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SOCIO-BEE

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Wearables and droneS fOr CIty Socio-Environmental Observations and Behavioral ChangE

Deliverable

D2.4 - Target user behaviours & determinants for Citizen Science driven green behaviour.R2

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Authors List

Leading Author (Editor)			
Surname	*Initials*	*Beneficiary Name*	*Contact email*
Varga	*DV*	*VUB*	*dorottya.varga@vub.be*
Co-authors (in alphabetic order)			
#	*Surname*	*Initials*	*Beneficiary Name*	*Contact email*
1	*Casado-Mansilla*	*DCM*	*DEUSTO*	*dcasado@deusto.es*

Contributors (in alphabetic order)				
#	*Surname*	*Initials*	*Beneficiary Name*	*Contact email*
1	*Hoogendoorn*	*EH*	*HKU*	*evert.hoogendoorn@hku.nl*
2	*Jimenez*	*AJ*	*ZGZ*	*ajimenez@zaragoza.es*
3	*Kotzagianni*	*MK*	*MRSI*	*mkotzagianni@maroussi.gr*
4	*Lopez Gomollon*	*CLG*	*ZGZ*	*clopezg@zaragoza.es*
5	*Morresi*	*NC*	*UNIVPM*	*n.morresi@pm.univpm.it*
6	*Recanatini*	*PR*	*ANCONA*	*paolo.recanatini@comune.ancona.it*
7	*Renger*	*WJR*	*HKU*	*willem-jan.renger@hku.nl*

Reviewers List

List of Reviewers (in alphabetic order)				
#	*Surname*	*Initials*	*Beneficiary Name*	*Contact email*
1	*Hernandez Jayo*	*UHJ*	*DEUSTO*	*unai.hernandez@deusto.es*
2	*Udina*	*SU*	*BETTAIR*	*sudina@bettaircities.com*

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List of definitions & abbreviations

Abbreviation	Description
AQ	Air Quality
BC	Behavioural Change
CS	Citizen Science
D	Deliverable
DB	Drone Bee
DEUSTO	University of Deusto
FAQ	Frequently Asked Questions
IBER	Ibercivis Foundation
KPI	Key Performance Indicator
M	Mean
M	Month
MBAA	Modular Behavioural Analysis Approach
MOOC	Massive Open Online Course
MVE	Micro-volunteering engine
QB	Queen Bee
SDT	Self Determination Theory
SD	Standard Deviation
VUB	Vrije Universiteit Brussel
WB	Worker Bee
WP	Work Package
WSN	Wearable Sensor Node
ZKF	Zaragoza City of Knowledge Foundation
ZGZ	Ayuntamiento de Zaragoza

Executive Summary

The deliverable belongs to Task 2.2 (Understanding CS Hives – Supporting strategies for Queen Bees. It provides an overview of engagement in Citizen Science (CS) (i.e., recruitment, support, communication, evaluation, project organization, behavioural change) as well as on the adaptability of the different elements to SOCIO-BEE. This deliverable contributes to establishing the basic building blocks of the SOCIO-BEE engagement methodology and toolkit and offers recommendations on how these different building blocks could be customized to the use cases in the project. The first iteration of this deliverable (D2.3), was due in month eight (M8) after the start of the project. It provided a strong conceptual background in various topics related to CS engagement identifying interdependencies between engagement strategies, technology, and pilot testing as well as opportunities to further explore in the project. The second iteration of this deliverable (D2.4, M22) revisits and refines the identified strategies, and offers more targeted recommendations based on the current status of technology development and pilot testing in SOCIO-BEE. In this deliverable, there is a strong focus on both the role of Beekeepers, who are key players in initiating the first artificial hives (i.e., first small-scale campaigns initiated and led by municipalities of pilot cities), and that of Queen Bees (QB), who are leaders of the artificial or organic hives (i.e., large-scale campaign spontaneously initiated and led by organisations / individuals outside of the pilot municipalities' scope)[1]. For a comprehensive overview, the document builds on both secondary (e.g., scientific literature, industry reports, MOOCs) and primary (e.g., interviews, workshops, survey) data sources.

[1] SOCIO-BEE builds on the metaphor of bees and how they work together to create and sustain a community (i.e., hive). The metaphor was initially proposed in the Grant Agreement and it is updated on an ongoing basis as the project evolves. In SOCIO-BEE, hives refer to the different groups of stakeholders (i.e., bees) involved in the air quality data-collection campaigns. In general, two types of hives are distinguished according to the pilot testing phase: 1) artificial hive: the first, small-scale campaigns initiated and led by pilot partners, 2) organic hive: spontaneously initiated and led by organisations / individuals outside of the pilot municipalities' scope. To date, the following Bee profiles have been identified and defined in hives: Beekeepers (i.e., initiators of hives bringing together other bees and overseeing activities), Queen Bees (i.e., leaders of data-collection campaigns), Worker Bees (i.e., data collectors), Drone Bees (i.e., spreading word-of-mouth), Larvae (i.e., individuals who are unaware of air pollution or citizen science but can be persuaded to become a Bee if they receive the right information), Bears (i.e., organizations or individuals benefitting from the gathered data). See Table 4 for more detailed profile descriptions.

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1 Introduction

1.1 Purpose of the document

The goal of this deliverable is to serve as a **guide on how to successfully design physical and digital engagement strategies** to recruit and support potential citizen scientists in the SOCIO-BEE project, particularly **Beekeepers** (i.e., people with key organizational responsibilities in the pilot cities) and **Queen Bees** (i.e., leaders of data-collection campaigns). Both Beekeepers and Queen Bees have a central role in the artificial (i.e., initial piloting) and organic (i.e., large-scale piloting) hive creations on how to engage potential Bees (i.e., participants) to varying degrees. The deliverable has a strong contribution to the SOCIO-BEE engagement methodology and toolkit developed in Work Package (WP) 2. In the second iteration of this deliverable, the document revisits a variety of recruitment, supporting and evaluating strategies that have been **(1)** investigated and applied in prior citizen science projects or **(2)** identified through qualitative and quantitative data-collection methods building up towards targeted engagement and communication strategies to be implemented. In addition, **(3)** the deliverable puts a strong focus on behavioural change putting forward a set of recommendations on how to conceptualize, measure and communicate behavioural change in SOCIO-BEE.

1.2 Relationship with other deliverables

This deliverable is an updated version of **D2.3** (Target user behaviours and determinants for Citizen Science driven green behaviour 1st release) revisiting and refining the opportunities for engagement and behavioural change in the project. The deliverable is strongly connected to **all other deliverables in WP 2**. First, it builds on the findings of **D2.1** (Profiling and instruments for CS Bees and Bears identification 1st release) and contributes to **D2.2** (Profiling and instruments for CS Bees and Bears identification 2nd release) on the different motivations, values, goals, and profiles of potential participants in citizen science, and particularly in SOCIO-BEE. Second, this deliverable lays the groundwork for the overall methodological design of the hives developed in **D2.5** and **D2.6** (SOCIO-BEE methodology for ecosystem and hive creation 1st and 2nd release). Third, following the first release of this deliverable (D2.3), an evaluation questionnaire was prepared by VUB and DEUSTO for a group of CS experts, who evaluated the initial version of the SOCIO-BEE engagement methodology in **D2.7**. Finally, this deliverable identifies the building blocks of the SOCIO-BEE engagement toolkit, further developed in **D2.8** and **D2.9** (SOCIO-BEE Toolkit 1st and 2nd release).

1.3 Structure of the document

The document builds up as follows: in the **first section**, the different types of CS projects are described. In the **second section**, an in-depth analysis is provided on CS and engagement including engagement metrics, profiles and strategies that can be used in different stages of a project. Finally, the **third section** explores behavioural change in relation to air quality and CS from both a conceptual and methodological perspective. Each section provides an overview of prior literature, the SOCIO-BEE approach, the available information in the project at the time of writing the deliverable, and/or design recommendations. Table

1 provides an overview of the primary and secondary sources that were used for the 1st and 2nd release of the deliverable.

Table 1: Primary and secondary data consulted for the D2.3 (1st release) and D2.4 (2nd release)

Data sources	Stakeholders involved	1st release	2nd release
Primary data[2]			
Stakeholder analysis	Pilot partners	x	x
Interviews	Pilot partners	x	
WP2 Workshop	WP2 Task Leaders	x	
Three topic-specific workshops 1) sensors, 2) data, 3) pilot city needs	Consortium members responsible for technology, data and piloting	x	x
Roundtable discussion at VUB on digital inclusion	Academic experts	x	
Interactive narrative building session	All consortium	x	
Workshop on behavioural change	CS practitioners		x
Prolific Survey	General populations in participating countries		x
Secondary data			
Scientific literature		x	x
Industry reports		x	x
Public information on past CS projects (e.g., project websites, project reports, etc.)[3]		x	x

[2] While originally, at the time of writing the proposal, a Delphi-method was suggested to identify the most effective intervention (i.e., engagement) strategies, given that the campaigns have not started at the time of writing the 2nd release of the deliverable, we opted for keeping the Bee profiles more inclusive, and the potential engagement strategies broader at this stage of the project. Instead of a Delphi-method, several stakeholder groups, including expert groups were consulted.

[3] Particular attention has been paid to sources to which VUB contributed to in past citizen science projects resulting in successful outcomes that are applicable to SOCIO-BEE. These resources include two guides published by SCivil [1], [2], the Flemish Citizen Science Association in Belgium, and the HackAir H2020 project[3]. The massive evidence gathered in these documents suggests that their wider uptake is beneficial for creating and implementing effective engagement strategies in SOCIO-BEE.

Volunteer engagement, management and care MOOC on eu-citizen.science[4]		x	x

2 Types of Citizen Science projects

There are several ways of involving the public in scientific research processes, steps, and activities. The degree and nature of involvement are dependent on multiple factors such as project aims, available resources or the project management team's expertise. To date, the two most widely adopted frameworks for classifying citizen engagement are that of Bonney et al. (2009)[5] and Haklay (2013)[6].

On one hand, Bonney et al.'s (2009)[5] model on public participation in scientific research can be divided into three major categories:

- **Contributory projects**: generally designed by scientists and for which members of the public primarily contribute data.
- **Collaborative projects**: generally designed by scientists for which members of the public contribute data but may also help to refine project design, analyze data, or disseminate findings.
- **Co-created projects**: generally designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process.

On the other hand, Haklay's (2013)[6] model distinguishes between four levels of participation:

Level 1 'Crowdsourcing': at the most basic level, participation is limited to the provision of resources, and the cognitive engagement is minimal. The advantage of this approach, from the perspective of scientific framing, is that as long as the characteristics of the instrumentation are known (e.g., the accuracy of a GPS receiver), the experiment is controlled to some extent, and some assumptions about the quality of the information can be used.

Level 2 'Distributed intelligence': at this level, participants are asked to take some basic training and then collect data or carry out a simple interpretation activity. Usually, the training activity includes a test that provides the scientists with an indication of the quality of the work that the participant can carry out. With this type of engagement, there is a need to be aware of questions that volunteers will raise while working on the project and how to support their learning beyond the initial training.

Level 3 'Participatory science': at the third level, the problem definition is set by the participants, and in consultation with scientists and experts, a data collection method is devised. The participants are then engaged in data collection but require the assistance of the experts in analysing and interpreting the results.

Level 4 'Extreme citizen science': at the highest level, participants can choose their level of engagement and can be potentially involved in the analysis and publication or utilization of results. This form of citizen science can be termed 'extreme citizen science' and requires that scientists act as facilitators, in addition to their role as experts. This mode of science also opens the possibility of citizen science without

professional scientists, in which the whole process is carried out by the participants to achieve a specific goal.

One project can be classified in multiple categories. In general, in most CS projects, the majority of participants will be at the bottom level, while participants who become committed to the project might move to the second level and help other citizen scientists when they encounter problems. The most highly committed participants might move to a higher level and be in direct contact with the scientists and the project coordinators to discuss the results of the analysis and suggest new research directions.

2.1 The SOCIO-BEE approach

One of the main goals of the citizen science approach in SOCIO-BEE is to make it accessible to people with diverse backgrounds by offering multiple ways of participation. The SOCIO-BEE profiles (D2.1 and D2.2) were created with this mindset (see **Table 4** for the latest profile descriptions). Following Haklay's[6] classification, In SOCIO-BEE, Worker Bees (WBs) (and potentially Larvae bees) are expected to be involved in the project in **Level 1** and **2**, while QBs might contribute on **Level 3** and, Beekeepers are on **Level 4**, extreme citizen science. As an extension to the framework, Drone Bees (DBs), whom we expect to only participate in low-effort dissemination activities (e.g., re-sharing a SOCIO-BEE post on social media) could be added as **Level 0** 'Minimal involvement'. The number and distribution of the different bees might also depend on pilot cities' (i.e., Zaragoza, Ancona and Maroussi) specific goals and prior experience with citizen involvement in local governance.

3 Citizen science & engagement

A scientifically engaged society is seen as essential for delivering democratic science governance and decision making, and for empowering individuals and communities to be aware of, and able to use, science in their everyday lives. The more an individual is involved in science, the higher this person's ability is to make informed and evidence-based decisions on important societal and environmental issues such as climate change [7]. Citizen science refers to research projects that involve non-scientists participating in some capacity during the scientific process, often in collaboration with scientists, and is an increasingly popular method to democratize science and engage a wider public [8]. Engagement in CS can take different forms ranging from passive to active, from local to global, from virtual to location-based and with different contribution and activity levels such as data collection, data classification and tagging, data analysis and interpretation, asking and answering research questions, community involvement and communication[9].

In the last decades, CS research has accumulated vast knowledge in a breadth of topics including how CS can serve as a method to inform and involve citizens in finding solutions to societal and environmental problems, to build active and engaged local communities, and to collaborate and communicate with different stakeholders in the quadruple helix (i.e., citizens, academia, industry, public sector). In the following, we will highlight the most important aspects of engagement in CS including potential measures of a successful project, different online and offline engagement and communication tactics, as well as principles of inclusion and diversity.

3.1 Different ways of measuring engagement in CS

Engagement, in general, can be defined as participation in any endeavour by self-investing personal resources, such as time, physical energy, and cognitive power [10]. While citizen science projects can take up a wide variety of forms in different domains, several overarching frameworks have been created evaluating citizens' participation. One approach that has been commonly applied in prior literature is determining engagement based on participants' **self-assessment**. These include **motivational, affective, cognitive**, and **social dimensions** of engagement. The most frequent methods of measurement include interviews, focus groups, surveys, and online content analysis (e.g., online posts) relying on user perceptions [11].

Studies on influence of motivation on participation focus on different internal and external factors for joining and staying on the project. Motivational factors can be broadly divided into **intrinsic** (those which stem from the task itself) and **extrinsic** (the outcomes of an activity) factors. Intrinsic motivation involves carrying out an action because it is inherently interesting or enjoyable. When intrinsically motivated, an individual acts for the fun or challenge of an activity, rather than because of external pressures, or rewards. On the other hand, an extrinsically motivated person is engaged when doing something that leads to a separable outcome such as a reward, or a desirable reaction from a significant other to whom they feel a connection (e.g., family, peer group, wider society).

In CS, examples of intrinsic factors include interest and curiosity in the topic of the project, contributing towards solutions to climate change, enjoyment derived from taking part in the project, interest in science, or involvement in a social movement. Examples of extrinsic factors include status gained for expertise or high-quality work, reward motives of reputation and social interaction, establishing a reputation as a competent coder or the possibility of securing of employment opportunities[12,13].
The affective dimension of engagement includes participants' feelings throughout the project such as concern, commitment, surprise, interest, excitement, recognition, etc. The cognitive dimensions of engagement may be learning new skills, knowledge gain or increased awareness. The social dimension of engagement includes relationships, mutual resources, shared knowledge, or role expansion[14].

Another line of research focuses on investigating citizens' **actual behavioural** patterns to determine user engagement. Previous studies have used clustering methods relying on objective data such as log data of the activity, daily devoted time, relative activity duration, and variation in periodicity ratios[9].

A third, yet less common approach is investigating both **motivations and psychological factors as well as actual behaviour**. Aristeidou et al. (2017)[15] argue that instead of looking at user perceptions and behavioural data in isolation, researchers should take into account the engagement factors behind the behavioural profiles and relate the observations to objective results and to possible future design actions and decisions. Similarly, Phillips et al. (2019)[14] recommends that when feasible, study designs should incorporate a mixed-methods approach and integrate findings from several different methodological sources to achieve holistic evaluation criteria.

3.2 Engagement metrics in CS

Engagement metrics in CS can be defined as **measures of volunteer interaction and involvement with a project**. Following the recommendation of applying a mixed evaluation method from Phillips et al. (2019)[14] and Aristeidou et al. (2017)[15], we propose a list of both **objective** (hard) **and subjective** (soft) **metrics** that can be adapted and used as key performance indicators (KPIs) in the SOCIO-BEE project (all KPIs are being assessed in SOCIO-BEE's WP5). Objective metrics refer to the performance of a citizen scientist that are clearly defined and can be measured through data retrieved from the project platforms. Subjective metrics refer to the self-assessment of a citizen scientist and can be measured through perceptual data. **Table 2** and **Table 3** provide an overview of potential hard and soft metrics with corresponding definitions based on prior literature. These metrics were presented to partners in WP 5 in to enrich established KPIs and enhance the CS approach when it comes to evaluation.

3.2.1 Hard metrics

Table 2: Hard metrics to measure engagement in citizen science

Objective (hard) metrics in CS engagement	Definitions
Lurking ratio	The proportion of days on which the citizen scientist is lurking in relation to the total days they visited the project. The closer to 1 means the more a citizen scientist lurks (i.e., logs into the platform and browses content but does not contribute) during the days they are online.
Activity ratio	The ratio of days on which the citizen scientist is active and executed at least one task in relation to the total days they remain linked to the project. The closer to 1, the more active a citizen scientist is during the days they are linked to the project.
Daily devoted time	The averaged hours the citizen scientist remains executing tasks on each day he/she is active. **Note*: because the human computation projects usually consist of different time-consuming tasks, the time devoted by citizen scientists executing tasks might be a better measure of their degree of engagement than the number of tasks they execute.
Relative activity duration	The ratio of days during which a citizen scientist is linked to the project to the total number of days from their joining to the end of the project. The closer to 1, the longer a citizen scientist remains linked (persistent) to the project, from their joining to the end of the project.
Variation in periodicity	The standard deviation of the multiset of number of days elapsed between each pair of sequential active days. The closer to 0, the steadier the rate by which a citizen scientist returns to the project.

Frequency of online exchanges	The number of online exchanges between citizen scientists and project organizers (e.g., project managers, scientists etc.) through analysis of e-mails, discussion forums, Listservs, and social networking sites.
Effort	The median of the number of submitted tasks or distribution of effort among citizen scientists through Gini coefficient or Lorenz curves.
Sustained engagement	The median time interval (e.g., in weeks) between a registered user's first and last recorded contribution divided by project active period squared.
Project appeal 1	The total number of citizen scientists who have contributed to the project divided by project active period squared.
Project appeal 2	The ratio of new citizen scientists (i.e., the percentage of new volunteers in relation to the total number of citizen scientists registered in the same period (e.g., day, week, month) of the project.
Dedication and learning effect	The share of contributions made over time across different types of tasks, as well as the growth in accuracy.
Social media engagement	The total number of followers, number of likes, number of comments, number of shares, or number of posts and their change over the course of the project.
Total App measurement time[4]	The time the application is turned on and capturing data.
Total distance covered during WSN measurements	The distance that is measured by the application while the app is working and transmitting. Calculation is possible per measurement campaign and/or the percentage of the measurements within the campaign area a citizen did.
Total number of WSN measurements submitted	Number of measurements obtained using the SOCIO-BEE App.
Number of WSN measurements per day / week	Number of measurements acquired in a given time frame.
Total WSN measurement time in stationary mode	Measurement time while WSN is used as a stationary unit using the WiFi connection to Cloud.

[4] The last five metrics in Table 2 were identified based on our current information of the WSN that is being used in SOCIO-BEE.

3.2.2 Soft metrics

Table 3: Soft metrics to measure engagement in citizen science

Subjective (soft) metrics in CS engagement	Definitions
Increased awareness	Increased knowledge, understanding of a subject, issue, or situation as a result of being involved to any extent in the project.
Knowledge gain	Learning new knowledge through training, materials, and resources provided by the project.
Experiential learning	Something a citizen scientist learns because of direct observation or "hands-on" experience with the project.
New skills	New expertise or tool use acquired as a function of practice
New behaviours	Undertaking new activities as a result of participation in the project
Commitment	Being dedicated to the idea, the project, the environment, or the science behind the project
Interest	Interest in a topic or issue as motivation for participation / feelings of interest resulting from the interacting with some specific content, tool, or experience related to the project
Sense of belonging	Feelings of acceptance, attention, and support from a group of participants in the project
Community concern	Any issues directly impacting a community or the need to bring people together and/or the need to empower community members
Environmental concern	Recognizing the importance of actions to minimize, or prevent and monitor, adverse effects on the environment
Satisfaction	Fulfillment of expectations or needs related to the overall project or to certain aspects of the project (e.g., platform, app, sensor, engagement strategies etc.)
Enjoyment	Personal excitement, fun, or satisfaction as a motivation for participation
Social connections	A desire to be with like-minded people or being introduced to the project by someone as a motivating factor
Technology acceptance	Intention of using the project technology (platform, sensor etc.) to contribute to the outcome (e.g., air quality monitoring)
Ease of use	Perceived ease of using the project technology (platform, sensor etc.)

User accomplishment	Self-perceived user performance on accomplished tasks within a project (e.g., editing profile, filtering data sources, uploading data, number of contributions etc.)

3.2.3 Engagement metrics in SOCIO-BEE

Following the recommendations from prior literature, **SOCIO-BEE will integrate objective, behavioural and subjective, self-assessed measurements** in evaluating the participation of citizen scientists. In terms of **hard metrics**, potential measurements of **Table 2** were presented to consortium members active in WP 5, that **can be captured through using the mobile app, the web platform, social media and the WSN, and to be integrated in the current list of KPIs defined in D5.6**(Definition and planning of pilots – 1st release)[5]**.** In terms of **soft metrics**, VUB and DEUSTO defined a series of questions that measure participants' perceived motivations, barriers, air quality knowledge, awareness, behavioural change, technology acceptance, satisfaction, and learning outcomes. Self-assessed measurements are captured on one hand, through the online survey distributed in the participating countries (see **Section 7.4** for the details), and on the other hand, through the PRE-, and POST-evaluation questionnaires filled out by participants of the pilot campaigns (the pre-, and post-evaluation surveys were designed in collaboration with WP5 partners). **Appendix 1** shows the online survey questions related to engagement and behaviours. The current KPI list as part of D5.6 includes the following soft engagement metrics: 1) interest in science, 2) increased AQ awareness, 3) technology acceptance and 4) satisfaction[6]. In order to strengthen the behavioural change aspect of the project, **it is recommended to include the following metrics from Appendix 1 in the KPI list of D5.6:** 1) concern about air pollution, 2) knowledge on air pollution, 3) perceived impact on policymaking, 4) pro-environmental behaviours, 5) outdoor air pollution exposure reduction.

3.3 Engagement profiles in CS

Profiling based on personal characteristics and user features is one of the most common ways to understand users and citizens. In the same vein, based on several engagement metrics, participants' involvement has been evaluated and clustered into different profiles in different projects. For example, Ponciano and Brasileiro (2015)[10] identified four distinct engagement profiles in the Galaxy Zoo[16] and The Milky Way[17] online citizen science projects: ***hardworking, spasmodic, persistent, lasting***, and ***moderate***. Calculations were made using objective, hard metrics such as activity ratio, activity duration or variation in periodicity. Hardworking volunteers typically work hard and regularly when arriving at the project but may leave the project quickly (larger activity ratio, low variation in periodicity and shorter relative activity duration). Spasmodic volunteers provide an intense contribution, at a short period of time and with irregular periodicity within this period (relatively high activity ratio and moderate variation in periodicity.). Persistent volunteers, in turn, remain in the project for a long period of time but contribute only a few days within this time period (larger activity duration and low activity ratio). Volunteers with

[5] The list of **KPIs** of **D5.6** are available here: https://docs.google.com/spreadsheets/d/1HENAm3RXIeRnYVgCr4NBzpRHt8DYnR5_/edit#gid=182538950

[6] The questions related to these metrics are available here: **PRE SOCIO-BEE Citizen Science Activists Evaluation Questionnaire** https://drive.google.com/file/d/1bKCfvmKsO96G7lPz8V87Jaob1VoiPCHY/view and here: **POST SOCIO-BEE Citizen Science Activists Evaluation Questionnaire** https://drive.google.com/file/d/1ayskL1hYo6O28ZhD6jZFRI-fIQL4caEK/view

lasting engagement profile are similar to persistent volunteers, with the difference that volunteers exhibit here a much shorter activity duration. Finally, moderate volunteers have intermediate scores in all categories of engagement metrics.

Combining hard and soft metrics, Aristeidou et al. (2017)[15] identified five engagement profiles in the Weather-it project[18]: ***loyal, hardworking, persistent, lurker, visitor***. Loyal members remain linked to the project the longest with steady visiting rates, and they are active nearly half of the days they are linked to it. They are enthusiastic, interested, and active, feeling part of the community and are willing to help other members. Hardworkers visit the platform at regular time intervals, and they are nearly always active during their visits. However, they do not stay in the project for a long time. They are interested, active and enthusiastic, yet do not feel part of the community. Persistent members remain linked to the project the longest, but they do not visit the project platforms at a steady rate. At the same time, activity ratio is quite low indicating the small number of active days they have during the period they are linked to the project. However, lurking ratio is also low, suggesting they are active during their visiting days. For lurkers, the low activity ratio combined with the comparatively high lurking ratio, indicate that they are active for only a few days during their stay in the project and exhibit lurking behaviour during the one third of their visiting days. Their main motivation to stay in the project is interest. Finally, visitors only contribute to the project on one or two days, or even never, and thus their variation in periodicity cannot be compared. Their second main characteristic is the short relative activity. This category includes the majority of participants.

3.3.1 Engagement profiles - Who are the Bees in SOCIO-BEE?

Contrary to projects carrying out a posteriori analysis of engagement profiles based on collected data (soft and hard metrics), the SOCIO-BEE project is unique in the sense that engagement profiles have been designed a priori to the implementation phase following the Modular Behavioural Analysis Approach (MBAA)[19]. In line with the MBAA, first the target behaviours and audiences were selected and specified (i.e., profiles), followed by understanding the determinants of behaviours (i.e., motivations and barriers for participation) to effectively design intervention strategies (i.e., engagement strategies).

The initial Bee profiles as defined in the Grant Agreement (i.e., Queen Bee, Worker Bee, Drone Bee, Bear) were created based on the in-depth review and integration of different literature streams and were refined through an iterative process of stakeholder dialogues. During this iterative process, new profiles were revealed, such as the Beekeeper (as a result of the stakeholder analysis of T2.2), or the Larvae, and existing profiles were refined. **Table 4** shows the latest description of the Bee roles published in D2.1 and D2.8, and was adapted according to the feedback of the municipality of Maroussi based on their first piloting experience. As the project progresses, and enters into the large-scale campaign phase (i.e., organic hives) it is possible that these role descriptions will change and/or new roles will emerge (e.g., wild bees).

Table 4: **Latest descriptions of the different SOCIO-BEE roles taken from D2.1 & D2.8, and adapted according to the first piloting experience of the municipality of Maroussi**

Concept/Role	Description

BeeKeepers	A BeeKeeper organisation can be an NGO, a museum, a university, a school, a sports club, community centre…. They are characterised by having natural access to Queen Bees or Bees. They are sympathetic to the air quality measurement cause. They are willing to kick start the Hives and provide some support and facilities, as they are fully aware of the priorities and processes of SOCIO-BEE initiative. Preferably they have their own building or access to a premises to organise workshops, keep and distributes sensors, invite Queen Bees and Bees, instruct, educate and support them. They have qualified personnel to carry out these tasks, like teachers, educators, youth workers, activity workers in a home of the elderly, etc. These institutions or public/private bodies will initially push Hives with effort, human resources and possibly budget to guarantee Hives future success once they become independent.
Queen Bees	Leaders of the Hives, so they participate and coordinate collective activities. They are knowledgeable participants interested in leading CS initiatives and who also aim to engage others to participate. They understand the barriers that can be present in the creation of a new Hive and during its whole lifecycle. Furthermore, QBs initiate and lead the discussions about an experimental hypothesis to be tested/answered/validated through a measurement campaign. QBs, via the AcadeMe web platform, they co-create and co-design together with the Worker Bees the measurement campaigns and collectively they decide on the location, duration and hypothesis of the experimental campaign.
Worker Bees	Participate intensively in collective activities organised by the Hive. These Bees are aware; they have self-efficacy and have skills that allow them to work in the team. They have pro-environmental values and attitudes driving their involvement. These are typically the most active Bees in the Hive and they take up a variety of tasks. This type of bees will be provided with the WSN sensors and through the SOCIO-BEE mobile app, will be able to carry out air quality measurements at various locations on the ground and/or using drones.
Drone Bees	They are available to acquire information and being consulted. They do not actively collaborate in the campaigns but may participate in co-creation activities and receive information on their results and ponder on their consequences. Their main role is increasing and raising awareness or create communication channels between Beekeepers and potential Queen Bees. But they might convert to another role, like a worker bee or eventually even a Queen Bee.
Larvae	They do not care or are unaware of the involvement of CS in fighting against climate change. They do not participate in dissemination activities or other pro-environmental activities. However, if they receive the right honey or royal jelly (information) they can become one of the previously described Bees.

Bears	Bears were originally conceived to be organisations benefiting from the data acquired by the Hives through measurements. Based on progressive insights we propose to extend this definition to include individuals, being subject matter experts on both science and air pollution. We believe these SME's can be quite important in supporting Hives in the definition and evaluation phase as advisors and can play an important role in carrying the data further towards impact. Examples of Bears: professor at a university; expert working for NGO; expert working within a municipality; expert working in a company.
Wild bees[7]	Wild Bee are individuals who are not part of any formal association or organization or member of an active hive, but they possess strong pro-environmental beliefs and a desire to contribute to the environment. After being informed about the SOCIO-BEE initiative, they are willing to participate, support its actions and work to fulfil its goals. So after, proper training and introducing them to an active Hive, they can actively participate in the design of the campaigns and carry out air quality measurements as Worker Bees.
Flower Locations[8]	Flower Locations represent the specific sites where air quality measurements are conducted. Similar to how bees are attracted to flowers for nectar, these locations serve as focal points for gathering air quality data. Flower Locations can be chosen based on various factors such as their relevance to the study area, potential sources of pollution, or areas of public interest and/or they might be indicated also by the Bears taking into account socio-economic and inclusivity factors. Furthermore, this map of flower locations might be useful to engage citizens with mobiles which cannot support the SOCIO-BEE mobile application (e.g., people with old Android devices or with iPhone) however they can provide audio and video footage of areas of interest.

3.3.2 Beekeepers and Queen Bees in the artificial and organic hives

While D2.1 and D2.2 provide an overview of all profiles in SOCIO-BEE, this deliverable focuses on **Beekeepers and Queen Bees**. The original goal of the task was to understand the target behaviours of QBs and establish effective intervention (i.e, engagement) strategies to involve and support them in the project. To this end, based on the initial profiles, a **stakeholder analysis exercise** was conducted in M3 with the three pilot cities participating in the project to better understand whom can be involved and in what capacity at each location, particularly who the QBs would be. **The stakeholder analysis made two important contributions to the project** and revealed: **(1)** that each pilot case starts from the participating municipalities resulting in a new and key role of the Beekeeper and **(2)** the analogy of the artificial and organic hives, which corresponds to a first, small-scale and more controlled piloting phase and a second, large-scale piloting phase. Given that the project has significantly advanced in its design and technology development since the initial exercise was conducted, pilot cities were asked to update their reflections based on the current situation (M22). **Figure 1, 2 and 3** shows the three stakeholder maps that were the outcome of the last exercise. The layers from bottom to top shows potential or actual Beekeepers, QBs,

[7] New role / concept of the **Wild bees** was added by the municipality of Maroussi.
[8] New role / concept of the **Flower locations** was added by the municipality of Maroussi.

WBs, DBs and Bears in the first and /or second piloting phase. **Appendix 2** shows the updated template questions that were shared and discussed with pilot cities.

As the figures demonstrate, the first **Beekeepers in the artificial hives** are the municipalities in the three pilot cities, and organisations that have close connections with them, such as the Ibercivis Foundation (IBER) and the Zaragoza City of Knowledge Foundation in Zaragoza (ZCKF). In later stages of the project (and after the project lifetime), we expect that new organizations (as described in Table 4) will take over the Beekeeper role and will kickstart multiple organic hives. Similarly, the first **QBs in the artificial hives** are individuals with close connections to the municipalities, such as civil servants or policy officers, who have great interest and/or expertise in improving air quality in their local communities. In the organic hives, we expect QBs with diverse backgrounds to appear (e.g., from inside and outside Beekeeper organizations), who can be simply environmental enthusiasts or experts and are willing to organize hive activities. **From an engagement perspective, the common element in these two profiles is that they do not need to be explained why air quality is important and convinced to participate since they already have the motivation to do so.** While some of the recruitment and communication strategies described below can serve to attract Beekeepers and QBs, we mostly recommend using these to engage other profiles, such WBs, DBs and also Bears. Thus, this deliverable aims to help the activities of Beekeepers and QBs. In turn, once the campaigns actively start in the pilot cities, we expect that Beekeepers and QBs will be able to provide us with valuable feedback in order to improve the engagement strategies and tools developed in the project.

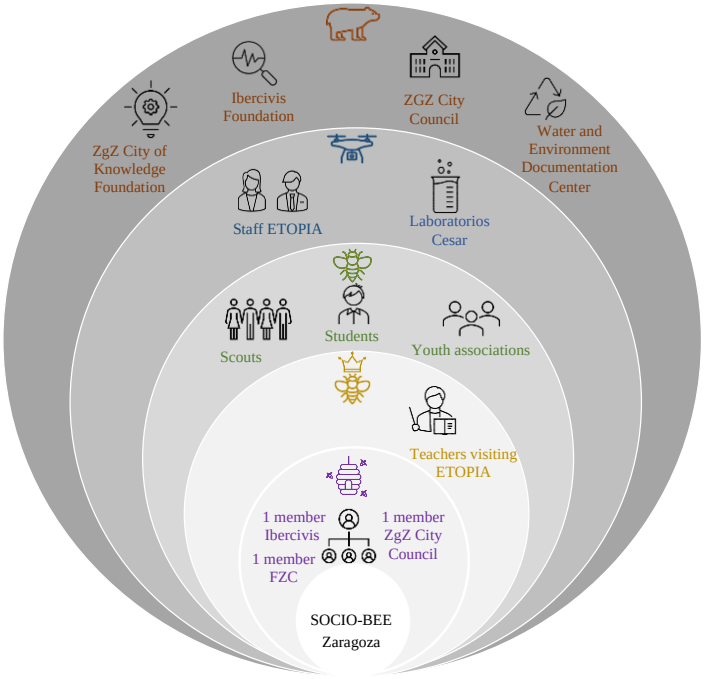

Figure 1: Zaragoza stakeholder map

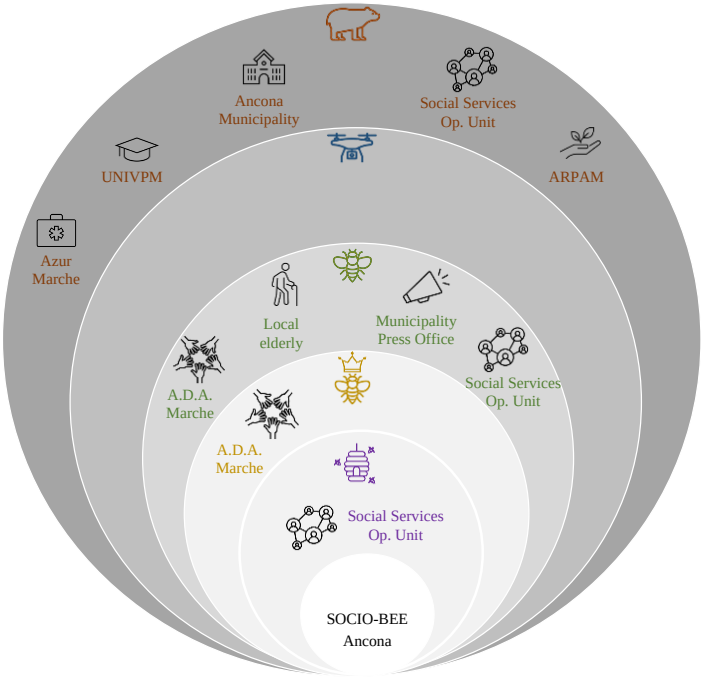

Figure 2: Ancona stakeholder map

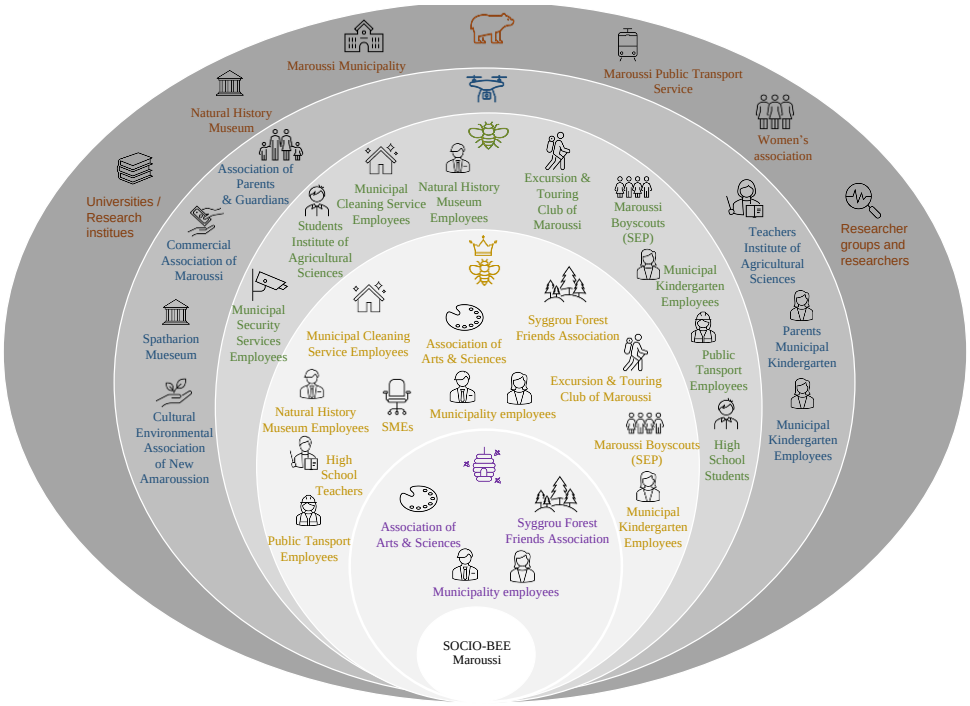

Figure 3: Maroussi stakeholder map

4 Engagement strategies

4.1 Recruitment

In broad terms, two engagement approaches are possible to attract and retain potential citizen scientists: generic and specific. Using a generic approach, the project is publicized through an open call via social media, the press, by handing out flyers, etc. The general public is targeted instead of specific audiences. In contrast, using a specific approach, project and pilot partners can rely on existing networks and communities, send out personal invitations or contact people on member lists. The choice of strategy will determine the diversity of the project participants. Research shows that the generic approach does not always deliver a diverse target audience in terms of gender, age, or education level.[1] It is recommended to combine a generic and a specific approach for the best outcome.

In SOCIO-BEE, we propose the following ***three-step recruitment strategy*** to attract different Bee profiles:

To mobilize the general public and in particular vulnerable social groups, a three-step recruitment process is recommended: (1): a **general call** with an open invitation to join, e.g., via social media, local newspapers or other relevant channels; (2): **identify specific inclusion criteria** (socio-economic and socio-demographic characteristics) relevant to the pilot cities' scope; (3): a **targeted approach**, focusing on the missing profiles and underrepresented groups through local partnerships with community-based organizations (e.g., welfare/poverty organisations, youth organisations or community centres, local cultural centres, museums, libraries).

Guidance is provided to the pilot cities throughout the three steps in multiple ways: by conducting a stakeholder mapping exercise and stakeholder interviews, identifying incentives, and providing templates and communication material (for example, in T2.5 with the creation of a Mother Deck that can facilitate the recruitment, awareness raising, and engagement). All three steps are important in all three pilot cities but will be used to different purposes. For example, Maroussi is focusing on the general public, thus an open invitation to join is important to attract Working / Queen Bees. In contrast, Ancona and Zaragoza have specific target audiences (i.e., older adults and children), thus the generic communication channels can serve to attract Bears or Drone Bees (or future Beekeepers), but they will rely on a targeted approach to reach out to Queen Bees and Worker Bees, particularly, through community-based organizations who represent the target audiences.

4.2 Online engagement

4.2.1 Gamification

Gamification refers to the **use of game design elements in non-game contexts** [20]. The goal of gamification is enhancing a service with affordances for gameful experiences to support user's overall value creation [21].

In prior literature, gamification is broadly conceptualized in three ways: (1) motivational affordances refer to the specific features that have been implemented to make the system a game and increase motivation; (2) psychological outcomes are the resulting variables that have been measured relating to motivation, attitude, and enjoyment, and (3) behavioural outcomes are those most typically reported in studies and relate to the resulting actions of the player[22].

4.2.1.1 Game elements

- ***Avatar***: the visual representation of the user's status, which can be the main character of the game. The goal is for the users to develop personal ownership [23].
- ***Points***

Points are referred to as a numerical metric of progress, representing the user's current score.

- ***Badges or trophies***

Badges or trophies are visual icons awarded for completing some form of achievement, whether this is from completing a specific task or accumulating a certain number of points.

- ***Ranking***

Players are ranked by their score on leader boards, and each individual's progression through the game is determined by the various milestones or key tasks they have achieved, such as completing certain levels or alternatively "levelling up." Depending on their current progression, a player may receive a particular title or "status," which may increase as the player traverses increasingly challenging levels or stages in the game.

- ***Rewards***

Players are motivated to continue in the game in the hope of receiving rewards, which may be real-world items or items to use within the game itself.

- ***Roles***

A player may take on one or more roles within the game, depending on the type of character they play as.

- ***Narrative***

Narrative is a key element in many games; it is the series or sequence of events that help to guide the player through the game's story.

- ***Ability to skip***

Players are allowed to move on to another task without completing the one they are currently assigned to.

- ***Tutorial***

Numerous games offer a tutorial or practice process that aims to get players started with the tasks involved and is necessary in more complicated games—for example, by completing a specially designed set of puzzles or tasks before proceeding to the true scientific task.

- ***Learning opportunity***

Many games also offer the opportunity for learning, and this is common in virtual citizen science projects as the games are based around scientific research, and the process of educating citizens is motivating for both the scientists and the volunteers themselves [24].

- ***Feedback loop***

Immediate feedback on players' in-game behaviour enables the user to adjust this behaviour almost in real time. When the users' behaviour is effective, the user sees immediate results leading to perceptions of control, and renewed motivation. When the behaviour is ineffective, the immediate (negative) feedback, allows the user to change behaviour or recover the loss. In turn, the user that is showing ineffective behaviour is also given a sense of being in control leading to renewed motivation to try again[25].

4.2.1.2 Motivations for engaging in online games

Previous citizen science projects indicate that players' motivations for joining and being engaged in games are mixed between intrinsic and extrinsic factors. These motivations also differ between different user segments. **Extrinsic motivations** include competing against others, achieving one's personal best, and earning rewards, for example in the form of badges. While **intrinsic motivations** are more line with the general motivations for engaging in citizen science such as: interest and contribution to science, entertainment value, learning something new, sense of community, and personal interests[26],[27]. However, from a design perspective, building on self-determination theory (SDT)[27,28], motivations are more nuanced. It is argued that designing a game for intrinsically motivated people is unnecessary because they are already motivated to join the cause and carry out the tasks. The extrinsic motivation of the design can even have a counterproductive effect on this group. Thus, game design always focuses on people with extrinsic motivation. According to SDT, extrinsic motivation can be divided into four subgroups from low to high autonomy (i.e., **external regulation, introject regulation, identified regulation, integrated regulation**). In game design, in general, end users who are confronted with external or introject regulation refer to this experience as "I have to….", while end-users confronted with identified or integrated regulation use the phrase "I want to…".

Simperl et al. (2018)[24] argue that although, competitive elements appear to be somewhat more common—and in some games form the backbone of gameplay— players as a whole are more engaged by opportunities for cooperation and for social interaction indicating that identified and integrated regulation play a stronger role in engaging in gamification. Bowser (2014)[26] found that both traditional citizen scientists (i.e., volunteers who would contribute in the absence of game elements) and gamer participants (i.e., volunteers who are motivated by the incorporation of game elements) are motivated by discovery and learning something new. However, traditional citizen scientists see the app as a tool to engage with nature, while gamer participants see the app as something that needs to have additional value (besides the game) and also has to be convenient. Eveleigh et al. (2013)[30] found that competitive gamification mechanisms which motivated some leading citizen scientists were either ignored by more casual participants or contributed directly to the decision to discontinue participation. This has important implications for offering a balanced range of game-like features in citizen science platforms, so as to support and encourage the most consistently active and productive contributors, while simultaneously seeking to minimize reduction in users, and to capture the attention of new citizen scientists trying out the project.

4.2.1.3 Design considerations

Prior literature indicates that the following design considerations should be considered for motivating and sustaining participation through gamification in citizen science:

- The scoring mechanism should provide **personal milestone targets**. More finely graduated stages of progression would help citizen scientists feel their contribution is always valued.
- **Immediate feedback loop** should be integrated into the game as a means to recognize quality rather than quantity. Participants should have a sense of control to be able learn from and correct their mistakes and have an impact.
- The game elements should **focus on intrinsic motivation** such as collaboration with others instead of competition.
- Participants should be allowed to **choose and follow their own narrative** path through the project (e.g., through offering choices).

- Using a **game-design approach instead of simple gamification** can help motivating a most participants in the project instead of appealing only to a niche target audience.
- Certain game-design elements can also be **counterproductive**. It can demotivate citizen scientists to find that their work is being evaluated, or that they are too slow to reach the targets set. Similarly, ranking participants might be demotivating on the long run as low-ranking players are likely to leave the game. Especially, if competitive performance and feedback is used as 'reward' instead of using the proposed engagement metrics as a source for game-based interpretation.
- Gamification only works when sufficient thought goes into the design of the game elements. It is important to **allocate sufficient time** and money in the design process.
- The scope of the project also has to be taken into account. In citizen science, gamification is at its most effective when **gathering data** is the main thing the citizen scientists do[1].

4.2.1.4 Gamification in SOCIO-BEE

At the time of writing this deliverable, it has not been decided yet whether and how gamification will be part of the SOCIO-BEE mobile app through the Micro Volunteering Engine (MVE), it is currently under development in WP4 by CERTH. If eventually gamification forms part of the SOCIO-BEE app and the MVE, it is recommended to keep it as an optional feature, or only use some gamified elements to make sure that all participants can and enjoy using the app. Based on prior research, the following elements could be part of the SOCIO-BEE game: points, badges, avatars, increasing complexity of tasks as the user advances in the game, real-time feedback/visibility of user contributions, hive recognitions. It is essential to dedicate enough resources for the development of the game and to take into account the preferences of the potential users in the target audience before and during the development process. HKU, experts within the SOCIO-BEE consortium in game-design, provided extensive feedback on the gamification section above**. It is recommended that a close collaboration is set up between HKU and CERTH to develop the gamified elements of the SOCIO-BEE app.**

4.2.2 Micro-volunteerism

Micro-volunteering refers to **volunteering actions that can be completed in short, discrete periods of time.** Prior literature has listed several benefits of micro-volunteering such as convenience, flexibility, potential to reach a large volunteer pool, and to sustain long-term engagement. These benefits are detailed below [31]:

- ***Convenient and flexible nature***: micro-volunteering tasks are generally quick to complete; require little on-going commitment; can be conducted remotely and with minimal supervision, training, and on-going support. Thus, ultimately, can fit into people's busy lifestyles.
- ***Potential to engage a larger and wider range of audience***: it has been argued that there is a large pool of potential volunteers outside the 'civic core' who are not interested in more formal, structured participation. Therefore, micro-volunteering might be a good opportunity to reach them. In addition, the online nature of micro-volunteering has the potential to involve those who are elderly, have disabilities or may feel uncomfortable in social settings, and connecting communities at a distance.
- ***Gateway to more sustained and long-term volunteering*:** another argument in favour of micro-volunteering is the likelihood that the volunteer will be gradually more committed to the cause of the project, dedicating more time to carry out more elaborate tasks.

Overall, the **two central elements** of micro-volunteering are: **speed** and **convenience**. In terms of the former, the time it takes an individual to complete an allotted task will naturally vary from person to person. However, the general guideline is that a reasonable timescale for such tasks is between 5 and 30 minutes. Examples of micro-volunteering include: campaigning and communication (e.g. signing a petition, writing a blog post), fundraising (e.g. sponsorship and charity collection), research (e.g. completing a questionnaire) and practical help (e.g. baking a cake for a sale, donating computer processing time).

Citizen science is one of the most important arenas, in which micro-volunteering has been applied. A large number of projects have made use of online volunteers who can create and analyse large-scale datasets and thus contribute to addressing major social challenges. These types of micro-volunteering platforms have proved particularly popular for large-scale environmental projects, such as Zooniverse[32]. To a lesser extent, micro-volunteering has also been used in projects with a more interpersonal nature. A notable example is "Be My Eyes" [33], a mobile application that allows blind and visually impaired people to connect with sighted volunteers via a live video connection.

Despite the important benefits of micro-volunteering, three major barriers have been mentioned in prior literature. Given the often remote nature of micro-volunteering, it does not have the capacity to cultivate interpersonal relations to the same extent as traditional volunteering leading to higher disengagement of volunteers. Another potential disadvantage is that the results of volunteers' accomplishment might be less visible to them leading again to only short-term or one-time participation. Furthermore, the capacity of micro-volunteering as an inclusion tool has also been questioned. The overall suggestion is that micro-volunteering should co-exist with other forms of volunteering within a project to obtain higher engagement rates [34].

4.2.2.1 The micro-volunteering engine in SOCIO-BEE

Within SOCIO-BEE, a MVE is being developed (T4.1) providing the opportunity for volunteers to make contributions to the project at varying times. Given participants' selected profile, they can contribute to existing or new hives' activities by creating campaigns, defining hypotheses and areas to cover, and recording their measurements. In addition, the BeeMate service (T4.4) that is currently under development allow citizen scientists to capture audio of activities that are either related to air pollution (e.g., traffic, construction) or non-related (e.g., wind, animal sounds, street music).

4.2.3 Social media

Social media communication serves multiple purposes within a CS project. Social media channels provide opportunities for **connecting with different target audiences**: active participants, potential participants and other stakeholders. There is a wide variety of ways project organizers can make use of social media such as creating a narrative, adding images or pictures, using hashtags, spreading information, sharing individual stories, or promoting, re-distributing others' posts by re-sharing them and running large-scale social media campaigns.

Among the available platforms, it has been recommended to use Facebook for content and event sharing or setting up groups targeting the general population. On the other hand, Instagram might be useful for easy to digest visual content that can appeal to a younger audience. Finally, Twitter and LinkedIn are excellent platforms to engage professional target audience such as scientists, journalists, domain experts or media professionals.
There are several message types that should be shared across social media:

- Through **project messages**, organizers can draw attention to the project, sharing information about its aims, events, news items, results and so on.
- **Subject-specific messages** can be used to share scientific background information, current affairs, inspiring examples of similar projects, related events and conferences.
- Through **regular "like" messages** funny clips, photos, stories, did-you-knows, GIFs, before and afters, or behind the scenes pictures can be shared [1].

Messages should stand out by being creative, playing with emotions, keeping it relevant, fostering action or interaction. Statistics can be tracked to check what messages or times are most popular. For example, the use of emotions, including fear, guilt, and even anger, creates a powerful discourse around environmental related projects that results in a moral imperative. This way of influencing emotions (e.g., expressing urgency with verbs) might be effective in creating a connection among young activists, but even more importantly can call to action older activists or parents by utilizing the desire to protect the future for young people [35].

4.2.3.1 Social media in SOCIO-BEE

SOCIO-BEE is active on multiple social media platforms: Facebook, Twitter and LinkedIn. D8.2 provides an overview on the completed and planned dissemination and communication activities via social media. This section of the document aims to put forward a few recommendations to help advance the design and implementation of social media activities. SOCIO-BEE already tweets and posts frequently about the project. **Suggested topics to share on social media** during pilot implementation phases including: **a)** updates about the SOCIO-BEE progress**, b)** progress on workshops or other offline events, **c)** generating interest about data-collection campaigns, **d)** spreading the word on upcoming events, **e)** communicating results on a specific day (aggregated, place specific, high density, high/low pollution area), **f)** sharing user-generated data, **g)** approaching common challenges/concerns from users, **h)** increasing awareness on air pollution, **i)** telling a participant's story. The recommendations of this deliverable will be shared with WP8 and pilot partners to create effective joint communication strategies.

4.2.4 4.2.4 Storytelling

Storytelling refers to **visuals, audio, or text to tell a story about a subject through digital media**. Stories are short and powerful strategy (2-3 minutes) introducing a personal perspective that arouses curiosity and interest in the target audience. In personal stories, the focus is on the personal experience of one of the participants of the project, such as why they joined, the knowledge and skill set they have acquired, the challenges posed by the research work, the measurement and collection of data, etc. To tell the story, project organizers might ask citizen scientists to record a short video or audio clip, in which they talk about their experiences, or they might be invited for a short interview. It is a recommended to choose people who are representative of the target audience(s) of the project to help other (potential) participants empathize with the story or character [1].

Storytelling in citizen science is a persuasive tool for learning, empathising reflecting and advocating, and has the potential to trigger change in attitudes and behaviour in a way that traditional science communication cannot. A personalized dialogue is created between the listener and a teller through a narrative focusing on emotions and experiences instead of statistics and scientific knowledge. Storytelling is also a great way to give voice to individuals and communities usually without [36].

4.2.5 Other online communication tactics

Depending on the target audience, a number of other communication tactics can be used **to engage different stakeholders** (Beekeepers, Bees, Bears and Larvae). The list below highlights the most popular ones.

Infographics

An infographic is a collection of imagery and data visualization in a story format. A good infographic is clear, memorable, visually, and textually concise. It is an effective tool to educate, inform or raise awareness. In citizen science, infographics can be used to target potential citizen scientists highlighting key information and ideas in an easy-to-understand, effortless way.

Photovoice

Photovoice is a commonly used method in community-based participatory research to document and reflect people's reality. Participants are asked to take photographs that highlight their personal point of views about the theme(s) of the project. Through photovoice, people of all ages, social background can be brought together leading to diverse, new insights or overlooked issues that might impact the community. Photographs can be collaboratively interpreted in group discussions or can be part of the digital storytelling to develop common narratives and initiate change in the community.

Fact sheet

Fact sheets are usually single paged documents providing key information about the project in a concise, simple language. Fact sheets can be disseminated to different stakeholder groups, such environmental groups, citizen scientists, policymakers, or industry players.

Summary reports

Summary reports are designed for non-specialist audiences providing a briefing on the details of the project. The report can include relevant charts, graphs, additional text, illustrations, and graphics to outline the report goals. Summary reports can be disseminated to different stakeholder groups, such as environmental groups, citizen scientists, policymakers, or industry players.

Technical reports

Technical reports are designed for audiences with some basic understanding of the topic of the project. Compared to a summary report, technical reports are more detailed focusing on process, progress and results of the research carried out in the project, describing relevant statistics, and using scientific language. Technical reports can be disseminated to the scientific research community or among people with a high interest in science.

Quiz

A quiz is an interactive way to engage citizen scientists in the topic of the project irrespective of their digital literacy or technical knowledge. Quizzes can be played on phones, computers or public screens and can be used as an information sharing and awareness raising tool. An example of a such a quiz on air pollution was used in the iSCAPE[37] project (https://quiz.iscape.smartcitizen.me/).

Celebrities

Next to personal stories, another way to reach potential citizen scientists is collaborating with a local celebrity or well-known person with non-scientific background. For example, by creating a short video or picture with a short description on the topic of the project (e.g., why it is important, what changes the

celebrity applied in their daily life etc.), a celebrity can create a bridge between scientists and the general population mobilizing them to participate in the project or make some changes in their own life.

4.2.5.1 Storytelling and other communication tactics in SOCIO-BEE

Making storytelling an integral part of the SOCIO-BEE social media strategy will ensure a focus on the human participation in air quality measuring. **Visible stories from participants across locations** would also ensure that citizens with diverse backgrounds and varying participation all have a voice in the project. In addition, impressions from participants in offline events should be collected that could be developed into a **storytelling narrative**. Participants across pilot locations could also be connected and tell a shared narrative combining social and technical elements of the project. This is in line with the **cross-pollination** concept, using storytelling as a powerful tool to increase communication and engagement across the pilot cases. The first SOCIO-BEE stories appeared from the Maroussi and Zaragoza pilots in the form of short videos, in which we can see the first Bees learning to use the WSN and taking measurements in their cities.

- **Behavioural change tips and personalized recommendations**

There are different ways of informing citizens about how they can contribute to reducing air pollution by taking small actions on an individual level. One way of sharing such tips and thus, increasing awareness and encouraging behavioural change is through the SOCIO-BEE platform or app. If shared through the platform (i.e., website), it is important to create engaging and visually appealing material. For example, an infographic or a video would certainly better capture participants' attention than a simple list of recommendations. If the tips are shared through the app, they could appear as pop-up messages (one at a time) to users who open the app, and users should also be able to disable these messages. Depending on the profile and interest of users, the messages could take a more targeted form as personalized recommendations.

- **Frequently Asked Questions**

It is recommended to make FAQ part of the SOCIO-BEE website to avoid the overload of inquiries from participants to the SOCIO-BEE communication team. Answers to FAQs should cover some of the following topics: necessary equipment for participants to carry out the different tasks, time requirements to carry out the different tasks, description of the measurement process, any potential costs participants have to endure (e.g., for shipping items), whether the tasks can be carried out remotely or in person, any privacy concerns, quality and value of the data.

- **Discussion forum**

Evidence from past CS projects suggest that the following points should be considered when deciding whether SOCIO-BEE should have a discussion forum [4]. Alternatively, group discussions can also take place on the social media platforms used by the project (e.g., Facebook group).

1) Are many volunteers likely to sign up to it? For example, do they have enough time, do they spend much time online already, do they trust online forums, do they have access to fast WiFi?
2) Is your project's task, or data, of the kind that can be easily shared on a forum - for example, images or tables?
3) Are your task's questions subjective or open-ended enough to require discussion, or is the data varied and interesting enough for people to have new ideas about it that they'd like to share?

4) Is your team receiving a lot of e-mailed questions of the kind that can't be fully addressed by an FAQ page, but which could potentially be answered by other volunteers?
5) Is there someone who can act as a moderator, to keep the place welcoming and organized?
6) Do you sense that your volunteers could benefit from talking to each other?

- **Feedback on data quality**

Citizen scientists should receive feedback every time they upload data to the SOCIO-BEE platform. The feedback should be as quick as possible on the quality of the data and how the individual data contributes to the overall data on the platform. In addition, it is important to establish a channel, through which participants can ask an expert and receive help if they are stuck with the measurement process.

- **Other communication**

To increase the outward communication of the project, infographics, summary reports, fact sheets and technical sheets should be foreseen to attract DBs, Larve, Beekeepers and Bears.

4.3 Offline engagement

Despite the rise of online CS projects and the use of social media, workshops and other in-person events remain cornerstone strategies for recruiting and sustaining engagement of different audiences. Project organizers can choose from a wide variety of workshops and other tactics depending on the goal and nature of their project. In the following, we elaborate on three areas of offline engagement: ambassadors, workshops, and data-collection campaigns.

4.3.1 Ambassadors

Project ambassadors can help with several aspects of a citizen science project such as logistics, administration, promotion, or communication. An ambassador can engage other, potential citizen scientists and can create a bridge between organizers and other participants increasing trust. Based on an extensive experience with a wide variety of citizen science projects, SCivil[1] recommends the following practical steps to set up a programme for ambassadors:

- **Define the task and the profile**

An ambassador can handle a wide variety of tasks within a project. Examples include helping with online or offline promotions (e.g., distributing flyers, forwarding newsletters or messages on social media, etc.), being the point of contact at events, helping at workshops by assembling sensors, etc. It is recommended to define tasks in advance, so potential ambassadors know what they can do (and when they can do it) and they are able to choose a role that suits them.

- **Find and train ambassadors**

The second crucial step in setting up an ambassador programme is identifying the right people and investing time in them by training them. There are different ways of identifying potential ambassadors: 1) through the project organizers' network ambassadors may offer their services, 2) by promoting the programme through social media and other communication channels and adding a registration module, 3) through in-person events and workshops. Once the ambassadors are identified, some level of training

is necessary. For more simple tasks, this can be a one-time event or online tutorials. For more complex tasks, regular training sessions might be necessary. After a while, it might be possible to use the *train-the-trainer* model, in which incoming ambassadors are trained by more experienced ambassadors.

- **Give your ambassadors visibility**

It is important to publicly recognize ambassadors' contributions to the project. For example, after a data-collection campaign, ambassadors can be thanked officially through the online communication channels of the project and / or at a physical feedback session. It is equally important to reward ambassadors for their work. Prior projects indicate that ambassadors are often intrinsically motivated, thus spending a day with the research team analysing the results or an excursion with professional scientists might be interesting and satisfying for them.

- **Adjust where necessary**

Ambassadors can be brought in for a single activity or stay involved with the project during a longer period. It is important to establish ways of supporting ambassadors as well as evaluation methods and to make adjustment as the project progresses over time.

4.3.1.1 Ambassadors in SOCIO-BEE – Queen Bees

In SOCIO-BEE project ambassadors are the Queen Bees, who lead the hives. As previously described, the first (or perhaps most) **QBs are likely having high level of environmental awareness and are already active** in some ways to tackle air pollution. However, **it is an important goal of SOCIO-BEE to be open to anyone and make it possible for people to assume or change roles**. Thus, it is possible that an individual with high enthusiasm and good organizational skills wishes to become a QB but lacks environmental or technological knowledge. For example, a tech-savvy QB, who is an early adopter, can connect new and interested participants to the digital tools and platform of SOCIO-BEE. In other capacities, Queen Bees can be present in physical events and activities and become trusted and knowledgeable members of the community. Therefore, through social media or in-person activities, QBs can become **visible figures within the project**, who can be approached by other participants creating a bridge between project organizers and citizen scientists. QBs can also emerge among the enthusiastic Worker Bees without a specific environmental background but with high motivation to contribute to the project more actively.

Queen Bees can be identified and recruited in different ways and at any point throughout the project: through the organizational network of pilot partners, through social media monitoring tools used in SOCIO-BEE or during workshops, or by using the instrument devised in T2.2 for auto self-assessment of bee roles. Eventually, more experienced Queen Bees could train subsequent Queen Bees using the "train the trainer" [38] approach.

In general, at least **three types of training** should be provided to potential Queen Bees (and other Bees) depending on their profiles and interests: **1)** in-depth knowledge on air quality, for example through the air quality crash course developed by the SOCIO-BEE consortium partners and offering a list of useful resources (e.g., as WP2 partners are doing with the mother deck in the context of T2.5), **2)** a quick guide on successfully handling social media to promote SOCIO-BEE, and **3)** a basic course on coding using free and open software (e.g., R Studio[39]) for people who are interested in understanding and sharing the results of the SOCIO-BEE air quality data. This could be done through short, step-by-step videos like the ones in existing online platforms such as DataCamp[40] or 101 courses. These training modules would not

only benefit SOCIO-BEE helping with the "train the trainer" approach but would provide an important contribution to future citizen science projects, and could be shared, for example on the website of eu-citizen.science as MOOCs.

4.3.2 Workshop types

By integrating information of various public databases [41],[42],[43],[44], **Table 5** below provides a snapshot of the most popular types of engagement events that have been effectively used in citizen science or other citizen participation projects.

Table 5: Popular in-person events / workshops in citizen participation projects

Popular in-person events / workshops in citizen participation projects	
Name	**Description**
SCIENCE CAFE	an event organized in an informal setting as a place of dialogue with participants coming from all walks of life and academia. An expert presents a subject in a concise and open manner after which the floor is open for a discussion. The moderator facilitates the sharing of a wide range of views on the subject at hand.
WORLD CAFE	follows the principle of a good conversation in a workshop format, where anybody is able to talk about things that matter to them. A World Café process begins with the first of three or more twenty-minute rounds of conversation for the small group seated around a table. After the first round each member of the small groups moves to another table. One person will stay at the table and is a table host for the next round and briefly fills them in on what happened in the previous round. Each round of a World Café is prefaced with a question designed for the specific context and desired purpose of the session.
SCENARIO WORKSHOP	The purpose of the scenario workshop is to assess different solutions to a specific problem. The solution can be technical, regulatory or an alternative method to organize or manage a problem. The scenario workshop is a two day meeting involving 25-30 local representatives such as citizens, policy makers, stakeholders, technology experts and private sector representatives. Before the workshop, a set of scenarios is developed and used as visions and inspiration at the scenario workshop. From these the participants develop visions in groups through discussion such as local plans of action to solve the problem.
RAPID APPRAISAL MAPPING	stopping people in the street and asking them to spend a little time sharing their local knowledge and experiences on a given topic (e.g., areas participants visited and liked, the routes they took, as well as those that they found problematic or avoided and the reasons why)
SCHOOL TECH DAY	School Tech-Day Event is a didactic unit for integrating citizen science activities on the topic of environmental sustainability at a primary or secondary school into the school curriculum. By means of different hand-on activities carried out in a single day, students are involved in all the different phases of a research study, from formulation of research questions to data collection, analysis and presentation of results.

COMMUNITY CONTRIBUTION CANVAS	The Community Contribution Canvas is an amusing activity that you can easily implement to gather information about your participants during a co-creation workshop or large event. Not only will it allow you to know how and to what extent they want to participate in the project, but you will also know the skills and knowledge they have and that you can leverage to develop the project activities.
SYMPTOMS MAPPING	This is an activity suitable for a co-creation workshop or an event. It consists in asking participants to map environmental problems and health symptoms that they experience in different areas of their city. Participants populate a map of the geographical areas with stickers that represent different problems. The resulting map provides valuable insights on citizens' concerns, thus showing areas of interest for the intervention.
POP-UP INTERVENTION	Pop up interventions are temporary spaces within the cities' infrastructure that combine playful materials and audiovisuals to stimulate reflection, action, and interactions among the general public. Pop up interventions are the perfect tool to approach everyday people and let them get to know your project and to start conversations about their interests and concerns. A pop-up intervention could be organized around a variety of different activities, such as play games on the street and using artistic installations.
EXPERIMENT DESIGN CANVAS	The decision-making canvas is a tool that helps researchers to guide conversations with citizens around decision-making processes in science. The tool allows you to identify: (1) At what stages of a research study do citizens want to be consulted to make decisions, (2) What decisions do they want to make and, (3) How we can involve them to make these decisions. The tool is meant to be used during a co-creation workshop, which can be carried out in different stages of a research study, preferably starting at the onset of the project.
CITIZEN COMMITTEE	A Citizen Committee is a decision-making body whose main role is to provide inputs to the research study, to veil for its correct implementation and ensure that citizens' concerns are taken into account. Usually, it is set up by a group of residents of a certain area to deal with issues of common concern such as health, the environment or any other. Structural, functional, and practical arrangements of the citizen committee can be the most diverse.
FOCUS GROUP	The focus group is a method similar to needs assessment surveys and is designed to help learning more about community and groups' preferences and opinions. The questions participants are asked are typically qualitative and open-ended, therefore the information is open to interpretation. The answers have depth, nuance, and variety. Group dynamics, interaction and non-verbal communication need also be observed. The focus groups can reveal what the participants are really thinking and feeling, even though their responses may be harder to score on a scale.

INTERVIEWS	Interviews are used to explore the views, experiences, beliefs, and motivations of individuals on specific matters. Interviews as a qualitative method are believed to provide a more in-depth understanding of a certain topic than would be obtained from purely quantitative methods (for example questionnaires). Interviews are, therefore, most appropriate where: i) little is known about the phenomenon under investigation; and ii) detailed insights are required from individual participants. In addition, they are appropriate for exploring sensitive topics, where participants may not want to talk about such issues in a group environment.
SCIENCE THEATER	Theatre based participation methods have become more widespread. These methods allow creative ways to bring complex topics to life; often to audiences who would not take part in a more traditional process.
OPEN SPACE TECHNOLOGY	A one-day Open Space event has three parts: i) An introduction to the whole plenum, explaining the method and what is expected of the participants in order to have a successful event. It is followed by the agenda setting, where workshop sessions are announced and scheduled and where the participants register for the workshops of their choice (It all takes a maximum of 1 hour – 15min for the introduction and the rest of the time is dedicated to agenda setting and enlisting). ii) The sessions themselves, where multiple workshops are conducted simultaneously. iii) A final round with the whole plenum in which the facilitator summarizes the events of the day and gives participants the opportunity to comment on their experiences and lessons learned.
HACKATHON	Hackathons are generally used for innovation, education or social purposes, and there is often a goal to create usable software or other technological improvements or innovations. They can involve technophiles but also people with non-technological background and community members to increase the use of innovation and drive changes in sustainability. Hackathons typically start with one or more presentations about the event and the specific subject (if there is one). Participants then suggest ideas and form teams based on individual interests and skills. The Hackathon then begins and can last anywhere from several hours to several days. Sometimes there is an element of competition with prizes for the best ideas. At the end of the Hackathon there are usually demonstrations in which each team demonstrates their results.
CITIZEN COMPASS	The citizen compass (in German 'Bürgerkompass') is a format of participation where citizens (randomly selected) evaluate the work of the government using criteria they develop. On this basis the citizens propose measures for the future work of the government. The citizen compass offers a platform for politicians to learn what citizens think about political topics and what recommendations they would give for policy making. The main event of the citizen compass is a moderated meeting with around 200 citizens which are randomly selected

	(representative sample regarding age, education, gender, origin). In three steps, the citizens work in this meeting on their recommendation to politics: 1. The citizens develop assessment criteria, which they find relevant to assess the "success" of the government; 2. Citizens judge the political work along these criteria; 3. Starting from the identified deficits, citizens propose suggestions for improvement for the work of the government. At the end of the event, the results are passed to political representatives who then assess, comment, and give feedback to the citizens as well as the public. Suitable proposals will be integrated in their further political work.
DATA AWARENESS ACTION	Moving from the digital space to the street to create awareness, an analogic data visualization kit is created to show the data collected by participants (e.g., data collected through sensors on local air quality).
SCIENCE SHOP	Science Shops mediate between citizens, citizen groups and research institutions. 'The Pop-up Science Shop' refers to a single event in time, that simulates the way civil society's requests and problems can be transferred into a research setup. Citizens are called clients, in the context of the "shop". This format helps include public participation in research. Science Shops' methodology transfers requests from community groups to research organizations. Thus, the event allows many important and pertinent questions to be raised – social, political, and ethical– with regards to a determined topic of your selection, and you can discuss with people how innovation is encouraged, and about who is involved in the research process. Science Shops as a way of transferring knowledge are innovative and effective and have a positive impact both on research and on civil society.

4.3.2.1 Workshops in SOCIO-BEE

At this stage of the project, it has not been decided what types of workshops will be conducted in the framework of the large-scale campaigns. In-person events can be used **in various project phases**: **(1)** to raise awareness and recruit participants, **(2)** to introduce them to air quality or how to use technology to collect data, **(3)** to interpret the results together with the participants or disseminate them to a larger public, **(4)** to discuss future scenarios for the city building on the collected evidence. In general, it is recommended for pilot cities to organize at least two in-person events with the interested citizen scientists, one at the beginning of the campaign, and another one at the end to allow reflections about their participation and discuss the results. **Appendix 3** provides guidance on **how to organize a workshop** adapted from the HackAir project [45].

4.3.3 Data-collection campaigns

Data-collection campaigns motivate **citizen scientists to gather as many data records as possible in a given time.** The organizer defines a task in very clear terms and sets the geographical area and time frame (e.g., from one day to several weeks) within which data records are to be submitted.

Data-collection campaigns can take many sizes and forms. They can be organized as a 1) **niche** campaign, 2) a **small-scale** campaign, or a 3) **large-scale** campaign. For a niche campaign, organizers should be specific about the type of citizen scientists they wish to appeal to. For a large-scale campaign, organizers should collaborate with local organizations that can help with logistics and promotion and have an active presence in the media to publicize the campaign. Campaigns can be linked to a specific event, public holiday, occasion, or season. For example, an air quality measurement on New Year's Eve, (when lots of fireworks are set off) or a rainfall measurement during a summer thunderstorm. Organizers could also have different communities of citizen scientists to compete against each other (e.g., hive X against hive Y in SOCIO-BEE).

At the end of a data-collection campaign, the results should be analyzed and communicated to the citizen scientists. It is recommended to organize an event at which results can be discussed with participants. In addition, every participant should be notified about the results as well as results should be published to reach a wider audience through (social) media[1].

Types of data-collection campaigns on air quality[45]:

1) ***Co-ordinated campaign in one city, site, or street*** – pilot partners could choose the most polluted areas in their local neighbourhoods, such as high traffic roads or intersections, or prominent sites. This campaign would target both environmentally aware and unaware citizens.
2) ***Comparative campaign across sites*** - this campaign could target interested volunteers in generating and comparing different air quality data.
3) ***Comparative campaign against official sources*** – this campaign could target technology or data enthusiasts interested in analysing larger datasets. Pilot partners will require an overview of specific sites and measurements of fixed reference points, while citizen scientists deploy stationary or wearable sensors in their local neighbourhood or targeted areas.
4) ***Seasonal campaign*** – different seasons or weather conditions could be crucial in terms of air pollution (e.g., in winter air pollution is more visible). Pilot partners could discover the possibility of conducting seasonal, and even joint campaigns in specific times of the year.

<u>Requirements to organize a successful data-collection campaign</u>:

- Communication of the **date, place, goal,** and **duration** of the campaign (e.g., using social media channels of the project)
- Organizing a (physical) **meet and greet** meeting to introduce users to the sensors and the SOCIO-BEE platform and app. Ideally, a local expert should join the meeting to discuss the project, air pollution and pro-environmental behaviour.

- Providing **incentives** (e.g., offering co-authorship on writing a journal article, manual, fact sheet, infographic etc., opportunity to design a local campaign or feedback session)
- **Data density**: it is important to engage as many users as possible, although the exact number depends on the specific campaign.
- Deciding on the **roles** participants can take up on (e.g., data collectors, campaign organizers, social media "managers", etc.).
- Communicating the **timeframe** of the campaign to participants (e.g., when the meet and greet takes place, start and end of taking measurements, when the results would be published, time of the feedback session, etc.)
- Providing a **feedback session** and acknowledging participants' contribution (e.g., involving a local expert).
- Maintaining a **communication channel** with participants to answer their questions. This may also require having an open channel with technical partners for timely responses to technical requests.

4.3.3.1 Data-collection campaign scenarios to be explored in the SOCIO-BEE

Below, we provide a list of potential data-collection campaigns that emerged through discussions with the pilot partners and other consortium members. These scenarios serve as first ideas to be implemented in the different locations (not all of them at each location) taking into account the currently available information on the SOCIO-BEE technology and pilot cities' preferences. At later stages and prior to implementation, these scenarios have to be refined determining the necessary technological and engagement specifications. In WP 5 (D5.6), campaign templates and blueprints were developed for Beekeepers and QBs detailing what a campaign is, the research process to follow (research question, hypothesis, experiment, data gathering, data analysis, conclusion), and guide for type 1 (area) and type 2 (source) investigation.

Scenario 1

Citizens measure air pollution through wearable sensors allowing pilot cities to map air quality routes at city hotspots, avenues with high traffic, etc. Sensor data can be complemented by audio recordings through the SOCIO-BEE mobile app (Bee-Mate). Wearable sensors can also be used in a workshop format, organizing walks with citizens in predetermined routes.

Scenario 2

Citizens measure air pollution through stationary sensors installed in their balconies or windows. Air quality can be measured at different heights. For example, to involve different target audiences (particularly in Ancona), an intergenerational approach can be applied targeting youngsters helping their grandparents installing the sensors and understand how they work.

Scenario 3

Citizens or organizations who possess a drone flying license fly their drones after completing a training session and capture images related to air pollution. This way we would overcome the problem that attaching a sensor to the smallest drones would exceed the legal weight limit.

Scenario 4

Pilot cities use stationary sensors in strategic public places at local shops, restaurants, road signs or traffic lights.

Scenario 5
Pilot cities use sensors attached to vehicles such as buses or cars. Using buses with fixed schedules and fixed routes can help measure air pollution in different points in time under different external conditions. Using cars / motorcycles with no fixed routes can help measure air pollution in different geographical locations.

Scenario 6
Citizens can build their own air quality sensors and experiment with them in controlled environments. DIY approach can help citizens learn new skills, have higher ownership, and can result in potential (unexpected) innovations. This scenario is less likely, since it is not foreseen to build and use sensors besides the WSN provided by Bettair. In addition, DIY sensors tend to be far less accurate and often poorly calibrated (compared to the Bettair sensor). This increases the risk of scientifically poor data that might inform citizens wrongly. And in general, the technological know-how needed to build a DIY sensor is often quite substantial, not fostering inclusivity.

Scenario 7
Pilot cities measure air pollution through sensors attached to kites or balloons. They could be used as part of the "build your own sensor" initiative. This scenario is less likely, since it is not foreseen to build and use sensors besides the WSN provided by Bettair. In addition, DIY sensors tend to be far less accurate and often poorly calibrated (compared to the Bettair sensor). This increases the risk of scientifically poor data that might inform citizens wrongly. And in general, the technological know-how needed to build a DIY sensor is often quite substantial, not fostering inclusivity.

5 Inclusion and diversity in CS & in SOCIO-BEE

In SOCIO-BEE, inclusion has a central and explicit role with the aim of creating a holistic view from an **engagement, communication, and legal perspective**. To accomplish this goal, SOCIO-BEE intends to make inclusion an integral part of the project narrative in various ways: **first**, by specifically targeting vulnerable social groups (i.e., elderly and minors) in two out of the three pilot sites and designing engagement strategies that are open to participants with diverse socio-cultural, socio-economic, educational, and ethnic backgrounds, and at the same time targeted to the specific audience we would like to reach (e.g., different mix of in-person and online recruitment and support, targeted messages for attracting participants and encouraging them to make small changes in their everyday lives). **Second**, the communication materials are aimed to be created and distributed in a way that no one feels excluded, for example using accessible language and inclusive colours and visual elements through a variety of online and physical channels. **Finally**, in Task 6.3 of WP6, an inclusion checklist is being created in various iterations to ensure equal, inclusive, diverse, and non-discriminatory participation in the project.

The SOCIO-BEE philosophy: inclusion is a state of mind. It is about how we respond and adapt to when we are confronted with the fact that someone felt excluded. Striving for inclusive spaces is a non-ending learning journey.

Based on an extensive literature review, past project experiences and ongoing discussions with experts and consortium partners, below we have **12 recommendations** [46] for future Beekeepers on how to design an inclusive CS initiative.

1. ***Invite actors of the quadruple helix to the conversation*.** Establishing a dialogue and co-creative practices early on between the public, (local) governments, academia, and industry has the potential to enhance active, inclusive, and wide participation in citizen science projects.

2. ***Have clear definitions, objectives, and KPIs for inclusion already at proposal level*.** We recommend clearly defining the social groups the project intends to reach, establishing clear goals, and developing measurable indicators for each goal already at the time of writing the project proposal. All partners should have a common, shared understanding from the beginning. The project objectives should be realistic, taking into account the potential tradeoffs between wider public participation and data usability.

3. ***Include partners and stakeholders with expertise in engaging those you want to engage***. Next to a general call for participation through offline and online channels, we propose following a specific engagement approach by involving (intermediary) organizations that already have contact and expertise with vulnerable groups.

4. ***Understand the barriers to participation***. One of the main reasons CS projects don't go beyond engaging the "usual suspect" is that the barriers of participation are too high for individuals with different backgrounds. Such barriers are often invisible to project organizers. For example, interest in science and technology is considered one of the most important motivations for participation, yet not everyone has prior knowledge or training to carry out the tasks determined in the project. Thus, project organizers should dedicate time to discover the different barriers to participation among their target groups and design the tasks accordingly (see the SOCIO-BEE inclusion checklist for self-assessment).

5. ***Center your strategy around the margins***. As a general rule, we recommend designing the project in a way that it is open to vulnerable groups (the specific target audience depends on the scope of the project). If this mindset is shared among all stakeholders from the beginning, every step can be designed inclusively or corrected along the way.

6. ***Publish participant demographics***. We encourage project organizers to collect demographic data on participants in every project and make them publicly available, so we have a better understanding of the different participant profiles. This should always be conducted with guidance from experienced data protection officers.

7. ***Make inclusion context-specific, taking into account local social realities***. While it is not possible to make every CS project accessible to everybody, project organizers should aim for an inclusive design by taking into account the local context of the challenge they are trying to solve. In some cases, this might mean focusing on people living in the poorest neighborhoods of a city, while in others, the focus might be on a specific age group such as older adults or children.

8. ***Use inclusive language according to the target audience***. Since over 90% of CS is communication, it is important to set the right tone with participants at every stage, and to consider their background, motivations, interests, and preferences.

9. ***Make interaction with the project flexible***. Being able to choose from different activities and complete them in their own time can better motivate participants with different barriers to interact with the project. Within the local context, vulnerable groups or their representative organizations should be involved in designing tasks according to their needs and resources.

10. ***Accommodate special needs*.** An inclusive CS design also entails that participants' specific needs need to be considered in every phase of the project. For example, training materials, communication channels, feedback, and support might need to be adapted to the target audience.

11. ***Be open to making mistakes and fixing them***. Striving for inclusion is a non-ending learning journey through which mistakes inevitably happen. It is not about having all answers ready but about how we adapt when we are confronted with the fact that someone feels excluded. It is also important to share these learning experiences (i.e., good and bad practices) with stakeholders outside the project to advance the overall knowledge on inclusive CS.

12. ***Protect your participants***. As the 10th principle of the European Citizen Science Association's (ECSA) 10 principles[47] of citizen science states, responsibility for complying with ethical requirements falls entirely on those developing the project. Participants should always feel safe that their rights are being protected. Thus, project organizers should always consult and/or collaborate with experts in ethics and law. This is particularly important when working with vulnerable social groups to make sure that no unintended harm is caused by involving them in the project, (e.g., causing emotional distress to participants by making them aware of a socio-environmental challenge or through inadequate engagement and communication practices).

6 Towards targeted strategies in the three pilot cities

While the overall engagement and communication toolkit of SOCIO-BEE follows one narrative, and consists of basic building blocks, it is also important to customize some elements of the strategy according to the pilot cases specific needs and goals. Below, there is a brief assessment of each pilot case considering the currently available information within the consortium, as well as recommendations to help creating targeted strategies to be implemented in the large-scale data-collection campaigns. **This section builds on D2.8 and follows the structure of the four hive creation phases: preparation, execution, monitoring, evaluation. In D5.6, detailed campaign templates were filled out by each pilot partner** including the goal of the specific campaign (e.g., effect of green areas on AQ), stakeholders involved, workplan, locations, equipment, and desired outcomes. The aim of this section is to provide a more holistic overview of how the proposed engagement strategies can be translated to pilot level and their entire ecosystems for the whole project duration.

6.1 Zaragoza

Preparation

The main goal of this pilot is to increase local population's awareness on air quality. Particularly, the target audience involve children and adolescents between 11 and 16 years old. At the time of writing this deliverable, the main concern is not receiving enough information on the SOCIO-BEE technology in time to be able to develop engagement activities for the next school year.

The pilot will follow a specific recruitment strategy through ETOPIA centre, the hotspot in the city for organizing educational and CS activities for schools. Thanks to ETOPIA, Zaragoza Beekeepers (i.e., municipality and IBER employees) are able to reach a large number of children and teenagers of various age groups and with different social, educational and economic backgrounds (potentially hundreds a month).

Besides Beekeepers, teachers and educators visiting ETOPIA are expected to take upon Queen Bee roles, while students will be Worker Bees. Given that citizen scientists in this pilot are minors, and parents need to be involved (e.g., asking for consent), they might also participate as Drone Bees, and perhaps as more active participants in later stages.

In this phase, it is of utmost importance to provide educators enough time, support, and materials to be able to integrate the educational activities in the school curricula.

Execution

The objective of the execution phase is carrying out (physical) activities with children and youngsters to varying difficulties. The main focus of the pilot case is engaging the target population using the WSNs. Workshops such as "*why air quality matters*" and "*how the SOCIO-BEE technology works*" could be interesting modules to develop and engage children with different backgrounds equipping them with important environmental and science skills that they can use in the future. A slide deck was developed by WP2 on all aspects of the project that can be adapted to different pilot needs. In terms of data-collection campaigns, scenarios 1, 6 and 7 are recommended to be explored further. In addition, social media and the SOCIO-BEE platform could play a primary role in this pilot case including gamification, photo voicing, quizzes, school competitions and digital storytelling.

Monitoring

The ETOPIA centre has an extensive experience working with children and using different technology, the monitoring will be carried out by the ETOPIA Queen Bees and the schoolteacher Queen Bees. All activities the children complete will be supervised, thus making sure that the tasks are understandable, enjoyable and no unintended harm is done. It is expected that the monitoring will be rather informal on an ongoing basis, as the campaign advances. Thus, it is important to set up close contact with the Queen Bees in Zaragoza and pilot partner, so the consortium receives all relevant information with the minimal time delay.

Evaluation

Given that the standard pre-, and post-evaluation questionnaires might not be understandable for all age groups participating in the campaign, it is recommended to 1) create a simplified version of the questionnaire focusing on the questions on awareness, knowledge and everyday behaviours, and/or 2) organize a follow-up activity to show and explain to the children the measurement results and ask them

what they liked, what they did not like, what they learned and what changed since their participation in an informal and friendly atmosphere.
For disseminating results and to reach a wider audience, communication and hive consolidation activities, social media and the SOCIO-BEE platform play a primary role in this pilot case including storytelling, infographics, fact sheets, summary and technical reports.

6.2 Ancona

Preparation
The goal of this pilot is to increase awareness on air quality and encourage outdoor physical activities, as well as to map AQ routes in the city. Particularly, the pilot aims to target older adults above 65 years. The main concern at the time of writing this deliverable is not being able to motivate the target population to participate in SOCIO-BEE. For recruitment, it is recommended to use a specific engagement strategy, mainly through existing channels of organizations' network. Ideally, the pilot is able to identify hotspots in the city (similar to ETOPIA) for older adults. The stakeholder mapping exercise conducted within the project is a good starting point. Prior to recruitment, it is highly recommended to organize focus groups to better understand the local elderly populations' motivations and barriers to participate and to create targeted messages and materials for the later stages.

Execution
Hive development in the first piloting phase will take place mainly through physical activities. Following the input from potential participants, it is suggested to create targeted workshops (e.g., socio-bee breakfast, bingo club) and pop-up stores in streets to grab the attention of and engage the target population. Regarding workshops content, introduction to air quality (including tips on how to reduce air pollution), and introduction to the SOCIO-BEE technology through a walking workshop could be interesting to explore in this pilot case. A slidedeck was developed by WP2 on all aspects of the project that can be adapted to different pilot needs. Scenarios 1,2 and 4 are recommended to be explored. In terms of feedback, physical follow-up events can be organized with participants, as well as making the SOCIO-BEE results visible in the city (data awareness action), for example through large interactive dashboards (e.g., in bus stops). Storytelling is also important, which can be moved from the digital sphere to physical workshops. However, it is equally important to build and use digital communication strategies in this pilot, particularly when the large-scale testing takes place and different target populations might participate. In this phase, Ancona could learn best practices from Maroussi (targeting the general population) as well as Zaragoza (targeting youngsters). For example, an inter-generational approach could be set up through which the municipality targets schools following Zaragoza's best practices. The generally digitally native children and youngsters could help their grandparents setting up sensors and explain how the SOCIO-BEE technology works.

Monitoring
Monitoring will be overseen by the pilot partner. It is important that the Queen Bees in Ancona have a close contact with the pilot partner to give feedback and report any issues. The consortium has set up a rapid communication channel (Slack) where the pilot partner can report on the monitoring on an ongoing basis. It is also recommended to create a monitoring form that can be shared with all the consortium and external partners.

Evaluation

For evaluation, the set of questionnaires developed in WP5 will be used. For disseminating results and to reach a wider audience, communication and hive consolidation activities, social media and the SOCIO-BEE platform play a primary role in this pilot case including storytelling, infographics, fact sheets, summary and technical reports.

6.3 Maroussi

Preparation

The main goal of this pilot city is to map AQ routes in the city, and to increase the general population's awareness on air quality. A major concern at the time of writing the deliverable is low data quality, and not having enough data as a result of the project. It is recommended to follow both generic and specific strategies, through social media and through existing channels and hotspots of the municipality's network. Before the recruitment phase, it is highly suggested to run a survey in the general local population to better understand motivations and barriers, as well as preferences in relation to the project.

Execution

In the development phase, physical and digital activities should take place simultaneously. In the Maroussi pilot case, there is no specific target population making social media and digital channels a cornerstone of both recruitment and support, next to the municipality's existing channels. Prior projects indicate that when the general population is targeted to participate in a CS project, one of the most important motivating factors are interest in science and technology. This suggests that the recommended training modules and ambassador program can be best explored in this pilot. Workshops such as "*making sense of the data*", "*introduction to air quality and technology*" are recommended. Workshops on technology can take a "walking workshop" format showing participants how the SOCIO-BEE technology works in action. Scenarios 1,2,3, 4 and 5 can be further explored in this pilot. In addition, the SOCIO-BEE platforms and social media can be exploited through photo voicing, storytelling, and quizzes.

Monitoring

Monitoring will be overseen by the pilot partner. It is important that the Queen Bees in Ancona have a close contact with the pilot partner to give feedback and report any issues. The consortium has set up a rapid communication channel (Slack) where the pilot partner can report on the monitoring on an ongoing basis. It is also recommended to create a monitoring form that can be shared with all the consortium and external partners.

Evaluation

For evaluation, the set of questionnaires developed in WP5 will be used. For dissemination, social media channels play an important role sharing infographics, stories, quick facts with citizens, as well as summary and technical reports with other stakeholders. For the large-scale testing, knowledge from the Zaragoza pilot can be shared with Maroussi, since targeting the younger generations can be beneficial not only in terms of increasing awareness but also enhancing future digital skills.

7 Behavioral change & air quality

The SOCIO-BEE project aims not only to engage citizens to participate in data-collection campaigns but to **encourage participants and non-participants to make changes in their daily lives, thus contributing to the reduction of air pollution.** However, while behavioural change is a declared goal in many CS initiatives, research is scarce on providing a clear conceptualization and measurement, particularly in relation to air quality (AQ). In order to provide insights for the subsequent stages of SOCIO-BEE, for example, for the development of the (1) toolkit in WP2 (D2.8 and D2.9), gamification and recommender system in the SOCIO-BEE app in WP4 (T4.1), (3) engagement campaigns in WP5 (T5.6), a 1) **scoping review** was conducted, followed-up by an 2) **expert workshop**.

7.1 Scoping review

For the overview of prior literature, Web of Science was selected as the main database since it is the most comprehensive reference database for social sciences. In order to arrive to a manageable number of documents for our analysis, we looked at behavioural change in relation to (1) air quality and (2) citizen science and AQ. Keywords were searched in the topic of the references, to keep the pool of records sufficiently broad. No additional restrictions were included. The following two search strings were used:

TS=("citizen science" AND (behav* AND (target OR change)) AND air)
TS=(engag* AND behav* AND (target OR change) AND "air quality")

Overall, 111 documents were retrieved. Following the removal of duplicates, 105 documents remained: 5 conference papers and 100 peer-reviewed articles. The inclusion criteria were established upon reading the abstracts of each article. Articles that were not related to air quality, did not describe behavioural change or did not focus on citizens were excluded. Overall, 16 articles were deemed eligible for in-depth analysis. **Table 6** summarizes the findings of the articles according to the following criteria: (1) scope / conceptualization of behavioural change, (2) methods for measuring behavioural change, (3) stakeholders involved, (4) timeframe, (5) number of participants. **Appendix 4** lists the selected sources from the literature.

The results indicate that the most widely used conceptualization of behaviour change related to AQ is increased awareness, reduced exposure through changing routes and reduced personal emission through changing mobility habits or other environmentally conscious behaviour. Popular methods to measure behavioural change include pre-, and post-surveys combined with qualitative methods (e.g., interviews, focus groups), and gamified mobile apps. In most cases, citizens were the research subjects, although, in some instances other stakeholders were consulted such as policymakers, environmental activists, and urban planners. With one exception, measurements were taken during the project duration.

Table 6: Overview of behavioral change articles on air quality and citizen science

Overview of behavioral change articles on air quality and citizen science		
Criteria	**Description**	**Articles**

Scope / conceptualization of behaioural change	***Increased awareness on AQ***	Varaden et al. 2021; Jaskulska et al. 2022; Booker et al. 2022; Grossberndt et al. 2021; Calvillo & Garnett 2019
	Knowledge gain on AQ	Varaden et al. 2021; Jaskulska et al. 2022; Booker et al. 2022
	Exposure reduction: *changing routes*	Varaden et al. 2021; Booker et al. 2022; Rappold et al. 2019; Hubbell et al. 2019; McCarron et al. 2022; Van Brussel
	Personal emission reduction: *mobility habits* *other environmental conscious behaviour*	Di Dio et al. 2020; Booker et al. 2022; Haddad & de Nazelle 2018; Ottaviano et al. 2019; Van Brussel 2019; Somerwill & When 2022
	Behavioral intentions: *mobility habits*	Grossberndt et al. 2021; Haddad & de Nazelle 2018; Gao et al. 2017; Somerwill & When 2022
	Word-of-mouth: *informing others on AQ*	Van Brussel 2019
	Negative consequences: *time spent outdoor* *less physical activity* *higher levels of anxiety* *worsened disparities/inequality*	Ward & Beatty 2016; Hubbell et al. 2019
Methods measuring behavioral change	***Pre / post surveys***	Grossberndt et al. 2021; Rappold et al. 2019; Van Brussel
	Mixed quantitative and qualitative methods: *pre/post-surveys* *cross-sectional surveys* *interviews* *focus groups*	Varaden et al. 2021; Haddad & de Nazelle 2018; Gao et al. 2017; Ottavio et al. 2019
	Gamified app: *burnt calories* *saved emitted CO2* *O2 points as virtual currency rewarding greener behaviors* *educational messages* *recommendations to change behavior*	Di Dio et al. 2020; Jaskulska et al. 2022; Rappold et al. 2019; Ottaviano et al. 2019

	Mixed qualitative methods: *participatory workshops* *interviews* *art installations and activities* *digital ethnography* *eco picnic* *VR, AR*	Jaskulska et al. 2022; Calvillo & Garnett 2019
	Interviews	Booker et al. 2022
	Longitudinal survey	Ward & Beatty 2016
	Systematic Literature Review	Riley et al. 2021; Somerwill & When 2022; McCarron et al. 2022
	Conceptual	Hubbell et al. 2019
Stakeholders involved	***Multi-stakeholders:*** *parents & teachers & children* *university students & local businesses* *citizens & children & activists & environmental experts* *environmental experts & activist & policymakers & architects*	Varaden et al. 2021; Di Dio et al. 2020; Jaskulska et al. 2022, Calvillo & Garnett 2019
	Students	Grossberndt et al., 2021
	Citizens	Gao et al., 2017; Haddad & de Nazelle 2018; Booker et al. 2022; Calvillo & Garnett 2019, Rappold et al. 2019; Ward & Beatty 2016
Timeframe	***Within project duration***	Varaden et al. 2021; Di Dio et al. 2020; Jaskulska et al. 2022; Rappold et al. 2019
	Beyond project duration	Di Dio et al. 2020; Ward & Beatty 2016
	One point in time	Gao et al. 2017
Sample size	***Below 100***	Gao et al., 2017; Haddad & de Nazelle 2018; Grossberndt et al. 2021; Booker et al. 2022
	Between 100-1000	Di Dio et al. 2020; Varaden et al. 2021; Jaskulska et al. 2022 Di Dio et al. 2020
	Above 1000	Rappold et al. 2019; Gao et al. 2017; Ottavio et al. 2019; Van Brussel 2019; Ward & Beatty 2016

7.2 Expert workshop

The scoping review served as a basis for an expert workshop that was organized as a joint effort with the Horizon 2020 CompAir project [48]. The workshop took place during the ECSA Conference on the 7th of October 2022, in Berlin. The biennial event attracts hundreds citizen science experts across a wide range

of disciplines, so it was a great opportunity to explore how to measure and stimulate behavioural change. The workshop had a World Café format, and participants were asked to reflect on two main questions: **1) *How to define and measure behavioural change, and why it's important?, 2) How to stimulate behavioural change, especially among the disadvantaged groups?*** Participants were given cards to note down keywords, and facilitation techniques included hierarchy, voting and clustering.
Overall, the experts' opinions aligned with the findings of prior literature. Most of them suggested that we should define BC from a broad perspective, including awareness, knowledge, and motivations. First, we need to understand where participants stand at the moment of encountering a CS project, so we can measure its impact (pre-, and post-measurements). Participants also stated that a project can stimulate participants to change behaviours to the best of the consortium members' abilities but can't force them. Change should come from within. The favourable conditions mentioned that a project should create were stemming from the motivations participants considered most important. These include, having high agency (e.g., actions are taken on policy-level), creating a learning opportunity for professional or personal development, making sure data is trustworthy and data-collection procedures are transparent, creating a safe and welcoming environment, rewarding participants (with monetary and/or non-monetary rewards).

7.3 Behavioural change and its communication in SOCIO-BEE

In line with the findings from prior literature, in SOCIO-BEE, we apply a broad conceptualization of BC, and consider change in (1) **awareness**, (2) **knowledge**, (3) **air pollution exposure**, (4) **air pollution emission**, and (5) **environmental-conscious behaviours** that were deemed to have the highest impact on AQ as part of it. While increased awareness and knowledge of AQ might not be directly measurable behaviours, under the right circumstances, information may lead to increased awareness, which in turn may lead to positive behavioural changes [36]. However, behavioural intentions will not be part of the SOCIO-BEE evaluation since prior literature has shown that intentions most often do not translate to actual behaviours [49]. **Appendix 1** shows the questions that were / are planned to be used among the general population of participating countries and pilot campaigns.

In terms of measuring behavioural change, SOCIO-BEE applies mixed-methods, through (1) focus groups, (2) surveys, and (3) gamified app involving a diverse audience of CS experts, policymakers, and citizens. At the moment of writing this deliverable, behavioural change evaluation is planned to take place during the second half of the project duration (organic hives).

An important finding of previous studies on BC communication is that engagement with AQ (and environmental) information is not dependent on the accuracy and completeness of the information but on the extent it captures the attention of the audience and results in their involvement. Elements that can trigger engagement include novelty, actionability, and relevance of the information [50]. Prior literature indicates that messages that are framed as improving health will likely to positively impact prevention behaviours (e.g., exposure) and messages that are framed as health damaging will likely to positively impact behaviours that identify that an exposure has occurred [51]. Similarly, Delmas & Kohli (2021)[52] tested various message types of AQ and found that combined positive and negative mixed message presenting a problem and then providing a solution to that message was the most effective message framing among all messages.

In general, the inward and outward communication on BC are organized along the following principles in SOCIO-BEE: (1) **positive message framing**, (2) **hands-on activities and solutions**, (3) **multiple communication channels**, (4) **inclusive mentality**.

In the next steps, BC communication are planned to be integrated in the engagement strategies of the project in various ways. In-person, through workshops. Communication materials shared with the wider audience (e.g., website, social media) and with pilot partners (e.g., WP2 slide deck) already has information on the importance and dangers of air pollution. These materials will be accompanied with activities individuals can do to either to reduce their exposure or their emissions and can be discussed in the preparatory workshops (next to more generic online dissemination). When AQ measurements will be available in the pilot sites, and after making sure participants can interpret the results, the information becomes relevant to the target audience and depending on the level of pollution, the environmental and health prevention (low air pollution) or protection (high air pollution) messages can be activated in participants' minds. One way to ensure this, is to integrate these messages in the recommendation engine of the SOCIO-BEE app, e.g., as pop-up messages. The recommendation engine could also go a step further, and if participants are willing to disclose personal information such as health status, more personalized messages could appear. For example, people with asthma and older adults are more vulnerable to air pollution and need to take extra precautions when air quality is low. Another way could be the integration in the gamification engine, e.g., rewarding participants for different healthy behaviours. Finally, it is important to use plain and inclusive language and avoid that participants become discouraged, if, for example, they relapsed in some of their behaviours. This can be done by communicating that every small step counts and assuring them that they have not failed if they have not achieved a specific goal in a specific timeframe.

As stated above, SOCIO-BEE considers AQ awareness and knowledge as part of behavioural change. It is equally important that participants feel more aware and more knowledgeable after encountering SOCIO-BEE on some level than before, as the actual behaviours they change in their everyday lives. The following elements, which are directly related to the SOCIO-BEE KPIs, are recommended to be translated to BC communication:

1. **AQ awareness**
    - Being aware that air quality is measured in one's city / neighbourhood
    - Being aware of the level of air quality in one's city / neighbourhood at different time points
    - Initiatives to tackle air pollution in one's city / neighbourhood

2. **AQ knowledge**
    - Causes of air pollution
    - Health effects of air pollution
    - Understanding the AQ values that are being measured (e.g., PM)
    - Things one can do to reduce exposure to harmful pollutants
    - Things one can do to reduce contribution to air pollution

3. **Exposure reduction**
    - Intentionally avoiding high-traffic roads when walking or biking
    - Avoiding travelling in rush hour
    - Avoiding being outside when air pollution is high
    - Wearing a mask when air pollution is high

4. **Pro-environmental behaviours**
    - Riding a bike or taking public transport to work/school
    - Rather walking than driving
    - Carpooling with friends / family / neighbours / co-workers
    - Turning off engine when one's car is not moving in traffic
    - Riding a bike or using public transport to nearby areas (under 30km)
    - Limiting airline travel when there are other mobility options
    - Limiting burning wood or coal
    - Buy products with as less packaging as possible
    - Pointing out an ecological behaviour to someone
    - Talking with others about environmental pollution
    - Boycotting a company with an unecological background
    - Reading about environmental issues

7.4 Preliminary survey results

In order to have an overview of the current situation regarding AQ awareness, knowledge, attitudes and behaviours in the participating countries (i.e., Greece, Italy, Spain), a large-scale cross-sectional survey was conducted using Prolific in July 2023 (see Appendix 1 for questions)[9]. 1127 responses were obtained in total. The mean age range was between 26-39, and gender balance was almost ensured with 46% of participants being female. Most participants did not have any children (63%), were paid employees (39%) or students (23%) with a bachelor's or master's degree (73%).

AQ concern, knowledge, and perceived impact on policy

Three questions were presented to participants on their level of concern regarding the air quality in their city/neighbourhood, their knowledge on different AQ aspects and their perceived ability to have an impact on policymaking related to AQ. Questions were measured on a 5-point Likert-type scale. The results indicate that most participants are somewhat concerned about AQ (M=3.3, SD=0.37). On the other hand, participants' perceived impact on policymaking is rather low (M=2.8, SD=0.56). Knowledge on AQ varies, with the higher perceived knowledge on the causes of air pollution (M=3.44, SD=0.77) and health effects (M=3.43, SD=0.84) and lower perceived knowledge on current levels of air pollution in their neighbourhoods/cities (M=3.03, SD=0.99), initiatives in the city to tackle air pollution (M=2.4, SD=1.1), reducing one's exposure (M=2.9, SD=0.97) and contribution to air pollution (3.15, SD=0.96).
These results indicate that SOCIO-BEE has the potential to make a difference using the right engagement and communication tactics in the pilot cities, since the general population seem to have limited awareness on AQ.

Preferred sources of AQ information

When participants were asked from which sources they would prefer to receive information on AQ, surprisingly, the vast majority indicated **academic scientists (73%**), the **internet (50%)**, **local administration (47%)** and **central government (41%). Figure 4** shows all potential sources with the corresponding percentages to receive AQ news and information. This result gives a great opportunity to

[9] A more in-depth analysis of the survey will be provided in D2.2.

SOCIO-BEE given that most partners in the consortium are academic scientists and/or belong to the local administrations of the pilot cities. Therefore, it is important to communicate to the public trustworthy and transparent AQ information (indicating for example, the source, how the information was obtained or calculated etc.,) that is relevant on the local neighbourhood or city level.

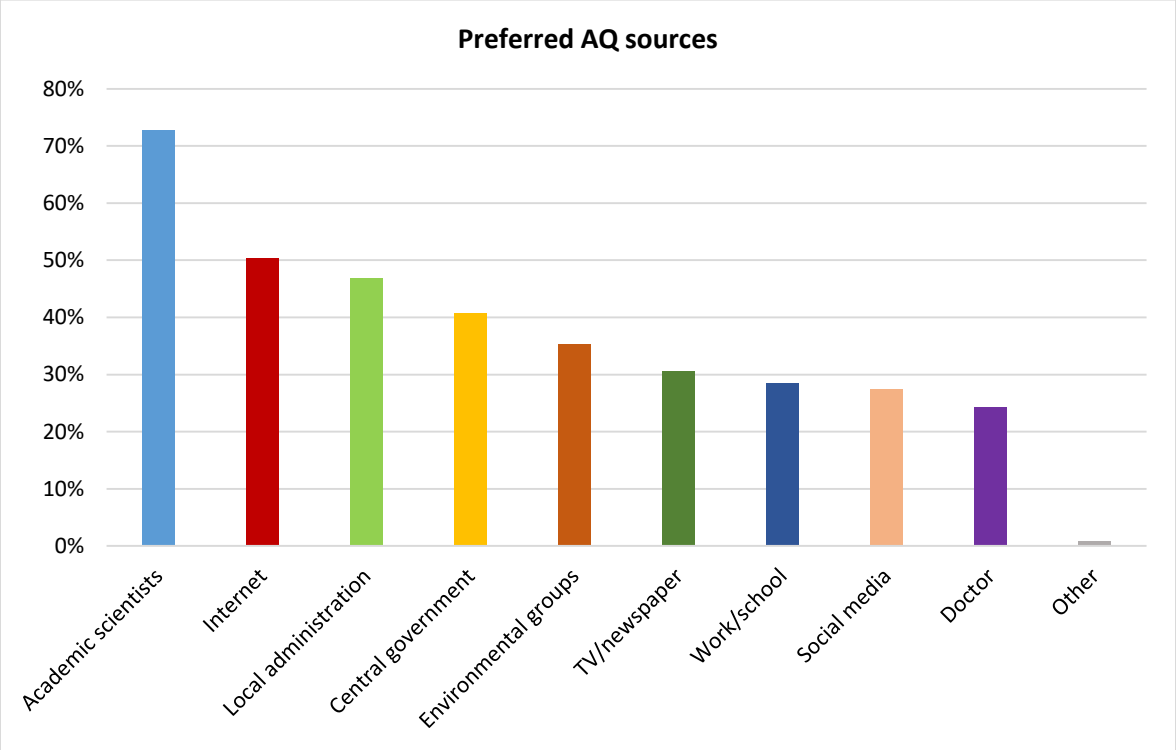

Figure 4: Preferred sources to receive information on air quality

Potential Bee profiles

After reading a hypothetical scenario of the SOCIO-BEE project, participants filled out the **profiling** part of the questionnaire. Developed by DEUSTO, this part consisted of six questions measured by a 5-point Likert-type scale. Depending on one's score, three questions were applicable to Queen Bees, three questions were applicable to Worker Bees and two questions were applicable to Drone Bees. The participant's mean score was calculated for each profile, and the profile in which the participant scored the highest was assigned to them. If the participant scored 2 or lower out of 5, the Larvae profile was assigned to them. For this question, 1078 usable responses were obtained. **Figure 6** shows the distribution of the different profiles. In line with our expectations, **50%** of participants, which is the largest group, see themselves as **Worker Bees**, where the main task is data collection. About **22%** of participants opted for being **Drone Bees** and would only commit of spreading the word of the project. However, contrary to previous project results, the percentage of **Queen Bees** is relatively high with almost **26%.** This indicates that participants have a high level of motivation to organize Hive activities. Therefore, the consortium's, and the pilot partners' engagement and communication efforts should focus on potential Queen Bees in the organic hives.

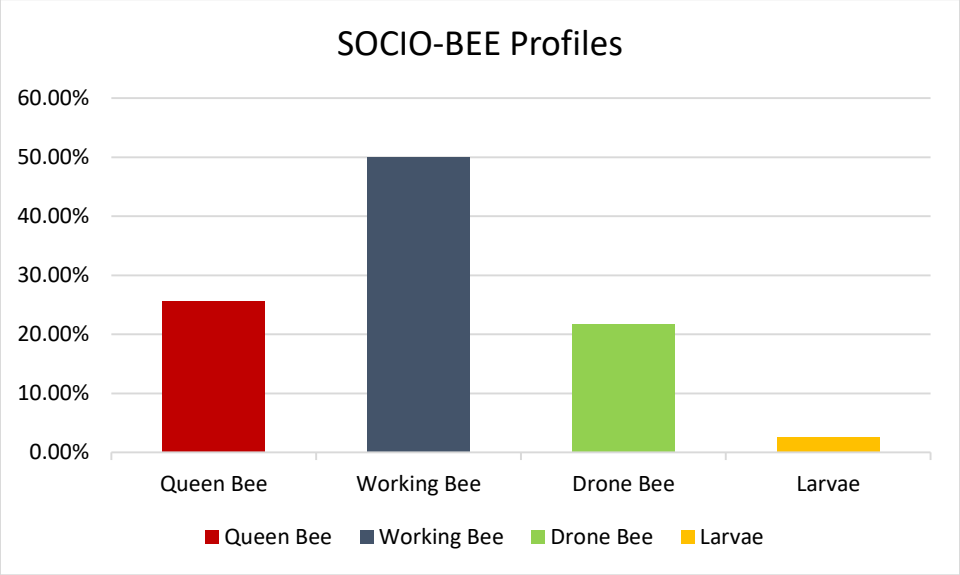

Figure 5: Potential SOCIO-BEE Profiles in the general population of the participating countries

8 Conclusion & next steps

This deliverable provides an important contribution to defining the overall engagement methodology of SOCIO-BEE, and lays the groundwork for WP2, WP4, WP5, WP6 and WP8. The second release of this deliverable provides on overview of potential engagement and behavioural change strategies to support Beekeepers, Queen Bees and other stakeholders. The engagement strategies include online and offline building blocks that can be used in different stages of the Hive life cycle (i.e., preparation, execution, monitoring, and evaluation) working towards targeted recommendations to the pilot cities. Furthermore, the deliverable identifies the concept, scope, measurement, and communication of behavioural change in SOCIO-BEE and shows a snapshot of the current situation in the general population of the participating countries. The survey results indicate the level of AQ awareness and knowledge, barriers and motivations to participate in CS, and the distribution of potential types of bees. In the next stages of the project, close collaboration is needed with the technological, pilot and communication partners to effectively prepare the large-scale campaigns and translate the recommendations of this deliverable to real-life actions.

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Annex I

Appendix 1

SOCIO-BEE Prolific Questionnaire

SOCIO-BEE Questionnaire on awareness, behaviours and motivations in relation to participating in a (fictional) AQ data-collection campaign		
Construct	**Question**	**Answer (5-point Likert scale)**
Concern about air pollution	I am concerned about the levels of air pollution in my city / neighbourhood.	Strongly disagree - Strongly agree
	In my opinion, air pollution in my city / neighbourhood has a negative effect on human well-being.	
	I feel that I can take actions that will reduce my individual source of air pollution	
	I feel that there is NOTHING I can do to decrease the air pollution I am personally emitting.	
	I think that I am able to cut back my individual contribution to air pollution.	
	In my opinion, air pollution is NOT a severe matter in my city / neighbourhood.	
Knowledge on air pollution	Causes of air pollution.	Nothing - A great deal
	Air pollution health effects.	
	Air pollution levels in your city/ neighborhood.	
	Initiatives to tackle air pollution in your city / neighbourhood.	
	The things you could do to reduce exposure to harmful pollutants.	
	The things you could do to reduce your contribution to air pollution.	
Perceived impact on policymaking	I feel that my concerns are taken into consideration by the local policy makers in my city / neighbourhood.	Strongly disagree - Strongly agree
	As a citizen, I believe that my voice is heard when the local policy on air quality is being made.	
	Right now, I think that policy makers do NOT care about the opinion of the citizens on air quality.	
Pro-environmental behaviors[10]	I ride a bike or take public transport to work or school.	Never - Always (Not applicable)
	If possible I rather walk than drive a car.	
	I carpool with friends / family / neighbours / coworkers.	
	I turn off the engine when the car is not moving in traffic.	
	In nearby areas (under 30 km), I use public transport or ride a bike.	
	I limit airline travel if there are other mobility options (e.g., railway, bus, etc.).	
	I limit the burning of wood or coal.	
	I buy goods with as less packaging as possible.	
	I have pointed out unecological behavior to someone.	
	I talk with others about environmental pollution / climate change.	
	I boycott companies with an unecological background.	

[10] Due to the length of the survey, this question was not distributed to the Prolific participants. However, we aim to measure pro-environmental behaviours within the project, as part of the data-collection campaigns.

	I read about environmental issues.	
	Other	
Outdoor air pollution exposure reduction	If I walk/bike, I intentionally avoid high-traffic roads.	Never - Always (Not applicable)
	I avoid travelling in rush hour.	
	If the air pollution level is high, I avoid being outside.	
	If the air pollution level is high, I wear a mask or protect my nose/face with some fabric.	
	I keep my car windows closed when moving in traffic.	
	Other	
Barriers for participation	I do not have time.	Strongly disagree - Strongly agree
	I do not have the financial resources.	
	I do not have the necessary skills or capacities.	
	It will not have any impact on my district / city.	
	It seems too complex to get involved and to participate.	
	It is focused on direct commercial or political benefit preventing the social and environmental aims.	
	It has an excessively hierarchical organization, decision-making is concentrated and there is insufficient transparency of the outcomes.	
	It doesn't allow different levels of participation and commitment.	
	It does not assess social and environmental value created or destroyed through the campaign.	
Motivations for participation	Profits are what guide my decision-making, I always prefer to earn or save money with every decision I take when participating in an Air Quality campaign.	Strongly disagree - Strongly agree
	Access to funding (my own savings, deductions, exemptions, and/or credits) is the main factor that allows me to make a decision of participating in an AQ campaign.	
	The evaluation of the risks of my participation in an AQ campaign is what will always guide my final decision.	
	I will only join an AQ campaign if my actions have an impact beyond the monetary gain/losses.	
	I am a thrifty person, so I only volunteer in actions that allow me to reduce my cost/impact/expenditures.	
	Every decision I take serves to foster the planet's preservation. If my choice might harm the environment, I will always avoid taking this action.	
	Having complete certainty that my actions comply with the legal, tax, and administrative regulations is what guide my actions.	
	I only make decisions to volunteer campaigns if I trust all the parties involved (e.g., public administration, neighbors) and the technology needed to accomplish my goal.	
	I only make decisions related to join AQ campaigns if the outcome of them ensures or improves my safety or the ones of my relatives.	
	I always review and assess the pros and cons of my decisions looking for the most cost-effective option.	
	I only make decisions if I have enough knowledge of the subject matter, in this case about AQ.	

	Feeling that I am competent to make an investment is what guides my decision-making when joining an AQ campaign.	
	I carefully check that the technology or equipment fits my lifestyle or the technical requirements before making a decision related to the use of technology for an AQ campaign.	
	I always review and assess the pros and cons of my decisions in relation to the environment before making a decision related to joining an AQ campaign.	
	I will only make a decision if I feel satisfied with the action and the expected outcome.	
	I only make a decision if I feel personally committed to the action and the expected outcome.	
	I will only make a decision if I feel I can sustain it.	
	Self-sufficiency and individual sovereignty are what guide my decisions. I will only make a decision related to joining an AQ campaign if I feel that the time invested will improve my control of all circumstances and potential outcomes.	
	I will only make a decision if it improves my well-being or the well-being of my relatives.	
	I will only make a decision if it improves my comfort or the comfort of my relatives.	
	I firmly believe that we live in a society where we have to adhere to regulations, laws, and community agreements by all means, so my decision to join a campaign has to agree with this vision.	
	My decision to join an AQ campaign is influenced by the opinions of others (such as my peers, relatives, or family).	
	I will only make a decision of joining an AQ campaign if it has the approval or support of the community I belong to.	
	I will only make a decision of joining an AQ campaign if it improves my possibilities to socialise with my peers and relatives.	
	I will only make a decision of joining an AQ campaign if the people affected by it (for example, my relatives, peers, or the community) agree with the decision cohesively.	
	I love to test new ideas and cutting-edge technology, so novelty is what drives my decision to join an AQ campaign.	
	Having fun is important to me. Therefore, I will only make a decision if it would be enjoyable and amusing for me.	
	I usually make decisions that lead to my increased status and I can show others what I achieved.	
	I usually follow the trends when making a decision. In particular, I usually find myself sticking to the ads I see, the recommendations of people I admire, or what I read in magazines or blogs I follow.	
	I only make a decision if it helps me improve my position as an expert on the subject matter.	
	I only make a decision of joining an AQ campaign if it improves my peers' opinions about me, even if this decision is not always what I would do only for myself.	
	I only make a decision if the action has a personal, inner meaning for me.	
Bee profiles	I would be willing to participate in collecting air pollution data while walking or roaming the city and no more (e.g., one or two hours of commitment per week to go to specific points close to the area where you usually roam).	Strongly disagree - Strongly agree

	I would be willing to study the outcomes of the air pollution campaigns and learn how to interpret the results (e.g., two to three hours of commitment per week to join other peers to collectively understand the data and information that is collected in order to make sense of it).	
	I would be willing to approach people I know to collaborate with me to gather more and better air pollution data (e.g., one day of commitment per week to think about ways and strategies to involve more people in the pro-environmental campaigns. This includes recruiting skills but also communication competences to easily make others understand your goals).	
	I would be willing to organise data collection campaigns on my neighbourhood / community (e.g., one day of commitment per week to define steps to carry out the pro-environmental campaign. Coordination and organizational skills are a plus to help running the campaigns successfully).	
	I can or I would like to reach out to third parties (e.g., policymakers, business actors, scientists, etc.) to promote changes in my neighbourhood / city / region based on the results of the collected air pollution data (e.g., one or two hours of commitment per week to spread the word about the results in social media, newspapers, or through other channels such as the citizens' mailbox or other communication means).	
	I can or I would be willing to share outcomes of the campaign with others and alert them on the consequences of air quality on our health and planet (e.g., one or two hours of commitment per week to assembly other peers and citizens to collectively think about ways to make a change in your neighbourhood / city / region).	
Scenario	The local administration of your city has made a commitment to improve air quality and they would like to involve local residents, businesses, non-profit, and academic organizations to achieve this. As a first step, they organise a campaign to know which areas and routes are the most polluted. One day, you come home and you find a leaflet in your mailbox informing you of this campaign asking you to get involved. The leaflet informs you that the local administration has set up a website, developed a mobile application, and acquired sensors that measure the quality of air. A picture of the sensor shows a small device that can be attached to a backpack or a bike and take measurements as you carry it with you. You decide to take a look at the website and the mobile app. You see a map of the city with spots where air quality has already been measured and where it has not. The current level of air pollution is shown and gets updated as more and more air quality data is collected by citizens. There are videos on air quality, social media posts, academic resources, instructions on how to use the sensor, testimonials, and opportunities to join the online community. It is also possible for anyone to download the collected data to their computer and analyse it. You scroll on the map to your neighbourhood and see that no air quality data is available yet.	

Appendix 2

Stakeholder analysis questions

Stakeholder name or group	Stakeholder role	Activities
Please describe the stakeholders who are / will be part of SOCIO-BEE in your pilot. Try to be as precise as possible and if you already know it, name the potential stakeholders.	**Name the role of stakeholder (i.e., Beekeeper, Queen Bee, Worker Bee, Drone Bee, Bear, Larvae)**	**Describe the activities of each stakeholder in the process based on the available role descriptions.**

Barriers of engagement	Motivations to participate	Recruitment strategies and channels
Known or potential barriers / issues related to the stakeholder's engagement in the process. Examples: lack of awareness, lack of technical knowledge, lack of time, data contribution process takes too much effort, technical limitations of sensors or apps, complex communication, technology not user-friendly, lack of attention to training or feedback, inaccessible language or interface, excessive feeling of competition, online reporting system too complicated/burdensome, limited feedback received, contribution not translated to impact, limited engagement between volunteers and organisers, inflexible employer, family committments, lack of financial resources, etc.	**What are the staleholder's motivations to participate?** Examples: contribute to scientific knowledge, learn new skills, have fun, seeing change in local neighborhood, view real time (air quality) information, receive information on how to reduce environmental footprint, have information on other projects, have access to high quality data, share concerns with policymakers and other stakeholders, career development, improve local neighborhood, be involved in a community initiative, interest in new technologies, develop new technologies, health conditions, think about future generations, general curiosity, spend time outside,neighborhood is highly polluted, develop STEM capacities, etc.	**How should the stakeholder be targeted and recruited (i.e., strategies, channels)?** Examples: websites with extensive information (e.g., publications, tools, resources, news, events, data etc.), social media markting, online contests on social media, influencer marketing, app using gamification, influencer marketing, e-WOM, workshops, in-person social and learning events, traditional media channels (TV, radio, newspapers), snowball, provide resources / incentives to employers, training videos, brochures, email, existing channles of specific groups (e.g., teachers' magazines, newsletters), conferences or events related to climate change, partnerships, etc.

Support	What do you need from the SOCIO-BEE Consortium?	How do you plan to involve Bears? (i.e., inform, guide, consult, work with)
How should the stakeholder be involved / consulted / informed throughout the project to overcome barriers and sustain motivations? Examples: technical support, financial support, network creation, training, feedback, provide physical/online space for communication and collaboration, design training packages, etc.	**Please describe what kind of support you need from the SOCIO-BEE Consortium the engage the different stakeholders. You don't need to fill out every box for each stakeholder, try to think along the different roles.**(e.g., Bears, Queen Bees, Worker Bees, Drones…). Examples: meeting with XY partners, templates, guidlines, email/phone support from XY partner for ad-hoc questions, etc.	**Please choose among the four types of involvement and fill out the boxes ONLY FOR BEARS** INFORM: Bears are only informed about results or development situation from the hives. GUIDE: Bears help with their knowledge or resources with carrying out a CS experiment. CONSULT: Bears are contacted before a CS experiment is carried out and their feedback is gathered and processed. WORK WITH: Bears participate in the co-creation process of a CS experiment (design, co-production, evaluation, etc.)

Appendix 3

How to organize a successful workshop?

1. **Workshop package ("workshop toolkit")**

Materials and support for workshops from SOCIO-BEE:

- A facilitation guide with methodology and steps of the workshop
- PowerPoint presentations and additional information for all modules
- Handouts for participants
- Checklists for the preparation of the event (timeline, materials, etc.)
- Promotional materials (press release, templates, flyers, infographics, merchandise, etc.)
- Telephone/email support for the preparation or facilitation of the event
- Suggestions of guest speakers / facilitators (e.g., consortium partners, interested parties in the SOCIO-BEE network)
- Information on materials for technological devices (e.g., sensors)

In addition, the local organizing team needs to:

- Secure and set up the venue
- Promote the workshop locally
- Translate materials, if required
- Receive and/or print workshop materials
- Recruit additional speakers and localize the modules

2. 4-6 weeks before the workshop

Local organizing team:

- Decides on date and location, and inform the SOCIO-BEE partners
- Select the preferred modules as building blocks for the workshop
- Establish needs for materials and order them (if applicable)
- Build links with other local organizations, and spread the invitation
- Invite participants and guest speakers

SOCIO-BEE partners:

- Share date and announcement on website
- Provide toolkit with all modules and facilitation guide
- Provide access to network of interest and social media for suggestions
- Provide support to writing invitations (if necessary), and use SOCIO-BEE social media to spread the invitation

3. Two weeks before the workshop

Local organizing team:

- Second round of invitations (focus on social media, or other channels depending on the target audience, ask partners to invite their networks)
- Send reminder to participants; share current numbers of participants with the SOCIO-BEE team

- Refine/adjust modules, read through facilitation guide, formulate clear goals and outcomes, print handouts
- Discuss workshop content and steps with guest speakers
- If needed, translate the presentations and handouts to the local language
- Check order and delivery of materials

SOCIO-BEE partners:

- Use SOCIO-BEE social media to spread the invitation
- Short telephone / mail support if needed, share best practices

4. In the week of the workshop

Local organizing team:

- Send a reminder to participants
- Collect all materials at one location, print handouts
- Last check with guest speakers

SOCIO-BEE partners:

- Short telephone / mail support if needed

5. The week after the workshop

Local organizing team:

- Send good quality pictures / video footage to SOCIO-BEE
- Write a short report / blog post about the workshop (or ask participants to do so)
- Gather feedback from participants through the feedback form

SOCIO-BEE partners:

- Use pictures, videos for social media, communication, dissemination activities
- Spread the post on social media
- Provide feedback form

Appendix 4

Selected articles of the scoping review on behavioural change

1. Calvillo, N., & Garnett, E. (2019). Data intimacies: Building infrastructures for intensified embodied encounters with air pollution. The Sociological Review, 67(2), 340-356. DOI: 10.1177/0038026118819602
2. Di Dio, S., Massa, F., Nucara, A., Peri, G., Rizzo, G., & Schillaci, D. (2020). Pursuing softer urban mobility behaviors through game-based apps. *Heliyon*, *6*(5). DOI: 10.1016/j.heliyon.2020.e03929
3. Booker, D., Walker, G., Young, P. J., & Porroche-Escudero, A. (2023). A critical air quality science perspective on citizen science in action. Local Environment, 28(1), 31-46. DOI: 10.1080/13549839.2022.2015372
4. Gao, J., Xu, G., Ma, W., Zhang, Y., Woodward, A., Vardoulakis, S., ... & Liu, Q. (2017). Perceptions of health co-benefits in relation to greenhouse gas emission reductions: A survey among urban residents in three Chinese cities. *International Journal of Environmental Research and Public Health, 14*(3), 298. DOI: 10.3390/ijerph14030298
5. Grossberndt, S., Passani, A., Di Lisio, G., Janssen, A., & Castell, N. (2021). Transformative potential and learning outcomes of air quality citizen science projects in high schools using low-cost sensors. *Atmosphere*, *12*(6), 736. DOI: 10.3390/atmos12060736
6. Haddad, H., & de Nazelle, A. (2018). The role of personal air pollution sensors and smartphone technology in changing travel behaviour. Journal of Transport & Health, 11, 230-243. DOI: 10.1016/j.jth.2018.11.007
7. Hubbell, B. J., Kaufman, A., Rivers, L., Schulte, K., Hagler, G., Clougherty, J., ... & Costa, D. (2018). Understanding social and behavioral drivers and impacts of air quality sensor use. *Science of the Total Environment*, *621*, 886-894. DOI: 10.1016/j.scitotenv.2017.11.124
8. Ward, A. L. S., & Beatty, T. K. (2016). Who responds to air quality alerts?. *Environmental and resource economics*, *65*, 487-511.
9. Jaskulska, A., Skorupska, K., Bubrowska, Z., Kwiatkowska, K., Stawski, W., Krzywicki, M., ... & Kopeć, W. (2021, December). Participatory Action for Citizens' Engagement to Develop a Pro-Environmental Research Application. In *Conference on Multimedia, Interaction, Design and Innovation* (pp. 198-207). Cham: Springer International Publishing. DOI: 10.1007/978-3-030-70880-9_18
10. McCarron, A., Semple, S., Braban, C. F., Swanson, V., Gillespie, C., & Price, H. D. (2022). Public engagement with air quality data: Using health behaviour change theory to support exposure-minimising behaviours. *Journal of Exposure Science & Environmental Epidemiology*, 1-11. DOI: 10.1038/s41370-022-00449-2
11. Ottaviano, M., Beltrán-Jaunsarás, M. E., Teriús-Padrón, J. G., García-Betances, R. I., González-Martínez, S., Cea, G., ... & Arredondo Waldmeyer, M. T. (2019). Empowering citizens through perceptual sensing of urban environmental and health data following a participative citizen science approach. *Sensors*, *19*(13), 2940. DOI: 10.3390/s19132940
12. Rappold, A. G., Hano, M. C., Prince, S., Wei, L., Huang, S. M., Baghdikian, C., ... & Hubbell, B. (2019). Smoke Sense initiative leverages citizen science to address the growing wildfire-related public health problem. *GeoHealth*, *3*(12), 443-457. DOI: 10.1029/2019GH000216

13. Riley, R., de Preux, L., Capella, P., Mejia, C., Kajikawa, Y., & de Nazelle, A. (2021). How do we effectively communicate air pollution to change public attitudes and behaviours? A review. *Sustainability Science*, 1-21. DOI: 10.1007/s11625-021-01038-2

14. Somerwill, L., & Wehn, U. (2022). How to measure the impact of citizen science on environmental attitudes, behaviour and knowledge? A review of state-of-the-art approaches. *Environmental Sciences Europe*, *34*(1), 1-29. DOI: 10.1186/s12302-022-00568-2

15. Van Brussel, S., & Huyse, H. (2019). Citizen science on speed? Realising the triple objective of scientific rigour, policy influence and deep citizen engagement in a large-scale citizen science project on ambient air quality in Antwerp. *Journal of Environmental Planning and Management*, *62*(3), 534-551. DOI: 10.1080/09640568.2018.1428183

16. Varaden, D., Leidland, E., Lim, S., & Barratt, B. (2021). "I am an air quality scientist"–Using citizen science to characterise school children's exposure to air pollution. *Environmental Research*, *201*, 111536. DOI: 10.1016/j.envres.2021.111536