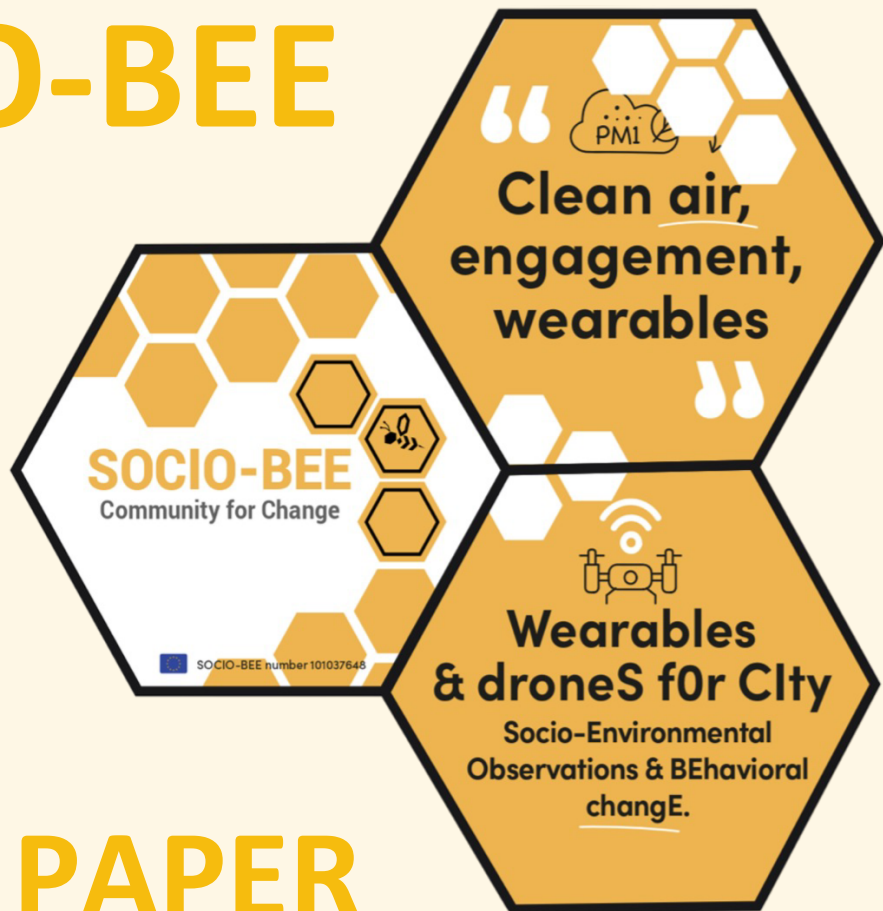


# SOCIO-BEE



# WHITE PAPER

## ENHANCING AIR QUALITY MONITORING THROUGH CITIZEN SCIENCE: INSIGHTS AND RECOMMENDATIONS FROM THE SOCIO-BEE PROJECT

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# INTRODUCTION

The **SOCIO-BEE Project** (Wearables and droneS for City socio-environmental Observations and BEhavioral change) is an innovative Horizon 2020 initiative, designed to empower European communities through citizen science to monitor and improve air quality. Made up of eighteen organisations across Europe, comprising local municipalities, academia, research institutions, and technical organisations, the project ran from October 2021 to September 2024. The project empowered citizens from three pilot cities – Ancona (Italy), Maroussi (Greece), and Zaragoza (Spain) – to engage in data collection using cutting-edge technology such as wearable sensors developed within the project. SOCIO-BEE engaged school children, older adults, and commuters to foster active participation in air quality monitoring while driving awareness and behavioural change on the local level.

The purpose of this white paper is to distil the findings of the SOCIO-BEE Project and present

## AIR POLLUTION

Air quality is a critical issue [in Europe](#) due to its direct impact on public health, the environment, and overall quality of life. Poor air quality is linked to a range of [severe health problems](#), including respiratory diseases, cardiovascular conditions, and premature deaths. More than 300,000 premature deaths per year ([according to data from 2020](#)) can be attributed to air pollution across the continent. Despite decades of policy efforts, such as the EU’s [Ambient Air Quality Directives and various emissions regulations](#), many cities still struggle to meet the World Health Organization’s [recommended air quality guidelines](#). Nitrogen oxides (NOx), ozone (O3), and particulate matter (PM) remain persistent challenges, particularly in densely populated urban areas and regions with heavy traffic and industrial activity.

Traditional air quality monitoring methods, while vital, can fall short of providing comprehensive coverage and timely responses. Fixed monitoring stations are not only expensive to install and maintain but also struggle to capture the variability of pollution at the local level, especially in under-monitored areas. Emerging technologies and

actionable recommendations for national and EU policymakers across Europe based on the experience and outcomes of the project. It seeks to highlight how citizen science can complement traditional air quality monitoring, translating data-driven scientific findings gathered by citizens to inform policies aimed at improving urban air quality and public health, as well as advancing community engagement in climate efforts.



citizen science approaches offer promising solutions, as they enable real-time data collection and expand the scope of monitoring efforts. This community-generated data can offer more granular insights into pollution patterns, which in turn can inform targeted policy interventions. By using this data to – for example – guide stricter emissions controls, urban planning that prioritises sustainable transport, and investments in green infrastructure, policymakers can more effectively develop pollution mitigation policy and reduce the harmful effects of emissions.

The success of these interventions, however, depends on collaboration between policymakers, scientists, researchers, and – crucially – citizens. Citizen science initiatives, like those pioneered by the SOCIO-BEE Project, enable communities to actively contribute to data collection and analysis, raising awareness and encouraging behavioural change that supports cleaner air. Taking a participatory approach enhances the effectiveness of air quality policies and ensures they are more attuned to local needs and realities.

# SOCIO-BEE & CITIZEN SCIENCE

## WHAT IS CITIZEN SCIENCE?

Citizen science involves the active participation of the public in scientific research, where individuals contribute their knowledge, skills, and resources to advance scientific understanding. Participants may engage in activities like pollution recognition, wildlife and biodiversity tracking, pattern tracking, or data analysis, thus enabling science to operate at a much larger scale and with greater local relevance and engagement.

Citizen science plays a pivotal role in addressing modern environmental challenges by involving communities directly in data collection, analysis, and the development of evidence-based solutions. It empowers individuals by integrating them into the scientific process, providing tools that allow them to influence urban planning and

environmental policymaking. In the context of air quality monitoring, this approach is particularly valuable for gathering data in under-monitored areas, generating a more detailed, localised picture of pollution. Moreover, citizen science raises public awareness and encourages people to take personal responsibility for recognising and mitigating their environmental impact.

The data collected by citizens can complement traditional monitoring methods, offering insights that help refine public policy and urban planning processes. Ultimately, this collaborative model connects scientific research with local communities, leading to more informed and effective environmental management strategies at the EU and national levels.

## SOCIO-BEE'S CITIZEN SCIENCE APPROACH

The SOCIO-BEE Project demonstrated how citizen engagement can enhance the scope of air quality monitoring by involving ordinary citizens in testing, measuring, and taking ownership of the air pollution in their communities. By empowering people where they live, work, and socialise, SOCIO-BEE sought to democratise scientific research and foster a deep sense of environmental stewardship. This participatory approach not only expanded the reach of data collection, often covering under-monitored areas, but also provided local perspectives crucial for designing effective policies within the pilot cities of the project. Additionally, by involving citizens in the research process, SOCIO-BEE strengthened the relevance of the

SOCIO-BEE's core objective was to harness the power of citizen science to collect air quality data and inspire behavioural change. Through structured campaigns, participants in the pilot cities engaged in the following tasks:

1. **Identifying air quality issues** in their local communities,
2. **Formulating hypotheses or 'what if' scenarios** to explore links between air pollution and their environments,



findings for the local municipalities, making scientific claims directly applicable to the real-world challenges present in those cities.

3. **Designing and implementing interventions** to test their hypotheses,
4. **Collecting data** using advanced wearable sensors and drones,
5. **Analysing and visualising data**, creating insights for the broader community,
6. **Communicating their findings** to raise awareness, foster behavioural change, and inform urban policy.

## THE SOCIO-BEE PROJECT

The project targeted diverse demographic groups, including school children (under 16 years old), older adults (over 65 years old), and commuters (people who travel by car or public transport in large cities or suburbs) in three pilot cities across Europe. It aimed to engage both environmentally aware and engaged citizens, as well as those less informed or passive about climate action.

SOCIO-BEE used the metaphor of a bee colony to categorise the diverse group of participants across the project, assigning roles that mirrored different levels of involvement. This approach facilitated the co-creation of sustainable solutions to urban air pollution while ensuring that everyone – from ordinary citizens to policymakers and local representatives – could play a meaningful role. The metaphor proved effective in developing strategies that fostered collaboration and engagement across a wide range of stakeholders.



**Citizen Hives** (groups that conducted campaigns in the pilot cities) were made up of:

**Beekeepers**



Hive managers, in charge of a collection of volunteers taking part in the project. Managed campaigns and project activities.

**Queen Bees**



Knowledgeable people interested in leading citizen science activities in their cities and engaging others in their communities.

**Worker Bees**



Citizens willing to collaborate, learn, and contribute to data collection and the interpretation of data in the project.

**Drone Bees**



Citizens unaware of the potential impact they can have on climate change. Although they did not participate directly in campaigns, they were informed and consulted about the project, which has a potential impact on their behaviour.

**Bears**



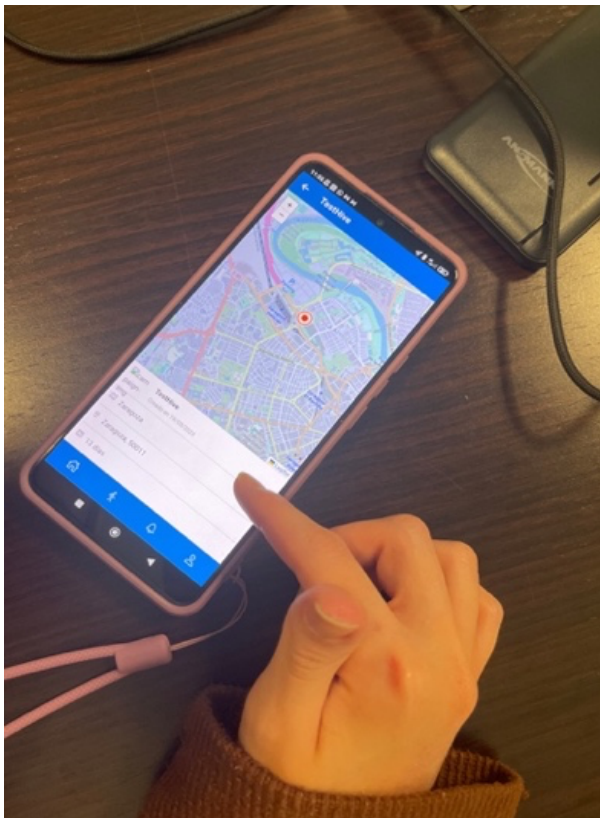
Organisations, policymakers, city planners, associations, or companies who set strategies, understood local environmental challenges, and supported pro-environmental behaviour change, connecting with Queen Bees and Beekeepers.

SOCIO-BEE placed strong emphasis on inclusivity and gender equality, seeking to empower diverse communities to actively engage in environmental research, contributing to a richer, more representative scientific landscape. To support this goal, the project developed a [Social Inclusion and Non-](#)

[Discrimination Checklist](#) to enhance inclusivity at every stage of citizen science initiatives. As well as ensuring that inclusivity targets were reached in SOCIO-BEE, this tool serves as a valuable resource for other citizen science projects, promoting equitable participation in environmental research.

## TECHNOLOGICAL INNOVATION

Given the growing concerns about the impact of air pollution on public health and the environment, effective air quality monitoring is essential, especially in urban and populated areas. Accurate and reliable data plays a crucial role in shaping policies, driving pro-environmental actions, and safeguarding community well-being. Citizen science data can be particularly valuable to authorities and policymakers in this regard, as it can help inform evidence-based large-scale and localised policy development, contributing to public health, environmental protection, and overall quality of life.



*SOCIO-BEE mobile app*

SOCIO-BEE’s innovative approach and technologies have been showcased at various international conferences, including the [EuroGEO 2022](#), [21st European Week of Regions and Cities 2023](#), [Ecsite 2023](#), [EU Green Week 2023](#), [SPlitech 2023 conference](#), and [XVIIth International Congress of Educating Cities 2024](#).



*BETTAIR’s portable air quality sensors*

The SOCIO-BEE Project recognised the importance of data accuracy for local governance and developed innovative, wearable technologies to monitor air quality. These included a mobile app (*pictured left*), the AcadeME web platform (which enabled Beekeepers and Queen Bees to organise campaigns and visualise collected data), and advanced portable air quality sensors developed by BETTAIR (*picture above*), which could also function as compact field sensors fixed to drones. Citizens used these devices while walking designated routes, measuring pollution levels at specific points (*see map pictured below*), with some sensors mounted on drones and buses for broader data collection. The SOCIO-BEE mobile app, which connected directly to the sensors, further encouraged participation by suggesting optimal routes for data gathering.



*Measurement points (Maroussi pictured)*

# SOCIO-BEE PILOT CITIES

## ANCONA, ITALY

Ancona, the capital of Italy's Marche region, is a key port city with a population of about 100,000 spread over 184km<sup>2</sup>. Its economy has historically been centred around its port, contributing to high urbanisation levels and increased traffic congestion. With only two main entry and exit points, the city experiences significant traffic, particularly in the city centre, leading to concerns about air quality. Although Ancona's air quality is generally in line with regional standards, heavy traffic creates localised pollution hotspots, especially during peak hours.



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### PILOT TARGET GROUP

The SOCIO-BEE pilot in Ancona focused on citizens over 65 years old, who make up 26% of the city's population. This group was selected due to its vulnerability to air pollution and the potential health benefits of promoting outdoor activities in non-polluted areas. The project aimed to engage those over the age of 65 in active outdoor monitoring and provide data that would support healthier urban planning.

### PILOT ACTIVITIES

From May to June 2024, the pilot involved senior participants in collecting air quality data using wearable sensors. Key public areas, such as the city's main avenue and the port, were measured. Participants measured pollution levels over one to two weeks, recording a total of 339 data points. Despite challenges, including technological difficulties and participant dropouts, the project successfully engaged a significant number of volunteers.



### KEY PILOT FINDINGS

- Elevated pollution levels were observed in areas with high traffic, particularly in the city centre.
- While overall air quality was within acceptable limits, localised hotspots presented health risks, especially during peak traffic hours.
- Outdoor activities like walking in these areas posed potential harm due to pollutant exposure.
- High community interest in the project under-scored the importance of citizen engagement in environmental monitoring.
- This pilot highlights the importance of community driven data collection in shaping effective urban environmental policies.

*Find more information about the pilot in the Policy Brief on Ancona, Italy*

## MAROUSI, GREECE



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The Municipality of Amaroussion (Maroussi), located 13km from Athens, is a key transportation hub, with major highways carrying over a million vehicles per day. This heavy traffic contributes significantly to air pollution, affecting nearby residential areas up to 400m from nearby roads. Additionally, post-2009 economic shifts towards biomass heating have increased pollution. Despite its accessibility, Maroussi faces elevated levels of nitrogen oxides (NOx) and particulate matter (PM), contributing to public health risks, including respiratory and cardio-vascular diseases. Air quality challenges are more severe than national averages but comparable to other Athens suburbs.

### TARGET GROUP

The SOCIO-BEE pilot in Maroussi primarily sought to engage local commuters (including students), as well as residents and schools, in efforts to monitor and address air quality issues in the city.

### PILOT ACTIVITIES

Led by the Municipality of Maroussi, the pilot used drones and wireless air quality sensors to collect data on air pollution. Two main campaigns were conducted, focusing on areas near a municipal air quality station. Wireless sensors were installed on public buses and drones gathered pollution data at various altitudes. Community engagement was a core element, with schools and local groups participating in data collection and awareness campaigns. The pilot engaged a diverse group, with a total of 85 participants collecting 1,161 air quality measurements.



### KEY PILOT FINDINGS

- Preliminary data analysis shows that the data collected from the sensors were comparable to the data collected from the air quality stations and align with expected trends.
- Pollution hotspots were primarily linked to traffic, with higher levels correlated with traffic density, particularly near highways and during peak hours.
- Community involvement exceeded expectations, with strong engagement from schools and volunteers.

*Find more information about the pilot in the Policy Brief on Maroussi, Greece*

## ZARAGOZA, SPAIN

Zaragoza, the fourth-largest city in Spain with over 700,000 residents, was selected as one of the '100 Climate-Neutral and Smart Cities by 2030' by the European Commission in 2022. The city generally enjoys good air quality due to its Mediterranean climate and balanced mobility options, including trams, bike lanes, and pedestrianised areas. However, the city's growing logistics sector has increased traffic pollution, presenting challenges, particularly for its ageing population and due to the urban heat island effect.

### TARGET GROUP

The SOCIO-BEE pilot in Zaragoza focused on youth aged 11-16, targeting students across four schools. This age group was chosen for their potential to drive long-term environmental change through

### PILOT ACTIVITIES

The pilot, conducted between May and June 2024, engaged 221 students in air quality monitoring through classroom-based campaigns. Staff from Zaragoza City Hall, IBERCIVIS, and ZCKF went to a number of schools/institutes to carry out the training, teaching participants to use air quality monitoring devices, interpret pollution data, and



citizen science and engagement in air quality monitoring.

visualise their findings. This hands-on experience not only provided them with technical skills but also encouraged critical thinking about their environmental impact. Despite challenges such as academic scheduling and some technology delays, the students remained highly engaged, successfully completing 13 citizen science campaigns.

### KEY PILOT FINDINGS

- The logistics sector and traffic are the primary contributors to pollution, especially in high-traffic areas in Zaragoza.
- Citizen-generated data identified pollution hotspots and provided valuable insights for urban planning.
- The pilot demonstrated strong youth engagement, raising environmental awareness and showing potential for long-term replication.
- Schools expressed interest in continuing air quality monitoring beyond the project, with students quickly adapting to the technology.
- The pilot fostered partnerships between schools, local authorities, NGOs, and the municipality, promoting long-term community involvement.

*Find more information about the pilot in the Policy Brief on Zaragoza, Spain*



# FINDINGS & ACHIEVEMENTS

The SOCIO-BEE Project demonstrated the potential of citizen science to enhance air quality research and foster public engagement in climate action across three pilot cities – Ancona, Maroussi, and Zaragoza – and across three different target groups. The experience of the SOCIO-BEE Project provides a replicable framework for integrating citizen science into air quality monitoring, offering insights that can inform future policy and climate action efforts across the EU. The project’s key findings and achievements can be summarised as follows:

## AIR QUALITY RESEARCH ACHIEVEMENTS

- **Enhanced Monitoring Networks:** SOCIO-BEE expanded air quality monitoring through citizen participation, resulting in more localised data collection, particularly in under-monitored areas.
- **Use of Wearable Technology:** Citizens used technologically advanced wearable sensors to monitor air quality, revealing pollution variations in different micro-environments.
- **Data Integration:** The project integrated citizen-generated data with existing monitoring systems (such as municipal air quality stations) and local infrastructure (such as public buses), improving overall accuracy and connecting new forms of data collection to urban planning efforts.

## CHALLENGES AND LIMITATIONS

- **Inclusive Participation:** Including high proportions of vulnerable groups within the research was challenging. Efforts were made to reach these groups and demonstrated the need for developing innovative engagement strategies in citizen science projects to reduce barriers to participation.
- **Engagement Barriers:** Tailored outreach was required to engage different groups, adapting to ensure a fit participants’ schedules and concerns proved to be invaluable.
- **Scalability:** The campaigns were limited by the timeframe. Having large-scale ongoing monitoring projects requires continuous resources and engagement, both financially and people power.

## CITIZEN SCIENCE ACHIEVEMENTS

- **High Community Engagement:** By tailoring initiatives to local demographics, SOCIO-BEE achieved strong participation, particularly in terms of engagement from schoolchildren in Zaragoza and commuters in Maroussi, and levels of interest in Ancona.
- **Increased Awareness:** Participants gained a deeper understanding of air pollution and its health impacts, fostering long-term environmental responsibility.
- **Sustained Involvement:** The project established a base for continued citizen engagement in air quality monitoring, equipping participants with the tools and knowledge to remain active in climate action.



## POLICY RECOMMENDATIONS

Building on the insights and outcomes of the SOCIO-BEE Project, the following policy recommendations are designed to enhance climate governance and maximise the potential of citizen science in tackling environmental challenges. These recommendations aim to promote more effective, inclusive, and data-driven approaches to air quality research and climate mitigation, fostering stronger policies and actions across Europe.

- 1 INVEST IN CITIZEN SCIENCE INITIATIVES AND INFRASTRUCTURE**

Increasing EU and national funding for large-scale, long-term citizen science initiatives recognises the dual benefits of public engagement and continuous data collection. As demonstrated in SOCIO-BEE, involving diverse groups not only enriched the dataset but also raised environmental awareness among participants, regardless of their level of prior interest in climate issues. This inclusive approach has the potential to drive meaningful behaviour change. Expanding citizen science efforts across Europe will provide more granular and interconnected air quality data, reflecting a wide range of geographic and demographic variations.
- 2 EXPAND & INTEGRATE CITIZEN SCIENCE INTO AIR QUALITY MONITORING NETWORKS**

Enhancing air quality monitoring networks by integrating citizen-generated data with traditional monitoring systems to achieve more localised and continuous air quality tracking. The SOCIO-BEE Project showed that citizen science can contribute to covering under-represented areas and improving the overall accuracy and spatial coverage of pollution measurements. Supporting the expansion of these networks by providing technical support and ensuring that citizen-collected data is effectively used in policy development will strengthen data-driven decision-making and ensures that air quality management is more inclusive and reflective of local conditions.
- 3 TAILOR CITIZEN SCIENCE INITIATIVES TO TARGETED AND ENGAGED AUDIENCES**

Designing citizen science projects that align with the specific needs, schedules, and interests of different groups maximises participation and data quality. SOCIO-BEE's success in Zaragoza highlights the value of tailoring initiatives to participants' routines (e.g., adapting to the school calendar). Engaging citizens with pre-existing pro-environmental attitudes is also a successful strategy to ensure more meaningful long-term impact and sustained behavioural change. In Maroussi, this approach led to a high level of volunteer participation, demonstrating how motivated individuals can inspire broader community involvement.
- 4 ENHANCE EDUCATIONAL INTEGRATION AND LIFELONG ENVIRONMENTAL TRAINING**

Encouraging member states to incorporate citizen science into both national education curricula and lifelong learning programs will cultivate long-term engagement with climate action. In this way, building on the success of SOCIO-BEE's work with students in Zaragoza, school-based citizen science projects should foster environmental stewardship from an early age. These educational programs should prioritise environmental literacy, empowering students to actively monitor air quality and contribute to local environmental health. In parallel, lifelong learning initiatives and community-based projects should be established to ensure adults also engage in environmental monitoring, creating a broad, informed base for sustainable air quality management.
- 5 INCENTIVISE MULTI-LEVEL SUPPORT FOR CITIZEN SCIENCE**

At the EU, national, and local levels, providing financial incentives and technical support to local and regional authorities for implementing citizen science programs, including funding the development of technological tools and community outreach, can build sustainable citizen science ecosystems that enhance long-term air quality monitoring. The SOCIO-BEE Project shows that local municipalities can effectively mobilise citizen scientists, especially when given resources to support these initiatives.

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#### **PROMOTE COMMUNITY-LED URBAN PLANNING FOR CLIMATE MANAGEMENT**

Encouraging the integration of citizen science data and community input into urban planning ensures that environmental policies reflect the needs and concerns of local populations. SOCIO-BEE demonstrated that involving citizens in data collection fosters a sense of ownership and responsibility, making people more supportive of resulting initiatives and climate actions that use the results. By fostering community-led policy development, cities can create more inclusive and responsive approaches to sustainable urban planning, addressing pollution in ways that directly benefit the communities most affected, while also building long-term public trust and commitment to environmental initiatives.

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#### **STRENGTHEN PARTNERSHIPS FOR FURTHERING MONITORING TECHNOLOGIES**

Promoting partnerships between governments, tech companies, and research institutions can help develop accessible and affordable air quality and other climate-related monitoring and mitigation technologies. SOCIO-BEE's use of innovative wearable sensors and drones illustrates how strengthening collaborations across sectors and across multiple EU countries can scale up technological solutions, making it easier for citizens across Europe to participate in local and national air quality initiatives, contributing valuable data.

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#### **SUPPORT CROSS-BORDER COLLABORATION ON AIR QUALITY**

Facilitating cross-border cooperation between cities and regions to address transboundary air pollution through the integration of citizen science into environmental protection frameworks can leverage the data collected by local communities. As demonstrated in the SOCIO-BEE pilot cities, this can enhance air quality monitoring in shared ecosystems and promote data exchange between member states. Best practices should be shared to create more unified regional responses to pollution challenges.

## **CONCLUSION**

The experience of the SOCIO-BEE Project underscores the critical role of citizen science in advancing both air quality monitoring and environmental policy development. Through active citizen participation, the project demonstrated how community-driven data collection and analysis can expand and reinforce existing monitoring efforts, increase public awareness, and provide valuable insights for policymakers. Key recommendations derived from the campaigns activities in the pilots, including integrating citizen-generated data into monitoring systems and policymaking structures, as well as fostering public engagement and environmental stewardship, offer a pathway for more comprehensive and localised approaches to air quality management.

European national and local policymakers are urged to prioritise air quality improvement initiatives by incorporating citizen science into their strategies and governance structures. Such initiatives not only democratise the scientific process but also empower individuals and communities to take ownership of their environmental impact. By supporting these collaborative efforts, the EU can drive more informed, inclusive, and effective policies to address the air quality challenges facing urban areas. The success of the SOCIO-BEE Project and the pilot cities highlight the transformative potential of this approach, emphasising the need for continued investment in citizen-led environmental research and action.

## EXTRA RESOURCES

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[SOCIO-BEE Project website](#)

[SOCIO-BEE Training Campaign Methodology and Materials](#)

[SOCIENTIZE ‘White Paper on Citizen Science’](#)

[European Citizen Science Association \(ECSA\) ‘Ten Principles of Citizen Science’](#)

[EU Citizen Science online resources platform](#)

[European Environment Agency \(EEA\) ‘Assessing Air Quality through Citizen Science’](#)

[SCivil ‘Guide on Citizen Science and Local Government’](#)

## THE SOCIO-BEE CONSORTIUM

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