ScienceUs

D2.1

WP2

BENCHMARKING CONCLUSIONS ON BEST PRACTICES IN CITIZEN SCIENCE

Report By :

FII & SUR

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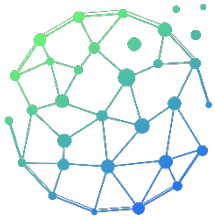

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Deliverable 2.1

Benchmarking conclusions on best practices in citizen science

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BENCHMARKING CONCLUSIONS ON BEST PRACTICES IN CITIZEN SCIENCE

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Executive Summary

Deliverable 2.1, Benchmarking Conclusions on Best Practices in Citizen Science, provides a comprehensive analysis of over 70 citizen science initiatives across Europe, focusing on climate change adaptation. This deliverable, part of Work Package 2 (WP2) of the ScienceUs project, aims to identify the barriers, challenges, and best practices that influence citizen science initiatives' scalability and long-term success, particularly in alignment with the New European Research Area (ERA) and EU missions.

The benchmarking process selected and evaluated these initiatives based on key metrics such as participation (both of scientists and citizens), data quality, impact, sustainability, gender balance, and diversity. The analysis identifies Key Strategic Topics (KSTs) in which citizen science can meaningfully contribute to climate adaptation, such as water resource management, biodiversity conservation, urban resilience, and flood risk mitigation. Challenges such as limited funding, insufficient long-term engagement, the need for institutional support, and access to technologies are highlighted as critical barriers to scaling these initiatives.

This deliverable outlines several best practices, including institutional solid collaboration, using digital tools for data collection, and engaging groups of citizens to ensure broad participation. The findings will support future work in scaling successful initiatives across Europe and inform the development of targeted strategies and policy recommendations to enhance the role of citizen science in addressing climate change. Also, it will ensure the framework for ScienceUs Open Call competition.

The conclusions drawn from this analysis will guide subsequent work packages, including the design of support services and tools for upscaling promising citizen science initiatives and the development of communication and dissemination strategies to foster an EU-wide network of interconnected citizen science projects.

Introduction

The Task within WP2: aim and objectives

Task 2.1 plays a crucial role in the ScienceUs project by exploring and analyzing citizen science initiatives across Europe. The main objective of this task is to conduct a comprehensive benchmarking of citizen science initiatives across various scientific disciplines, with a particular emphasis on climate change. The goal is to identify barriers, needs, and challenges hindering citizen science initiatives' implementation, impact, and scalability.

Key Steps of Task 2.1

Task 2.1 includes four key steps:

1. **Identification of Benchmarking Metrics** for defining parameters such as participation, data quality, impact, sustainability, gender balance, diversity, and inclusion used to evaluate citizen science projects.
2. **Selection of Relevant Projects** for identifying citizen science projects according to the previously established metrics.
3. **Data Collection and Analysis** for assessing the performance of the selected projects based on the identified metrics, providing a clear picture of their effectiveness and challenges.
4. **Evaluation of Barriers and Opportunities** for pinpointing the main obstacles, opportunities, and challenges faced by citizen science initiatives within the context of research and innovation.

WP2 Overview

Task 2.1 is integral to the effective execution of Work Package 2 (WP2) and contributes significantly to the overall goals of the ScienceUs project. WP2's broader aim is to benchmark citizen science practices, highlighting areas for improvement and sharing best practices to enhance the effectiveness and impact of citizen science initiatives. This benchmarking analysis identifies key metrics and best practices that facilitate scaling across Europe.

Task 2.1 and the entire ScienceUs project are rooted in the policy context of the New European Research Area (ERA) framework, which seeks to create an EU-wide network of

interconnected citizen science projects. In this context, Task 2.1 focuses on adaptation to climate change as a guiding framework for analyzing the benchmarking data collected.

Through this task, ScienceUs identified 70 representative citizen science initiatives, providing substantial data to demonstrate the value of citizen science to key Quadruple Helix actors—citizens, industry, academia, and policymakers. Engaging these stakeholders supports the New ERA's mission to promote knowledge exchange and encourage research reforms that make science more accessible and participatory.

A significant feature of Task 2.1 is the establishment of a Stakeholder Advisory Board (SAB), which comprises over 20 representatives from academia, industry, government, and civil society. The SAB supports benchmarking activities, offers guidance on project evaluations, and contributes to the ScienceUs Upscale Academy, which aims to scale up successful citizen science initiatives across EU regions.

Key Performance Indicators

To ensure the effectiveness of the project, ScienceUs has defined Key Performance Indicators (KPIs) for this deliverable, which include:

- Number of benchmarked citizen science projects: >50
- Key Strategic Topics (KSTs) identified: >10

In summary, Task 2.1 is not only essential for the effective execution of WP2 but also directly contributes to the broader objectives of the ScienceUs project by facilitating the development of a robust network of citizen science initiatives that can adapt to and address climate change challenges across Europe.

Relation to the other WPs and tasks

The insights gained from Task 2.1 are fundamental to the subsequent work packages in the ScienceUs project. The benchmarking results from WP2 will directly support WP3 in designing the ScienceUs call (e.g., identification of the call challenges, adapting the call application and evaluation process, and supporting the transitions between Seed, Flourish, and Harvest phase). The consortium will select and support 25 high-potential citizen science initiatives during the Seed phase and five in the Flourish and Harvest phases, helping them scale up and connect across European regions. These projects will be encouraged to foster greater citizen engagement at the European level, promoting participation in research, advocating for funding, and sharing outcomes with local communities.

The case studies and testimonials collected during WP2 will guide the design of calls and support services in WP3, ensuring that scaling and networking are built on proven examples. WP4 will further build on these findings by conducting impact analyses and providing policy recommendations based on the best practices identified through Task 2.1.

WP5 will then take the lead in communicating, disseminating, and exploiting the project results across Europe, aiming to create a sustainable, long-term framework for citizen science. Meanwhile, WP1 will ensure seamless coordination and management across all tasks, from benchmarking in WP2 to dissemination in WP5, maintaining a coherent and effective approach throughout the project.

In summary, Task 2.1 lays the groundwork for WP3's implementation of support measures and WP4's evaluation and policy recommendations, creating a cohesive flow across all work packages to achieve ScienceUs's overall objectives.

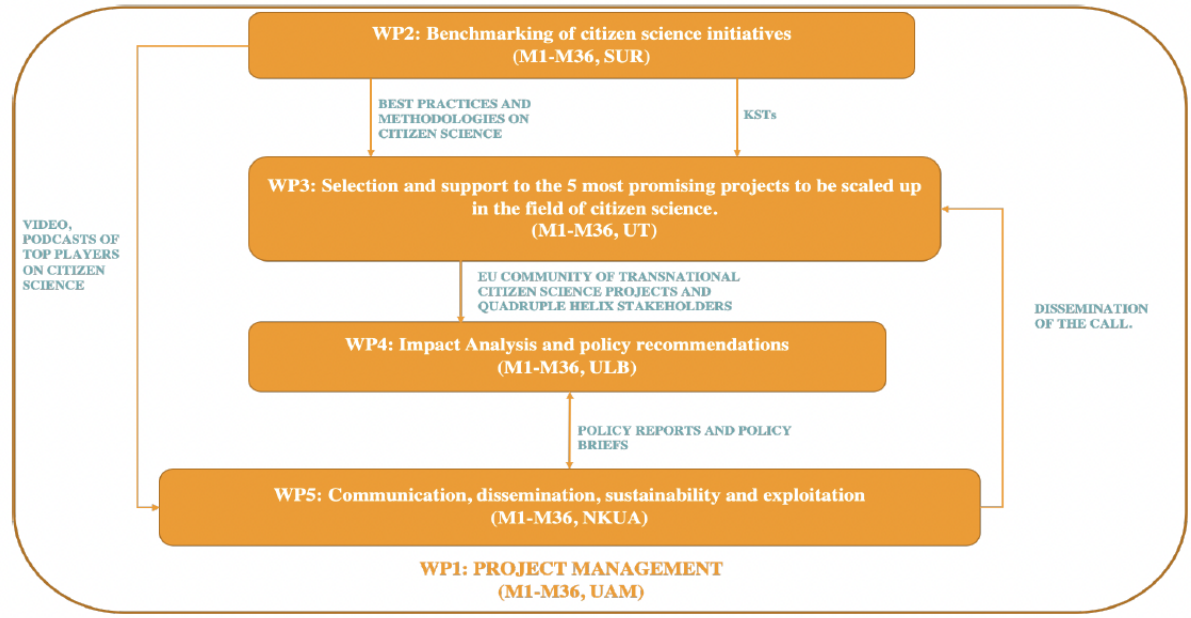

Figure 1. WPs interconnections withing the ScienceUs Project

Document's purpose and structure

The primary purpose of this deliverable is to serve as a foundational report for the ScienceUs project, providing a thorough analysis of citizen science initiatives that can inform subsequent work packages. Indeed, the deliverable synthesizes key findings, identifies best practices, and highlights the barriers these initiatives face, ultimately guiding future efforts in scaling and sustaining successful citizen science projects. By identifying best practices, obstacles, challenges, and opportunities, this deliverable aims to enhance the effectiveness of citizen science in addressing pressing environmental issues. Last but not least, it seeks to foster a collaborative and informed approach to citizen science that aligns with EU objectives for climate resilience and sustainability, driving knowledge exchange and empowering communities to take action in the face of climate change.

The deliverable provides a comprehensive overview of the benchmarking analysis conducted on citizen science initiatives, focusing on their contributions to climate change adaptation in the European Union. It is structured as follows.

After an introduction, the deliverable details the specific aims of the benchmarking effort, which include identifying Key Strategic Topics (KSTs) relevant to climate adaptation and

defining the metrics necessary for evaluation. The objectives outlined enhance the overall effectiveness of citizen science by providing a clear framework for assessment.

The methodology chapter provides a detailed account of the process in selecting the initiatives for benchmarking, the specific metrics (criteria) for the evaluation process, and the data collection techniques applied. This section highlights the collaborative efforts among project partners to define a robust evaluation framework, ensuring that the benchmarking is comprehensive and relevant.

The key findings from the benchmarking analysis are presented in the subsequent chapter. This includes an examination of the challenges faced by citizen science initiatives, identification of best practices, and strategic topics that emerged from the data analysis. This chapter aims to provide an in-depth understanding of the current landscape of citizen science in Europe.

The recommendations section is informed by the analysis's findings and outlines actionable steps for enhancing the scalability and sustainability of citizen science initiatives. This part emphasizes the importance of developing targeted support mechanisms and policies that foster collaboration among stakeholders to maximize the impact of these initiatives.

Finally, the conclusions chapter summarizes the key takeaways from the benchmarking analysis, reinforcing citizen science's crucial role in contributing to climate adaptation efforts. It also highlights the potential for future research and initiatives to build on the insights gained from this deliverable, promoting sustainable engagement and development in citizen science. This document serves as a foundational report for the ScienceUs project, guiding future actions and facilitating the effective integration of citizen science into broader climate resilience strategies.

Aim of the deliverable: definitions, approach and methodology

Benchmarking purpose and objectives

The benchmarking process in ScienceUs identifies and analyzes best practices in citizen science initiatives, particularly those addressing climate change adaptation. This involves a thorough evaluation based on key metrics chosen by project partners, ensuring a comprehensive and targeted approach. The selected metrics include participation, data quality, impact, sustainability, gender balance, diversity, and inclusion. 70 citizen science initiatives were chosen for this process, focusing on projects with solid relevance to climate change.

Climate change adaptation has been a framework for reading the data collected towards the EU Mission[1]. The focus data from these initiatives are collected and analyzed to uncover the Key Strategic Topics (KSTs), which serve as critical factors for successfully scaling and replicating these initiatives across Europe. The map of countries reached through this benchmarking process demonstrates the broad geographical scope of the study, ensuring that a diverse range of projects and contexts are represented in the analysis.

[1] The SDGs set by the United Nations provide a related and comprehensive framework for addressing the social, economic, and environmental challenges within the EU mission for which citizen science initiatives can significantly contribute to achieving these goals, particularly in the context of climate adaptation.

Scaling up, scaling out, and scaling deep

WP2 adopts three scaling framework models, namely scaling up, scaling out, and scaling deep, as discussed by Radicchi et al. (2023).

Scaling up involves implementing institutional changes through expanded citizen science projects or initiatives. These may be incorporated as a fundamental element of a policy or methodology within a specific organization, ultimately resulting in potential policy and/or legal updates.

Scaling out primarily focuses on quantitative aspects involving the replication and dissemination of citizen science projects and initiatives across various dimensions, including geographic and temporal coverage, research scope, community involvement, data collection volume, and technology/methodology utilization.

The concept of 'scaling deep' highlights qualitative aspects, such as the ability of citizen science initiatives to impact cultural shifts and attitudes, for instance by fostering trust in science among the public and trust in citizen science among professional researchers. It recognizes the significant influence of culture on instigating change, where lasting transformation occurs when individuals' beliefs, values, cultural customs, and interpersonal connections undergo significant shifts.

The three models can lead to scaling through a deliberate top-bottom approach or accidentally through a bottom-up approach since scaling as a whole involves expanding methods or strategies, moving from a limited geographic area to a broader one, or moving from a local community to an entire city and eventually encompassing a larger region (Maccani et al., 2020).

Search strategy and limits of the analysis

The process for selecting citizen science initiatives in ScienceUs is based on a well-structured methodology that involves identifying relevant metrics and validating them through a collaborative effort among project partners. Initially, a first group of initiatives was chosen from existing networks and platforms. These initiatives served as a foundation for gathering metrics, which were drawn from other similar projects. The proposed metrics, which included elements like participation, impact, and sustainability, were then shared and discussed with the partners to ensure their relevance and applicability. Following this, additional initiatives were selected to validate the metrics, ensuring that the chosen parameters are robust enough to be applied across various citizen science contexts. This structured approach allowed for a thorough benchmarking that identified best practices while laying the groundwork for the Key Strategic Topics (KSTs), which will drive the scalability of these projects.

Synthesis of the steps followed.	
1	**Research of existing platforms and networks**: the initial group of initiatives is identified from established networks and platforms.
2	**First selection of initiatives**: a preliminary group of citizen science projects is selected for an in-depth analysis.
3	**Compilation of existing metrics**: metrics from other related projects are gathered and considered.
4	**Proposed metrics for discussion**: the first metrics draft is created and shared among project partners for feedback and refinement.
5	**Selection of additional initiatives**: more initiatives are selected to validate and test the proposed metrics.
6	**Validation process**: the shared metrics are finalized after further discussion and validation from additional initiatives.

Table 1. The main steps followed

This method ensures that the benchmarking process is comprehensive, that the metrics used are shared among partners, and that they are applicable across a wide range of citizen science projects.

Criteria for Selecting the Most Relevant Initiatives for Best Practice Construction

The selection of the initiatives for constructing best practices is based on several key criteria. Priority is given to those with: a) comprehensive data collection (following the FAIR principles), and b) that received specific attention through partners' feedback. Additionally, transnational projects and those with strong potential for replicability are favored. Citizen science performance is crucial, ensuring that only well-performing initiatives are included. Although essential data are often unavailable, some considerations are given to the participation of citizens, scientists and stakeholders, and gender balance when possible. The complete dataset can be consulted at De Leo, Altamore, Ariani, 2024.

Methodological Limitations

The methodology used in Task 2.1 has limitations that partially affect the benchmarking process. Indeed, one critical issue is the availability of high-quality data from the citizen science initiatives being analyzed. To address this limitation, in cases where quantitative data were insufficient or unavailable, the analysis relied on qualitative approaches to draw meaningful conclusions.

Metrics definition

The metrics used for benchmarking citizen science initiatives were carefully selected to evaluate the process's quality and impact level comprehensively. These metrics are linked to Key Strategic Topics (KSTs) and the challenges of scalability of initiatives, with a focus on relevance to climate change adaptation. Key domains of benchmarking include general project information, details about climate change adaptation relevance, available resources, and participation levels. Additional metrics assess engagement, data quality, impact, and sustainability. Scalability and replicability were also prioritized to identify projects with potential for broader application. Gender balance, diversity, and inclusion were considered to ensure a holistic view of the initiatives. These criteria enable the identification of best practices and barriers, supporting the scaling of successful citizen science initiatives across Europe.

A specific form has been elaborated and shared among partners for collecting about 70 citizen science initiatives. Thus, the final overview of the initiatives showed columns providing key information for each metric. The metrics have been selected by considering the relevance of the scalability of citizen science initiatives, divided into three main domains: **Needed Preconditions**, **Quality of the Process**, and **Level of Impact**. The **explanation of Scalability for Each Category regards:**

- **Preconditions**: These are the elements necessary for a citizen science initiative to consider scaling. Scalability becomes impractical without proper coordination, diverse citizen involvement, and adequate resources.
- **Process Quality**: As the project grows, maintaining the quality of data collection, participant engagement, and institutional coordination becomes increasingly challenging. Metrics focused on process quality ensure that scaling does not compromise the initiative's effectiveness.
- **Impact**: Scaling aims to increase the initiative's societal and environmental impact. Metrics in this category assess whether the project can be scaled without losing its ability to influence public awareness, policy, and adaptation efforts across broader regions.

Needed Preconditions in citizen science Initiatives define the foundational aspects that must be in place for an initiative to achieve successful scaling by considering the following:

- **Coordinator and Partners**: Well-organized and reputable institutions or partners are essential for providing technical expertise, resources, and credibility.
- **Duration and Sustainability**: The longevity and sustainability of the project, as well as a clear timeline and a vision for the long term, are crucial factors for meaningful engagement with a broad range of stakeholders and communities.
- **Variety of Citizens Involved**: A diverse citizen base (in terms of age, education, gender, employment status, place of residence) ensures that projects are adaptable to different demographics and valuable for other purposes.
- **Technology Access and Digital Tools**: The use of digital platforms and mobile applications facilitating remote participation and real-time data sharing can enhance accessibility and participant motivation.
- **Funding and Resources**: Adequate financial support and access to material resources increase the project's capacity and sustainability.

Quality of the Process reflects the internal workings of the initiative, ensuring that the process is efficient, participatory, and capable of managing increased scale.

- **Training and Capacity-building for Citizens**: Proper training ensures citizens are prepared to engage meaningfully, maintaining data quality as the initiative scales. Thus, the capacity to educate and train many participants is essential.
- **Citizen Engagement and Collaboration**: Initiatives that engage participants continuously and meaningfully ensure more robust and long-term participation. This process becomes vital as the initiative expands.
- **Data Collection Methods**: Consistent and well-defined data collection protocols ensure that the data quality is maintained even when the initiative in question is scaled up.
- **Institutional Support and Coordination**: A robust process for coordination between institutional partners (research bodies, universities, governments) is critical. It ensures the initiative can handle larger scales while maintaining quality.

Level of Impact assesses the project's ability to have a broader, scalable impact in terms of policy influence and societal change.

- **Potential for Upscaling**: This metric serves to assess whether a project has the

potential for broader application across different regions or contexts. Projects with straightforward replication plans are more likely to have a scalable impact.

- **Geographic Scope**: Initiatives involving multiple countries or regions from the start are more likely to achieve scalable impact. They are designed to handle more extensive, diverse challenges and address a larger territory.
- **Success Perspective**: This criterion pertains to the project's success and perceived effectiveness, particularly regarding its contribution to societal challenges like climate change adaptation, influence its scalability.
- **Community Impact and Public Awareness**: Projects with a clear and measurable impact on public awareness or behavior change demonstrate the scalability of the initiative's outcomes. Influencing public policy or citizen behavior is vital to scaling impact.

Citizen science initiatives can scale and replicate across regions and contexts by ensuring vital preconditions, maintaining process quality, and maximizing impact.

	C	D	E	G	H	I	J	M	N
1	**Name of the CS project**	**Coordinator and partners**	**Country or countries**	**Starting year and the total duration of the CS project**	**Selecting the level of the project**	**Main topic**	**Addressed topics for climate change adaptation (please specify or list if more than one)**	**The contribution of CS project related to climate change adaptation**	**Type and leve funds**
2	**AdaptivGreece «LIFE-IP AdaptInGR - Boosting the implementation of adaptation policy across Greece»**	Ministry of Environment and Energy (MEEN), Green Fund (GRFU), National Technical University of Athens (NTUA), Natural Environment and Climate Change Agency (NECCA), Union of Greek Regions (UGR), The Central Union of Municipalities of Greece (KEDE), Region of Sterea Ellada (RSE), Region of Ionian Islands (RII), Region of Western Greece (RWG), Municipality of Katerini, Municipal Water Supply and Sewerage Company of Komotini (DEAYK), Municipality of Larissa, Municipality of Agii Anargiri-Kamatero (AAK), Municipality of Rhodes, Bank of Greece, Academy of Athens (AA), National Observatory of Athens (NOA), ELLINIKI ETAIRIA Society for the Environment and Cultural Heritage (ELLET), Mariolopoulos-Kanaginis Foundation (MFK)	Greece	2019-2026	National	Adapting Greece to climate change. The project aims to catalyse the implementation of the Greek National Adaptation Strategy and of the 13 Regional Adaptation Action Plans at the current 1st adaptation policy cycle (2016-2025) and to prepare the passage to the 2nd adaptation policy cycle (2026+), through appropriate action at national, regional and local levels.	Flood risk management, coastal zone management, forest fire protection in drought-prone areas, sustainable water management, land-use planning and regeneration, Climate change adaptation strategy, action plan and policy reccomendation	Adaptation strategy, action plan and policy recommendation, disseminate good practice examples, raise public and stakeholders awareness of climate change adaptation	European fund National funds funds
	AGORA - A Gathering place to cO-design and co-cReate Adaptation	Consortium: CMCC_FONDAZIONE CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI (project coordinator), Verein der Europäischen Bürgerwissenschaften e.V. / European CitizenScience Association (ECSA) – Germany Barcelona Supercomputing Center (BSC) – Spain Fondazione Centro Internazionale in Monitoraggio Ambientale (CIMA) – Italy	Italy, Sweden, Spain, Germany (pilot studies) Greece, Switzerland, Austria (Partners involved)	01/01/2023 36 month	European	To support communities and regions participating in the Mission on Adaptation to Climate Change2 by leveraging and advancing best practices to effectively engage citizens and stakeholders in adaptation decision-making and action. to promote societal transformational processes in different social, economic and political contexts through transdisciplinary tools and approaches. Citizens, civil society organizations, academics, experts,		develop knowledge and management of uncertainty, changing behavior, participation in building climate change adaptation measure, co-production arena to co-design, co-develop and co-implement climate adaptation solutions	European fund

Figure 2 – The Dataset of Benchmarking phase

The Benchmark Analysis

Selection of citizen science initiatives and overview

Most citizen science initiatives focus on addressing **climate adaptation and environmental sustainability**, with a strong emphasis on engaging local communities in monitoring and data collection efforts. These initiatives harness the collective efforts of citizens to track environmental changes, such as water quality, biodiversity loss, urban heat islands, and other climate-related issues. Many projects target the effects of climate change on ecosystems and urban environments, contributing valuable data that inform adaptation strategies and resilience planning.

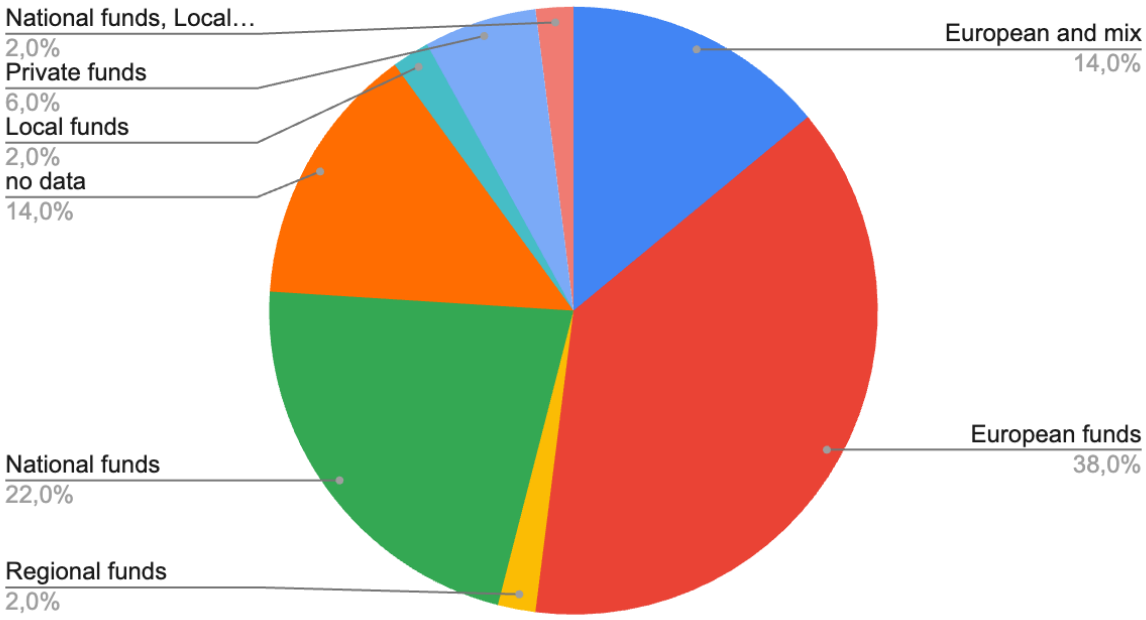

Figure 3 – The projects funds level

A common characteristic among these initiatives is their focus on **scaling up and replicability**. Indeed, many projects aim to expand geographically or be replicated in other regions, enhancing their potential for broader impact. This adaptability is crucial for addressing climate change's diverse and widespread challenges.

Furthermore, the initiatives are often carried out in **collaboration with research institutions and governments**, ensuring that the data collected by citizens integrates into broader scientific and policy frameworks. This collaboration helps to ensure that

these initiatives' findings are credible and actionable, supporting regional or national adaptation efforts.

Overall, these citizen science initiatives reflect a growing involvement and recognition of citizens' role in **climate adaptation actions**. By involving the public in monitoring and addressing climate-related challenges, citizen science projects contribute to scientific knowledge development and empower communities to engage in climate action actively. Many initiatives are designed to overcome resource limitations by leveraging digital tools and institutional partnerships, making them candidates for broader application across different regions and contexts.

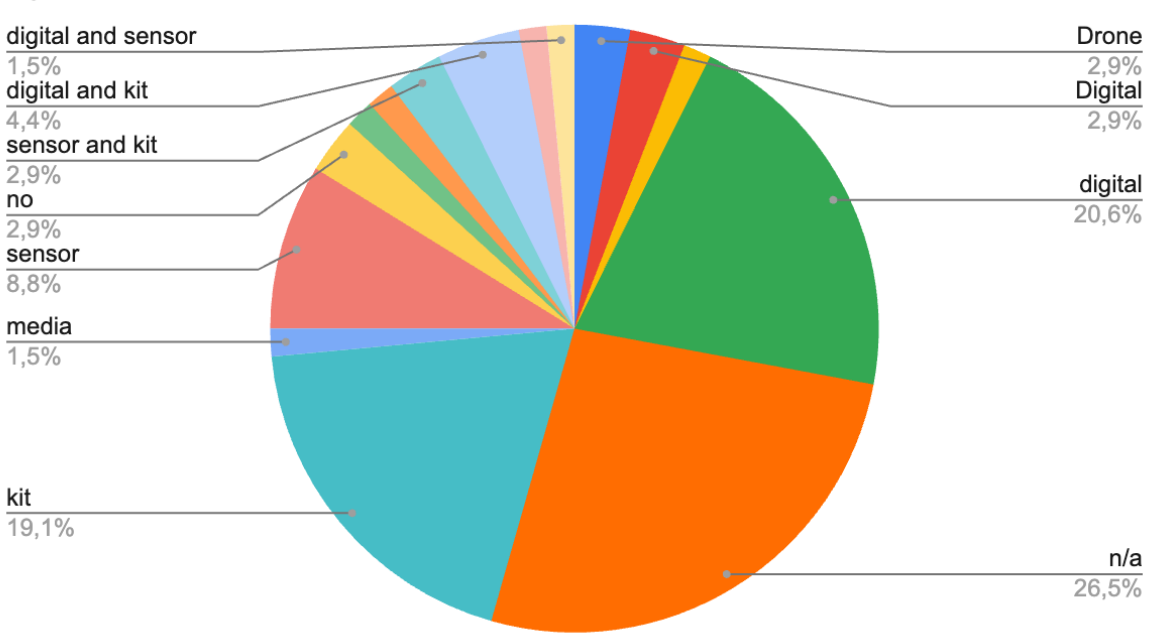

Figure 4 . The types of the equipment used

Key Strategic Topics

The Key Strategic Topics (KSTs) are the core areas or issues where citizen science initiatives can substantially contribute to climate change adaptation. These topics represent the most pressing issues that need to be addressed. By aligning citizen science efforts with KSTs, the initiatives can focus on areas where collective action and public involvement can significantly influence climate adaptation strategies.

KSTs act as a guiding framework for selecting and designing citizen science projects. These topics ensure that these initiatives address the most critical issues related to adapting to climate change in a focused, effective, and impactful manner. Each KST targets specific environmental or societal domains directly or indirectly affected by climate change.

From the analysis of citizen science initiatives, 12 Key Strategic Topics have been selected:

1. **Quality and better use of water resources**

   Citizen science initiatives have the potential to influence holistic water management through tracking and monitoring water chemical quality, temperature, precipitation, and restoration of water bodies, promoting sustainable practices for water use, and promoting citizen-driven initiatives that can influence water policies for adaptation and future resilience. These efforts related to water resources focus on strategies beyond monitoring to incorporate efforts and initiatives aimed at sustainable water management, climate resilience, and public engagement to mitigate the impacts of climate change on water bodies (e.g., lakes, rivers, wetlands, etc.).

2. **Preserving Ecosystems and Biodiversity**
   These efforts help maintain ecosystem balance and biodiversity in response to societal challenges and environmental changes and inform conservation strategies. Citizen science initiatives can include strategies promoting monitoring species patterns and understanding how climate change is affecting species distribution, identifying habitat shifts and migration patterns, assessing species loss and extinction risks, ecosystem restoration efforts, population changes, and fostering public awareness and education. Efforts like these help uphold conservation policies by ensuring that adaptation strategies are guided by science and supported by the community.

3. **Mitigating and Adaptation to Urban Heat Islands**
   Citizen science initiatives are a powerful way to engage communities in addressing the increasing urban heat islands caused by climate change in cities

and metropolitan areas through engaging citizens in science activities related to urbanization. Citizen science initiatives can help map and monitor temperature hotspots, support the development of nature-based cooling strategies, investigate how urbanization exacerbates heat waves, explore green spaces, nature-based solutions, or innovative building materials, and advocate for greener urban policies. These initiatives significantly improve the quality of life in cities impacted by urban heat islands and make cities more resilient to rising temperatures.

4. **Increasing Flood Resilience**
   Strengthen the community to improve preparedness and response to floods by gathering real-time data on rainfall, river levels, and flood events. These strategies are tailored to the needs of specific areas, enhancing overall resilience. Citizen science initiatives can involve communities in monitoring flood variables and drivers, taking part in warning systems, and creating flood protections to enable the communities to enhance their flood resilience while also helping local governments prepare for and implement flood defense mechanisms in vulnerable areas. These efforts will improve flood risk management, particularly in regions prone to extreme weather events.

5. **Addressing Coastal Erosion**
   Coastal erosion is one of the most apparent effects of climate change, caused by rising sea levels, increased storm frequency and intensity, and human activities. Citizen science initiatives such as monitoring and documenting shoreline changes and rising sea levels, engaging citizens in restoration projects, implementing coastal defense strategies, and raising awareness can actively contribute to the long-term resilience and preservation of shorelines affected by climate change. The initiatives can provide valuable data that inform protective measures, such as constructing barriers or employing natural solutions like mangrove planting.

6. **Strengthening Forest Resilience**
   Citizen science has the potential to strengthen forest resilience by engaging communities in tracking forest health, ecosystem services demand, supply and flow, monitoring biodiversity, and contributing to reforestation efforts while enhancing the health and sustainability of forests in the face of climate change. Citizen science projects can monitor tree growth, soil quality, and wildlife health, contributing to reforestation and forest restoration efforts and forest management plans to improve forest resilience and adapt to changing environmental conditions.

7. **Advancing Sustainable Agriculture**
   Promote climate-resilient farming practices through citizen science activities on crop performance and environmental factors. Citizen science initiatives can aid in developing and sharing sustainable agricultural techniques, such as water-efficient irrigation and soil preservation, helping to share knowledge on sustainable and best farming practices to ensure food security in the face of shifting climate conditions.

8. **Preparedness for Extreme Weather Events**
   Due to climate change, extreme weather events like heat waves, storms, and droughts are becoming more frequent and severe; hence, involving citizens in documenting and analyzing these occurrences prepares them to minimize the impacts. Citizen science efforts can provide localized early warning systems, engage and prepare vulnerable populations for adverse events, and provide localized and relevant data that inform the public responses, ultimately reducing risks to people and infrastructure in vulnerable areas.

9. **Improving Air Quality and Reducing Pollution**
   Citizen science initiatives can be crucial in mitigating the health impacts of air pollution exacerbated by climate change through community-driven air quality monitoring. Engaging citizen science initiatives can help identify local pollution sources and hotspots, support policy changes, and promote solutions such as adapting citizen behavior and reducing vehicle emissions and industrial pollutants to improve overall air quality, also in connection with climate change.

10. **Community Resilience and Awareness**
    These initiatives empower local communities to actively participate in climate adaptation efforts by building resilience through education, fostering behavioral changes, and developing co-created solutions while influencing policy and governance on adaptation measures. Citizen science initiatives can focus on helping communities adapt to local climate impacts, such as heatwaves, water scarcity, and natural disasters, enhancing their long-term resilience.

11. **Green Infrastructure Development**
    Green infrastructure is an accepted planning and design solution for a more connected, multifunctional, and inclusive nature for society. Citizen science projects that encourage the most efficient infrastructure planning, design, management, help and monitoring, considering a large diversity of components: parks,, gardens, water bodies, nature-based solutions (e.g., green roofs, green

walls, rain gardens helps to improve the ecosystem services supply, but also quantity, quality, accessibility to green infrastructure components of all citizens.

12. **Energy Efficiency**
    Enhancing energy efficiency is a vital element in fighting climate change, especially through adapting strategies supported by communities. Citizen science projects can promote energy-saving behaviors, improve energy efficiency and insulation in buildings, promote the switch to renewable energy, drive the transition to low-carbon communities, and contribute to lower emissions and greater resilience against climate change.

Challenges for addressing climate change adaptation

The **three main challenges** identified for citizen science initiatives addressing climate change adaptation represent the key obstacles and opportunities the projects encounter when aiming to mitigate the impacts of climate change. These challenges are **transversal**, meaning they cut across various **Key Strategic Topics (KSTs)**, the focal issues that citizen science initiatives can effectively address to foster adaptation strategies. Each KST highlights an area where citizen engagement can contribute to broader climate goals. For each challenge, **specific barriers** emerge as means that obstruct the achievement of the challenges and hinder the ability of citizen science initiatives to grow, reach broader audiences, and fully contribute to climate change adaptation.

Challenge 1: Enhancing Education and Awareness Regarding Climate Change Adaptation

Raising public awareness and educating communities about the importance of **climate change adaptation** is critical for building climate resilience. However, many people need more knowledge and understanding concerning how climate change impacts their local environment and actionable steps that can be taken. Citizen science initiatives, as climate change adaptation measures, are vital in increasing awareness by engaging people directly in data collection and climate adaptation activities. The main hurdle lies in ensuring that this engagement translates into widespread understanding and tangible, actionable changes in behavior, especially in communities most vulnerable to the impacts of climate change. Scaling up the successful initiative could enhance the education and awareness regarding Climate Change Adaptation measures.

Specific Barriers to Scaling Up Citizen Science Initiatives for Education and Awareness

1. **Limited Reach and Engagement**
    - **Barrier:** Many citizen science projects remain confined to specific geographic and localized locations and need help attracting a broader audience. Expanding to new regions requires additional resources, partnerships, and outreach efforts, often constrained by limited funding or organizational capacity.
    - **Reasons for CS project:** With broad engagement, the initiative's ability to drive large-scale behavioral change and increase awareness is maintained, thus diminishing its overall effectiveness in climate change adaptation measures.

2. **Resource Constraints for Sustained Campaigns**
    - **Barrier**: Resource limitations present a significant challenge for long-term citizen science initiatives. Many citizen science projects depend on short-term or temporary funding or volunteer labor, limiting the capacity to run and conduct continuous education and awareness campaigns. Scaling up requires consistent resources for materials, training, outreach, and long-term community engagement, which often need to be made available.
    - **Reasons for CS project:** The consequences of needing sustained campaigns and engagement are profound. First, the educational influence of the initiatives needs to be expanded in scope and duration, preventing

them from fully realizing the objectives of increasing awareness and promoting climate change adaptation strategies. Second, the impact of the projects remains minimal and short-lived, preventing the project from achieving its full potential in raising awareness and driving adaptation.

3. **Perception of Climate Change as a Distant Threat**
    - **Barrier**: Climate change is still perceived as a problem that is far off in the future or a distant threat. This often leads to a lack of interest or concern towards making necessary climate change adaptation measures. Convincing citizens that immediate action is required can be complex, particularly if they do not witness direct impacts on their lives.
    - **Reasons for CS project**: This perception can significantly impede participation and make it more challenging for large-scale projects involving citizen science.

Challenge 2: Increasing Engagement, Participation and Collaboration for Science within and among citizens and Institutions

One of the critical challenges in citizen science for climate change adaptation is fostering sustained **engagement and participation** from citizens while building effective **collaborations with institutions** such as local governments, academia, industry, and policymakers. Although citizen scientists play a critical role in collecting data and raising public awareness, scaling up these initiatives requires solid and robust institutional support to ensure that the data collected is effectively utilized and influences decision-making processes. The challenge lies in establishing a collaborative framework where citizens, institutions, and scientists can collaborate seamlessly to achieve long-term adaptation goals.

Specific Barriers to Scaling Up Citizen Science Initiatives for Increasing Engagement and Participation

1. **Mistrust in Institutions and/for Science**
    - **Barrier**: Lack of trust between citizens and institutions, particularly in regions where governments or organizations have been historically perceived as unresponsive or ineffective. This mistrust can hinder citizens' willingness to participate in initiatives that require collaboration with institutional actors.
    - **Reasons for the CS project:** Without overcoming this mistrust, scaling up initiatives that rely on institutional backing or require policy changes based on citizen-collected data becomes difficult.

2. **Limited Institutional Capacity or Interest**
    - **Barrier**: Some public and private institutions may need more resources, interest, and collaboration capacity. Engaging institutions requires them to prioritize adaptation and allocate resources, which may only sometimes align with their immediate goals or capabilities.
    - **Reasons for CS project**: Even with solid institutional partners and support, citizen science initiatives face obstacles to expanding their reach and impact, resulting in missed opportunities to influence larger policy changes or secure long-term funding.

3. **Coordination and Communication Gaps**
    - **Barrier**: Effective collaboration between citizen science initiatives and institutions requires clear communication and **well-coordinated efforts**. However, aligning various stakeholders' goals, timelines, and processes (e.g., institutions, scientists, industry and citizens) can be challenging, particularly in large-scale projects or multi-regional collaborations.
    - **Reasons for CS project**: Poor coordination and communication among the stakeholders can lead to fragmented efforts that impede initiatives' ability to generate meaningful impact and establish long-term relationships with institutions. This lack of alignment can prevent the full potential of citizen science initiatives from being realized.

4. **Low Incentives for Citizen Participation**
    - **Barrier**: Limited incentives for citizens pose a challenge in maintaining ongoing citizen engagement, especially in initiatives that require long-term collaborations with organizations. Sustaining citizen engagement can only be possible if there are **limited tangible incentives**. If citizens do not see clear outcomes or personal benefits from their involvement, they will likely lose interest and gradually disengage.
    - **Reasons for CS project**: Insufficient incentives lead to declining overall participation levels. By supporting public participation, climate change adaptation measures will be able to maintain momentum. However, this will reduce the volume and quality of data collected and hinder institutional collaboration.

5. **Institutional Bureaucracy and Policy Barriers**
    - **Barrier**: Institutional bureaucracy and **rigid policy frameworks** impede the flow of communication and data sharing between citizens and institutions. As a result, citizen science initiatives need help aligning their data and findings with existing policy structures, leading to delays in incorporating citizen input in decision-making processes.
    - **Reasons for CS project**: These barriers can frustrate both citizens and project organizers, making it harder to advocate for policy changes or institutional action based on the data collected by citizen scientists.

Challenge 3: Expanding Inclusion of Diversity (class, race, and gender) in Citizen Science Initiatives

Ensuring the **inclusion of diverse groups and gender balance** is a significant challenge in citizen science initiatives related to climate change adaptation. Often, participation in these projects is skewed towards specific demographics—such as the more educated and the urban populations—while marginalized groups, women, and those from different cultural or socioeconomic backgrounds are typically underrepresented. This lack of diversity can result in biased data, limited perspectives, and missed opportunities to engage communities most affected by climate change. The challenge lies in developing inclusive citizen science initiatives involving people of different genders, ages, cultures, and socioeconomic statuses to ensure comprehensive and equitable adaptation solutions.

Specific Barriers to Scaling Up Citizen Science Initiatives for Addressing the Inclusion Challenge

1. **Technology Gap**
    - **Barrier**: Marginalized groups may need help accessing the necessary technology (such as smartphones, the internet, or different online platforms or software) or resources (such as time and education) required to participate in citizen science initiatives. This lack of access can result in exclusion from opportunities for data collection or engagement.
    - **Reasons for CS project**: Limited access leads to underrepresentation in the data collected, which can skew the findings and reduce the inclusiveness and effectiveness of climate adaptation measures.

2. **Language and Communication Barriers**
    - **Barrier**: The lack of communication materials and training available in various languages makes it difficult for non-native speakers to participate fully in citizen science initiatives. Often, the materials and training provided are not available in multiple languages or are too technical and filled with scientific jargon, posing a challenge for participants with lower literacy levels or those unfamiliar with scientific terms.
    - **Reasons for CS project**: Without accessible communication, many groups—particularly those in rural or immigrant communities—are excluded from participating in these initiatives due to lack of accessible communication, limiting the overall reach and impact of the initiative.

3. **Perceived Lack of Relevance**
    - **Barrier**: Certain groups, particularly in rural or underprivileged areas, may fail to perceive the immediate relevance of climate change adaptation in their daily lives. Their disinterest stems from a primary focus on other pressing economic or social challenges, which can lead to low participation among diverse populations.
    - **Effect**: If diverse communities do not recognize the importance and relevance of their involvement, they are unlikely to engage, which diminishes the potential for citizen science projects to capture a wide range of data on how different populations are affected by climate change.

4. **Underrepresentation in Leadership Roles**
    - **Barrier**: Women and minority groups are often underrepresented in leadership positions or decision-making roles within citizen science initiatives. This can significantly hinder their ability to participate, shape the direction of projects, or influence how data is used and interpreted.
    - **Reasons for CS project**: The absence of diverse leadership can lead to failure in addressing crucial issues that are significant to underrepresented communities, ultimately diminishing the initiative's overall effectiveness in meeting the diverse needs of stakeholders involved in climate change adaptation efforts.

Other barriers for citizen science initiatives upscaling

The following structural and societal barriers represent critical obstacles to the upscaling and broader impact of successful projects. By addressing these barriers, which limit growth, participation, and long-term sustainability, citizen science can unlock its full potential across Europe, enhancing its ability to contribute significantly to climate change adaptation and other strategic goals.

- **Funds and resources limitation**

Funds and resources can be significant barriers to scaling up citizen science initiatives. Limited financial support restricts the ability to expand projects, hire necessary personnel, or invest in new technologies, hampers efforts to reach larger audiences and improve methodologies. Additionally, shortages in human resources, such as trained volunteers or staff, can limit project capacity, while insufficient material resources, like equipment, can hinder effective data collection and analysis. A lack of digital resources further impedes communication and engagement with participants. These constraints prevent citizen science initiatives from achieving their full potential and effectively addressing more considerable scientific or community challenges.

- **Citizen scientist lacks skills and capabilities**

Citizen scientists can pose a barrier to citizen science initiatives due to variations in participation and engagement. The individuals involved often have differing expertise, making recruiting those who can effectively follow scientific protocols challenging. This difficulty can lead to excluding groups needing more skills or resources. Consequently, the required skills and capacities may deter potential participants, limiting diversity and effectiveness in contributions and ultimately hindering the objectives of citizen science projects.

- **Limited interest of scientists**

Limited interest and involvement from scientists can be a barrier to citizen science initiatives for different reasons. For example, obstacles to collaborating with citizens could concern data quality and public engagement and can discourage scientists from participating. A lack of organizational support (from the institution) and personnel capacity for the complex organization of citizen science initiatives can be part of the barrier. Additionally, a lack of recognition for their contributions within research careers may diminish motivation to engage in citizen science projects. These challenges can lead

to reduced support and involvement from the scientific community, ultimately affecting the success and sustainability of citizen science initiatives.

- **Time constraint**

Time constraints can significantly hinder citizen science initiatives for several reasons. Long-lasting and impactful require a substantial time investment that may deter participation. Moreover, adapting research methodologies is often time-consuming, delaying the launch of calls for volunteers or citizen scientists. These demands can overwhelm researchers, making it difficult to commit fully to citizen science projects, ultimately affecting their effectiveness and sustainability.

- **Limited Engagement**

A lack of sustained participation—stemming from mistrust in institutions, time constraints, or limited incentives for citizen scientists—diminishes the potential impact of these projects. Maintaining consistent and meaningful engagement over time is a significant challenge. In climate change adaptation, citizen science initiatives depend heavily on the ongoing involvement of individuals and communities to collect data, share local knowledge, and advocate for effective climate action.

- **Inequality in Access**

Diverse communities often need help with participation in citizen science initiatives due to unequal access to essential resources, such as digital tools, reliable internet, and scientific training. This digital divide limits their ability to engage fully in data collection or analysis, leaving their unique insights and experiences underrepresented. Additionally, lacking scientific literacy or technical skills can prevent these groups from meaningfully contributing to decision-making processes. As a result, the absence of these perspectives weakens the inclusiveness and overall impact of citizen science efforts in climate change adaptation.

Best practices in citizen science

The best practices observed from benchmarking citizen science initiatives can be categorized into several strategic areas. Here are the **best practices** that stand out, based on the above analysis and insights:

1. Collaboration with Institutional Partners

Many of the most successful initiatives involve **strong collaboration between institutions**, including universities, research centers, and government bodies. These partnerships provide:

- Access to technical expertise and resources.
- Credibility, which encourages broader citizen participation.
- Institutional support for scaling and sustainability.

Example:
The **AGORA** project involves a consortium of multiple institutions in Italy, Sweden, Spain, and Germany. This consortium ensures robust coordination and supports scalability by pooling resources from different countries.

2. Use of Technology and Digital Tools

Citizen science initiatives that leverage digital platforms, apps, and tools for **data collection** and **analysis** show higher levels of engagement and more robust data collection. This use of technology makes it easier for citizens to participate remotely and enables real-time data sharing.

Example:
The **"Lakes in Spare Time"** project in Denmark provides digital tools for volunteers to monitor lakes, making collecting data on water quality easier.

3. Community-Driven Projects with Local Impact

Initiatives focusing on local community challenges—such as urban heat islands, flood risk resilience, or biodiversity conservation—tend to succeed when they directly engage the **local population** and address **immediate concerns**. These initiatives maintain stronger and longer-term citizen involvement by making the issues tangible and locally relevant**—Regions4Climate**, a Horizon-funded project, aims to create scalable and replicable frameworks for climate resilience by.

Example:
RomaUp in Italy is a citizen-led initiative involving local communities in monitoring urban issues such as air quality and urban heat. It demonstrates how local relevance can drive sustained participation.

4. Adaptability and Replicability for Scaling

Projects that are **modular** and **adaptable** to different regional contexts are more successful in scaling across larger geographic areas. Best practices include designing methodologies that can be replicated with minimal adjustments, allowing for easy adaptation to new regions or target groups.

Example:
R4C - Regions4Climate, a Horizon-funded project, is built on the premise of creating scalable and replicable frameworks for climate resilience, engaging citizens in various European regions.

5. Multi-Demographic Engagement

Successful projects engage citizens across a **wide range of demographics**. Best practices include focusing on age, gender, and educational diversity, which ensures that the data collected is representative of broader societal needs and that all community groups have a voice in the initiative.

Example:
The **"Joint Effects of Land Use and Climate Change on Aquatic Communities"** project in Finland ensures participation across diverse groups by organizing targeted outreach and training for different citizen segments.

6. Long-Term Sustainability Plans

Some of the more effective initiatives have clear plans for long-term sustainability beyond initial project funding. They achieve this by diversifying funding sources, building ongoing community ownership, and integrating their work with policy or educational systems.

Example:
The **Joint Effects of Land Use and Climate Change on Aquatic Communities** initiative from Finland showcases a well-structured plan for long-term sustainability. With its collaborative approach between citizens and research institutions, the project ensures ongoing monitoring of aquatic environments and engages a wide range of stakeholders to maintain continuity beyond its initial funding.

7. Capacity Building and Training

Providing **training and capacity-building** opportunities to citizen scientists enhances the quality of participation. Well-designed educational programs help citizens contribute more effectively to data collection, increasing the project's credibility and impact.

Example:
The **Biodiversa+** project in Spain is an excellent example of capacity building through training. The initiative focuses on engaging citizens in biodiversity conservation, and its success is underpinned by comprehensive training programs that equip participants with the knowledge and skills to monitor species and environmental changes effectively.

These best practices enhance the effectiveness of the initiatives and provide models for scaling and replication in other regions. They demonstrate how combining community engagement with institutional backing and technological tools can lead to impactful and sustainable citizen science projects.

Conclusions and recommendations

The benchmarking analysis of citizen science initiatives has revealed several key conclusions. A critical finding is that initiatives that provide participants with adequate training consistently report higher levels of engagement and quality of the impact. This highlights the need for comprehensive training programs tailored to varying skill levels, focusing on methodologies for data collection, project management, and effective engagement strategies. By empowering citizen scientists with the necessary skills and knowledge, projects can foster greater involvement and ensure that the data collected is reliable and meaningful.

Moreover, successful citizen science initiatives often leverage **collaboration with institutional partners**. Strong partnerships among citizen scientists, local communities, and academic or governmental institutions enhance the credibility and effectiveness of the initiatives. These collaborations provide technical expertise and resources and encourage broader participation by engaging diverse demographic groups. Initiatives involving a wide range of citizens (across different ages, genders, and educational backgrounds) create a more suitable data set and foster a greater sense of community ownership.

The analysis also emphasizes the importance of **data-driven decision-making**. The data collected through citizen science initiatives can significantly inform policy decisions and contribute to evidence-based climate adaptation strategies. However, many initiatives face challenges in gaining institutional recognition and support, which are critical for their scalability and sustainability. Therefore, establishing clear **policy advocacy channels** is essential. These channels can facilitate engagement between citizen science representatives and policymakers, ensuring that citizen-generated data is integrated into relevant discussions and decision-making processes.

Furthermore, the role of effective **communication strategies** cannot be overstated. Many successful initiatives employ tailored communication approaches to engage diverse audiences, emphasizing the importance of clear and accessible messaging. Utilizing digital platforms and social media is increasingly crucial for outreach, allowing projects to broaden their engagement and foster community involvement. Despite the progress, there remains a need for increased public awareness regarding the value and impact of citizen science. Public education campaigns highlight the benefits of participation and

showcase opportunities for local involvement, thereby building stronger connections between citizens and scientific endeavors.

In conclusion, the insights gathered from this benchmarking analysis serve as a crucial foundation for enhancing the effectiveness and scalability of citizen science initiatives. By focusing on capacity building, fostering collaboration, ensuring data-driven decision-making, and employing effective communication strategies, these initiatives can significantly address pressing environmental challenges and advance climate adaptation efforts.

This not only strengthens the impact and relevance of citizen science but also involves the scientific community in a greater engagement in the entire process of change.

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