Action 5.1: (Public authorities at EU level and in Member States; academia/research organisations) Promote citizen science champions in EU and Member State organisations

The champions would raise awareness of the value of citizen science and help to identify opportunities to participate or facilitate environmental initiatives. They could contribute by fostering cooperation with key partners, communicating their knowledge needs and facilitating the use of citizen science data and information in their institutions. They could

¹⁵³ <https://samenmeten.rivm.nl/dataportaal/>

¹⁵⁴ <https://pecbms.info/> and <https://easin.jrc.ec.europa.eu/easin>

also reach out to local communities, engage with the public, schools and youth organisations (developing the citizen scientists of the future), and the private sector, raise awareness of environmental issues and build trust in environmental monitoring, in particular among more sceptical authorities.

Action 5.2: (Public authorities in the Member States) Develop environmental citizen science strategies or frameworks within Member States

Such strategies or frameworks would highlight the potential role of citizen science in institutions and agencies. The strategies (which some Member States have already developed or are working on) could, for example, set strategic goals for its use in the context of environmental monitoring and reporting, including specific actions, the allocation of responsibilities and the evaluation of impact. They should convey that citizen science is a scientific approach that not only focuses on producing environmental monitoring data to support their mandate, but also contributes to community building, social empowerment and science education. The development of such strategies or frameworks would send a message of support for such activities and provide overview, visibility and grant credibility to initiatives already run by the authorities, thereby facilitating further policy linkages.

3. PROMOTING DATA QUALITY AND INTEROPERABILITY STANDARDS; SHARING TOOLS

Recommendation 6: Promote the adoption, effective use and transparency of data management and sharing principles, methodologies and quality assurance/quality control in citizen science initiatives

Data management and sharing practices, including collection protocols and quality assurance procedures should be encouraged and documented within the metadata, to enable end-users to assess potential sources of bias and uncertainty, and fully understand the limitations of the data. This would facilitate their scrutiny on an equal footing with data from more traditional sources. Where feasible, open access and open data licences should be promoted.

This recommendation could be underpinned by the following specific actions:

Action 6.1: (Public authorities at EU level and in Member States) Promote the application of data management and sharing principles

Public authorities at EU level and in Member States, in cooperation with citizen science networks and associations, could promote the application of data management and sharing principles for citizen science data, as for data from any other source. This could include promoting FAIR¹⁵⁵ data principles and open access, including the use of standard open data licences in both human and machine-readable form (e.g. creative commons licences¹⁵⁶ such as CC-BY or CC0). Open science guides and training are available and could be used for the benefit of diverse communities¹⁵⁷. However, care should be taken where an open access policy could have harmful consequences (e.g. by exposing the location of endangered species). The use of existing data repositories for data-sharing and storage¹⁵⁸ could be

¹⁵⁵ Findability, Accessibility, Interoperability, and Reusability.

¹⁵⁶ <https://creativecommons.org/use-remix/cc-licenses>

¹⁵⁷ <https://www.openaire.eu/support>

¹⁵⁸ Especially in the context of the open science agenda and the European open science cloud.

promoted (or even required) for this purpose. This could be accompanied by guidance on open data licensing issues, best practices and resources for granting data access.

Action 6.2: (Citizen science communities) Communicate transparently on methodologies used and adhere to standards of good practice

Especially where data are to be used for official purposes, citizen science communities, with guidance from their associations and networks, should ensure the application, documentation and transparent communication of the methodologies and procedures they use for data collection, data management and QA/QC. This includes information and metadata on uncertainties and potential biases, and activities, analysis and testing approaches used to identify and minimise bias in the outcomes. All information should be formulated using the appropriate policy language and cover how it is ensured that contributors have the necessary expertise, where relevant (e.g. training/instruction where initiatives require specific knowledge/skills). This would help dispel doubts about impartiality that authorities and academia/research organisations may have when using citizen science information.

In this context, citizen science communities could build trust in the data/knowledge they generate if they visibly endorse, promote and adhere to the relevant standards of good practice and legal frameworks applicable in the relevant scientific disciplines. This relates in particular to transparency in methodologies, data collection and management protocols and policies, data robustness and representativeness, research integrity, data privacy, data ownership and security, safety aspects and FAIR data principles.

Action 6.3: (Citizen science associations and networks; academia/research organisations) Provide training and resources on data (quality) management methodologies and on standards of good practice

To help citizen science communities on action 6.2, associations/networks and academia/research organisations could provide training and resources on data management and QA/QC methodologies for initiatives, especially those in their initial stages or where citizen science approaches are starting to emerge. They could also highlight the importance of data protection, intellectual property rights, licensing, etc. and provide training-related actions similar to those already introduced on QA/QC methodologies.

They could thus support the (transition to the) use of standards, recommendations and good practices pursuant to the relevant European legislation (e.g. Open Data and PSI Directives and INSPIRE, the latter addressing geospatial information, and the General Data Protection Regulation¹⁵⁹). To help citizen science practitioners with questions on the legislation, associations/networks could help to connect to facilities and groups (such as law clinics) with the relevant expertise¹⁶⁰. Also, the issue of how to consider sensitive information collected by volunteers (e.g. sensitive species, nesting of rare birds, etc.) could be addressed in specific guidance and training, in cooperation with citizen science initiatives and public authorities. This would address aspects of the complex challenge that citizen science communities are facing.

¹⁵⁹ General Data Protection Regulation (GDPR), [Regulation \(EU\) 2016/679](#).

¹⁶⁰ Following, for example, the law clinics approach offered by the recently established policy working group of the US Citizen Science Association (CSA).

Academia/research organisations, public authorities and citizen science initiatives, associations and networks may share research and knowledge on other areas of concern, such as data donation, privacy-preserving technologies and decentralised data governance¹⁶¹. This could be covered by dedicated working groups involving all the above stakeholders. The work should build on ongoing initiatives at a more general level¹⁶² (i.e. not specific to citizen science or environmental monitoring), take account of any particular requirements and ensure the consistent application of emerging practices.

Recommendation 7: Support the creation of citizen science capacities, reach out to the next generation of citizen scientists and promote the uptake of innovative technologies and approaches

This recommendation could be underpinned by the following specific actions:

Action 7.1: (Public authorities in Member States) Support capacity-building to provide training, technical and legal support, outreach and education on citizen science

Public authorities in Member States could consider setting up national/regional centres of excellence to provide citizen science practitioners with training and technical/legal support, and reach out to local communities and schools. The centres could be based on existing infrastructures/organisations or be new ones.

Through these centres of excellence or through other means, authorities could promote training in digital skills and support the inclusion of citizen science activities in primary and secondary schools, to raise environmental awareness and engagement among young people, thus fostering behavioural change and nurturing the citizen scientists of the future. Partnerships with citizen science associations and local communities may facilitate outreach to schools and support this process.

Action 7.2: (Public authorities, in partnership with academia/research organisations and citizen science associations/networks) Foster innovation by sharing open tools and investigating emerging scientific and technological trends

In order to foster innovation and citizen science communities' uptake of new technological approaches, technology and tools could be shared and released as open access, so that they can be adapted and re-used in other environmental areas or in the context of other initiatives.

Also, support should be provided for further investigation of artificial intelligence (AI) and methodological approaches, including Earth observation and big data analytics in the context of environmental monitoring and citizen science. These novel approaches should be tested and piloted with the relevant partners, such as the Group on Earth Observations (GEO), and their impact assessed, ultimately facilitating their transfer to and uptake by the citizen science initiatives themselves.

¹⁶¹ Apart from projects such as DECODE, CitizenHealth, etc., university libraries and library science in general might also provide valuable advice.

¹⁶² e.g. <https://ec.europa.eu/digital-single-market/en/news/public-sector-information-group-main-page>

4. SUPPORTING COORDINATION, COOPERATION AND RESOURCES FOR POLICY IMPACT

Recommendation 8: Seek and promote cooperative approaches and strategic partnerships, enhancing engagement, the societal impact of citizen science initiatives and uptake in environmental monitoring and policy-making

This recommendation could be underpinned by the following specific actions:

Action 8.1: (All potential stakeholders) Use co-creation and seek strategic partnerships

When initiating an activity, a co-creation exercise should be undertaken, involving members of the public/civil society, academia/research organisations, public authorities, SMEs and businesses and (where necessary) EPAs and statistical offices. Co-creation can cover all stages of an initiative, including its sustainability and management of its legacy. This process could be enabled, for example, by encouraging stakeholder mappings, organising match-making meetings or co-designing methodologies, data-collection protocols and QA processes. Strategies could involve co-design workshops, participatory budgeting, public fora, stakeholder vision building and participatory scenario planning. Relevant stakeholders could sit on steering committees in citizen science associations/networks, and working groups on data management in environmental monitoring and citizen science could be established, involving all interested parties¹⁶³.

To foster such co-creation and amplify their impact, initiative leaders could consider partnerships with:

- researchers in academia/research organisations, to strengthen the scientific basis of their initiative and build trust in the scientific and regulatory communities;
- NGOs, civil society organisations and social movements, which often have an active network of volunteers who can be mobilised, and relevant policy expertise and communication skills and networks/tools, which could make them valuable partners in citizen science activities in the environmental domain;
- schools and youth organisations, to engage (and educate) children and youngsters;
- authorities in Member States, including local environment agencies, which need knowledge and monitoring data for nature management plans, impact assessments, etc. Raising their interest may open perspectives for mutually beneficial cooperation (e.g. on data requirements). Public authorities should be aware that their interaction with citizen science initiatives may be perceived as a form of surveillance. They should consider measures to counter such perceptions (e.g. clear communication and transparency);
- community champions, especially people who go to particular lengths to engage peers and link up with researchers in academia/research organisations or public authorities;
- media companies that can publicise the initiative, not only to attract more volunteers/participants, but also to promote results and findings;
- the maker community (e.g. health-hackers¹⁶⁴), who can develop low-cost tools (sensors, etc.) tailored to citizen science needs; and

¹⁶³ This could include co-leadership by a governmental authority, as is the case with the Flemish Citizen Science Knowledge Centre.

¹⁶⁴ This is a grassroots movement of volunteers who connect and work together (e.g. during workshops or ‘hackathon’ events) to accelerate innovation and create solutions to improve healthcare (e.g. <https://hacking-health.org/>).

- the private sector, where there is largely unexploited potential to contribute to environmental citizen science, in terms of time and financing. Businesses present opportunities for meaningful public involvement in environmental research and potential funding. For instance, small- or medium-sized enterprises (SMEs) can provide initiatives with useful advisory services or material (sensors). Companies that have sustainability in their mission statement may be particularly interested. Initiatives can even enable a project partner to launch a new SME spinoff based on a service or product developed for the project, although account should be taken of ethical issues relating to partiality and vested interests.

Action 8.2: (Citizen science networks) Facilitate partner identification and networking

Citizen science networks could facilitate partner identification and policy uptake by offering networking opportunities (e.g. thematic events on environmental monitoring), online platforms and other types of ‘market place’ bringing together experts, initiative leaders, funders and other potential partners with an interest in environmental initiatives. Such brokering activity and peer-to-peer exchange would be an additional incentive for (busy) initiative leaders to engage with networks. Regular events (possibly focused on specific policy topics, e.g. field visits) where citizen science groups present their activities to policy-makers and/or government representatives could improve the alignment of activities with policy-related data needs and promote their value for policy-makers.

Recommendation 9: Improve EU/national/regional coordination among citizen science initiatives
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This recommendation could be underpinned by the following specific actions:

Action 9.1: (Citizen science networks) Promote coordination of citizen science activities

National/regional networks could highlight key national/regional environmental targets, and current environmental monitoring and evaluation gaps/needs, building on platforms and portals such as those referred to in action 1.1. They could help identify key areas for the development of new citizen science programmes. Coordination at national/regional level could enhance cooperation between local initiatives and avoid duplication of effort. Platforms and networks will be considered more attractive if they offer interesting networking opportunities and peer-to-peer interaction.

Action 9.2: (Public authorities in Member States, CSOs, academia/research organisations and private partners) Support citizen science networks

Public authorities in Member States, CSOs, academia/research organisations and private partners can support networks by partnering with them and/or providing resources, e.g. they could support and contribute to the organisation of networking events. Public authorities could help identify opportunities relating to knowledge needs for environmental monitoring, and cooperate with and contribute to platforms and portals. They could also support EU-wide networking and exchanges between national/regional networks. This is especially important for countries and regions where networks and communities are still in their infancy.

ANNEX III: SUMMARY OF RECOMMENDATIONS AND ACTIONS

RECOMMENDATIONS AND ACTIONS		STAKEHOLDERS LEADING (dark) OR CONTRIBUTING (light)				
		EU authorities	Public authorities in Member States	Researchers in academia / research organisations	Citizen science communities and initiatives	Citizen science networks / associations
Match-making between knowledge needs for environment policy and citizen science activities						
1 Pool information on citizen science initiatives, tools and resources to enhance visibility and exchange						
1.1	Set up an online information portal on citizen science, including a knowledge base on initiatives across Europe, topics covered, tools and resources					
2 Support the creation, extension and/or upscaling of pan-European citizen science initiatives in priority areas under the Green Deal						
2.1	Increase support for citizen science in areas where it could fill knowledge gaps relating to priorities under the Green Deal					
3 Promote suitable reporting mechanisms, guidelines and methodologies to facilitate the use of citizen science data and information in environmental reporting						
3.1	Promote the availability of citizen science data on existing or new open platforms and ensure that official reporting mechanisms can accept and integrate these data					
3.2	Review and communicate relevant data quality requirements and methodologies					
3.3	Co-develop raw monitoring data-capturing methodologies and QA/QC mechanisms					

Promote awareness, recognition and trust						
4 Give visibility and recognition to citizen science outcomes						
4.1	Give explicit credit and feedback when using citizen science contributions					
4.2	Highlight and reward inspiring examples of citizen science					
5 Raise awareness of citizen science for environmental monitoring and promote it within public institutions						
5.1	Promote champions in EU and Member State institutions					
5.2	Develop environmental citizen science strategies or frameworks in Member States					
Promote data quality and interoperability standards and share tools						
6 Promote the adoption, effective use and transparency of data management and sharing principles, methodologies and QA/QC in citizen science initiatives						
6.1	Promote the application of data management and sharing principles					
6.2	Communicate transparently on methodologies used and adhere to standards of good practice					
6.3	Provide training and resources on data (quality) management methodologies and standards of good practices					
7 Support the creation of citizen science capacities, reach out to the next generation of citizen scientists and promote the uptake of innovative technologies and approaches						
7.1	Support capacity-building to provide training, technical and legal support, outreach and education in citizen science					
7.2	Foster innovation by sharing open tools and investigating emerging scientific and technological trends					

Support coordination, cooperation and resources for policy impact						
8 Seek and promote cooperative approaches and strategic partnerships, enhancing engagement, the societal impact of citizen science initiatives and uptake in environmental monitoring and policy-making						
8.1	Use co-creation and seek strategic partnerships					
8.2	Facilitate partner identification and networking					
9 Improve EU/national/regional coordination among citizen science initiatives						
9.1	Promote coordination of citizen science initiatives					
9.2	Support citizen science networks					