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## **Transformative effectiveness of citizen science: "Participate, co-research, put into practice?"**

Results from the *EfficientCitizens* and *COMPAIR* projects

### **Summary**

Citizen science has proven to be an effective tool for tackling environmental and social challenges. The two citizen science projects *EfficientCitizens* and *COMPAIR* will be used to highlight the special features of the citizen science approach from the perspective of energy-efficient building refurbishment, air pollution control and mobility along with the research design, methodology and project results.

The *EfficientCitizens* project investigated how a peer-to-peer exchange of experience can support energy-efficient building renovations in single-family homes. The aim of the study was to find out whether and under what conditions these exchange formats can reduce uncertainty regarding possible refurbishment measures and facilitate preparation for refurbishment steps. By involving citizens who had already gained renovation experience, a transformative learning process was created, the effects of which on the motivation and decision-making of the participants were analysed.

The *COMPAIR* project investigated how citizen science can contribute to providing reliable and valid data, raising awareness and changing personal environmental behaviour and supporting policy action against air pollution in cities. The aim of *COMPAIR* was to develop concrete personal and political recommendations for action by fostering close collaboration between citizens, researchers, policy makers and other stakeholders. With easy-to-use stationary or mobile sensors, citizens encountered air and traffic measurements within Berlin.

### **Introduction**

Citizen science has established itself as an effective method for tackling environmental and social challenges. Using the *EfficientCitizens* and *COMPAIR* projects as examples, the paper illustrates how this approach is used in the areas of energy-efficient building refurbishment and air pollution control and mobility. The focus is on the specific aspects of the research structure, the methods used and the results achieved and discusses the connectivity of citizen science research. The two projects are presented one after the other in the individual chapters.

Citizen science is a participatory research approach in which people actively take part in scientific projects without being active in the scientific community themselves. The type of participation varies from data collection tasks to co-designing the research design. There are no entry requirements for participation. The only decisive factors are that scientific standards are adhered to, that there is methodological transparency and that the results are publicly accessible. The participatory research approach is becoming increasingly important in research practice.

In view of rising energy costs and climate change, the focus is increasingly shifting to energy-efficient building renovations. Despite numerous technical solutions, many homeowners are unsure which refurbishment measures are suitable for them. The *EfficientCitizens* project, funded by the Federal Ministry for Economic Affairs and Climate Protection (BMWK) and implemented by inter 3 GmbH and co2online, aimed to facilitate access to tried-and-tested solutions for those interested in refurbishment and reduce inhibitions through a peer-to-peer exchange of experiences.

The EU Horizon 2020-funded *COMPAIR* project (2021 - 2024), on the other hand, aimed to make the results of citizen science air and traffic measurements available to citizens and raise their awareness, as well as to use the data obtained for environmental policy decisions to develop more effective measures to combat air pollution and improve the quality of life in cities. Although the number of deaths caused by particulate matter in the European Union (EU) fell by 41% between 2005 and 2011, air pollution remains the biggest environmental health risk to the European population. For the most part, air pollution in the EU is above the guideline values recommended by the World Health Organisation (WHO). Urban areas are particularly affected (see European Environment Agency<sup>1</sup>). The project developed innovative technical tools, such as sensors and virtual reality apps, to improve the quality of citizen science results and promote their use in urban decision-making processes. At the same time, it investigated how collaboration between citizen scientists, scientists, policy makers and other stakeholders and local initiatives can be strengthened to develop actionable recommendations for better urban air quality.

## Research design and methodology

The *EfficientCitizens* project broke new methodological ground by involving citizen scientists in energy renovation research. While participatory energy research projects had existed before, collaborative approaches were rare. A meta-analysis from 2020 showed that no citizen science project had previously been assigned to the global sustainability goal "Affordable and clean energy" (SDG 7). Current platforms such as

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<sup>1</sup>[www.eea.europa.eu/en/topics/in-depth/pollution](http://www.eea.europa.eu/en/topics/in-depth/pollution)

"mit:forschen"<sup>2</sup> also recorded only a few energy-related projects by 2024. In contrast to projects that mainly use citizens as data providers, *EfficientCitizens* was based on the principles of good citizen science.<sup>3</sup> This included educational and training activities as well as intensive communication and collaboration.

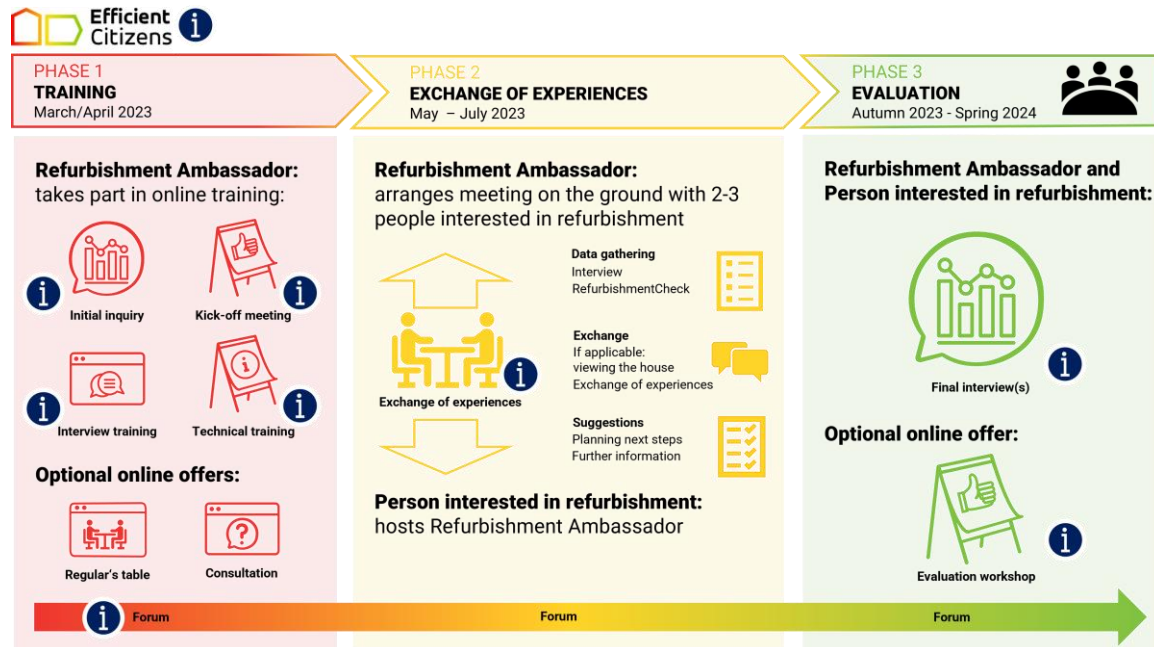


Figure 1: *EfficientCitizens* project process © inter 3 GmbH

The project followed the recommendations on environmental education and fulfilled key roles of citizen science in sustainability research, such as setting agendas, mobilising resources and promoting innovation. The open-source platform Moodle, which is already successfully used in educational institutions worldwide, was used to support the processes. inter 3 customised the platform with additional modules for collaboration, video conferencing and surveys to optimally support the citizen science project. The concept included training, interactive formats and the process of exchanging experiences.

The 'refurbishment ambassadors' played a central role in the citizen science project. These specially trained individuals served as a link between the homeowners and the project team. They took on two key roles:

- As citizen researchers: They worked on collecting and analysing data on the knowledge and concerns of those interested in redevelopment as well as on the detailed design and further development of the exchange of experiences.

<sup>2</sup> [www.mitforschen.org](http://www.mitforschen.org)

<sup>3</sup> [ECSA - Ten principles of Citizen Science](#) (PDF)

- As refurbishment ambassadors: They shared their own renovation experiences and did educational work.



Figure 2: Energy consultation © co2online

In both roles, they not only supported the project team in imparting knowledge, but also motivated others to become active themselves. Refurbishment ambassadors carried out training sessions, accompanied the collection of data on site and were available as contact persons for queries. To optimally support the refurbishment ambassadors, the online seminars for the technical training were divided into six topic-specific, shorter modules and made available together with the presentations in the Digital LERNHAUS. Background information was collected and continuously added to in the form of links and PDFs. In addition, the recordings, handouts and presentations from the kick-off conference and digital roundtables were prepared and made available to the refurbishment ambassadors in the respective courses. This strengthened their ability to provide in-depth information on refurbishment and energy efficiency and to inspire other homeowners to take action. The technical preparation included two online seminars and a citizen science training course for refurbishment ambassadors, which was supplemented by mock interviews and tutorials.

COMPAIR also followed a three-stage project structure. In the internal round (June - September 2022), the scientific partners of the Berlin consortium tested the technical



devices - sensors and visualisation platforms and apps - themselves and gathered feedback on user-friendliness and handling in two workshops with interested parties to optimise the technical tools before the citizen science participation phase. A small number of citizens took part in the open round (June - October 2023). In two groups, the participants analysed the air quality in Berlin and the inner-city traffic flow - either from home (static sensors, fixed in place) or on a bicycle (mobile sensors, in motion). The static group recorded particulate matter, soot and traffic flow from the comfort of their own homes by installing sensors on their windows or balconies in the Graefe neighbourhood in Berlin-Kreuzberg.

As a traffic policy experiment (Graefekiez project<sup>4</sup>) was taking place there at the time anyway, this area was ideal for testing whether greening and traffic calming measures have an impact on air quality and traffic flow. The mobile group measured the air quality with small particulate matter sensors on the bicycle handlebars during their daily commute. Using the sensor light and an online platform, they received information on where it was worth taking an alternative route due to better air quality and were thus able to find out how polluted the air was at junctions, main roads or on hot days. In the public round (February - May 2024), a significantly larger cohort of citizen scientists took part. The division into a static and mobile measurement campaign was retained. This time, the static campaign was carried out a) in the Bellermannkiez neighbourhood in the Berlin district of Wedding and b) in the Donau- und Flughafenkiez neighbourhood in the Berlin district of Neukölln. The Bellermannkiez is a neighbourhood block, i.e. a residential area in which traffic calming measures are intended to reduce through traffic. In contrast, the Donaukiez and Flughafenkiez neighbourhoods are not neighbourhood blocks and are affected by heavy through traffic. The aim was not to compare the measured values of the different neighbourhoods with each other, as this was not possible in the short time available and due to the structure of the research design, but to collect neighbourhood-specific measured values on particulate matter, soot and traffic flow. In the mobile measurement campaign of the public round, cyclists again measured their air pollution levels of particulate matter on their commutes. This time, the focus was even more on commuting routes from the outer to the inner districts to record areas where there are no official measuring stations and to collect small-scale data.

In the open and public round, introductory, intermediate and final workshops were held with the citizen scientists, in which they received an intensive introduction to the handling of the technical devices and subsequently exchanged views on the measured values collected and interpreted them together. In addition, suggestions for improvements to the technical tools were implemented directly wherever possible to directly improve the participants' research experience. The open round also included a survey on changes in environmental behaviour. Here it was investigated whether

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<sup>4</sup> District of Friedrichshain-Kreuzberg: [Graefekiez project \(in German\)](#)

and to what extent the environmental behaviour of the participants - changed mobility and everyday behaviour - changed after the targeted information campaign and the evaluation and interpretation of the collected data. *COMPAIR* also followed and reflected on the citizen participation process using the ten principles of citizen science (see above) and the four fair data principles<sup>5</sup> to ensure good citizen science practice. Examples of the ten principles are participation, democratic co-determination and feedback loops.

## Results and lessons learnt

The peer-to-peer exchange of experiences as part of the *EfficientCitizens project* was based on a relationship of trust between the refurbishment ambassadors and those interested in refurbishment. This trust was successfully established in almost all cases, supported by the clearly defined process and the professional and structural framework. The fact that the refurbishment ambassadors are homeowners themselves and have already had their own refurbishment experience was particularly helpful for the quality of the exchange. This was perceived as very valuable by almost all those interested in refurbishment.

The descriptive results of the assessment of the exchange of experiences show that almost all the participating refurbishment ambassadors and those interested in refurbishment had very positive experiences. The main reasons for this are the friendliness and mutual sympathy, the appreciative exchange at eye level and the shared professional expertise and interests of both groups. These factors contributed significantly to the satisfaction and quality of the exchange.

Another important effect of the positive evaluation of the exchange of experience is the continued commitment of many refurbishment ambassadors. Many of them want to continue their involvement, be it through further training as energy efficiency advisors, continuing to support those interested in renovating in the implementation of measures, exchanging ideas with other interested parties outside the project or participating in civil society initiatives such as the *Aktionskreis Energie* or *BürgerSolarBeratung*. Some people interested in refurbishment can also imagine sharing their own refurbishment experiences with other homeowners, as they have seen how much fun the exchange is and how it can contribute to the energy transition.

The very positive experience meant that almost all those interested in refurbishment would recommend the exchange of experience to others. The individual aspects of the content, such as the answers to technical questions or information on energy advice, were also rated as very good or good by most participants. Particularly high approval

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<sup>5</sup> [The FAIR Guiding Principles for scientific data management and stewardship](#)

ratings, almost 100 per cent, were given to the statement that the refurbishment ambassadors were able to respond very well to questions and interests and empathise with the situation of those interested in refurbishment. The usefulness of the practical experience and the provision of new information by the reorganisation ambassadors were also rated extremely positively.

Interestingly, the refurbishment ambassadors themselves were more critical of their mediation skills than those interested in refurbishment. Nevertheless, almost three quarters of those interested in refurbishment and around 70 per cent of the refurbishment ambassadors found that the exchange of experiences had increased their motivation to implement refurbishment measures promptly.

In the *COMPAIR project*, the measurement results were certainly of interest but were not the focus of the project and the evaluation. The focus was on the citizen science approach and how citizens manage to use DIY measuring devices and innovative visualisation platforms and apps and what awareness-raising and empowerment effects result from a citizen science project.

In the open round, eleven citizens took part in the static and 32 in the mobile measurement campaign. The particulate matter, soot and traffic values collected during the static measurement campaign in the Graefe neighbourhood did not allow any conclusions to be drawn about effects due to the delayed unsealing and therefore too short measurement duration. Overall, the particulate matter values were on average below the applicable EU annual average limit value for PM 2.5 of 25 µg/m<sup>3</sup>, but above the annual average value for PM 2.5 of 5 µg/m<sup>3</sup> recommended by the WHO. This picture also continued in the static campaign of the public round (32 people static, 56 mobile) and the mobile measurement campaigns of both rounds. The measured particulate matter concentrations of the cyclists emphasised that the air pollution was particularly high during rush hour as well as in intersections and on busy roads. Avoiding quiet side streets and green parks proved to be sensible. Overall, the measured values collected in the *COMPAIR project* were well in line with those of the official measuring stations of the Berlin air quality monitoring network (BLUME<sup>6</sup>). This indicates that the data produced by these low-cost DIY measuring devices is highly valid. In the introductory, intermediate and final workshops, the participants received the necessary knowledge and tools to record and interpret air quality and traffic flow through practical training. The result was a group of informed, sensitised and empowered citizen scientists who conducted their own research and became more aware of their environmental choices.

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<sup>6</sup> <https://luftdaten.berlin.de/lqi>

The results of the *COMPAIR project* also include key learning experiences:

*Recruitment:*

The recruitment of participants, especially in the static measurement campaign, requires sufficient time and personnel to be present in the neighbourhood, to talk to citizens, to distribute information and answer questions and to build trust with citizens and local initiatives as multipliers.

*Transparent communication:*

The registration process for participation in the project should be detailed and transparent, showing citizens the exact amount of work required for the various tasks to the minute and hour (e.g. changing the sensor filter). This reduces drop-outs during the measurement campaign (participants who stop).

*Accessibility:*

In addition to transparent communication, it is also important that citizens can easily reach the project team for questions and dialogue beyond the workshops offered. This corresponds, for example, to the principles of involvement and participation of the ten principles of good citizen science practice.

*Flawless technical tools:*

It is essential that the technical equipment used in the project works perfectly, is easy to use and that technical support is guaranteed at all times. This minimises potential frustration and drop-outs.

*Co-operation with the administrative level:*

It is advantageous to seek cooperation with political decision-makers and the administration right from the start of the project. This is the best way to utilise and exploit the project results at the end.

## **Discussion**

The *EfficientCitizens* project has shown that the citizen science approach can make a valuable contribution to energy-efficient building renovations by promoting dialogue between homeowners with renovation experience and those interested in renovations. The intensive support of the refurbishment ambassadors and the close cooperation with the participants made it possible to gain practical insights and reduce uncertainties.

The challenge was to recruit a sufficiently large number of participants to obtain statistically relevant results. In addition, the supervision of the citizen science approach was very intensive and required many different formats in which the participants had to be accompanied and supported. The project offered a variety of support formats, including instructional videos, regular meetings and telephone



counselling. Despite these challenges, the project was able to provide valuable insights into the transformative effect of peer-to-peer experience sharing in the course of the heat transition.

The *COMPAIR project* has shown how effective citizen science can be in air pollution control and mobility and in supporting policy changes in this field. By using mobile and static measurements, the participants were not only able to record particulate matter pollution during commuting, but also to understand any effects of traffic calming measures in various Berlin neighbourhoods. This approach raised awareness and empowered citizens with regard to air pollution and mobility and encouraged them to change their environmental behaviour.

Although the measurement results from *COMPAIR* do not meet the standards of the official Berlin measuring stations and therefore have no direct political applicability, the values collected fit in well with the official ones and illustrate the potential of citizen science measurements and DIY measuring devices. In order to increase the validity of the data, cooperation with the administrative level would be required from the start of the project in order to agree on the research design in line with political standards. It would also need to be ensured that the measurement periods are designed to be long enough and that citizens are a reliable source of measurement. However, what the *COMPAIR project* was certainly able to achieve with its measurement data is that the measurement results have stimulated discussions with political decision-makers, highlighted research needs and helped the topic of air pollution control and sustainable mobility to gain more socio-political visibility.

However, the success of *COMPAIR* did not depend largely on the data collected, but above all on the quality of the cooperation between the participants and the scientists. Continuous support and transparent communication with the citizen scientists as well as comprehensive technical support were particularly important in order to strengthen the citizens' experience of their own research.

Nevertheless, citizen science projects in general, including *COMPAIR*, cannot be realised without considerable human and time resources. They require careful planning and continuous maintenance of the relationships between the participants. A successful project not only strengthens the knowledge and research experience of the participants but also promotes positive and sustainable cooperation that benefits both the individual citizens and society.

## **Conclusion**

The *EfficientCitizens project* has successfully demonstrated that citizen science can play an important role in promoting energy renovation measures. The exchange of experiences between citizens is an effective means of disseminating knowledge, increasing motivation and driving the implementation of measures. This model could also be used in other areas of sustainability research in the future.

The *COMPAIR project* has impressively demonstrated how the citizen science approach can contribute to raising awareness of air pollution and sustainable mobility in cities. In *COMPAIR*, citizen science proved to be an effective approach to empower citizens, encourage them to make new environmental decisions and strengthen them as multipliers in the field of air pollution control. Furthermore, citizen science measurements on air quality and traffic flow have the potential to be converted into usable and valid data sets for policymakers if the scientific and political framework conditions are created. With its project, *COMPAIR* was able to contribute to putting the issue of air pollution control higher on the socio-political agenda.

The *EfficientCitizens* and *COMPAIR* projects illustrate the transformative potential of citizen science in tackling social challenges. *EfficientCitizens* showed how peer-to-peer exchange can promote trust and motivation in energy-efficient building refurbishment. *COMPAIR* demonstrated how citizen science participation contributes to raising awareness and changing environmental behaviour in relation to air quality and mobility. Both projects emphasise the importance of active citizen participation, both for the generation of knowledge and for political influence. Their results show that citizen science can be a valuable tool for promoting sustainable change in society.

*More information on the projects:*

[www.efficient-citizens.de](http://www.efficient-citizens.de)

[www.wecompair.eu/berlin](http://www.wecompair.eu/berlin)

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