COMPAIR

DELIVERABLE

D6.3 Pathways to environmental change

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1.0	28/10/2024	Christophe Stroobants	VMM	Final version

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Executive Summary

The COMPAIR project aims to leverage community observation, measurement, and participation in air science to address environmental challenges. The motivation behind this deliverable is to convert the diverse approaches used in COMPAIR pilots into a set of actionable pathways that can inspire and guide future projects. These pathways provide essential strategies to achieve environmental impact through citizen science or participation in general. Step-by-step we explore these pathways to uncover key stakeholders, critical success factors and delve deeper into examples and blueprints from COMPAIR pilots.

The document outlines four key pathways:

1. **Participative implementation of policy**: Involves traffic-calming measures to reduce emissions and improve air quality.
2. **Citizen science experimentation**: Engages citizens in monitoring activities to identify local environmental issues and drive policy actions.
3. **Online tools**: Utilises tools like CO_2 calculators to provide insights into individual environmental impacts and promote sustainable behaviours.
4. **Awareness raising campaigns**: Educates the public on the benefits of sustainable practices and encourages behavioural change.

Each pathway includes detailed steps for implementation, critical success factors, and typical stakeholders involved.

The COMPAIR pilots demonstrated significant environmental impacts, described in other reports. At a more general level we conclude the potential impact of each pathway as summarised in ***Table 1***. In this table environmental impact reflects a pathway's positive impact on environmental factors (on air quality or traffic intensity) that was observed in COMPAIR pilots. The co-benefits in a similar way reflect the co-benefits that were observed such as impact on traffic safety, STEM-education… often through the ability to link other messages. Likewise the ease of implementation reflects how much effort, budget, stakeholder management etc. go into applying a certain pathway. Finally, the behavioural change column indicates to what degree a pathway can yield behavioural changes. These elements are discussed for each pathway throughout the deliverable.

***Table 1**: Summary of all 4 pathways to environmental change and their environmental impact, co-benefits, difficulty of implementation and impact on behavioural change.*

Pathway	Environmental Impact	Co-benefits	Ease of implementation	Behavioural Change
Participative implementation of policy	High	High	Low to moderate	Moderate to High
Citizen Science Experimentation	Moderate to High	Moderate	Moderate	High
Online Tools	Moderate	Low	Moderate to High	Moderate
Awareness raising campaign	Moderate to high	High	Moderate	High

As community involvement and the use of technology are crucial for achieving environmental change, COMPAIR's key recommendations to future projects are therefore:

1. **Enhance Volunteer Training and Support**: Ensure high-quality data collection and sustained engagement.
2. **Foster Strong Community Engagement**: Tailor projects to local needs and gain broader support.
3. **Integrate Data Transparency and Open Access**: Build trust and encourage broader participation by making data publicly available.

By following these pathways and recommendations, future projects can more effectively address environmental challenges and promote sustainable practices through citizen science and community engagement.

1. Introduction

This document provides an overview of some essential pathways to achieve environmental impact in citizen science projects as performed in COMPAIR. For the readers' convenience we have moved the essence to the first chapters and dig deeper into the COMPAIR specific illustrations in each following chapter.

Hence the first chapter outlines the identified pathways and their key aspects such as expected impact & co-benefits, steps to undertake, critical success factors, typical stakeholders & how to involve them. This is followed by our main recommendations to future projects in achieving environmental impact. We then add generalised COMPAIR examples to illustrate the basis these essential pathways were built upon. Lastly, we provide an overview of the specific COMPAIR approaches to provide another level of examples. If even more detail is required, we refer the reader to our Closed, Open and Public Round reports.

With these 'Pathways to environmental change', our consortium does not merely report on the environmental outcome of the COMPAIR pilots but converts our various approaches into an overseeable set of pathways that can inspire and guide future projects attempting to establish environmental change through citizen science, participation & technology. Please keep in mind that before any of COMPAIR's pilots started to experiment, develop tools or contact citizens, we had workshops in every pilot region to assess the needs and aligned our next steps to the outcome of these workshops. Our D2.X deliverables outline all of the steps taken prior to pilot actions. Our co-innovation reports (D5.5 and D5.7) describe ensuing stakeholder involvement throughout these next steps.

2. Potential pathways to environmental change and their key aspects

2.1 Pathways to environmental change

2.1.1 Pathway 1: Participative implementation of Policy

By implementing a specific policy like traffic-calming measures, the expected impact is a reduction in traffic volumes and related emissions, leading to improved air quality. An example of this was the pilot in Berlin, where traffic-calming measures in Bellermannkiez reduced traffic volumes significantly, which contributed to lower $PM_{2.5}$ levels. Besides improved air quality, there are other co-benefits like enhanced safety for pedestrians and cyclists, decreased noise pollution due to reduced traffic and increased community involvement in local planning. Another advantage is that traffic-calming measures will result in streets that are safer and more pleasant for non-motorized users, which will encourage residents to use alternative transportation methods like walking and cycling.

IMPLEMENTATION STEPS

To achieve this, the following **implementation steps** might be considered:

1. **Identify target areas:** Select neighbourhoods or areas with high traffic congestion and poor air quality.
2. **Engage stakeholders:** Involve local authorities, residents, and businesses in planning.
3. **Develop and approve plan**: Create a detailed traffic-calming plan and obtain necessary approvals.
4. **Install measures:** Implement measures such as speed bumps, pedestrian zones, school buses, school streets, one way streets and bike lanes.
5. **Monitor and evaluate:** Continuously monitor air quality and traffic patterns to assess impact. Include a baseline measurement before policy implementation.
6. **Adjust and improve:** Make necessary adjustments based on data and feedback.

To achieve this successfully, it is crucial to engage all stakeholders to ensure buy-in from local residents and business. Also strong backing from local authorities is necessary. Another crucial element is accurate monitoring of air quality and traffic patterns.

Because this pathway requires significant planning, coordination, and investment, and because there might be potential resistance from local businesses and residents, this pathway might be in some cases challenging to implement.

CRITICAL SUCCESS FACTORS

To implement this pathway, one has to keep in mind the following critical success factors:

- **Community Involvement**: Active participation from residents and businesses ensures the measures are well-received and effective.
- **Clear Communication**: Transparent communication about the benefits and changes helps in gaining public support.
- **Continuous Monitoring**: Regular data collection and analysis help in making timely adjustments to the measures. Make sure the measurement data is fit-for-purpose, i.e. sufficiently accurate to monitor the expected effect.
- **Policy Integration**: Aligning traffic-calming measures with broader urban planning and environmental policies ensures long-term success. Make adjustments based on data and feedback.

Typical stakeholders for this pathway are included in **Table 2**, including a rating of their importance and the main reason for involving them. Further on in this section we provide a brief description of each stakeholder's role, contribution and typical engagement alongside examples from the COMPAIR project.

Table 2*: Rating of the importance of key stakeholders for pathway 1*

Stakeholder	Importance	Reason
Local government Authorities	★★★★★	Crucial for policy approval, funding, and implementation.
Environmental scientists and researchers	★★★★☆	Essential for designing the study, providing training, analysing data, selecting devices and managing quality
Urban planners and traffic engineers	★★★★☆	Essential for designing and planning effective traffic-calming measures.
Residents and community groups	★★★★☆	Important for gaining support and ensuring the measures meet community needs.
Local businesses	★★★☆☆	Necessary for assessing economic impacts and gaining business support.
Environmental organisations	★★★☆☆	Helpful for advocacy and promoting the environmental benefits of the measures.

Local government authorities	
Role	Approve and implement traffic-calming measures, provide funding, and ensure policy alignment.
Contribution	Policy support, regulatory approval, and resource allocation.
Engagement	Early and continuous involvement in planning and decision-making.

COMPAIR EXAMPLES

- In **Berlin**, the Senate Department for Mobility, Transport, Climate Protection, and the Environment was involved in workshops and discussions to align traffic-calming measures with broader urban policies.
- The City of **Athens** and its departments such as the Department of Resilience and Sustainability and the Social Affairs Agency that operates the Friendship Clubs, approved and contributed to the citizens science campaigns, especially on senior citizens communication and enrollment. That was an important liaison for successful campaigns.
- The City Council of **Sofia** Municipality approved first testing rounds and then a whole-year school bus service. It was made as part of public transportation, providing suitable buses and professional drivers.
- The **Plovdiv** Deputy Mayor for Ecology and the Deputy Mayor for Education jointly organised a primary schools recruitment campaign, resulting in 2 schools participating. The municipal department of Ecology was involved in co-creation workshops and discussions about air quality around schools.
- In **Flanders** the eldermen and civil servants on mobility, environment and/or climate were involved in Herzele, Ghent and Sint-Niklaas pilots. In Herzele we could link our project to the introduction of a school street, in Ghent and Sint-Niklaas to a circulation plan. Especially in Herzele the involvement of policy makers allowed us to optimise the implemented policy based on citizen science results and citizen feedback.

Environmental scientists and researchers	
Role	Design the study, provide training, and analyse data to a further extent than possible with standardised tools. Support in selecting fit-for-purpose measurement devices and quality assurance.
Contribution	Scientific expertise and data analysis.
Engagement	Leading training sessions and data analysis, contributing to increased acceptance of the implemented policy.

COMPAIR EXAMPLES

- The **Flanders** pilot lead (VMM) and imec-OnePlanet led the experimental design process for all pilot areas in COMPAIR. The exact process is described in the Open Round Report (D5.4).
- Environmental experts in the **COMPAIR** consortium drafted the D5.1 deliverable providing a compendium of useful information for organising workshops and training.
- In **Flanders**, environmental experts helped in managing expectations on the impact of policy and performed more in depth analyses of the available datasets. Additionally they can run model simulations to further support policy impact evaluations.

Urban planners and traffic engineers	
Role	Design and plan traffic-calming measures.
Contribution	Technical expertise in designing effective traffic-calming solutions.
Engagement	Collaborative design and planning sessions.

COMPAIR EXAMPLES

- In **Berlin**, urban planners worked closely with local authorities to design effective traffic-calming measures that addressed specific community needs.
- The Transport Department of **Sofia** Municipality worked on developing the routes of the school bus service taking into consideration the feedback gathered from surveys spread among parents. Transport Experts and representatives of the City Council took part also in an ideathon aiming to gather ideas for developing the service further.
- In **Flanders** the mobility department in Herzele discussed flanking measures with COMPAIR traffic engineers, allowing us to quickly scan the feasibility of additional policy options. In Sint-Niklaas the involvement of urban planners allowed the project to introduce temporary setups using tree trunks and temporary flower beds to simulate the future layout of redesigned streets. The involvement of traffic engineers led to more thorough discussions on traffic measurements with citizens (objectivising) and even simulations in Sint-Niklaas.

Residents and community groups	
Role	Provide feedback and support for the measures.
Contribution	Community engagement and advocacy for safer streets.
Engagement	Regular community meetings and feedback sessions.

COMPAIR EXAMPLES

- In **Berlin**, residents were engaged through neighbourhood management offices, ensuring their concerns and suggestions were incorporated into the traffic-calming plans.
- The **Sofia** pilot directly involved school administration to support the project, conducted several surveys gathering feedback from parents, and organised workshops and an ideathon to engage children, parents and city officials and build a community for creating the pilot municipal school bus service.
- In **Plovdiv** the active citizens organisations were involved in co-creation workshops volunteers involvement, and a rising awareness campaign and contributed to the Proposal with a list of possible measures for the reduction of traffic and improvement of air quality around schools for the municipality of Plovdiv. Directors, teachers and students were engaged with experiments, training, WS and Ideathon.
- In **Flanders** we involved students by reaching out to school principals, which allowed us to actively work with students during a 1 to 2 month project leading to measurable changes in their behaviour and modal choices. Additionally, in Herzele members of a local group of citizens organising a monthly get together were involved which helped in recruiting participants for our events and experiments through their network.

Local businesses	
Role	Assess the impact of traffic changes on business operations.
Contribution	Feedback on potential economic impacts and support for implementation.
Engagement	Impact assessments and consultations.

COMPAIR EXAMPLES

- In **Berlin**, local businesses were consulted to understand the economic impacts of traffic changes and to gain their support for the measures
- A local shop in **Sofia** was involved in testing a Telraam device - the owner of a small grocery installed it and measured the traffic on the street. He was interested in the number of potential clients passing by the shop.
- In **Plovdiv**, in the local shops and offices were installed Telraam v1 sensors for traffic data collection

Environmental organisations	
Role	Advocate for measures that improve air quality and reduce emissions.
Contribution	Support and promote the benefits of traffic-calming measures.
Engagement	Advocacy and promotional activities.

COMPAIR EXAMPLES

- Environmental organisations in **Berlin** promoted the benefits of traffic-calming measures and helped raise public awareness about their positive impact on air quality.
- NGO and **Plovdiv's** Public council for air quality participated in co- creation WS, rising awareness campaigns, and evaluation of collected measures for the reduction of traffic and improvement of air quality around schools for the municipality of Plovdiv
- In **Flanders**, the environment agency was already involved as a COMPAIR partner. Their involvement allowed the project to organise training on air quality, air quality sensors and even co-develop the bcMeter sensor device together with citizens.

2.1.2 Pathway 2: Citizen Science Experimentation

A second pathway to environmental impact we discern in COMPAIR is through citizen science experimentation. Citizen science in environmental monitoring not only democratises data collection but also drives tangible environmental impact. By involving citizens in monitoring activities, communities can identify and address local environmental issues more effectively. For instance, data collected on air and water quality can prompt regulatory actions and inform policy decisions. Additionally, the widespread participation raises public awareness and fosters a culture of environmental responsibility. This collective effort can lead to more sustainable practices, conservation initiatives, and ultimately, a healthier environment. Through citizen science, individuals become active agents of change, contributing to long-term environmental resilience and sustainability. The driving force here - as seen in COMPAIR - is the LEARN-DO-REFLECT approach where participants - through their closer involvement in environmental monitoring - go through a deeper learning process yielding a sense of environmental responsibility, knowledge on personal behavioural options and a shared local agenda.

Typically, environment quality (e.g. air quality) is not directly improved through this pathway. However, citizen science projects focused on environmental impact can significantly enhance our understanding of local air quality issues and help identify pollution hotspots. For instance, in Athens, such projects involving air quality sensors have provided valuable data on NO_2 and $PM_{2.5}$ levels. Indicatively, by comparing the NO_2 data collected among the two areas of Athens where the NitroSense sensors were installed, it is evident that both measuring locations provide data that follow the same trend. However, the measuring station in the Neos Kosmos area is close to a large avenue of the city, hence provides higher values of NO_2 concentration.

Devices were installed with the aim of monitoring the air quality around the school area in Sofia and eventually to detect any seasonal differences and any effects from the implementation of the school bus service. Examining the data we can definitely observe the seasonal trends as the air pollution picks are exactly in the winter months starting from November and finishing in March, as in December and January is the highest measured data.

The comparison of NO_2 data collected by a mobile laboratory and traffic intensity measurements from Telraam sensors in the areas around two schools in Plovdiv reveals a clear correlation. The findings show that the peak NO_2 concentrations align with traffic intensity peaks, especially during the busiest times of the day—when children are commuting to and from school.

In Flanders, a mobile measurement campaign with SODAQ AIR devices through the local environmental council allowed us to map the occurrence of wood burning hot spots in a municipality. These hotspots align well with local nuisance reports and provide a basis for neutral discussions on this topic. Local authorities now have a reference point to design potential policy interventions.

One of the key outcomes of this pathway is the stimulation of behavioural change. By engaging citizens in data collection and analysis, they become more aware of their environmental impact, which encourages them to adopt more sustainable behaviours.

A co-benefit detected in COMPAIR is empowering communities by involving citizens directly in environmental monitoring, thereby raising awareness about air quality issues. Additionally, the data collected can inform local policy decisions, making the projects influential in shaping environmental policies.

IMPLEMENTATION STEPS

Implementing this pathway in general requires the following steps:

1. **Recruit Volunteers**: Engage citizens to participate in data collection efforts. Have in mind that sometimes you need to get permission to reach the targeted groups - e.g. children and parents in schools. COMPAIR recommends inclusive experiments to reduce a risk of bias due to participant behaviour, living area and other factors.
2. **Provide Training and Tools**: Equip volunteers with air quality sensors and provide training. Use the moments of interaction with participants (training, data workshops …) to manage expectations regarding what will be observed in measurements, tools…
3. **Conduct Data Collection**: Volunteers collect data on air quality over a specified period.
4. **Analyse Data**: Compile and analyse the collected data to identify trends and problem areas.
5. **Share and Discuss Findings**: Communicate the results to the community and policymakers and discuss the results with these different stakeholders. It is common practice to communicate with participants (individually) throughout the experiment so they are aware of results prior to any broader communication.
6. **Develop Action Plans**: Based on the findings, develop action plans to address identified issues.
7. **Implement and Monitor**: Implement the action plans and continue monitoring to assess effectiveness.

Crucial elements for the success of these projects include ensuring continuous volunteer engagement and motivation, maintaining high data quality through proper selection of equipment, quality assurance procedures (cf. COMPAIR deliver[1]and training, and involving the community through regular feedback sessions and workshops. While the implementation of such projects is moderately challenging, requiring coordination and support for volunteers, they can be scaled up effectively with active community involvement.

CRITICAL SUCCESS FACTORS

The following success factors are critical when implementing this pathway:

1. **Effective Training**: Providing comprehensive training tailored to specific target groups ensures volunteers collect high-quality data. In COMPAIR's approach this

[1] COMPAIR deliverables D3.1, D3.2, D5.1, D5.3 provide more information on sensor devices, quality criteria and quality assurance procedures

training was tailored to recommended technology (devices and tools), but the essence was applicable in a broader sense.

2. **Ongoing Support**: Continuous support and engagement keep volunteers motivated and committed.
3. **Data Transparency**: Sharing data and findings openly with the community builds trust and encourages participation. Open and personal communication with participants helps in keeping up motivation.
4. **Policy Integration**: Using the collected data to influence local policies enhances the impact of the project.

Typical stakeholders for this pathway are included in **Table 3**, including a rating of their importance and the main reason for involving them. Further on in this section we provide a brief description of each stakeholder's role, contribution and typical engagement alongside examples from the COMPAIR project.

Table 3*: Rating of the importance of key stakeholders for pathway 2*

Stakeholder	Importance	Reason
Local government authorities	★★★★☆	Important for providing support, resources, and integrating data into policy-making.
Environmental scientists and researchers	★★★★★	Essential for designing the study, providing training, and analysing data.
Community organisations	★★★★☆	Crucial for recruiting volunteers and facilitating community engagement.
Volunteers and citizens	★★★★★	Central to data collection and community involvement.
Educational institutions	★★★☆☆	Useful for integrating projects into educational programs and engaging students.
Technology providers	★★★☆☆	Important for supplying sensors and providing technical support.

Local government authorities	
Role	Provide support and resources for citizen science projects.
Contribution	Funding, policy integration, and data utilisation.
Engagement	Providing support and integrating data into policy-making.

COMPAIR EXAMPLES

- In **Athens**, the Municipality of Athens supported citizen science projects by providing resources and using the collected data to enhance environmental strategies.
- In **Sofia**, the kindergarten and school administration gave us permission to inform parents and involve them and their children to support citizen science and participate in testing rounds.

Environmental scientists and researchers	
Role	Design the study, provide training, and analyse data.
Contribution	Scientific expertise and data analysis.
Engagement	Leading training sessions and data analysis.

COMPAIR EXAMPLES

- In **Athens**, scientists provided training to volunteers on using air quality sensors and analysed the collected data to identify pollution hotspots.
- In **Plovdiv** scientists analysed the collected data and formulated the main outcomes from experiments.
- The **Flanders** pilot lead (VMM) and imec-OnePlanet led the experimental design process for all pilot areas in COMPAIR. The exact process is described in the Open Round Report (D5.4).

Community organisations	
Role	Recruit volunteers and facilitate community engagement.
Contribution	Mobilisation and support for citizen participation.
Engagement	Mobilising volunteers and facilitating engagement.

COMPAIR EXAMPLES

- Community organisations in **Athens** played a key role in recruiting volunteers and organising workshops to keep the community engaged.
- In **Athens** residents and other community groups provided feedback and supported the CO_2 calculation campaign, also through the SynAthina platform of the city that hosts communities' initiatives and events
- Schools, participating in the project activities in **Sofia** and implementing the school bus service, help to spread the information about the sensors and to gather volunteers for testing rounds.
- In **Plovdiv** active citizens organisation (BG Be active) and volunteers were engaged in CO_2 calculator testing, rising awareness campaign, suggestion of measures for the reduction of traffic and improvement of air quality around schools for the municipality of Plovdiv.
- In **Flanders** the local environmental council of Hove was involved to design an experiment on wood burning. Their involvement allowed us to tap into a set of participants that had a prior motivation (local environmental issues), which was particularly useful as this experiment required a rather big involvement of participants (multiple daily walks).

Volunteers and citizens	
Role	Collect air quality data using provided sensors.
Contribution	Data collection and community involvement.
Engagement	Regular training and feedback sessions.

COMPAIR EXAMPLES

- In **Athens**, volunteers were regularly trained on data collection techniques and participated in feedback sessions to discuss findings and improvements.
- Children from two **Sofia** schools participated in workshops for assembling DIY sensors. The sensors were installed at the two schools and measured the outdoor air quality.
- In **Plovdiv** volunteers were trained on how to install and maintain the sensors, and participated in a rising awareness campaign.

Educational institutions	
Role	Integrate citizen science projects into educational programs.
Contribution	Student participation and educational support.
Engagement	Integrating projects into curricula.

COMPAIR EXAMPLES

- Children in 4th grade in schools in **Sofia** participated in training and raising awareness on the importance of taking measures against air pollution, conducted during the workshops, too. Similar training and demonstration of COMPAIR-provided sensors was performed also for other students from 4th and 5th grades, who were participating in another EU project - Shared Green Deal "Sustainable Mobility in Schools". They were inspired to continue discussing such topics and proposed to have additional classes for children interested in environmental topics.
- For Grade 5 Environmental Science students in **Plovdiv** (aged 11-12), an interactive and hands-on learning experience was organised when they reached the topic of air quality. The students participated in a training workshop that included a visit to a mobile AQ laboratory. During this visit, they had the chance to become familiar with the equipment used to measure air pollutants and learned about the principles behind the data collection and analysis process. The students had the opportunity to assemble DIY PM_{10} air quality sensors, giving them practical insights into how such devices function and are used in real-world monitoring. When the students encountered the topic of tables and graphs in their mathematics class, the data collected from the AQ measurements was presented to them. They were tasked with analysing the results by creating tables and graphs. This cross-curricular approach allowed them to apply mathematical concepts to real environmental data, enhancing both their scientific and mathematical understanding. A group of students aged 12-14 received specialised training on how to use a CO_2 calculator. After mastering the tool, these students took on the role of peer educators by presenting the CO_2 calculator to their classmates.
- In **Flanders**, we worked with both a primary and high school. Working with the primary school allowed us to perform a month-long project explaining air quality to pupils, performing some simple experiments and raising some basic interest in the topic. In the high school we were able to put more emphasis on experimentation. Students designed their own experiments with our help leading to insights in clean air routes, local sources etc.

Technology providers	
Role	Supply air quality sensors and data collection tools
Contribution	Technical support and equipment provision.
Engagement	Supplying and maintaining sensors.
COMPAIR EXAMPLES	
• Technology providers in **Athens** ensured the availability and functionality of air quality sensors, providing technical support to volunteers.	

2.1.3 Pathway 3: Online Tools

To achieve environmental change by stimulating behavioural change in citizens participating in the project, the pathway involves providing technological tools that offer insights into their behavioural options and individual environmental impact.

This approach aims to reduce household carbon footprints through informed decision-making, as exemplified by the CO_2 calculator used in Athens, Sofia and Plovdiv, which helped residents understand their carbon emissions and provided recommendations for reduction. The co-benefits include personalised feedback with tailored recommendations for reducing emissions, data to inform local environmental policies, and increased awareness about individual carbon footprints. By providing personalised feedback and recommendations, users are encouraged to adopt sustainable lifestyle choices.

Similarly, COMPAIR also used the Policy Monitoring Dashboard (PMD), Dynamic Exposure Visualisation App and Dashboard (DEV-A/DEV-D) to generate insights into the local environment and personal behaviour. The PMD essentially provides a before/after comparison illustrating the impact of local policy. However in the browse mode participants can look at trends over time of individual sensors. Furthermore the dashboard can also be configured to uncover modal shifts and spark thought on individual behavioural options. The DEV-A/DEV-D combination is aimed at individual exposure and typically allows participants to compare routing choices which again empowers them to change their behaviour to adapt to these outcomes. Compared to the CO_2 calculator, these tools have some crossover with the previous pathways because they are fed by local monitoring data - often through citizen science - and/or relate to implemented policy. Therefore, the elements below will focus on the CO_2 calculator as a more pure example but some PMD, DEV-A and DEV-D examples are included as illustrations when they provide additional insights.

IMPLEMENTATION STEPS

Implementing this pathway in general requires the following steps:

1. **Develop the Tool**: Create an online CO_2 calculator for households or other relevant tool(s). It is common practice to co-create these tools based on user needs.[2]
2. **Promote the Tool**: Conduct online campaigns and collaborate with local organisations to promote the tool(s).
3. **User Engagement**: Encourage residents to sign up and use the tool(s). Pay specific attention to usability and accessibility of tools to lower SES participants.
4. **Collect Data**: Gather data on household emissions from various sources.
5. **Analyze Data**: Identify major sources of emissions and provide personalised feedback.
6. **Scenario Simulation**: Use simulation tools to explore the impact of different policy measures.
7. **Policy Dialogue**: Engage citizens in discussions about potential policy actions and their preferences.
8. **Monitor and Improve**: Continuously monitor usage and feedback to improve the tool(s).

Crucial elements for success include ensuring continuous user engagement, protecting user data and ensuring privacy, and providing technical support for users to understand and use the tool effectively. The difficulty of implementation is considered low to moderate, requiring initial development and promotion but can be easily scaled up.

CRITICAL SUCCESS FACTORS

The following success factor are critical when implementing this pathway:

1. **User-Friendly Design**: A simple and intuitive interface encourages more users to engage with the tool.
2. **Effective Promotion**: Strong marketing and outreach efforts increase tool adoption. Consider tailoring marketing to specific groups of participants.
3. **Personalized Feedback**: Providing actionable and personalised recommendations enhances user satisfaction and impact.
4. **Data Security**: Ensuring robust data privacy measures builds trust and encourages participation.

Typical stakeholders for this pathway are included in **Table 4**, including a rating of their importance and the main reason for involving them. Further on in this section we provide a

[2] COMPAIR's co-innovation reports (D5.5 and D5.7) describe stakeholder involvement throughout the pilot experiments

brief description of each stakeholder's role, contribution and typical engagement alongside examples from the COMPAIR project.

Table 4*: Rating of the importance of key stakeholders for pathway 3*

Stakeholder	Importance	Reason
Local government authorities	★★★★☆	Important for promoting the tool, providing funding, and using data for policy development.
Technology developers	★★★★★	Essential for developing, maintaining, and improving the CO_2 calculator tool.
Environmental organisations	★★★★☆	Crucial for promoting the tool and educating the public on its use.
Community organisations	★★★☆☆	Useful for encouraging community members to use the tool and providing outreach.
Citizens	★★★★★	Central to using the tool, providing data, and adopting sustainable practices.
Educational institutions	★★★☆☆	Helpful for integrating the tool into educational programs and engaging students.

Local government authorities	
Role	Promote the tool and integrate data into policy-making.
Contribution	Funding, promotion, and policy development.
Engagement	Promoting the tool and using data for policy development

COMPAIR EXAMPLES

- In **Athens**, municipal employees were targeted through MailChimp campaigns to promote the CO_2 calculator, and the data collected was used to inform local policies.
- The CO_2 campaign in **Athens** was received and provided feedback by the Ministry of Environment and Energy, the Management Organization Unit of Development Programmes, the Greek Agriculture Organization, the Municipality of Athens etc.
- Representatives of the Environmental Department and the Digital Department of **Sofia** Municipality took part in workshops and provided feedback on the features and usability of CO_2 Calculator and Carbon Footprint Simulation Dashboard. After that PR experts from the Municipality were involved in building a media strategy and validating the key messages for promoting the CO_2 Calculator via outdoor and online raising-awareness campaigns in Sofia.
- In **Flanders**, local authorities also used the tools to interpret results. Making sure policy makers use the tool(s) results in greater uptake by participants as well because both parties experience this as a valid basis for their discussions.

Technology developers	
Role	Develop and maintain the CO_2 calculator tool or other tool(s).
Contribution	Technical expertise and tool development.
Engagement	Continuous development and user support.

COMPAIR EXAMPLES

- Developers in **Athens** worked on improving the CO_2 calculator based on user feedback and provided technical support to ensure a smooth user experience.
- in **Athens** the CO_2 calculator was promoted and used by technology providers in the fields of environment and IT such as DRAXIS, Space Hellas, the Open Technologies Alliance, the Technical Chamber of Greece, Technometrics company etc
- Throughout **COMPAIR** technology developers were involved in the partnership to develop the required tools. Important considerations are:
    - co-creative development: involve your stakeholders and first grasp their needs
    - Functional design: work from these needs to develop only the essential functions a tool should perform and design it to fit this analysis as tightly as possible
    - Architecture: work with technology providers to draft the most efficient underlying architecture (which technology components, how they interact …) also taking into account flexibility in light of future considerations.

Environmental organisations	
Role	Promote the tool and educate the public on its use.
Contribution	Advocacy and public education.
Engagement	Promoting the tool and educating the public.

COMPAIR EXAMPLES

- Environmental organisations in **Athens** promoted the CO_2 calculator through campaigns and workshops, educating the public on its use and benefits
- Feedback on the **Athens** CO_2 calculation was provided by WWF, the Ecological Recycling Society, the Natural Environment & Climate Change Agency, the Mediterranean Information Office for Environment, Culture and Sustainable Development etc .
- Throughout **COMPAIR** we involved environmental experts (i.c. air quality and traffic) to provide input on the added value of certain parameters, (non)sense of visualisations etc. This allowed us to ensure the tools would lead to proper conclusions and provide valuable insights.

Community organisations	
Role	Encourage community members to use the tool, involve them in development through co-design activities.
Contribution	Outreach and engagement.
Engagement	Encouraging community use and providing outreach.

COMPAIR EXAMPLES

- Community organisations in **Athens** encouraged residents to use the CO_2 calculator and provided outreach to ensure widespread adoption such as the Impact Hub of Athens, the SynAthina community etc.
- NGO partners and community organisations promoted the CO_2 Calculator and Carbon Footprint Simulation Dashboard using their social media channels.
- Active citizens organisation in **Plovdiv** encouraged residents to use the CO_2 calculator and to share their results with us.

Citizens	
Role	Use the CO_2 calculator or other tool(s) to measure and reduce their carbon footprint.
Contribution	Data input and behaviour change.
Engagement	Providing feedback and participating in policy discussions.

COMPAIR EXAMPLES

- CO_2 Calculator was promoted on billboards, in metro stations and on public transportation stops in **Sofia**, so that citizens can scan a QR code with call to action to register to the CO_2 Calculator and track their carbon footprint periodically.
- As part of an awareness campaign in **Plovdiv**, the CO_2 calculator was introduced to the citizens. The campaign encouraged participants to test the calculator to better understand how their daily activities contribute to their overall carbon footprint.

Educational institutions	
Role	Integrate the tool into educational programs to teach about carbon footprints.
Contribution	Student engagement and educational support.
Engagement	Integrating the tool into educational programs.

COMPAIR EXAMPLES

- Schools and universities in **Athens** used the CO_2 calculator as an educational tool to teach students about carbon footprints and sustainable practices.
- The CO_2 campaign in **Athens** was received by schools in the city of Athens and by the relevant associations of parents in each municipal district.
- In **Athens**, universities were engaged that have curriculum related to the environment such as the University of Piraeus, the Geology Dpt of the University of Athens, the Panteion University of Social and Political Sciences etc.
- The **Sofia** team made a cross-collaboration with the schools participating in the Shared Green Deal Project “Sustainable Mobility in Schools” and introduced to parents and students the CO Calculator during a Future Mobility Forum. They were one of the first testers of the CO Calculator.
- The CO_2 calculator was introduced in one school in **Plovdiv**, the group of students were trained on how to use it and then they trained their classmates.

2.1.4 Pathway 4: Awareness Raising Campaign

Environmental impact with this pathway is achieved by more people adopting sustainable behavioural choices such as active transportation methods, leading to reducing emissions from vehicles and consequently significantly improved air quality. Other examples are changes in household energy management (e.g. less wood burning, as use), dietary options (reducing livestock emissions) etc. This shift is expected to decrease levels of pollutants such as $PM_{2.5}$ and NO_2 in urban (and rural) areas. Additionally, this pathway will enhance mobility and personal health or wellbeing, e.g. by promoting the increased use of public transport, cycling, and walking, which will help reduce traffic congestion and improve road safety.

This pathway also yields several co-benefits. Health benefits include improved respiratory and cardiovascular health due to better air quality, and increased physical activity from walking and cycling. Economically, an awareness raising campaign will reduce healthcare costs associated with air pollution-related illnesses and provide savings on fuel (also in household heating) and vehicle maintenance for individuals. Socially, a campaign will enhance community engagement and social cohesion through shared activities and goals, and increase awareness and education on environmental issues.

To stimulate behavioural change, an awareness raising campaign should focus on raising awareness and knowledge by educating people about the impact of their (transportation) choices on air quality and health, and providing practical tips and alternatives for a sustainable lifestyle. It will also work to establish social norms by creating a culture of sustainability where sustainable practices are seen as the norm, and encouraging peer influence and community support for behaviour change. Incentives and motivation will be highlighted by showcasing the personal and community benefits of adopting sustainable practices, and using positive reinforcement and recognition for individuals and groups who make significant changes.

Stakeholder interaction is relevant to all pathways but primordial to this one. Because of that, interactivity with stakeholders is discussed more elaborately for each stakeholder in this pathway, providing potential workshops and links to policy. This information is also applicable to stakeholder interaction in other pathways.

IMPLEMENTATION STEPS

Implementing this pathway in general requires the following steps:

1. **Identify target audience(s)**: Focus on specific groups such as school children, parents, commuters, and local communities.
2. **Develop educational materials**: Create engaging content such as brochures, posters, videos, and social media posts that explain the importance of air quality and sustainable mobility. Include information on the health impacts of poor air quality and the benefits of sustainable transportation.
3. **Organise workshops and events**: Conduct workshops in schools, community centres, and workplaces to educate people about air quality and mobility. Host events like car-free days, bike-to-work days, and public talks to promote sustainable practices.
4. **Leverage media and social media**: Use local media outlets and social media platforms to spread awareness messages. Share success stories and testimonials from individuals and communities who have adopted sustainable practices.
5. **Collaborate with influencers and local leaders**: Engage local influencers, community leaders, and celebrities to endorse the campaign and reach a wider audience.
6. **Monitor and evaluate**: Collect feedback from participants to assess the effectiveness of the campaign. Adjust the campaign strategies based on feedback and observed changes in behaviour.

Successful implementation of an awareness raising campaign will require active engagement and participation from the community and stakeholders. The campaign must be inclusive and accessible to all demographics. Clear and consistent messaging is crucial, delivering relatable messages that resonate with the target audience through multiple channels. Continuous feedback and adaptation will be necessary to improve the campaign's effectiveness, ensuring responsiveness to the needs and preferences of the community.

The implementation of this campaign is considered to be of moderate difficulty. It requires coordination and collaboration with various stakeholders and needs continuous effort and adaptation to maintain engagement and effectiveness.

CRITICAL SUCCESS FACTORS

Critical success factors for this pathway are:

1. **Community Engagement**
   - Ensures broad participation and buy-in from the target audience.
   - Enhances the reach and impact of the campaign.
2. **Effective Communication**
   - Clear, consistent messaging helps in conveying the importance of air quality and sustainable mobility.
   - Relatable content increases the likelihood of behaviour change.
3. **Stakeholder Collaboration**
   - Involvement of local leaders, influencers, and organisations amplifies the campaign's reach.
   - Collaborative efforts ensure resource sharing and support.
4. **Continuous Monitoring and Feedback**
   - Regular feedback helps in identifying areas for improvement.
   - Adaptation based on feedback ensures the campaign remains relevant and effective.
5. **Incentives and Recognition**
   - Positive reinforcement motivates individuals and groups to adopt sustainable practices.
   - Recognition of efforts encourages continued participation and engagement.

Typical stakeholders for this pathway are included in **Table 5**, including a rating of their importance and the main reason for involving them. Further on in this section we provide a brief description of each stakeholder's role, contribution and typical engagement alongside examples from the COMPAIR project.

Table 5: *Rating of the importance of key stakeholders for pathway 4*

Stakeholder	Importance	Reason
Local Government and Municipal Authorities	★★★★★	Provide essential support, resources, and policy backing, ensuring the campaign aligns with local regulations and has the necessary permissions for events and activities.
Environmental and health organisations	★★★★☆	Offer expertise and credibility, enhancing the campaign's scientific and health-related content. Their involvement ensures accurate and reliable information is disseminated.
Schools and educational institutions	★★★★☆	Play a crucial role in educating young people and integrating air quality and mobility topics into the curriculum, fostering early awareness and long-term behavioural change.
Community groups and NGOs	★★★★☆	Mobilise community members and volunteers, providing grassroots support and local insights, which are vital for community engagement and participation.
Local businesses and employers	★★★☆☆	Can promote sustainable commuting practices among employees and support the campaign through sponsorships and partnerships, extending the campaign's reach and impact.
Media and social media influencers	★★★★☆	Amplify the campaign's messages through various media channels, reaching a wider audience and increasing visibility. Their influence can attract and retain public interest.
Healthcare providers	★★★☆☆	Educate the public on the health impacts of poor air quality and provide data and insights on pollution-related health issues, enhancing the campaign's focus on health benefits.
Transportation authorities	★★★☆☆	Provide data on traffic patterns and pollution levels and support initiatives like car-free days and improved public transport, facilitating changes in transportation infrastructure.
Citizens and community members	★★★★★	Drive behavioural change. Their participation, feedback, and support are crucial for the campaign's success and sustainability

Local Government and Municipal Authorities	
Role	Provide support, resources, and policy backing for the campaign. Facilitate permissions for events and workshops. Validate or approve, if needed, key messages and visuals of an awareness raising campaign.
Contribution	Ensure alignment with local policies and regulations. Offer platforms for public engagement and dissemination of information.
Engagement	Actively involve local government from the start to gain support and access to necessary resources. For example, the Municipality of Athens was involved in identifying areas for sensor deployment and supporting citizen engagement. Use the data collected to inform local policy decisions. For instance, the data from the pilots were intended to enhance environmental strategies and develop policies on climate mitigation.

COMPAIR EXAMPLES

- Representatives of the PR and marketing teams of the Environmental Department and also of the Urban Mobility Centre, as well as the director of the Waste Department of **Sofia** Municipality, were invited to participate in a small-scale ideathon on creating a raising-awareness campaign. They got familiar with the COMPAIR tools and took part in the co-creation of the future "It's cool that you care" campaign and shared their ideas for the information campaign and were involved in the process of validation of the messages and finalisation of the visuals that would promote the COMPAIR-provided tools, Sofia pilot projects and also programs, projects and policy measures of Sofia Municipality calling for sustainable living habits among the general public and personal contribution to Sofia becoming a greener city. Developing this campaign was a synergetic process and a collaboration between many departments and entities.
- In **Flanders** the local authorities involved provided us with direct communication channels to potential citizen participants. They helped in letterbox campaigns, echoed our communication on social media, provided a local meeting place yielding a trusted environment to participants.
- In **Berlin** two representatives of the Berlin Senate Department for Mobility, Transport, Climate Protection and the Environment (SenMVKU) were available during the open and public round for discussions about the COMPAIR project to discuss whether and how our technical and citizen science/participation data can be used by politics. In addition, a representative of the Senate Administration took part in the closing event and the panel discussion there. This also gave citizens the chance to put their questions to policymakers in an exciting dialogue.

Environmental and Health Organizations	
Role	Offer expertise on air quality, health impacts, and sustainable practices. Provide educational materials and resources.
Contribution	Enhance the credibility of the campaign with scientific data and health information. Support in organising workshops and events.
Engagement	Develop educational materials and resources with the help of these organisations to ensure accurate and reliable information is disseminated. For example, Sofia team provided to the TSA Foundation, which is working with Roma communities, some Air quality educational materials and training materials. Involve experts from these organisations in workshops and events to provide insights and support.
COMPAIR EXAMPLES	
• In **Flanders**, the involvement of air quality experts allowed COMPAIR to draft simple and concise messages informing participants on environmental challenges. Furthermore, COMPAIR's D5.1 deliverable - development by the involved experts - provides a solid basis for teachers or workshop hosts to inform pupils or citizen scientists on these environmental challenges.	

Schools and Educational Institutions	
Role	Engage students, teachers, and parents in the campaign. Integrate air quality and mobility topics into the curriculum.
Contribution	Foster early education and awareness among young people. Facilitate workshops and hands-on activities.
Engagement	Integrate air quality and mobility topics into the school curriculum. For example, schools in the Flanders pilot participated in programs like “Schools Count!” to promote sustainability and climate awareness. Also in Sofia one of the schools, participating in the school bus service also took part in a discussion on ”Sustainable mobility in school” together with partners from Shared Green Deal project and presented their experience in COMPAIR project. Conduct hands-on activities and experiments with students to raise awareness about air quality. This approach was used in the pilots to engage students in measuring air quality and understanding its impact. Organise workshops and gather feedback from students and teachers to continuously improve the educational materials and activities.
COMPAIR EXAMPLES	
• In **Flanders**, we organised 1 to 2 month long project work in both a primary and high school. Schools appreciated this effort as it provides anchor points for STEM education, school kids are engaged through the varying activities in our learn-do-reflect approach. Lastly, knowledge absorbed by kids is conveyed onto their parents as they talk to them about their school day, share experiences from experiments and excursions etc.	

Community Groups and NGOs	
Role	Mobilise community members and volunteers. Provide grassroots support and local insights.
Contribution	Increase community engagement and participation. Help in organising local events and spreading awareness.
Engagement	Mobilise community members and volunteers through local NGOs and community groups. This was evident in the pilots where local residents, including school children, were involved in data collection and analysis. Leverage the local insights provided by these groups to tailor the campaign to the specific needs and preferences of the community. Organise interactive workshops, data cafés and ideathons to engage citizens and educate them about air quality and traffic management.

COMPAIR EXAMPLES

- In **Flanders**, we are engaging the GoodPlanet NGO to further expand our educational approach. Through the data café approach we also involved non-citizen scientists to discuss results, providing us with a platform to discover how they experience their local environment and discuss this based on supporting data from our experiments.
- In **Berlin**, we worked closely with the civil society initiative Changing Cities during the open and public round. In addition to a regular exchange and support in mobilising citizens for our project, the press spokesperson also took part in the final event and panel discussion. This meant that civil society perspectives on mobility, air quality and citizen science engagement could also be presented in a targeted manner during the panel discussion. In addition, we presented our project results at Changing Cities events and strengthened the scientific-research-civil society network.

Local Businesses and Employers	
Role	Promote sustainable commuting practices among employees. Support the campaign through sponsorships and partnerships.
Contribution	Encourage employees to adopt sustainable transportation. Provide resources and incentives for participation.
Engagement	Engage local businesses to support the campaign through sponsorships and partnerships. This can help in extending the campaign's reach and impact. Encourage businesses to promote sustainable commuting practices among their employees. This was seen in the pilots where businesses were involved in promoting sustainable transportation options. Provide incentives and recognition for businesses that actively participate and support the campaign.
COMPAIR EXAMPLES	
• Not applied in COMPAIR, but we see these stakeholders as necessary to consider in future projects.	

Media and Social Media Influencers	
Role	Amplify the campaign's messages through various media channels. Share success stories and testimonials.
Contribution	Reach a wider audience and increase visibility. Create engaging content to attract and retain public interest.
Engagement	Use local media outlets and social media platforms to spread awareness messages. Share success stories and testimonials to attract and retain public interest. Collaborate with local influencers and celebrities to endorse the campaign and reach a wider audience. This approach was used in the pilots to increase visibility and engagement. Create engaging content such as videos, posts, and articles to keep the audience informed and interested.

COMPAIR EXAMPLES

- In **Athens** three major campaigns took place in the media in order to raise awareness and promote the project, namely in the online editions of the national newspapers: CNN Greece, News247 media and Kathimerini. Additionally, DAEM participated in the live broadcast of Athens 9.84 Municipal Radio to promote the actions.
- **Sofia** team released a raising awareness campaign "It's cool that you care" which included attractive visualisations on different sustainable topics. It aimed to show positive examples of people living sustainably plus calls to action for behavioural change - e.g. going to work or school by bike, recycling your domestic waste, using an ecological heating system, unplug devices when not used to save energy. The campaign also promoted the CO_2 Calculator developed under COMPAIR project. It was spread outdoors in 40 locations in total - including locations in the metro stations, locations of city lights around the city and billboards. All the locations are around big boulevards and highways and also the busiest metro stations and public transport stops mainly in the centre of the city and along the main two diameters of the city to increase visibility and to reach bigger audience. The campaign continued also online with social media posts.

Healthcare Providers	
Role	Educate the public on the health impacts of poor air quality. Provide data and insights on pollution-related health issues
Contribution	Enhance the campaign's focus on health benefits. Support workshops and provide expert speakers.
Engagement	Provide data and insights on pollution-related health issues to support the campaign's messages. Involve healthcare professionals as expert speakers in workshops and events to provide credible information.
COMPAIR EXAMPLES	
• Not applied in COMPAIR, but we see these stakeholders as necessary to consider in future projects.	

Transportation Authorities	
Role	Provide data on traffic patterns and pollution levels. Support initiatives like car-free days and improved public transport.
Contribution	Facilitate changes in transportation infrastructure. Offer insights and data to measure the campaign's impact.
Engagement	Support initiatives like car-free days and improved public transport to facilitate changes in transportation infrastructure. Participate in workshops and discussions to provide insights and support for the campaign.
COMPAIR EXAMPLES	
• Not applied in COMPAIR, but we see these stakeholders as necessary to consider in future projects.	

Citizens and Community Members	
Role	Participate in workshops, events, and sustainable practices. Provide feedback and support for the campaign.
Contribution	Drive the behavioural change needed for the campaign's success. Share personal stories and experiences to inspire others.
Engagement	Encourage citizens to participate in workshops, events, and sustainable practices. Their involvement is crucial for driving behavioural change. Collect feedback from community members to continuously improve the campaign. This was a key aspect of the pilots where citizen feedback was used to refine the initiatives. Share personal stories and experiences to inspire others and create a sense of community. For example, Sofia invited parents whose kids are using the school bus service to share their experiences with other participants in an ideathon. Small focus groups of citizens could be used to verify once again the validation messages and to gather useful feedback on how citizens understand and see the visuals of the campaign as first impressions. For example, the Sofia pilot used such small group of citizens to share their opinions on the first drafts of the "It's cool that you care" campaign after the validation of the city officials.
COMPAIR EXAMPLES	
• In **Berlin**, we received support for the public round from the neighbourhood management teams in three neighbourhoods. Through their access to the neighbourhood and as an important community actor, we benefited greatly from their support in mobilising citizens for the static campaign. We were able to present the COMPAIR project at a citizens' council, appeared in a neighbourhood magazine and were able to share our call for participation in the project via their social media channels.	

2.1.4 Overview of four pathways

At the onset of COMPAIR we mapped our principal use cases on the one hand to the degree to which an approach was based on awareness raising rather than taking action (e.g. through implementation of measures) and on the other on whether the approach was aimed at individual participants rather than a collective. We see that this basic analysis still holds when mapping the four pathways we elucidate from our work in COMPAIR. Figure 1 re-iterates our original analysis but adds the pathways to it.

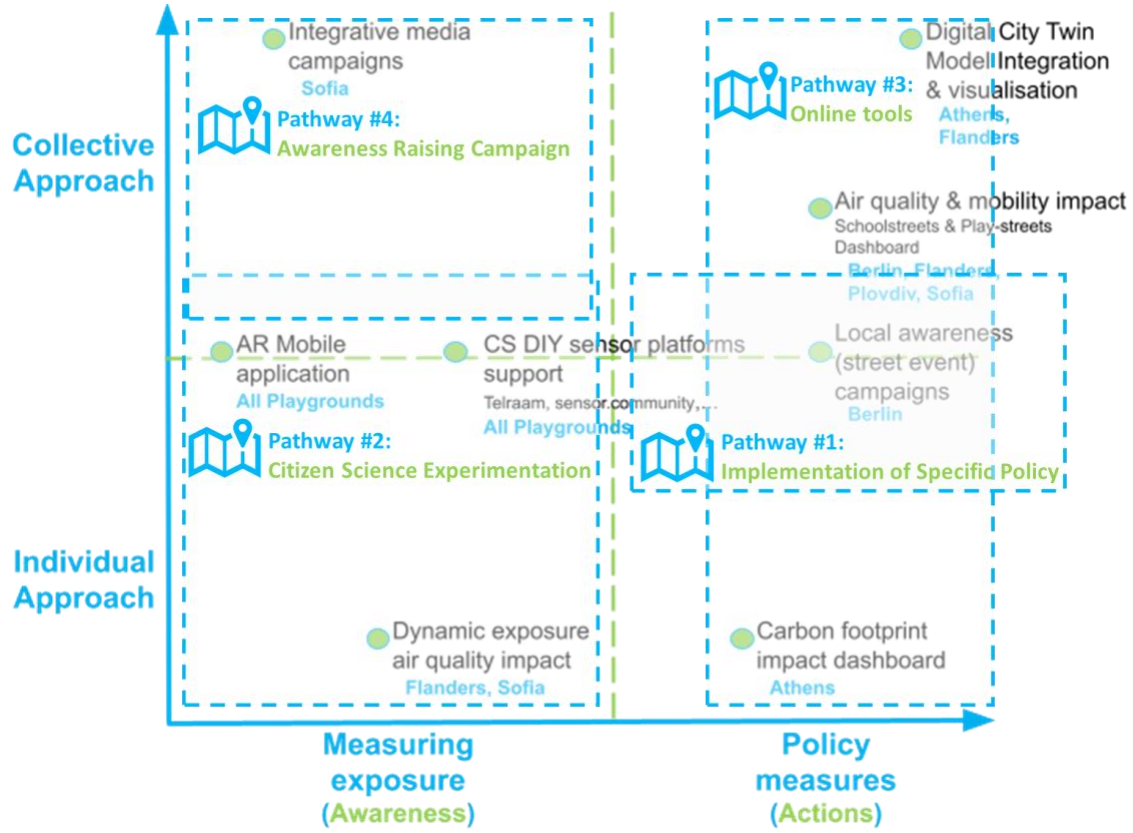

Figure 1*: Pathways & COMPAIR pilot types mapped in light of directness towards citizens (Y) and environmental impact (X)*

In the table below, the environmental impact, benefits, ease of implementation and the impact on behavioural change of the three pathways are compared. Each pathway offers unique advantages and challenges, but all contribute significantly to improving air quality and mobility through different approaches.

Table 6: *Summary of all 4 pathways to environmental change and their respective environmental impact, co-benefits, difficulty of implementation, impact on behavioural change and critical success factors.*

Pathway	Environmental Impact	Co-benefits	Difficulty	Behavioural Change	Critical Success Factors
Participative implementation of policy	High	High	Moderate to High	Moderate to High	Community Involvement, Clear Communication, Continuous Monitoring, Policy Integration
Citizen Science Experimentation	Moderate to High	Moderate	Moderate	High	Effective Training, Ongoing Support, Data Transparency, Policy Integration
Online Tools	Moderate	Low	Low to Moderate	Moderate	User-Friendly Design, Effective Promotion, Personalized Feedback, Data Security
Awareness raising campaign	Moderate to high	High	Moderate	High	Community engagement, Effective communication Stakeholder Collaboration Continuous Monitoring and Feedback Incentives and Recognition

3. Recommendations for future endeavours

3.1 Recommendation 1: Enhance Volunteer Training and Support

Effective training ensures high-quality data collection and sustained volunteer engagement[3]. High-quality data collection leads in turn to more accurate and reliable results, which can better inform policy decisions and community actions.
Continuous support helps maintain motivation and addresses any challenges volunteers face. Sustained volunteer engagement ensures long-term data collection and community involvement.
An example of this was Athens, where scientists conducted workshops to train volunteers on using air quality sensors and provided ongoing support through a hotline and online forum.

Implementation steps:

1. **Develop comprehensive training programs:** Create detailed training materials, including manuals and videos.
2. **Conduct hands-on workshops:** Organise workshops where volunteers can practise using the equipment.
3. **Provide ongoing support:** Set up a support hotline and online forum for troubleshooting and questions.
4. **Regular refresher sessions:** Hold periodic refresher sessions to reinforce training and address new issues.

3.2 Recommendation 2: Foster Strong Community Engagement

Community involvement ensures that projects are tailored to local needs and gain broader support. Engaged communities are more likely to participate actively and advocate for policy changes.
Strong community engagement leads to higher participation rates, better data quality, and increased advocacy for environmental policies.
In Berlin, for example, neighbourhood management offices facilitated meetings with residents to gather input on traffic-calming plans and kept the community informed through newsletters and public meetings.

Implementation steps:

1. **Organise community meetings:** Hold regular meetings to discuss project goals, progress, and findings.
2. **Use multiple communication channels:** Utilise social media, newsletters, and local media to keep the community informed**.**

[3] COMPAIR's D5.1 deliverable offers a compendium of essential training aspects to achieve this goal

3. **Create feedback mechanisms:** Establish online portals and suggestion boxes for community feedback.
4. **Recognize and reward participation:** Acknowledge the contributions of community members through awards and public recognition.

3.3 Recommendation 3: Integrate Data Transparency and Open Access

Transparency builds trust and encourages broader participation. Open access to data allows for independent analysis and fosters collaboration.
Transparent and accessible data can be used by various stakeholders to advocate for policy changes, conduct further research, and implement community-driven solutions.
In Athens, for example, air quality data collected by volunteers was made publicly available through an online platform, and regular reports were issued summarising the findings.

Implementation steps:

1. **Provide open data access:** Make collected data publicly available through an online platform.
2. **Publish regular reports:** Issue regular reports summarising the data and key findings.
3. **Host data workshops:** Organise workshops to teach community members how to access and interpret the data.
4. **Encourage independent analysis:** Invite researchers and community groups to use the data for their own analyses and projects.

4. The road travelled by COMPAIR pilots

This chapter summarises the various approaches - or “roads” - used in the COMPAIR pilots to further illustrate the potential pathways highlighted above. As detailed descriptions of our approach can be found in the Closed, Open and Public Round reports, we only provide a more generic summary of key activities in this section to allow for a SWOT (strengths, weaknesses, opportunities, and threats)-analysis. Next policy involvement, resulting environmental impact and the inherent limitations we encountered in our approaches are briefly discussed for each pilot and/or use case.

By following these steps and considering the SWOT analysis, other parties can set up their own pilots and initiatives to promote sustainability and environmental awareness.

4.1. Key activities undertaken & SWOT-analysis

Road #1: Participative implementation of policy

Participative implementation of policy involves actively engaging the community in the development and execution of policies, particularly those related to air quality and traffic management.

Applicable COMPAIR pilot use cases

- Flanders use case 4 - Schoolstreet in Herzele
- Flanders use case 6 - Circulation plan Ghent
- Flanders use case 7 - Circulation plan Sint-Niklaas
- Sofia use case 1 – School bus service
- Plovdiv use case 2 - Proposal with a list of possible measures for the reduction of traffic and improvement of air quality around schools for the municipality of Plovdiv

Key activities undertaken:

1. **Identify Problem Areas:** Determine areas with high traffic congestion and poor air quality.
2. **Engage Stakeholders:** Involve local authorities, policymakers, and the community to gather input, raise support and sustain the planning process.
3. **Assess The Need:** Uncover motivation for behavioural choices (e.g. transportation mode chosen) and identify solutions to alter these choices, preferably in co-creation with stakeholders.
4. **Planning and Approval:** Cooperate with local authorities to plan the policy intervention, set a timeline, obtain necessary approvals and outline communication to promote the desired change.
5. **Install Monitoring Devices:** Set up sensors to measure air quality and traffic patterns before and after implementation.

6. **Launch the Plan:** Implement the changes (e.g. mobility plan, school bus service, school street …) and communicate the changes to the community.
7. **Monitor and Evaluate:** Continuously monitor air quality and traffic data to assess the impact. Conduct surveys and workshops to gather hands-on feedback from stakeholders.
8. **Adjust and Improve:** Make necessary adjustments based on the data and feedback from the community. Expand to other areas when the implementation is deemed successful by reiterating all steps, do not assume what has worked in one area will work identically in another.

SWOT Analysis:

Table 7 provides an SWOT analysis of the general COMPAIR approach outlined above. One of the primary benefits of this approach is its immediate and measurable impact on air quality and traffic (both intensity and safety). By involving citizens in the decision-making process, policies can be tailored to address specific local issues, leading to more effective and timely improvements. This direct involvement ensures that the policies are relevant and practical, resulting in tangible benefits such as reduced pollution levels and smoother traffic flow.

Another significant benefit is that it encourages sustainable transportation habits. When people are part of the policy-making process, they are more likely to understand and support the initiatives being implemented. This can lead to increased use of public transportation, carpooling, cycling, and walking, and a decreased number of car-driven children to school, all of which contribute to lower emissions and healthier communities. Additionally, a participative approach fosters a sense of ownership and responsibility among citizens, motivating them to adopt and maintain sustainable practices.

Furthermore, a data-driven approach allows for continuous improvement. By collecting and analysing data from the community, policymakers can make informed decisions and adjust policies as needed. This iterative process ensures that policies remain effective and responsive to changing conditions. Continuous feedback from the community helps identify areas for improvement and allows for the fine-tuning of strategies to achieve better outcomes.

However, there are several drawbacks to consider. One potential challenge is resistance from the community. Not everyone may agree with the proposed policies, and some individuals or groups may oppose changes that affect their routines or interests. Overcoming this resistance requires effective communication, education, and sometimes compromise to build consensus and ensure broad support.

Additionally, the initial setup, implementation and or operational costs can be quite high depending on the policy that is being implemented. It is important to take these factors into account when designing the desired intervention.

Finally, participative implementation requires ongoing monitoring and adjustments. Maintaining an open dialogue with the community and regularly updating policies based on feedback can be resource-intensive. It demands continuous effort from both policymakers and

participants to keep the process dynamic and effective. Despite these challenges, the benefits of a participative approach can lead to more sustainable and impactful policy outcomes when managed effectively.

Table 7*: SWOT analysis of road #4: Participative implementation of policy*

Strengths	Weaknesses
• Direct impact on reducing traffic and improving air quality. • Data-driven approach to measure effectiveness. • Focus on key areas such as schools, kindergartens.	• Potential resistance from the community and local businesses. • Requires significant planning and coordination with multiple stakeholders. • Costs can be quite high depending on the policy implemented. • Often requires continuous support.
Opportunities	**Threats**
• Can serve as a model for other areas and cities. • Potential to integrate with broader urban planning & mobility initiatives.	• Political and economic challenges, changes in policy will disrupt the implementation. • Unforeseen consequences (e.g., traffic displacement). • Resistance to change is inherent to many individuals in a community • Technical issues and challenges in monitoring effects with low-cost equipment.

Road #2: Citizen Science for Environmental Monitoring

Citizen science for air quality monitoring is an approach that leverages the power of crowdsourcing to gather valuable environmental data.

Applicable COMPAIR pilot use cases:

- Flanders use case 4 - Citizen science in Herzele (black carbon monitoring & development)
- Flanders use case 5 - Environmental council in Hove (wood burning walks)
- Flanders use case 8 - Sensor validation Ghent
- Athens use case 1 - Creating awareness on air quality among elderly habitants of Neos Kosmos
- Athens use case 2 - Creating awareness on air quality among elderly habitants of Kipseli
- Athens use case 3 - Calculate carbon footprint using dashboard
- Sofia use case 1 - Measuring the air quality around schools, participating in the School bus service
- Sofia use case 2 - Measuring indoor air quality in a kindergarten
- Sofia use case 3 - CO_2 Calculator and Carbon Footprint Simulation Dashboard usage
- Plovdiv use case 1 and case 3 - Creating awareness of the impact of traffic on air pollution among students
- Plovdiv use case 2 - Creating awareness of the impact of traffic on air pollution and seasonal variation of PM_{10} among citizens

Key activities undertaken:

1. Engagement and Recruitment:
    - Identify target groups (e.g., low Socio-economic status (SES) populations, elderly citizens, students).
    - Collaborate with local organisations and municipalities to recruit participants.
    - Conduct outreach campaigns to raise awareness and encourage participation.
    - Engage citizens to participate in data collection efforts.
2. Distribution of Sensors:
    - Provide participants with low-cost air quality sensors.
    - Conduct workshops to train participants on sensor usage and data collection.
3. Data Collection and Monitoring:
    - Deploy sensors in various locations (e.g., homes, public spaces).
    - Collect data on air pollutants (e.g., $PM_{2.5}$, NO_2) over a specified period.
4. Data Analysis and Visualization:
    - Use digital tools (e.g., dashboards) to analyse and visualise collected data.
    - Compare data across different locations and time periods to identify trends and hotspots.
5. Community Feedback and Policy Recommendations:
    - Share and discuss findings with participants and the broader community through workshops and meetings.
    - Engage policy makers to discuss data insights and potential policy actions.

- Create surveys to gather feedback and policy recommendations from key stakeholders, users or volunteers.
- Develop and propose policy recommendations and action plans based on collected data to address identified issues.

6. Implement and Monitor: Implement the action plans and continue monitoring to assess effectiveness.

SWOT Analysis:

Table 8 provides a SWOT analysis of the general COMPAIR approach outlined above. One of the primary benefits of this approach is that it empowers citizens to actively contribute to environmental monitoring. By involving non-professionals in data collection, communities can gather localised and real-time data on air quality, which can be crucial for identifying pollution hotspots and understanding local air quality trends or even air pollution sources. This participatory approach also enhances community awareness and engagement in environmental issues, fostering a sense of responsibility and encouraging proactive measures to improve air quality.

However, there are several drawbacks to consider. The quality of data collected by citizen scientists can vary significantly due to the lack of professional training and standardised methodologies. This variability can pose challenges for researchers and policymakers who rely on consistent and accurate data for decision-making. Additionally, citizen science initiatives require ongoing support and training for participants to ensure data accuracy and reliability. This can be resource-intensive and may require sustained funding and organisational efforts. Another challenge is maintaining participant motivation over time. Without continuous engagement and incentives, participants may lose interest, leading to gaps in data collection and reduced effectiveness of the monitoring program.

However, many COMPAIR insights and deliverables provide guidelines on how to cope with these challenges. Most relevant for this road is COMPAIR's sensor benchmark and development of calibration pipelines to clarify and improve sensor performance.

Overall, while citizen science for air quality monitoring offers numerous benefits, it also presents challenges that need to be addressed to maximise its potential. By providing adequate support and training, and by fostering a strong sense of community involvement, these challenges can be mitigated, leading to more effective and impactful environmental monitoring efforts.

Table 8: *SWOT analysis of road #1: Citizen Science for air quality monitoring*

Strengths	Weaknesses
• High community engagement, empowerment and ownership. • Low-cost and scalable approach. • Real-time data collection and monitoring. • Large dataset from diverse sources. • Empowers citizens to contribute to environmental monitoring.	• Potential variability in data quality due to non-professional data collectors. • Limited coverage if participation is low or when certain groups do not participate (e.g. lower SES, age group, neighbourhood) • Dependence on participants' commitment and consistency. • Requires ongoing support and coordination.
Opportunities	**Threats**
• Increased public awareness and education on air quality issues. • Can lead to community-driven solutions and policy changes (policies and regulations). • Collaboration with academic and research institutions for advanced analysis. • Potential to expand to other areas and issues. • Co-design and regular feedback on developing processes, services or tools.	• Technical challenges with sensor deployment, performance[4] and data transmission. • Potential resistance from stakeholders or policy makers. • Data privacy and security concerns. • Volunteer fatigue and drop-off[5]. • Dependence on continuous funding and support.

Conclusion

This road provides a structured approach to achieving environmental impact through education, mobility planning, and citizen science. This road has its strengths and weaknesses, but collectively, it offers a comprehensive strategy for improving air quality and mobility. By engaging the community, leveraging data, and continuously monitoring and adjusting plans, other parties can set up their own pilots to achieve similar environmental benefits.

[4] COMPAIR deliverables D3.1, D3.2, D5.1, D5.3 provide more information on sensor devices, quality criteria and quality assurance procedures
[5] COMPAIR deliverable D7.1 on participation covers these aspects more elaborately

Road #3: CO_2 Footprint Measurement and Reduction

Measuring and reducing one's CO_2 footprint is a proactive approach to mitigating climate change.

Applicable COMPAIR pilot use cases

Athens use case 3 - Calculate carbon footprint using dashboard
Sofia use case 3 - CO_2 Calculator and Carbon Footprint Simulation Dashboard usage
Plovdiv use case 2 - Raising awareness

Key activities undertaken:

1. Identify the Need:
    - Assess the need for a tool to help citizens calculate their carbon footprint and identify areas for improvement.
2. Stakeholder Engagement:
    - Engage with citizens, local authorities, and environmental organisations to gather support and input for the CO_2 calculator.
3. Tool Development
    - Develop a CO_2 calculator tool for households to measure their carbon footprint.
    - Conduct testing with a small group of users to gather feedback and make improvements
4. Tool Promotion and Awareness
    - Promote the tool through outdoor or online campaigns and collaborations with local organisations.
    - Conduct workshops and campaigns to raise awareness about the importance of reducing carbon footprints.
5. User Engagement and Data Collection:
    - Launch the CO_2 calculator for public use, providing support and guidance to users.
    - Encourage residents to sign up, create accounts, and use the CO_2 calculator on a regular basis and get motivation for changing habits.
    - Collect data on household emissions from various sources (e.g., transportation, energy use).
6. Data Analysis and Feedback:
    - Analyze collected data to identify major sources of emissions.
    - Provide personalised feedback and recommendations to users for reducing their carbon footprint.
7. Scenario Simulation and Policy Dialogue:
    - Use scenario simulation tools to explore the impact of different policy measures.

- Engage citizens in discussions about potential policy actions and their preferences.
- Communicate findings and recommendations to policy makers.

8. Implementation and Monitoring:
   - Support the implementation of recommended policies and actions.
   - Monitor the impact of these measures on household emissions and overall air quality.
   - Continuously monitor the usage and feedback from users to identify areas for improvement of the CO_2 calculator.
   - Use the feedback and data collected to make improvements to the CO_2 calculator and expand its reach.

SWOT Analysis:

Table 9 provides an SWOT analysis of the general COMPAIR approach outlined above. One of the key benefits of this approach is that it provides personalised recommendations for reducing emissions. By using CO_2 calculators, individuals can receive tailored advice on how to lower their carbon footprint, such as reducing energy consumption, opting for sustainable transportation, and making eco-friendly lifestyle choices. This personalised guidance can make the process of reducing emissions more manageable and effective, as well as more motivating for participants.

Another significant benefit is that it engages citizens in understanding and addressing their carbon footprint. By actively participating in CO_2 measurement, individuals become more aware of their environmental impact and are more likely to take steps to reduce it. This heightened awareness can lead to broader community engagement and collective action towards sustainability goals. Additionally, the data collected from CO_2 footprint measurements can support data-driven policy development and implementation. Policymakers can use this information to design and enforce regulations that promote carbon reduction on a larger scale.

However, there are several drawbacks to consider. The success of CO_2 footprint measurement and reduction relies heavily on user engagement and participation. High levels of commitment are required to consistently track and reduce emissions, which can be challenging to maintain over time. This approach also faces potential challenges in keeping users motivated. Without continuous incentives and engagement strategies, individuals may lose interest, leading to decreased participation and effectiveness.

Furthermore, the accuracy and effectiveness of the CO_2 calculator tool are crucial. If the tool provides inaccurate or misleading data, it can undermine the entire effort. Ensuring that the CO_2 calculators are reliable and user-friendly is essential for the success of this approach. Hence, COMPAIR used initial workshops in all pilot regions to capture use needs and ensure alignment to start co-designing our tools. Regarding this road travelled co-design and early stakeholder involvement are key elements. Despite these challenges, with proper support and continuous engagement, the CO_2 footprint measurement and reduction approach can play a vital role in promoting sustainable practices and reducing overall carbon emissions.

Table 9: *SWOT analysis of road #2: CO_2 Footprint Measurement and Reduction*

Strengths	Weaknesses
• Provides a valuable tool for citizens to calculate and reduce their carbon footprint • Provides actionable insights for reducing household emissions. • Engages citizens in policy dialogue and decision-making. • Facilitates data-driven environmental policy development. • Engages the community in environmental sustainability efforts.	• Requires significant user engagement and participation. • Potential challenges in accurately measuring and attributing emissions. • Dependence on the effectiveness of the CO_2 calculator tool. • Requires continuous updates and improvements to the tool. • Dependence on user engagement and participation. • Initial costs for developing and promoting the tool.
Opportunities	**Threats**
• Potential to significantly reduce household emissions. • Increased public awareness and education on carbon footprint reduction. • Collaboration with local governments and organisations for broader impact. • Potential to expand the tool to more users and areas. • Can serve as a model for other cities looking to promote carbon footprint.	• Resistance to behaviour change from participants. • Technical challenges with the CO_2 calculator tool. • Potential data privacy and security concerns[6] • Additional costs for maintaining the tool.

[6] COMPAIR deliverable D2.7 covers our data security and privacy strategies

Road #4: Educational and Awareness Campaigns

Educational and awareness campaigns are powerful tools for promoting understanding and action on important issues like air quality and mobility.

Applicable COMPAIR pilot use cases

- Flanders use case 1 - A primary school in Ghent (mobile measurements and excursion)
- Flanders use case 2 - A high school in Herzele (2 project months, experimentation with sensors)
- Flanders use case 3 - A college in Geel (mobile measurements)
- Sofia use case 1 – School bus service (incl. measurements about the effectiveness of the service via DIY sensors and surveys among parents)
- Sofia use case 4 – Awareness raising campaign (incl. workshops at schools and measurements)
- Plovdiv use case 1 - primary school “Dimitar Talev” - workshops with students (AQ topics, mobile AQ laboratory visit, sensor assembling, experiment results)
- Plovdiv use case 2 - experiments with sensors, rising awareness campaign
- Plovdiv use case 3 - workshops with students (AQ topics, mobile AQ laboratory visit, sensor assembling, Ideathon, experiment results)

Key activities undertaken:

1. **Identify Target Audience:** Determine the demographic (e.g., primary school children, secondary school students, college students, citizens). Don’t forget to include maintenance staff, visitors, parents or perhaps even relatives of employees, depending on the target organisation or area.

2. **Assess The Need:** talk to your key stakeholders and identify (a) knowledge they lack, (b) their motivation behind (undesired) behavioural choices and (c) preferred forms of interaction (workshops, classes, DIY activities, get togethers …)

3. **Develop Educational Materials:** Create lesson plans, experiments, and interactive activities focused on air quality and mobility. When working with schools - but this is also valid for other stakeholders - bear in mind that teachers require ready-to-use materials, they already have a fully packed schedule. A good practice is to test any materials you develop early on in a smaller group to gather feedback and improve.

4. **Engage Experts and Stakeholders:** Involve environmental experts to provide insights and support. Engage with local authorities, environmental organisations, and the community to gather support and input for the campaign.

5. **Planning and Approval:** Cooperate with teachers, principals, local authorities etc. to draft a planning that is complementary to existing educational tracks.

6. **Promotion and Awareness:** Launch the campaign through various communication channels, including social media, workshops, and events.
7. **Conduct Workshops and Sessions:** Organise workshops, lessons, and interactive sessions to educate the target audience.
8. **Feedback and Improvement:** Continuously monitor the campaign's reach and impact, gather feedback from participants and refine the educational materials, activities, the campaign and its reach.

SWOT Analysis:

Table 10 provides an SWOT analysis of the general COMPAIR approach outlined above. One of the primary benefits of these campaigns is the increased awareness and knowledge they provide. By educating the public about the sources and impacts of air pollution, as well as sustainable mobility options, these campaigns can foster a more informed and environmentally conscious community. This heightened awareness can lead to better individual choices and collective efforts to improve air quality and promote sustainable transportation. These changes can multiply an effect already obtained through e.g. policy implementations.

Another significant benefit is the empowerment of participants to take action. When people are equipped with the knowledge and tools to make a difference, they are more likely to engage in behaviours that contribute to positive environmental outcomes. Educational campaigns can inspire individuals to adopt practices such as using public transportation, reducing vehicle emissions, and supporting clean energy initiatives. This sense of empowerment can also extend to advocating for policy changes, as informed citizens are more likely to push for regulations and initiatives that protect the environment.

Moreover, educational and awareness campaigns have the potential to drive community-driven policy changes. When a community is well-informed and engaged, it can collectively influence local government and policymakers to implement measures that address air quality and mobility issues. This grassroots approach can lead to more effective and sustainable policy solutions that reflect the needs and priorities of the community.

However, there are several drawbacks to consider. Educational and awareness campaigns can be resource-intensive, requiring significant time, funding, and effort to develop and implement effectively. This can be a challenge for organisations with limited resources. Additionally, the impact of these campaigns may be difficult to measure immediately. Changes in awareness and behaviour can take time to manifest, and it may be challenging to directly attribute improvements in air quality or mobility to specific campaigns. Despite these challenges, with careful planning and sustained effort, educational and awareness campaigns can play a crucial role in fostering a more informed and proactive society.

COMPAIR provides future projects with a standardised slide deck (D5.1) on air quality and traffic to host workshops, educational tracks and the approaches described in this document to help you alleviate these potential threats and drawbacks.

Table 10: *SWOT analysis of road #3: Educational and Awareness Campaigns*

Strengths	Weaknesses
• High engagement and awareness among participants. • Direct involvement of the community. • Potential for long-term behavioural change. • Can reach a wide audience through various communication channels.	• Requires significant resources, often also involvement of staff at the target organisation, and coordination. • Initial costs for development and promotion. • Impact may be limited to the participants. • Awareness raising is about dialogue and interactivity, do not expect a one off effort to pull this off!
Opportunities	**Threats**
• Potential to scale up and involve more communities. • Can lead to policy changes based on community feedback. • Can be integrated with other environmental, health and/or safety initiatives to reduce the effort required and facilitate planning and approval.	• Resistance from participants or community members. • Dependence on continuous funding and support. • Lack of expertise with any of the participating entities - challenging questions will be raised!

4.2. Travel essentials of COMPAIR's pilots

The previous chapters provided (1) 4 generic pathways to achieve environmental impact using citizen involvement, and (2) a set of general recommendations. In Chapter 4 the first section presented the roads travelled in COMPAIR pilots mapped to the same concepts presented in the generic pathways. This included key activities undertaken in the pilots and a SWOT analysis to inform future projects. In the following sections we provide specific elements from each pilot and use case on policy involvement, environmental impact and limitations experienced in COMPAIR. These are provided in brief bullets as they are intended to inspire, trigger questions or ideas on future projects, rather than provide a full review of the pilots. A complete description of activities undertaken, engagement, results and findings can be found in the Closed, Open and Public Round reports.

4.2.1. Policy involvement in COMPAIR pilots

Overall, policymakers were involved in various capacities, from organising information sessions and implementing circulation plans to participating in environmental council meetings and collaborating on sensor validation projects. Their involvement was crucial in ensuring the success and community acceptance of these initiatives.

4.2.1.1. Athens Pilot

Use Cases 1 and 2: Air Quality Monitoring

Policy makers were involved with:

- Municipality of Athens: The Municipality of Athens was actively involved in identifying areas for sensor deployment and supporting the engagement of citizens, particularly those from low SES groups.
- Workshops and Meetings: Policy makers participated in workshops and meetings to understand the objectives of the pilot and the role of citizens in data collection.
- Data Utilisation: The data collected from the sensors were intended to be used by city authorities to enhance environmental strategies and develop policies on climate mitigation.

Use Case 3: CO_2 Footprint Measurement

Involvement of Policy Makers:

- Municipal Employees: The initial communication for the CO_2 calculator campaign was launched through MailChimp campaigns targeting municipal employees, who were also residents of Athens.
- Policy Formulation: The Scenario Simulation Dashboard facilitated dialogue with the city and opinion mining of citizens regarding city policies. This tool helped map citizens' intentions to adopt initiatives proposed by the municipality, region, or government.

- Policy Recommendations: Citizens provided feedback and recommendations on policies such as creating bicycle lanes, improving public transport, and enhancing energy efficiency, which were communicated to policy makers for consideration.

4.2.1.2. Berlin Pilot

Use Case 1: Mobile Air Quality Measurements

Involvement of Policy Makers:

- Senate Department for Mobility, Transport, Climate Protection and the Environment: A representative from this department participated in the final workshop, providing insights on Berlin's clean air plan and policy.
- Panel Discussion: Policy makers were involved in a panel discussion with citizens and representatives from civil society initiatives, focusing on the role of citizen science data in informing public policy.

Use Case 2: Static Air Quality Measurements

Involvement of Policy Makers:

- Neighbourhood Management: The neighbourhood management offices in Bellermannkiez and Neukölln were involved in coordinating the engagement campaign and supporting the implementation of traffic-calming measures.
- Policy Influence: The data collected from the static measurements were intended to inform policy decisions on traffic management and air quality improvement. The results were discussed with policy makers to evaluate the effectiveness of traffic-calming measures and consider further actions.

4.2.1.3. Flanders pilot

Use case 1: Environmental Council in Hove

Policymaker Involvement:

- Environmental Council Meetings: The project involved members of the environmental council who collected data and discussed the results during council meetings. This indicates direct involvement of local policymakers in understanding and addressing air quality issues related to wood burning.

Use case 2: Circulation Plan in Ghent

Policymaker Involvement:

- Circulation Plan Implementation: The circulation plan was implemented by local authorities to reduce motorised traffic and improve air quality. The document mentions that the plan faced postponements due to protests from local residents and merchants, indicating active engagement and decision-making by policymakers.

Use case 3: Circulation Plan in Sint-Niklaas

Policymaker Involvement:

- Information Sessions: Policymakers organised information sessions about air pollution, traffic sensors, and NO_2 devices. These sessions aimed to educate citizens

and gather feedback, showing active involvement in the implementation and communication of the circulation plan.

Use case 4: Sensor Validation in Ghent

Policymaker Involvement:

- Collaboration with City of Ghent: The validation of Telraam traffic counting devices involved collaboration with the City of Ghent, where manual counts were executed by the police. This indicates that local policymakers were involved in validating and supporting the use of new traffic monitoring technologies.

4.2.1.4. Sofia pilots

Use case 1: School Bus Service

Policymaker Involvement:

- Sofia City Council: Approved the continuation and expansion of the school bus service for the entire school year 2023-2024.
- Transport Department and Urban Mobility Center: Collaborated in planning and releasing the school bus service.
- Workshops and Webinars: Policy makers participated in workshops and an ideathon discussing the impact of transport on air quality and the potential for expanding the school bus service.
- Data Café Workshop: Representatives from the City Council, Transport Division, and Urban Mobility Center attended a workshop to discuss survey data and gather ideas for improving the service.

Use case 2: Kindergarten Air Quality Monitoring

Policymaker Involvement:

- Digitalisation Department of Sofia Municipality: Collaborated in planning the air quality measurements and the installation of window meshes to prevent PM entry.
- Policy Delays: The project faced delays due to mayoral elections and budget constraints, highlighting the need for policy support for such initiatives.

Use case 3: CO_2 Calculator Usage

Policymaker Involvement:

- Workshops: Conducted workshops with policy makers to gather feedback on the CO_2 calculator and its features.
- Integration with Municipal Platforms: Discussions with the Digital Department of Sofia Municipality about integrating the CO_2 calculator with other municipal digital tools like waste.sofia.bg.
- Feedback and Improvements: Policy makers provided feedback on how the tool could be further developed and used to assess policy measures.

Use case 4: Awareness Raising Campaign

Policymaker Involvement:

- The PR team of the Deputy Mayor of Environment and the Urban Mobility Center and other representatives of the Environmental Department: Engaged in planning and approving the campaign messages and visuals.

- Stakeholder Meetings: Conducted meetings with various stakeholders, including policy makers, to align the campaign with municipal plans and policies.
- Coordination with Municipal Plans: Efforts were made to ensure the campaign messages were in sync with other municipal initiatives like the Low Emission Zone (LEZ) and Pay as You Throw programs.

4.2.1.5. Plovdiv Pilots

Use case 1: Traffic and Air Pollution Awareness

Policymaker Involvement:

- Workshops: Policy makers participated in workshops to discuss the impact of traffic on air pollution and the results of the measurements.
- Proposal Submission: Collected citizen proposals for traffic reduction and air quality improvement were presented to the municipality.

Use case 2: Seasonal Variation of PM_{10}

Policymaker Involvement:

- Data Sharing: Shared data on PM_{10} and NO_2 concentrations with policy makers to inform them about seasonal variations and pollution sources.
- Policy Recommendations: Provided recommendations for appropriate year-round landscaping and other measures to reduce pollution.

Use case 3: Mobile Air Quality Laboratory

Policymaker Involvement:

- Workshops: Policy makers attended workshops where the results from the mobile air quality laboratory were presented and discussed.
- Traffic Sensor Deployment: Collaborated with policy makers to deploy traffic sensors and analyse the data collected.

4.2.2. Environmental impact of COMPAIR pilots

4.2.2.1. Athens Pilot

Use Cases 1 and 2: Air Quality Monitoring

- Objective: Evaluate citizens' ability to provide stable air pollution measurements and change environmental behaviour.
  - Activities: Distribution of air pollution sensors (SODAQ and sensor.community) to citizens, especially low SES groups.
  - Quantitative Impact:
    - NO_2 Measurements: Data collected from December 2023 showed lower NO_2 levels in Kipseli compared to Neos Kosmos due to less traffic in Kipseli.
    - $PM_{2.5}$ Measurements: Significant increase in $PM_{2.5}$ levels during metro station excavation in Kipseli, peaking at 27.29 µg/m³.
    - African Dust Event: $PM_{2.5}$ levels spiked to over 16 µg/m³ during the African dust event in May 2024.

- Winter Pollution: Higher PM2.5 levels in Neos Kosmos during winter due to wood burning for heating.

Use Case 3: CO_2 Footprint Measurement

- Objective: Calculate household carbon footprints and provide recommendations for reducing emissions.
- Activities: Use of the CO_2 Calculator and Scenario Simulation Dashboard by Athens residents.
- Quantitative Impact:
  - User Engagement: 281 users visited the CO_2 calculator, 83 created accounts, and 80 provided household footprint data.
  - CO_2 Emissions: Main sources of emissions were buildings, flights, and vehicles. Waste and rail emissions were relatively low.
  - District Analysis: The 2nd district had the highest transportation-related emissions, while the 3rd and 2nd districts had the highest building-related emissions.

4.2.2.2. Berlin Pilot

Use Case 1: Mobile Air Quality Measurements

- Objective: Measure air quality exposure of cyclists on their daily commutes and raise awareness.
- Activities: Distribution of 45 SODAQ AIR devices to cyclists.
- Quantitative Impact:
  - $PM_{2.5}$ Exposure: Average $PM_{2.5}$ levels for participants ranged from 3.66 to 16.43 µg/m³, with higher values during the Sahara dust event.
  - Measurement Frequency: Participants conducted between 22 and 23,859 measurements, with some “power users” contributing significantly to the data pool.

Use Case 2: Static Air Quality Measurements

- Objective: Compare air quality in a traffic-calmed neighbourhood (Bellermannkiez) with non-traffic-calmed neighbourhoods (Donau- and Flughafenkiez).
- Activities: Installation of SODAQ fine dust sensors, bcMeters, and Telraam traffic devices.
- Quantitative Impact:
  - $PM_{2.5}$ Levels: Average $PM_{2.5}$ levels were similar in both neighbourhoods, despite different traffic conditions.
  - Traffic Correlation: Lower traffic volumes in Bellermannkiez did not significantly reduce $PM_{2.5}$ levels compared to Donau- and Flughafenkiez.
  - Black Carbon: Measurements were well below the old German test value of 8 µg/m³, indicating low soot pollution.

4.2.2.3. Flanders pilot

Use case 1: Primary School in Ghent

- Purpose: Raise awareness about air quality among primary school children.
- Activities: 4-week project with lessons, experiments, and feedback sessions.
- Impact: Students observed varying air quality levels during walks, influenced by sources like construction sites and car garages.
- Quantitative Impact: Not explicitly quantified in the document.

Use case 2: Secondary School in Herzele

- Purpose: Raise awareness about air quality among secondary school students.
- Activities: 5-week project with lessons and independent student projects.
- Impact: Students noted dynamic exposure to air quality and the effect of local activities like farming.
- Quantitative Impact:
    - 20% of students indicated they would use cars less.
    - 7% more students would use public transport or carpool.

Use case 3: College of Geel & University of Leuven

- Purpose: Raise awareness about air quality among college students.
- Activities: Students used sensors and apps to measure air quality over several weeks.
- Impact: Feedback led to improvements in the DEVA app and DEV-D dashboard.
- Quantitative Impact: Not explicitly quantified in the document.

Use case 4: Citizens in Herzele

- Purpose: Evaluate the BC sensor and measure the impact of a school street on air quality.
- Activities: Citizens performed measurements with BC sensors.
- Impact: Issues with sensor connectivity and data availability were identified.
- Quantitative Impact: Only 29.8% of possible measurements were successfully recorded.

Use case 5: Environmental Council in Hove

- Purpose: Raise awareness about wood burning and air quality.
- Activities: Members collected $PM_{2.5}$ data while walking, cycling, or running.
- Impact: Identified hotspots for wood smoke and other local pollution sources.
- Quantitative Impact:
    - 95% of local peaks in $PM_{2.5}$ were attributed to wood smoke.
    - Over 9000 measurement blocks were collected.

Use case 6: Circulation Plan in Ghent

- Purpose: Assess the impact of a circulation plan on traffic and air quality.
- Activities: NO_2 sensors measured air quality before and after the plan's implementation.
- Impact: Preliminary data suggested a reduction in NO_2 concentrations at certain times of the day.
- Quantitative Impact:

- Mean NO_2 concentrations before the plan: 11.265 µg/m³ (Paul de Ryckstraat), 5.938 µg/m³ (Wolterslaan).
- Mean NO_2 concentrations after the plan: 10.704 µg/m³ (Paul de Ryckstraat), 8.004 µg/m³ (Wolterslaan).

Use case 7: Circulation Plan in Sint-Niklaas

- Purpose: Assess the impact of a circulation plan on traffic and air quality.
- Activities: NO_2 sensors measured air quality before the plan's implementation.
- Impact: Initial data showed varying NO_2 concentrations across different locations.
- Quantitative Impact:
  - Mean NO_2 concentrations: 24.581 µg/m³ (NS-2), 22.457 µg/m³ (NS-1).

Use case 8: Sensor Validation in Ghent

- Purpose: Validate the accuracy of Telraam traffic counting devices.
- Activities: Comparison with manual counts and pneumatic tubes.
- Impact: Demonstrated strong agreement between Telraam and traditional methods.
- Quantitative Impact:
  - Accuracy for car counts: 90-95%.
  - Accuracy for bike counts: 80-85%.

These use cases collectively contributed to a better understanding of air quality and traffic patterns, with some showing significant quantitative impacts on behaviour and air quality measurements.

4.2.2.4. Sofia Use Cases

Use case 1: School Bus Service

- Objective: Reduce car traffic around schools by providing a school bus service.
- Impact:
  - Reduction of car traffic by at least 50 vehicles during morning peak hours.
  - Positive feedback from parents, with 382 survey responses indicating satisfaction and support for the service.
  - Seasonal air quality measurements showed higher pollution in winter months, but the school bus service contributed to reducing traffic-related pollution around schools.

Use case 2: Kindergarten Air Quality Monitoring

- Objective: Measure indoor air quality and raise awareness among preschoolers and their parents.
- Impact:
  - Seasonal trends in indoor air pollution were observed, with higher levels in winter.
  - Awareness raised about the importance of ventilation and reducing indoor pollutants.

Use case 3: CO_2 Calculator Usage

- Objective: Engage citizens in calculating their carbon footprint and promote sustainable behaviours.

- Impact:
    - Increased awareness and engagement, with more than 470 visits to the CO_2 calculator.
    - Feedback indicated the tool was useful for understanding individual carbon footprints and promoting behaviour change.

Use case 4: Awareness Raising Campaign

- Objective: Promote sustainable living habits and raise awareness about air quality.
- Impact:
    - Campaign planning involved multiple stakeholders and was launched on 1 st August 2024.
    - The campaign was spread outdoors in 40 locations in total - 20 locations in the metro stations, 10 locations of city lights around the city and 10 billboards, and also online using social media posts.
    - Positive feedback on campaign messages and visuals, promoted and increased the recognition of the COMPAIR-developed CO_2 Calculator and also programs, projects and incentives Sofia Municipality is providing to improve air quality and sustainable living, sustainable daily commuting, etc., and expected to increase public engagement in sustainable practices.

4.2.2.5. Plovdiv Use Cases

Use case 1: Traffic and Air Pollution Awareness

- Objective: Raise awareness about the impact of traffic on air pollution around schools.
- Impact:
    - Seasonal variation in PM_{10} and NO_2 concentrations observed, with higher levels during the heating season.
    - Correlation between traffic intensity and NO_2 concentrations established.

Use case 2: Seasonal Variation of PM_{10}

- Objective: Measure and analyse seasonal variation of PM_{10} around schools.
- Impact:
    - Higher PM_{10} concentrations during the heating season.
    - Data used to inform local policies and raise awareness among students and parents.

Use case 3: Mobile Air Quality Laboratory

- Objective: Measure air quality around schools using a mobile laboratory.
- Impact:
    - Data collected showed peak NO_2 concentrations coinciding with school activity hours.
    - Seasonal variations in PM_{10} levels, with higher concentrations in winter.
- Quantitative Impacts
    - CO_2 Calculator: Over 103 visits, indicating engagement and awareness.
    - Plovdiv Air Quality Measurements: Higher PM_{10} and NO_2 concentrations during the heating season, with specific peaks during school hours.

4.2.3. Limitations of the COMPAIR pilot approaches

These areas of further research and scientific clarification are essential to enhance the understanding and effectiveness of the pilot projects, leading to more informed policy decisions and improved environmental outcomes.

4.2.3.1. Athens use cases

Use Cases 1 and 2: Air Quality Monitoring

Further research needed:

- Behavioural Change: More research is needed to understand the long-term impact of increased awareness on citizens' environmental behaviour.
- Data Correlation: Further analysis is required to correlate air quality data with specific environmental conditions and activities, such as traffic patterns and weather extremes.
- Sensor Accuracy: Continued evaluation of the accuracy and reliability of low-cost air pollution sensors used by citizens.

Use Case 2: CO_2 Footprint Measurement

Further research needed:

- Policy Impact: More research is needed to assess the effectiveness of policy recommendations provided by the Scenario Simulation Dashboard.
- User Engagement: Further studies are required to understand the factors influencing user engagement with the CO_2 calculator and the impact of personalised recommendations on reducing carbon footprints.
- Data Analysis: Continued analysis of the collected data to identify trends and patterns in household emissions across different districts.

4.2.3.2. Berlin use cases

Use Case 1: Mobile Air Quality Measurements

Further research needed:

- Exposure Patterns: More detailed analysis of individual exposure patterns to identify specific hotspots and times of high pollution exposure.
- Health Impact: Research to understand the health impacts of long-term exposure to varying levels of particulate matter ($PM_{2.5}$) among cyclists.
- Sensor Calibration: Ongoing calibration and validation of mobile air quality sensors to ensure data accuracy. Specifically calibration strategies that can be applied by citizens themselves.

Use Case 2: Static Air Quality Measurements

Further research needed:

- Traffic Calming Impact: More comprehensive studies to evaluate the long-term impact of traffic calming measures on air quality and traffic flow.
- Pollutant Correlation: Further research to correlate traffic data with different types of pollutants, such as nitrogen dioxide (NO_2), which may be more indicative of traffic-related pollution.

- Community Engagement: Continued efforts to engage more residents in citizen science projects to enhance data collection and community involvement.

4.2.3.3. Flanders use cases

Use case 1: Citizens in Herzele

Further research needed:

- BC Sensor Issues: The trials highlighted issues with the BC sensor, including connectivity problems and negative concentration measurements. Further investigation is needed to address these issues, such as internal heating or light leaks affecting the sensor.

Use case 2: Circulation Plan in Ghent

Further research needed:

- NO_2 Sensor Calibration: The calibration of the NitroSense devices needs extensive testing to account for sensor bias and drift. A co-location trial after the experiment is suggested to ensure accurate measurements.

Use case 3: Circulation Plan in Sint-Niklaas

Further research needed:

- Initial Data Analysis: Since the circulation plan has just taken effect, more data is needed to make definitive statements about its impact on air quality and traffic patterns.

4.2.3.4. Sofia Use Cases

Use case 1: School Bus Service

Further research needed:

- Long-term Impact: Further research is needed to assess the long-term impact of the school bus service on traffic reduction and air quality.
- Extended Service: Investigate the potential for extending the service to other schools in Sofia and the impact on broader traffic patterns and air quality.

Use case 2: Kindergarten Air Quality Monitoring

Further research needed:

- Comparative Analysis: Due to technical issues with the Canary system, comparative analysis between indoor and outdoor air quality measurements was not possible. Further research is needed to obtain and compare this data.
- Ventilation Impact: More detailed studies on the impact of ventilation practices on indoor air quality in kindergartens.

Use case 3: CO_2 Calculator Usage

Further research needed:

- User Engagement: Further research to understand the factors that influence citizens' willingness to use the CO_2 calculator and how to increase engagement.
- Policy Impact: Investigate how policy makers can effectively use the data from the CO_2 calculator to assess and implement environmental policies.

Use case 4: Awareness Raising Campaign

Further research needed:

- Message Effectiveness: Research on the effectiveness of different messaging strategies (positive vs. negative) in changing public behaviour towards more sustainable practices.
- Behavioural Change: Studies to measure the actual behavioural changes resulting from the awareness campaign.

4.2.3.5. Plovdiv Use Cases

Use case 1: Traffic and Air Pollution Awareness

Further research needed:

- Traffic-Pollution Correlation: More detailed studies to establish a stronger correlation between traffic intensity and PM/NO_2 concentrations.
- Seasonal Variations: Further research on the seasonal variations of air pollutants and their sources.

Use case 2: Seasonal Variation of PM_{10}

Further research needed:

- Pollution Sources: Detailed analysis of the sources of PM_{10} during different seasons and their impact on air quality.
- Mitigation Strategies: Research on effective strategies to mitigate PM10 pollution, especially during the heating season.

Use case 3: Mobile Air Quality Laboratory

Further research needed:

- Extended Monitoring: Longer-term monitoring to gather more comprehensive data on air quality around schools and the impact of traffic.
- Traffic Management: Studies on the effectiveness of different traffic management strategies to reduce pollution around schools.

5. Conclusion

This report identifies four key pathways to achieve environmental change in citizen science or participative projects: implementation of specific policies, citizen science experimentation, online tools, and awareness-raising campaigns. Each pathway is detailed with implementation steps, critical success factors, and stakeholder involvement.

1. **Participative implementation of policy**: Involves traffic-calming measures to reduce emissions and improve air quality.
2. **Citizen science experimentation**: Engages citizens in monitoring activities to identify local environmental issues and drive policy actions.
3. **Online tools**: Utilises tools like CO_2 calculators to provide insights into individual environmental impacts and promote sustainable behaviours.
4. **Awareness raising campaigns**: Educates the public on the benefits of sustainable practices and encourages behavioural change.

The COMPAIR pilots demonstrated significant environmental impacts across various cities, some examples are:

- **Participative policy implementation**: Traffic-calming measures in Berlin and Flanders effectively reduced traffic volumes and improved air quality.
- **Citizen science experimentation**: Projects in Athens and Sofia provided valuable air quality data, leading to increased public awareness and policy recommendations. Citizen scientists in Flanders co-developed the bcMeter device.
- **Online tools**: The CO_2 calculator in Athens engaged citizens in understanding and reducing their carbon footprints.
- **Awareness raising campaigns**: Campaigns in Sofia and Plovdiv successfully raised awareness about air quality and promoted sustainable transportation methods. Educational tracks in Flanders yielded clear behavioural change.

Key considerations that future projects should take into account are:

1. **Community involvement**: Active participation from residents and stakeholders is crucial for the success of environmental initiatives. Engaging the community ensures that projects are tailored to local needs and gain broader support.
2. **Technology integration**: Utilising online tools and citizen science methodologies enhances data collection and analysis, providing actionable insights for policy development and individual behaviour change.
3. **Education and awareness**: Raising awareness through educational campaigns and workshops fosters a culture of environmental responsibility and encourages sustainable practices.
4. **Policy support**: Strong backing from local authorities and policymakers is essential for implementing and sustaining environmental measures. Policy integration ensures long-term success and scalability of initiatives.

By following these pathways and recommendations, future projects can effectively address environmental challenges and promote sustainable practices through citizen science and community engagement. The COMPAIR project serves as a model for leveraging community involvement and technology to achieve significant environmental impact.