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Executive Summary

CITI-SENSE has developed “Citizens’ Observatories” (COs) with the aim to empower citizens to contribute to and participate in environmental governance, to enable them to support and influence community and societal priorities and associated decision making to address contemporary urban environmental (health) issues. It has developed, tested, demonstrated and evaluated a community-based environmental monitoring and information system (i.e. CO) using innovative and novel Earth Observation applications. This system, restricted to air quality and noise monitoring, has been implemented in multiple European locations as cases with different users, known colloquially as ‘case studies’ or technically as Empowerment Initiatives (EIs). These locations – of varying air quality and authoritative regulation – include Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava and Vienna.

To achieve the creation of COs in these locations, the project aimed to: (i) raise environmental (air quality and noise) awareness in citizens, (ii) raise user participation in societal environmental decisions and (iii) provide feedback on the impact that citizens had in decisions. In many regards it addressed the call’s request for effective participation by citizens in environmental stewardship, based on stakeholder and user involvement in support of both community and policy priorities.

The concept of CITI-SENSE, and the work of WP2 as described in this deliverable, rests on three pillars constructed by other WPs: technological platforms for distributed (wide-spread) monitoring; information and communication technologies; and societal involvement. Three pilot case studies focused on a range of services related to environmental issues of societal concern: combined environmental exposure and health associated with air quality; noise and development of public spaces; and indoor air at schools. Attention was given to representativeness of citizen participation. The case studies were designed in collaboration with citizen groups and decision makers. They were based on distributed data collection using innovative static, portable and personal devices (low-cost microsensor packs) that communicate with data repositories through mobile phones or other devices. Development of participatory methods, data management strategies, and applications to facilitate exploitation of the data and information for policy, and society, was attempted.

This document (D2.4) is being made available upon completion of several final tasks (T2.4, 2.5, 2.6) and thus completion of the CITI-SENSE project. These tasks, since the previous deliverable (D2.3; and associated tasks T2.3, T2.4) included complete implementation of the engagement strategy, the commencement of individual and focus group (evaluation) assessments of subject experience with the project’s technological products project (both as T2.5), as well as the development of contributions to the Citizens’ Observatory (CO; T2.6). As these previous, non-public documents are available on the EU portal with restricted access, a summary of their contents are given here.

The first project deliverable (D2.1) of work package 2 (WP2; responsible for tasks associated with urban air quality) was:

- A protocol, compiled of the different pilot study elements.

- Aimed to give specific operational details for how the work was to be performed in each location, EI and each phase of the EI.
- A detailed description of the set-up and deployment plans (as different phases) of the end-to-end prototype (information chain for the main study), describing aims and objectives of particular pilot case studies, site descriptions, and social and technical methods.

The second WP2 deliverable (D2.2):

- Detailed the main study protocol for the location-based EIs. Upon its delivery, the locations had started to gather environmental sensor-enabled, health-relevant information on outdoor inhabited (urban) spaces.
- Facilitated the creation of a location-based citizens' observatory to engage and empower citizens, authorities and policy-makers (as stakeholders).
- Enable all Location Officers (LOs; managing location-based EIs) to attempt or approach their case study work in a similar, co-ordinated way.
- Allowed a case study or citizens' observatory piloted in a one location to be set-up in another location, i.e. be transferable. For example, the piloted use of the Little Environmental Observatory (LEO) with schoolchildren in Barcelona could be carried across to other locations such as Belgrade.

The third deliverable (D2.3):

- Presented an evaluation of the work described in D2.2 to provide insight on which of the citizens' observatories can be up-scaled, would be transferable and can be implemented elsewhere, and why.
- Summarised the conclusions of the Pilot Study in respect to the participants and stakeholders.
- Gave a brief and general description of the Full Implementation (i.e. the main study protocol, following the pilot study) process while touching-upon four aspects: (1) citizens observing their environment; (2) building a community of citizens that are participants in a citizens' observatory; (3) participatory evaluation of the quality of citizen empowerment in a case study, and; (4) comparative analysis between cities.

While these above listed deliverables are not for public consumption, the Citizens' Observatory Toolbox (COT[1]) with contributions to the citizens' observatory from WP2 (and other WPs) has been made available online, with user support for a limited time, to be used and evaluated firstly by the project and finally by the public.

The tools, all associated with atmospheric quality, range from subjective reporters (e.g. citizens giving their opinions) to objective monitors measuring air quality levels to a novel air quality indicator and online visualisations. The subjective reporters used the *Long Air-Quality*

[1] http://co.citi-sense.eu/CitizensObservatoriesToolbox.aspx

Perception Questionnaire[2] and *CityAir* application[3], which give general and momentary assessments (observational reports) of citizens' perceptions. The air quality monitors used were the *AQMesh pods* and the *Personal Air Monitoring Toolkit*, which provided city-wide and personal measurements, respectively. These measurement results are expressed as the *Air Pollution Indication Number* (APIN) visualised on the *Citizens´ Observatory* web portal.

The tools developed, used and evaluated within the project are as follows:

- The **CITI-SENSE Citizens' Observatories web portal** (http://co.citi-sense.eu) provides an access point to all the project apps, widgets, web pages and sensor based tools and questionnaires.
- The **Personal Air Monitoring Toolkit (Little Environmental Observatory – LEO)** allows users to assess air quality in their immediate surroundings. It is based on a sensor device that monitors three gases (nitrogen dioxide, nitrogen monoxide and ozone) and a corresponding mobile application.
- The **CityAir smartphone app** allows users to share their perception of air quality, and of the dominant source, anytime, anywhere.
- The **Environmental Monitoring Toolkit for Public Places** can be used in campaigns to assess thermal comfort, soundscapes and visual qualities of outdoor places such as parks or public areas in need of rehabilitation.
- The **On-Line Air Quality Perception Questionnaire** was used to assess in-depth perception of air quality.
- The **Data Visualisation Web Pages** provide an overview of the data collected using all the sensor-based tools.

Evaluation exercises aiming at learning how the use of different tools contributed to the participants' ability to engage in environmental issues were done using focus groups and interviews in all locations. These exercises are described in detail by the WP5 final deliverable (D5.5). For example, individual interviews involved the users (hosts) of a LEO, for example, being interviewed at the end of their participation period. They were asked about their experience, if the tool helped them to do something differently and if they thought they might use it as part of their daily life. Similar questions were posed in focus groups of multiple stakeholders for other tools. For example, local authorities were presented the data fusion mapping visualization portal and asked if they thought such a tool (service) could help them to improve their services.

[2] civicflow
([3] Google Play & App Store links)

The range of tools, and the varied quality and quantity of data generated using them, allowed many opportunities for public engagement. The CITI-SENSE project made appearances in multiple news channels and even a US-produced documentary entitled "The Crowd and The Cloud[4]". The legacy of CITI-SENSE, while shortly-lived through these media, will be carried by the Citizens' Observatory providing open access to the COT, where tools can be accessed, re-used in their application and applied by various stakeholders of different levels of enthusiasm and expertise. For example, in Barcelona, the ClimateKiosk initiative using AQMesh pods and their information chain to provide the public with environmental information in recreational spaces (e.g. kids playgrounds).

Figure 1 - Representation at the European Citizen Science Association annual conference

The Location Officers (LOs – case study coordinators) of WP2 learnt many lessons on using such novel technology with stakeholders at different levels of technological capability and general understanding about air quality. Most lessons were learnt from the main study, since the pilot study was with a limited amount of external (to the project) users. Certain stakeholders have benefited from this project more than others. For example, Zerohub in Barcelona (at the time of writing this) had successfully received funding to pilot their LIQUENS units on the basis of consultation with the LO and WP8 and further use of project partner technology (AQMesh). Another example is in Edinburgh where a workshop[5] focused on the use of 'low cost sensor technology to monitor air quality and engage with citizens' was held. Local stakeholders from research, local authorities, NGOs, sensor manufacturers, etc., shared their opinions on the opportunities and challenges to consider when using such tools to engage with citizens so that efforts in this area can be appropriately moved forward. Yet another example is in Vienna where a university seminar took place over the duration of three months which aimed at making students aware of citizen science, it´s practical applications and the empowering effects these approaches can have if understood and applied correctly. Some of the benefits will be felt after the project ends, following the dissemination of the project outputs and the continued use and development of such technologies. For example, the Edinburgh workshop documentation which explores the use of low-cost sensor technologies and thus is of value and of interest when looking at further projects and what stakeholders actually want.

The project learnt from citizen experience and perception and in some regards enabled citizenship co-participation in community decision making and co-operative planning (in other words, "empowered"). As examples, environmental awareness was raised in young citizens (students) of Barcelona, where mobile sensor technology allowed them to observe the behavior of important components of their environment such as air quality and noise. In Ljubljana, young citizens (again students) were enabled by online platform technologies to develop their own smartphone application for reporting air quality levels to raise participation

[4] https://youtu.be/qvjDp93eiSo

[5] A joint activity of the **Scottish ResearcH partnership for Air Pollution health Effects** (SHAPE) and the EU FP7 project CITI-SENSE, funded by the EPSRC network SECURE

by their peers in important decisions regarding their environment Finally, the citizens of Ostrava worked with local Non-Governmental Organisations (NGOs) to address, from another angle, the long-standing issue of air pollution due to industrial emissions to heighten their impact on the political landscape.

The Ostrava case study has posed possibly the most interesting “empowerment” challenge. In this area, air pollution levels are exceptionally high compared to most European cities, and also many locally based studies have shown a relationship between health impairment and air pollution. Thus, providing air quality information is not the main need in this area: people rather ask ‘what can be done to improve the situation?’. It has been the ambition of the project to contribute to such societal dialogue through the involvement of the local community, which also resulted in media attention. Cooperation with the city authorities unveiled a demand for raising children's awareness on air pollution. Subsequently, educational programs about air, air pollution and its prevention have been carried out in kindergartens and primary schools with some success. At the end of all EI activities, a public seminar was organized in Ostrava for all stakeholders presenting the project results and enabling a discussion about air pollution problems in the region and potential solutions. Steps towards empowerment have come through raising awareness not on the level of air quality, but on the methods for monitoring and sharing such information on solutions. In other cases like Vienna, where the authorities had been skeptical about data quality coming from the microsensors employed, they still were able to see the benefits from low-cost technology for local air pollution monitoring and sharing information to move towards empowerment.

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Abbreviations

AQ	Air quality
AQM	Air quality monitoring station
AQPQ-L	Air quality perception questionnaire (long version)
AQPQ-S	Air quality perception questionnaire (short version), “CityAir” smartphone app
CO	Citizens’ Observatory
COP	CO Portal (http://co.citi-sense.eu/)
COT	CO Toolbox (http://co.citi-sense.eu/CitizensObservatoriesToolbox.aspx)
DoW	Description of Work (document)
EI	Empowerment Initiative (case study)
FI	Full Implementation
GAP	Geotech AQMesh pod (public sensor node)
KPI	Key Performance Indicator
LEO	Little Environmental Observatory (personal sensor pack, PSP)
LO	Location Officer (case study coordinator)
NGO	Non-Governmental Organisation
PSP	Personal sensor pack (e.g. LEO)
WP	Work package

A. Introduction

This document "Evaluation of the performance of the case studies" is the fourth and final deliverable (D2.4) produced from Work Package 2 (WP2) of the CITI-SENSE project. This publically available document has been written and provided for general dissemination, to inform any interested individuals or parties as to how a Citizens' Observatory may be made. Such observatories are useful to hasten the process of improving environmental conditions in urban areas, where increased population and deteriorated air quality are mixing to produce poorer public health outcomes. The political initiative needed to bring about change needs to be inspired by informed and vocal citizens who vote for respective politicians or 'change-makers'. An observatory, as a collection of information and a meeting-point of minds, can help to facilitate this change. Information for this purpose can be the product or the tool, and this document will give concrete examples of tool use (or case studies) that have occurred in the CITI-SENSE project's urban air quality empowerment initiative.

This deliverable will introduce and detail the case studies (tool uses) in general and by location were performed and evaluated. The locations include Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava, and Vienna. More importantly, the tools used within the case studies are:

a) Long (general) air quality perception questionnaire
b) Short (spatiotemporally-relevant) air quality perception questionnaire
c) Static (publicly-applicable) air quality sensor network
d) Mobile (personally-applicable) air quality sensor pack

The deliverable is being made public so that future initiatives can build upon the vast knowledge base and infrastructural platforms resulting from the CITI-SENSE project work. All of this was made in an effort to increase the potential of citizens to improve their urban environment, particularly in the face of poor or worsening air quality and other threatening environmental conditions such as climate change propelled by greenhouse gas emissions from cities. While this is not a project relying on citizen science methods, the tools produced are not strictly needing to be focused on environmental conditions; the tools produced and made public via the Citizens' Observatory Toolbox (COT http://co.citi-sense.eu) can be used for various scientific initiatives in the area of citizen science and beyond.

Here we will provide a summary of the current deliverable structure to help guide the reader. Within the various annexes at the end of this document, more detail on the locations' specifics (e.g. differences in strategy adopted, key location relevant results, etc.) is provided. The main body, however, gives the general description of the performance and evaluation. Within this, there are the following key sections, starting from this (section A, 'Introduction'):

B. Aims and objectives
C. Evaluation of the Empowerment Initiatives ('Case studies'): (1) methodology employed to achieve these and any differences to those plans previously proposed in earlier deliverables; (2) Results both generally across all the locations and also with reference to location specifics.

D. Contributions to Citizens' Observatories: (1) lessons learned; (2) assessment of impact; (3) keys to making a citizens' observatory.

This last section is a synthesis of how the project has contributed to the emerging practice of a Citizens' Observatory.

B. Aims and Objectives

Here we provide a brief description of the general aims and objectives for development and use of products in the case studies of the CITI-SENSE project – to develop and to evaluate methods (tools) within the Citizens' Observatory Toolbox (COT).

Reflecting upon the DoW, the main objective of the CITI-SENSE project was to be accomplished by developing, using and evaluating an environmental monitoring and information system (chain) based on innovative and novel Earth Observation capabilities and applications focused on the citizen's immediate environment (Citizens' Observatory). Although the focus of the proposed work was on atmospheric pollution in cities and agglomerations, the capability of monitoring of a wide range of environmental issues was envisaged longer term. The project, now in its fourth and final year, has had its focus shifted from monitoring the environment to evaluating the user within an environment with a particular product of the project. This was done to determine if and by how much empowerment potential was offered to users by the project products (tools). The tools empowerment potential are discussed in more detail in another work package's deliverable (D5.5).

To achieve the project's main objective, the project consortium aimed to:

1) Learn from citizens' experiences and expectations;
2) Raise environmental awareness in the society;
3) Stimulate stakeholder groups' participation in community and societal environmental decisions; and
4) Provide a transparent link between citizens and the decision-making process.

The effort to achieve these aims was supported by the use of novel technological solutions. This combination of technology and social knowledge led to both technological and social science innovation. In this way, the project consortium partly addressed the European Commission funding call's request for effective participation by citizens in environmental stewardship, based on broad stakeholder and user involvement in support of both community and policy priorities." This is seen as only partly addressed because of only limited exhibitions of efficacy in citizens or stakeholders using the tools to observe and care for their environment. Not all locations achieved this, and not all case studies in the locations that achieved empowerment somehow were successful. Thus, case studies (or tools) are specifically evaluated with targeted interviews and focus groups.

Guiding the main body of work to achieve these aims was the assessment of the pilot end outputs and outcomes. This assessment was not only an internal reflection process performed by the consortium (as documented in earlier project deliverables, e.g. D2.3), but an external evaluation process performed by the European Commission in Brussels. Outcomes such as the microsensors not providing accurate data meant a shift in focus to subjective data collection.

Due to the myriad of atmospheres and cultures included in the project, coming from the inclusion of cities in countries of the north, east, south and west of Europe (i.e. Spain, Serbia, Scotland, Israel, Slovenia, Norway, Czech Republic, Austria), the broader aims and objectives of the city project work were refined in some locations to suit the literal and political climate.

Aims were also tailored to ensure success in locations according to the dependency on local expertise of the WP2 partners. These special cases meant specific application and evaluation of certain tools.

C. Evaluation of the Empowerment Initiative case studies

This section has two sub-sections, which will detail the (1) methods and (2) results of the WP2 Empowerment Initiative (EI) of urban air quality, and the case studies within it. Overall, there were three EIs, one for each work package (WP2, WP3a, WP3b). The first EI is that of WP2, pertaining to 'Urban Quality', or more precisely urban air quality. For completeness, the second EI is 'Public Spaces' and reported as a public document in D3.4. The third and final EI is 'School Indoor Quality', also being reported in D3.4. The following graphic (Figure 2 – CITI-SENSE concept) shows how the Empowerment Initiatives of each work package and location within it are supported by the methods (products and services) linked into the Citizens' Observatory (CO).

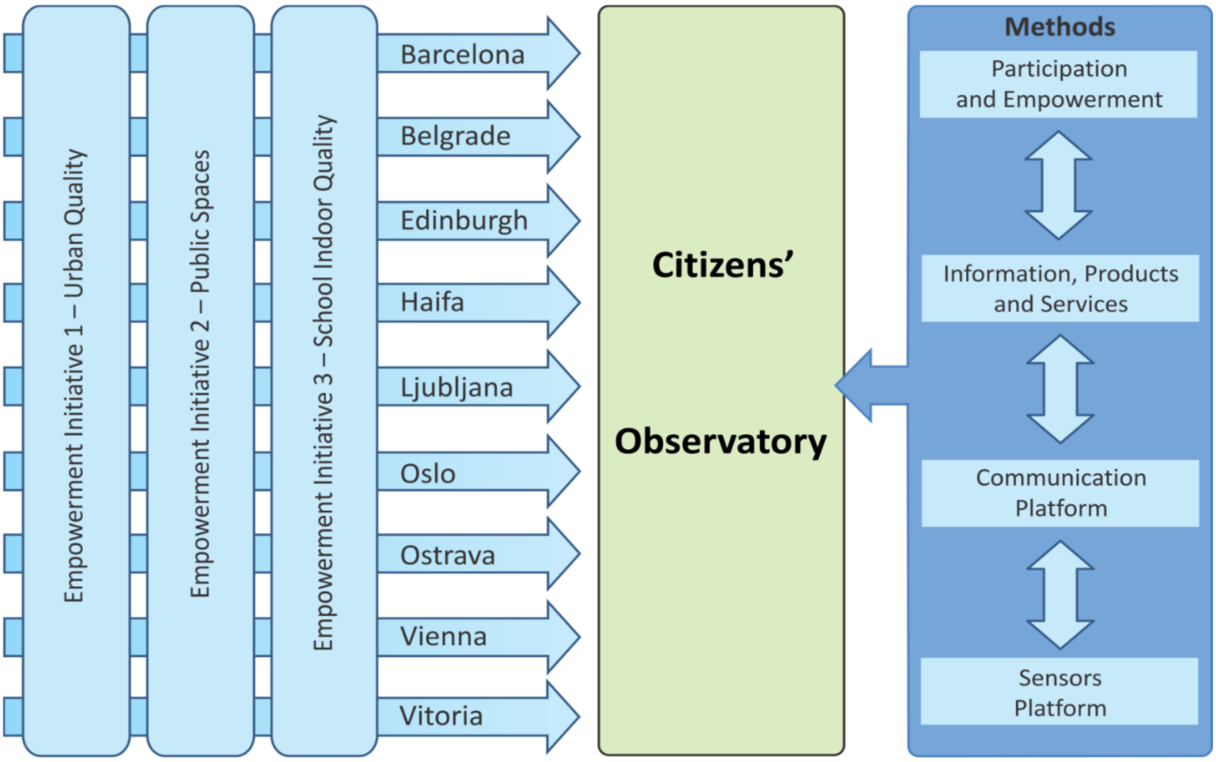


Figure 2 – CITI-SENSE concept: how the Empowerment Initiatives of each location are supported by the methods

Each location under the WP2 urban quality EI1 umbrella (i.e. Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava and Vienna) has a unique user case. The products (tools and services), however, were designed to be applicable to a wide-range of case studies that could be found in either of the WP2 locations. Some locations officers (LOs) chose to focus on specific products that would suit more prominent case studies in their location – this will be noted in the following sections of this chapter. When and where each tool was used, an evaluation of that use was documented if possible (considering project resource constraints). Mixed results were seen in some locations despite using the same tools and services.

1. Method

This section will briefly describe the products and services that have been developed, but in more detail; how and in what phases they were implemented and evaluated through the case studies of locations as the fieldwork of LOs. The evaluation process of the tools and services is seen by the project as an essential part of the product development process. Having users evaluate (or document their experience) with the products and services allows this. More detail on the products and services can be found on the CITI-SENSE Citizens' Observatory Toolbox website[6].

The next graphic **Error! Reference source not found.**

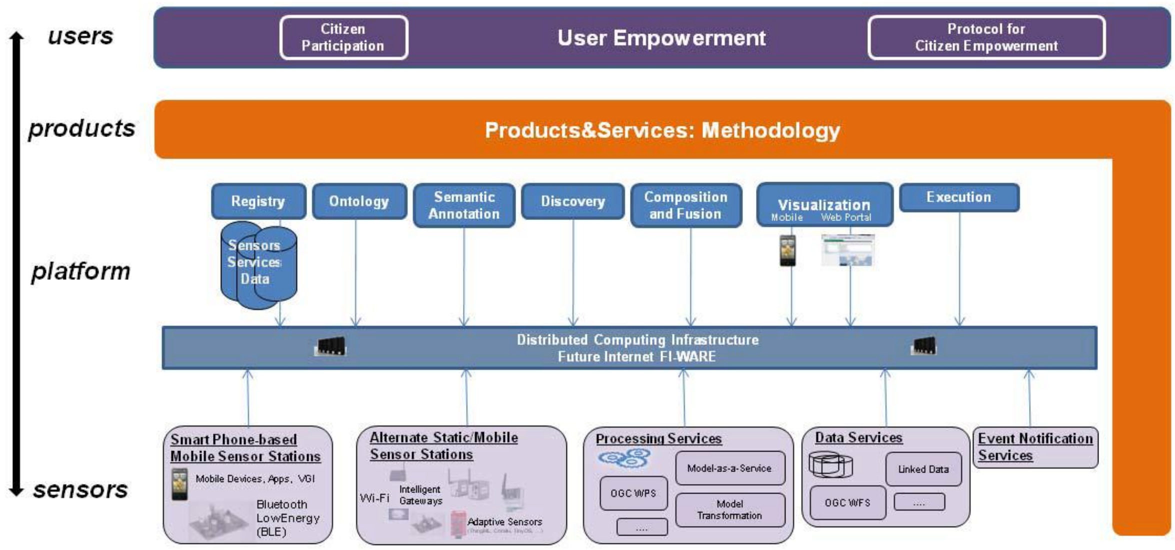


Figure 3 – CITI-SENSE information chain: how the methodology (products and services) component fits into the complete information chain of users-products-platform-sensors to form a Citizens' Observatory.

Here we will list the successive project phases of CITI-SENSE empowerment initiatives, being the plan for the full implementation of the CITI-SENSE location case studies:

(a) the development of tools and products;
(b) the recruitment of users;
(c) the engagement of stakeholders and users; and,
(d) the evaluation of the tools by users.

In the next section, as Contributions to Citizens' Observatories, this user evaluation will have its outcomes processed and presented on the CITI-SENSE platform.

[6] http://co.citi-sense.eu/CitizensObservatoriesToolbox/

a) Development of tools and services

The CITI-SENSE product development process in its early stages (e.g. pilot study of 'end-to-end' information chain prototype) was largely guided by feedback and development loops by/with, the LOs in terms of creative preferences from previous experience and forced solutions made from current awareness of technological limitations. The best example of this is the 'end-to-end' prototype and first testing of the personal sensor pack (PSP) on its path to become the Little Environmental Observatory (LEO). Developers relied on LOs to test the products early in development. An example of some of the key ideas of the LOs for development of the tools and services is to attach the LEO to the upper arm, but also having the capability (attachment) to host the LEO on the belt of the user. This is to maximize accuracy of monitoring what the user is exposed to (at the breathing zone), but also to allow for user preference in how the product is hosted (e.g. made more or less visible). Other feedback included having Bluetooth re-connect automatically between the LEO and smartphone-hosted ExpoApp after a connection was lost or battery depleted (and thus device reset). The most important development stages using feedback will be detailed in respective WP final deliverables (i.e., by WP6, WP7, and WP8, for products and services, and WP5, for engagement activities and user evaluation).

The platform of Confluence was used to share feedback with developers, such as that for the CityAir application, which can be seen in the table below (and found online http://confluence.nilu.no/display/citi/Issue+tracker, although not publically available).

Table 1 - Feedback of CityAir application piloting by location officers – logging issues on Confluence for the developer to address

Log#	Date	Feedback	Comment	Fed by:	Importance	Status
I01	16.09.2015	Change of text for the Only-wifi description		mff	major	Done
I06	25.09.2015	Add extra "perception" to app description	Ref email (Nuria/Karen)	Karen		
I12	07.10	No localization even if gps is turned on	Can be the same problem as I11. Alex: can you check?	Alexander	major	Won't fix
I15	*16.10*	*Allow choice of user language in same window*	*Duplicate of I09*	*Tom*	*Crucial (should do if possible)*	

Log#	Date	Feedback	Comment	Fed by:	Importance	Status
		as personal info screen (e.g. gender) upon first use of app.				
I19	*16.09.2015*	*a link of the meaning of the coulored icons, below the icons* *better than only in the info tab*	*Good idea (mff) Duplicate /I13*	*Tania*	*nicetohave*	
I23	25.09.2015	Translate MAP = MARA SATELLITE = SATELITSKI PRIKAZ.	I think this is part of Google API and not translatable / part of the app	Milena		

b) Recruitment of users

This section will describe the common, general methods used for recruitment across the locations, and define the different ways in that different user groups across locations were recruited. Material which helped to promote the project can be found in the Annex. Common effort to re-use designs was assured through sharing the examples on Confluence.

Table 2 - Sharing of participant/'user' recruitment materials

Location	Material
BARCELONA	Poster: citisense english.JPG Flyer (in Catalan): peticio_pacients.docx
EDINBURGH	T-shirt: IMG_0217.jpg Gym bag: IMG_0218.jpg
HAIFA	Flyer/poster (in Hebrew): Call for Participation - Haifa CS.pdf
LJUBLJANA	Flyer/poster: Call_for_participation_LJ_v1_2ideas_in_one.jpg

Some of the key strategies used by the LOs were:

1. Social media campaigns (utilising software such as Hootsuite for Facebook and Twitter);
2. Sharing a YouTube video using footage of locations and case studies;
3. Advertisements in local newspapers and TV;
4. Cooperation with local, regional, national and international NGOs, advertisements on their web pages, increasing awareness through the network of active (mainly local) people;
5. Promotion of the activities on the CITI-SENSE web site;
6. Distribution of leaflets by post to public libraries, schools, kindergartens, etc:
   - Collaboration with local family doctors (advertisements in the waiting rooms)
   - Advertisements in local schools, which were connected with the project and where the educational programs where carried out
   - Adverts / flyers in local newspapers and placed at key centres that citizens frequent (e.g. leisure centers, libraries, community centres).
   - Dissemination of flyers to promote project initiatives at local railway stations and park and ride during rush hour
   - Open day events with stands, flyers and experiments.
   - Using a network of local contacts from previous research projects; Promotion of the activities using mailing lists;
7. Direct engagement with stakeholders with a perceived interest in air quality issues (e.g in Edinburgh had a stand / gave out flyers and questionnaires at 'cycling events' such as the Edinburgh Cycling Festival 'Bike Breakfast' and Pedal on Parliament;
8. Selection of users by special Focus on different stakeholder groups with various backgrounds. I.e. general public with special interest in AQ like cyclists (lobbies, asthma patient groups, parents, groups with scientific interest in AQ like medical or athomspheric scientific working groups, NGO´s with focus on pollution and environmental awareness;
9. Snowballing effect:
   - contact IOM employee/ contacts and encourage them to spread the word via their local friends, family and contacts
   - Participating in Eurocities workshop in Ljubljana resulted a new stakeholder contact, who later introduced us to more stakeholders. (Ljubljana);
10. Participation in a scientific events organized towards the public (e.g., science day, researchers night).

c) Engagement of stakeholders and users

Here is given a summary of some key engagement activities in the eight cities. A more detailed description of the engagement activities at the different locations may be given in Annex II (City Descriptions and City-specific Results) or the final deliverable of WP9 (Dissemination, exploitation and training). Some of the key strategies used by the locations were:

1. Regional and international competitions
   - a student smartphone application (Ljubljana)
2. Public science fairs
   - European Citizen Science Association (Berlin)

- Edinburgh Science Festival (Edinburgh)
- Conferences for environmental health, e.g. International Society of Environmental Epidemiology (Barcelona), International Society of Exposure Science (Edinburgh) , International workshop on Metrology for Meteorology and Climate (Slovenia) International Multiconference Information Society (Ljubljana), Genetic Toxicology and Prevention of Cancer (Telc), Central and Eastern European Conference on Health and the Environment (Prague)

3. Fieldwork with users
   - the LEO and CityAir app (Barcelona, Edinurgh) , biomonitoring and field campaigns in Ostrava
   - Satellite projects, e.g. Urban Bees, ClimateKiosk (Barcelona), Kanárci (Ostrava)
   - Advisory committee convened in Edinburgh which was focused on urban air quality and the CITI-SENSE project. This included representatives from Friends of the Earth (Edinburgh), Scottish Environmental Protection Agency (SEPA), City of Edinburgh Council and local air quality researcher from the Centre of Ecology and Hydrology, Greenpeace (Prague), NGO Vzduch (Ostrava), NGO Čisté nebe – Clear sky (Ostrava), NGO Rozchodník (Ostrava), Municipalities (Ostrava)
   - Involvement of primary schools and kindergartens (during the educational programs) with teachers, students and parents of children
   - Use of low costs sensor technology to monitor air quality and engage with citizens workshop' (Edinburgh) which engaged with NGOs, Local authorities, researchers, sensors developers, citizen.
4. Public events
   - Bike Breakfast, Pedal on Parliament (Edinburgh)
   - Various outdoor activities with primary schools, where portable sensors were used as part of the activities (Ljubljana)
   - Meetings with local cyclists lobbying groups and campaigning via social media posts (Vienna)
   - Participation in local authority meetings (Vienna)
   - Participation in local citizen science days (Vienna)
   - Organization of collaboration with different university departments (Vienna)
   - Expert meetings with external air quality modeling groups
   - Public relation work via flyers, social media and press releases

For these strategies, the locations and their officers did learn from each other – what worked in one city was sometimes picked up and used in other cities.

d) Evaluation by users

This section will describe the methods and tools (questionnaires and/or interviews) that have been used to obtain feedback from the users regarding how the EIs have contributed to awareness rising, engagement and empowerment.

Some of the key users as identified by the LOs were:

- Air quality monitoring authorities (all cities)

- Parents of school children (Barcelona, Belgrade, Ljubljana)
- Commuter bicyclists (Vienna, Edinburgh)
- Local advisory board (a researcher, NGO rep and member of SEPA) (Edinburgh)
- Hospital outpatients (Barcelona)
- Citizens actively participating in biomonitoring campaigns (Ostrava)
- Active citizens and NGOs (Ostrava)
- Municipalities (Ostrava)
- General public / citizens

General evaluation

For a general evaluation of the CITI-SENSE products, a Google Form was produced by WP9 for online evaluation of any product in any location (Figure 4). This was distributed to a general audience mostly via social media (e.g. Facebook, Twitter) since it was administered solely on an online platform. In some locations, individuals participating in tool empowerment evaluations were directed to complete the form as part of their evaluation. The forms were translated into local languages, and some locations provided users with printed (physical, rather than digital) forms for completion and conversion into digital format.

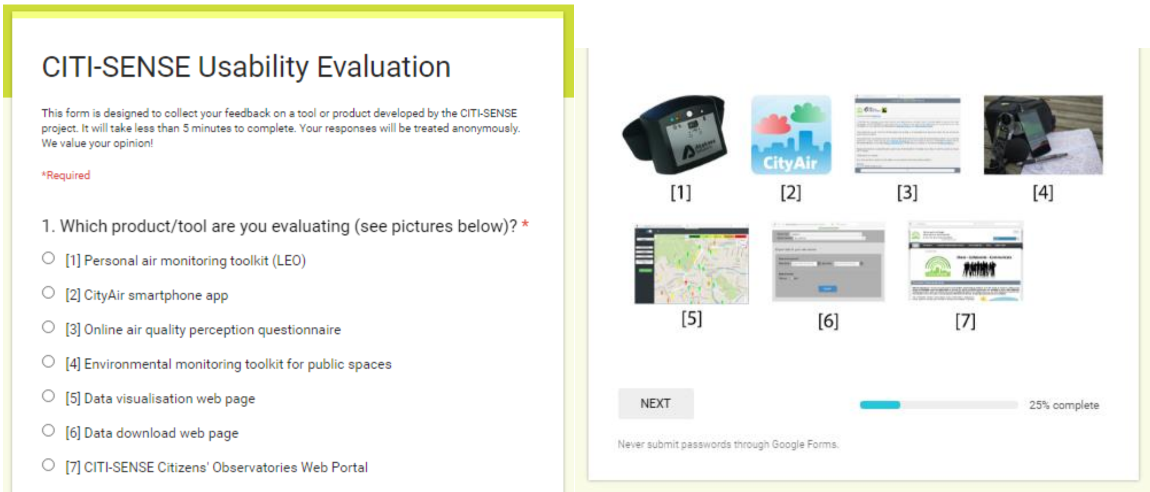


Figure 4 - Google Forms questionnaire for all tools and products

Focus group evaluation

To allow a more targeted audience, interviews and focus groups were performed to collect (evaluator) feedback on the tools and products of the project. Categories of users can be made according to the level of participation, either direct and frequent or indirect and infrequent. The key users that fall under such categories as identified by the LOs were:

- those who were recruited into the project to help (fieldwork participants, including physical sensor hosts);
- those who, through the various dissemination channels, learned about some of the tools and then participated (but that we have no knowledge of who they are), including responders to the short (CityAir app) and long perception questionnaire, as fieldwork participants or not, and users of data visualization web platform;

- those which are very targeted, obtaining the feedback from authorities on the outputs of the tools (such as interim results of the LAQP.

The interviews and focus groups were recorded where possible, and these were transcribed verbatim and then sent to WP5 for analysis. This information will be included in the final WP5 deliverable (D5.5).

Key Performance Indicators

A previous deliverable concerning the outcomes of the pilot study (D2.2) explained how the case studies performed according to key indicators of success, using a self-evaluation technique by LOs. It was foreseen that external evaluation by users might then be done for the main study. While the indicators were not strictly measured as done in the pilot study, the essence of their meaning was evaluated from the questioning during the interviews and focus groups done by WP2 on behalf of WP5.

LOs completed a self-evaluation upon completion of the pilot study. The summary of results of this exercise can be found in the Annex. Collating the results in this way allowed evaluation of the performance of the overall system in different locations and facilitated the identification of strengths, weaknesses, opportunities and threats for each user case. The same set of KPIs was not re-used after the main study by the LOs because instead the interviews and focus groups became the main measure of evaluating project products.

This deliverable was going to describe how key performance indicators (KPIs) were used as a self-evaluation exercise in the main study, however it was then realized that this provides little information owing to the differences in how people assess their performance, and the value of such exercise to the project was seen as low. However, the set of KPIs used for the locations by the LOs, after the pilot study, are found in Annex III. A set of KPIs for use by external entities (i.e. evaluation of the project) was simplified from that which was used with the LOs.

2. Results

a) Engagement potential (engagement and recruitment of users)

This section will detail the experience (results) of recruiting users of our products (tools and services) as a whole (across all eight cities) and will note any location-specific experiences.

Due to physical sensor issues, some cities held back in terms of active recruitment of users, not knowing when products would be available or what their capabilities would be. This was a difficult tight-rope of managing expectations. Therefore, it is difficult to compare numbers recruited because of differences in focus, recruitment strategies, and so on.

Long air-quality perception questionnaire

Regarding the perceptual sensors, monthly conference calls were held with a working group for the development and evaluation of a long air-quality perception questionnaire (LAQPQ). In the first few months of 2016, when a substantial amount of data was collected, the number of users was summarised with descriptive analysis using two approaches. The first was via the CivicFlow portal itself. The second was via the statistical software R. Here, we described who our users were, including the distribution of age, of gender and educational achievement, see Figures 5.

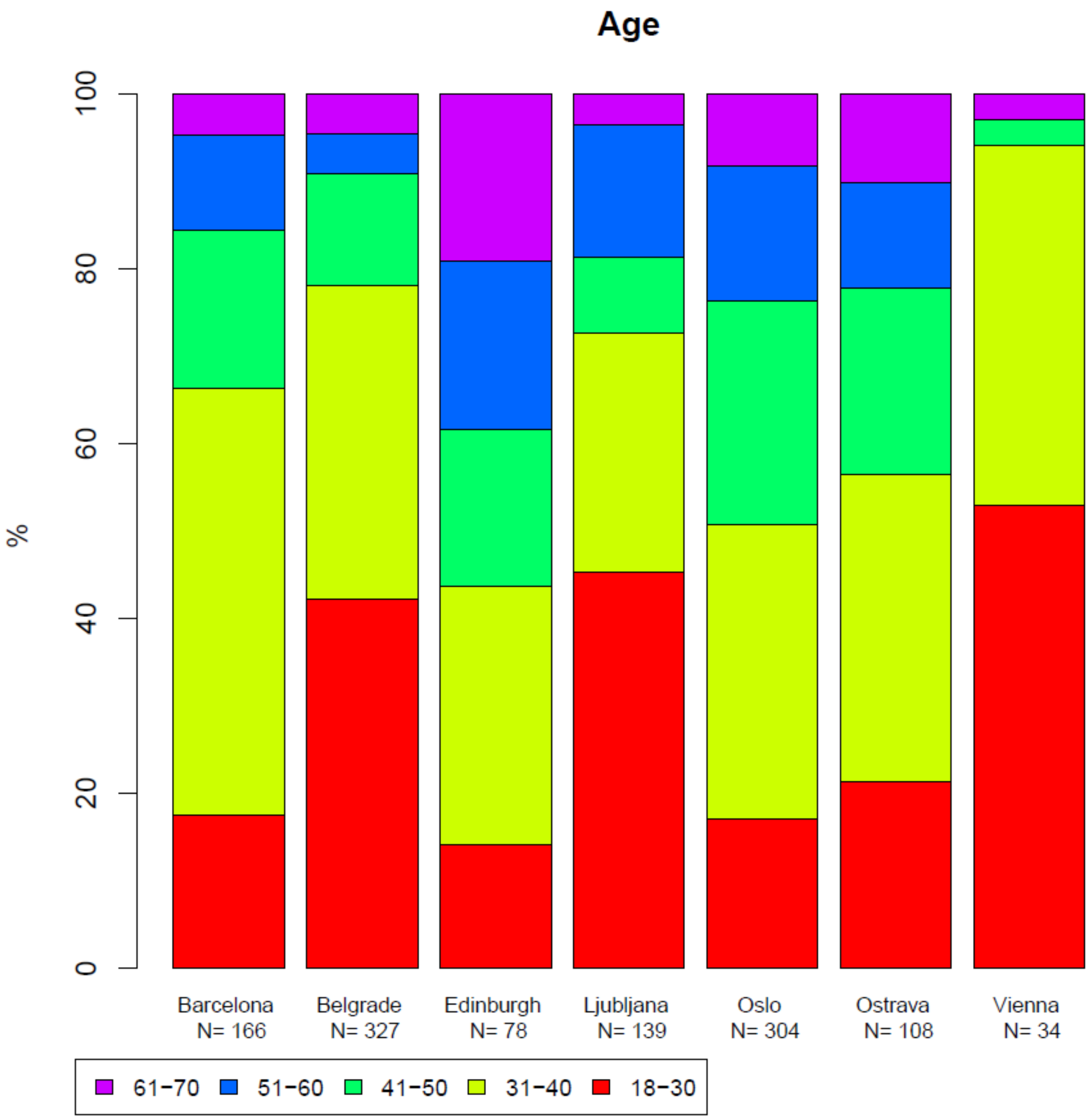


Figure 5a - Sociodemographics of Long Air-Quality Perception Questionnaire respondents (preliminary results)

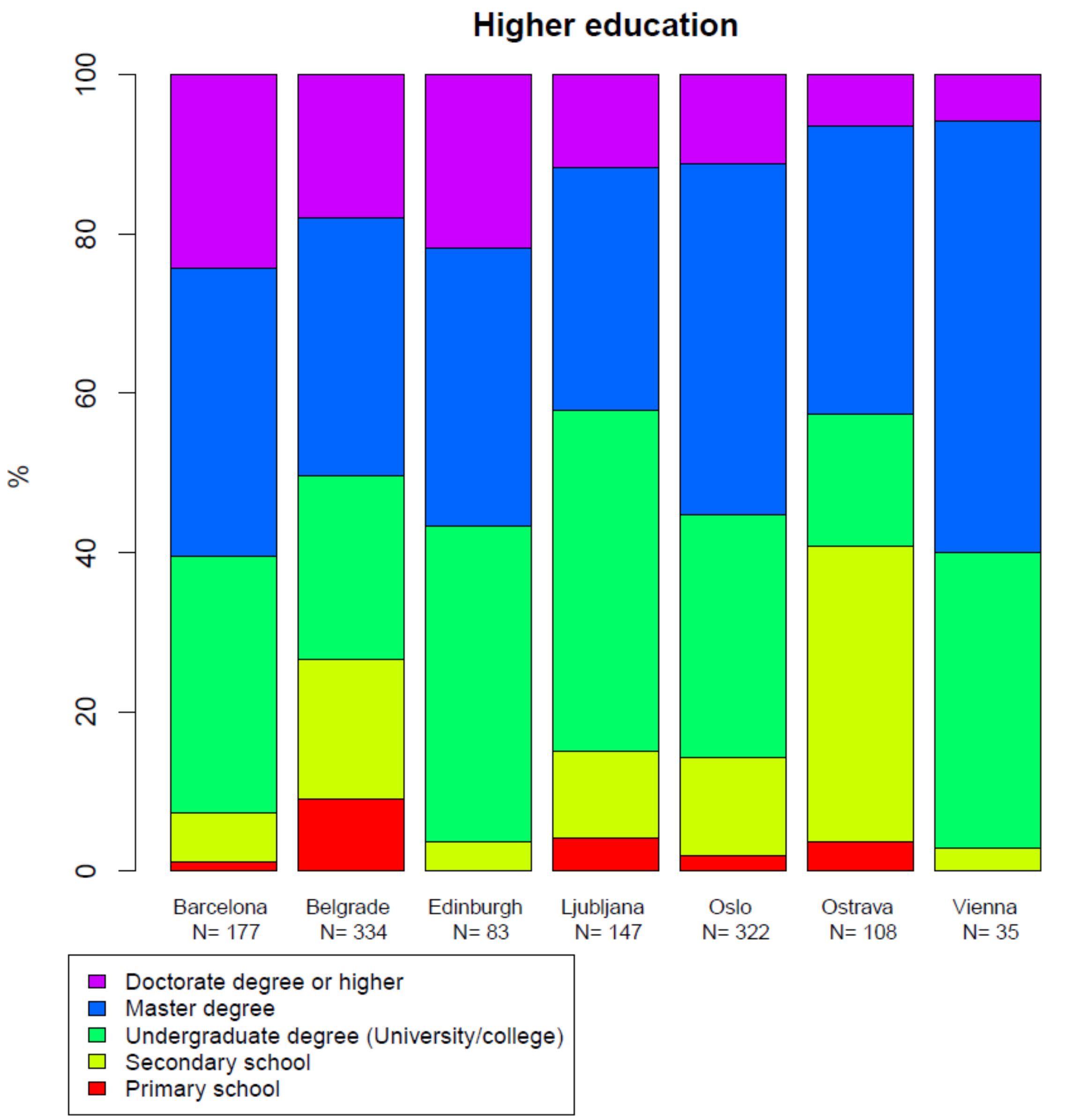


Figure 5b - Sociodemographics of Long Air-Quality Perception Questionnaire respondents (preliminary results)

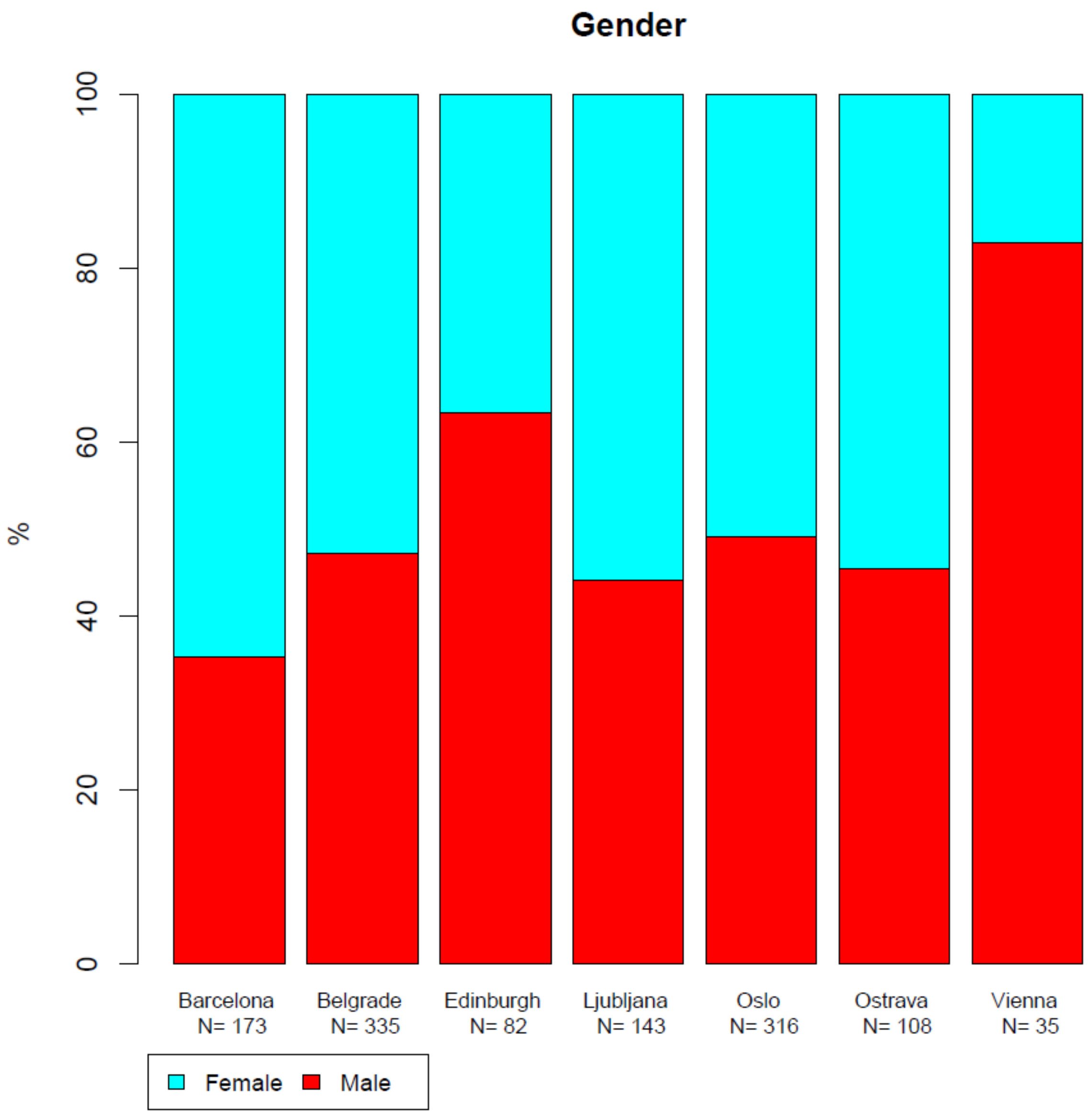


Figure 5c - Sociodemographics of Long Air-Quality Perception Questionnaire respondents (preliminary results)

The location officers are aware that there are other respondents that are not considered in these numbers. It should also be highlighted that the LAQP was never intended to be representative of the city populations (although data from each of the cities was also gained and posted on Confluence to look at this).

Short air-quality perception questionnaire ('CityAir' application)

WP6 (NILU) provided fortnightly updates of the CityAir app use. This update included observations (spatially) made (see Figure 6a, as an example for Belgrade in April), as well as new and total installs (Figure 6b, 6c), during the last month and week period.

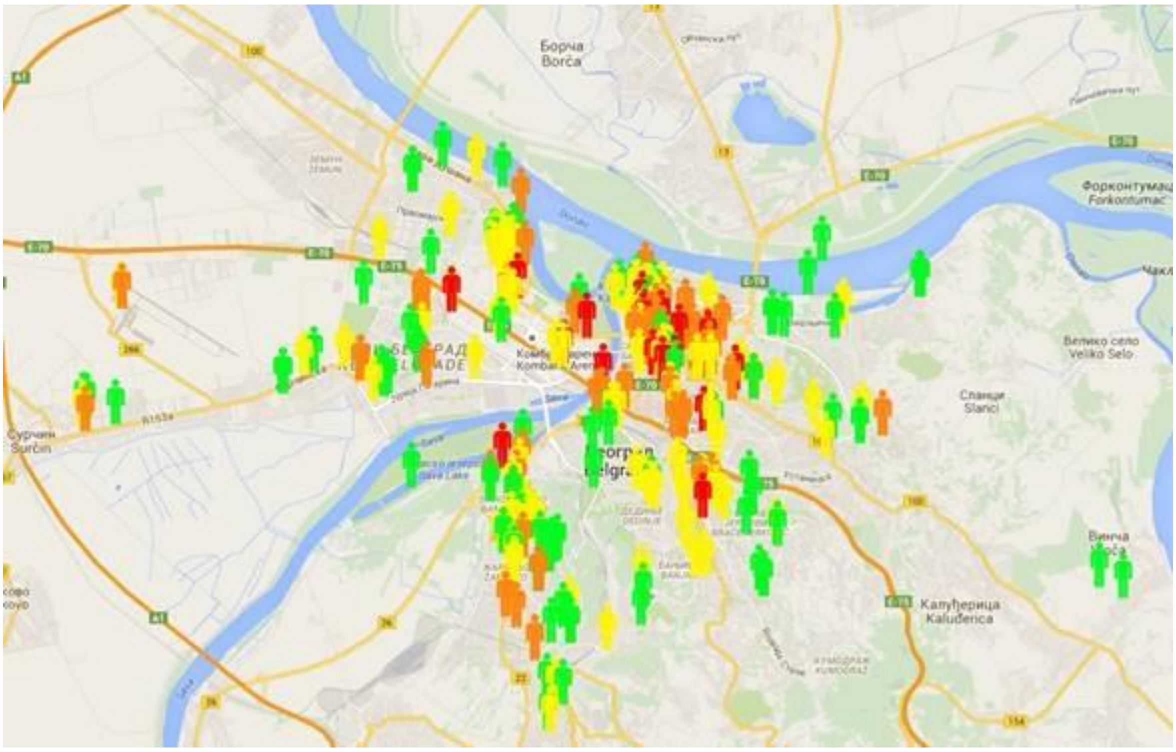
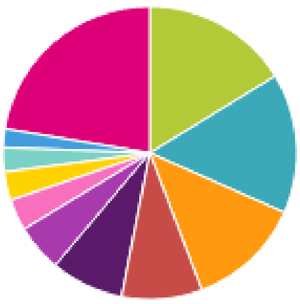


Figure 6a - CityAir app results: example of Belgrade city 'campaign'

TOTAL INSTALLS BY USER ON APR 23, 2016



	YOUR APP	
Spain	103	16.22%
Serbia	98	15.43%
Czech Republic	80	12.60%
Norway	56	8.82%
Austria	51	8.03%
Slovenia	33	5.20%
United Kingdom	22	3.46%
Romania	20	3.15%
Italy	17	2.68%
India	13	2.05%
Others	142	22.36%

Figure 6b - CityAir app results: total number of installs by user, according to country (including those of CITI-SENSE EI and others)

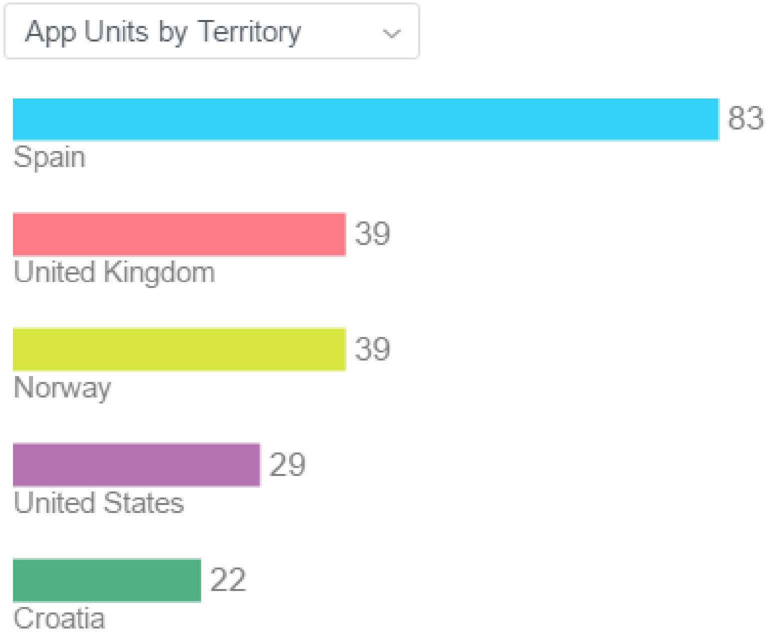
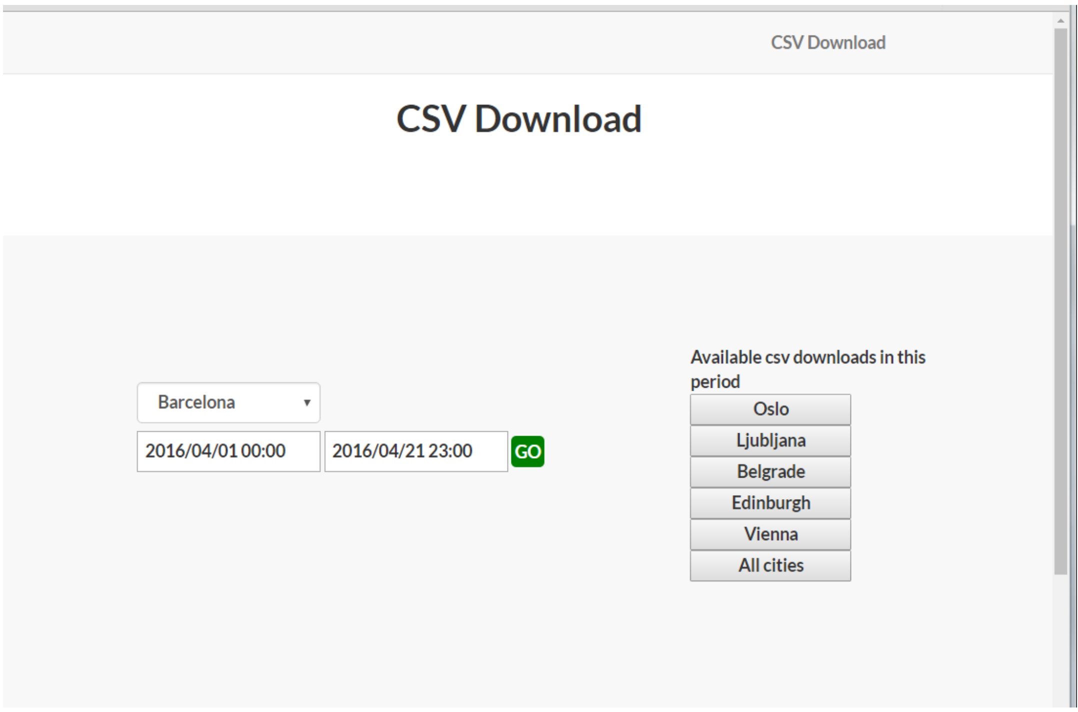


Figure 6c - CityAir app results: current installs (as of 25.04.2016), according to country (including those of CITI-SENSE EI {Croatia is believed to actually represent Slovenia} and others)

An example summary of public response visualized by specially made widgets is in Figure 7, at end April 2016.



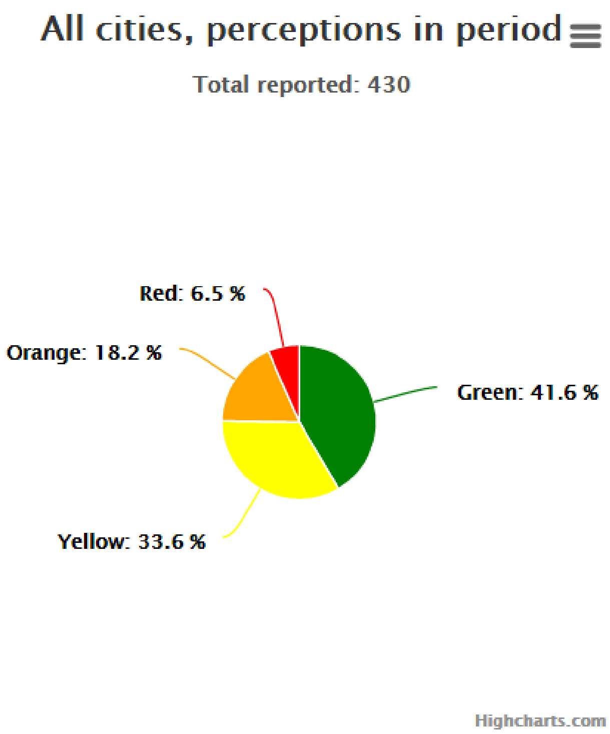


Figure 7 - CityAir data downloading function on portal (captured 25.04.2016)

Little Environmental Observatory

LEO users were limited by the number of LEOs and smartphones (for which they had to be coupled via a smartphone application, ExpoApp); however, rather than achieving a certain quantity of users, the goal was to achieve a varied mix of users for a general population-applicable evaluation of the tool/s. This goal was achieved by inter-city rather than intra-city variation of users. That is, different users groups were seen only across locations rather than within locations. For example, focus groups with the general public using the LEO were carried out in Ljubljana, however more targeted groups like cyclists and patients were interviewed in Edinburgh and Barcelona, respectively. Additionally, to increase participation, the LEOs were rotated among users in the locations. Not all cities were able to provide smartphones, but relied on users having their own Android-operated device. This unfortunately ended-up excluding many interested participants who otherwise had a iOS or a Windows-operated smartphone.

The COP users were tracked via Google Analytics (see Figure 8).

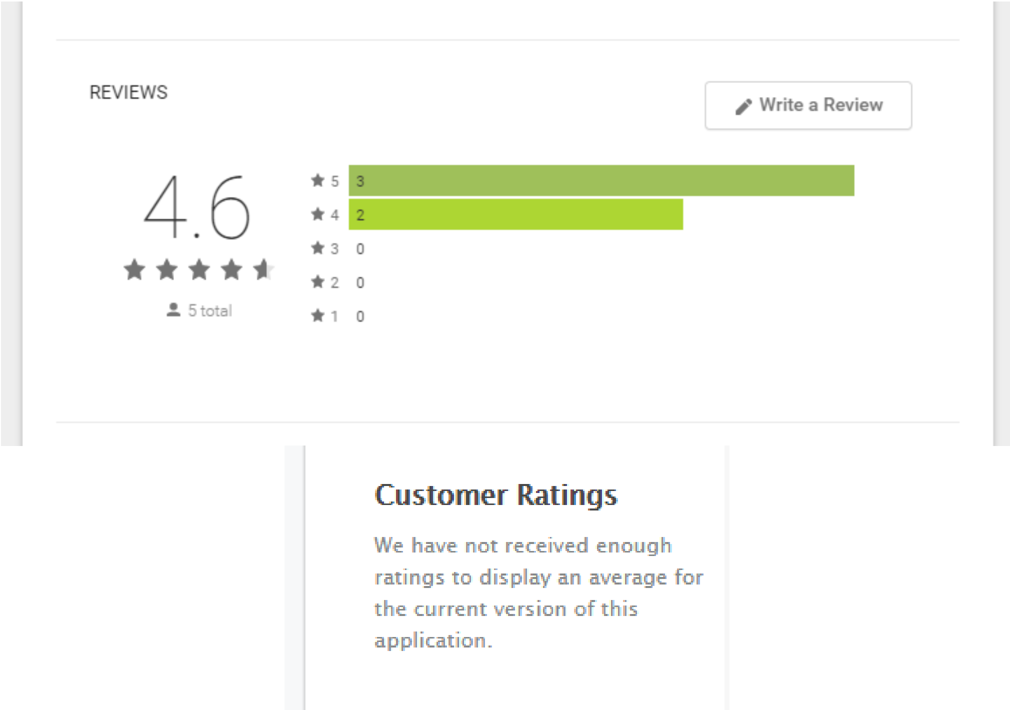


Figure 8 - Google Play review platform of the CityAir app (captured 25.04.2016).

Social media
In Ljubljana, Facebook (https://www.facebook.com/CitiSenseLjubljana/) posts about local activities resulted as many as 873 post views in the most popular post in 2016. In 2015, the most popular one reached as high as 1045 post views. The number of followers in the Ljubljana (as in 12.8.2016) is 118. The following figures are examples of social media platforms successfully used by LOs, also in other locations than Ljubljana (Figures 9-13):

Figure 9a – Facebook posts: example, Ljubljana; the most popular post in 2016 reached 873 views

Figure 9b - Facebook posts: example, Ljubljana; the most popular post in 2015 reached 1045 views

Figure 10 - Twitter account: example, CITI-SENSE Barcelona; 450+ 'followers'

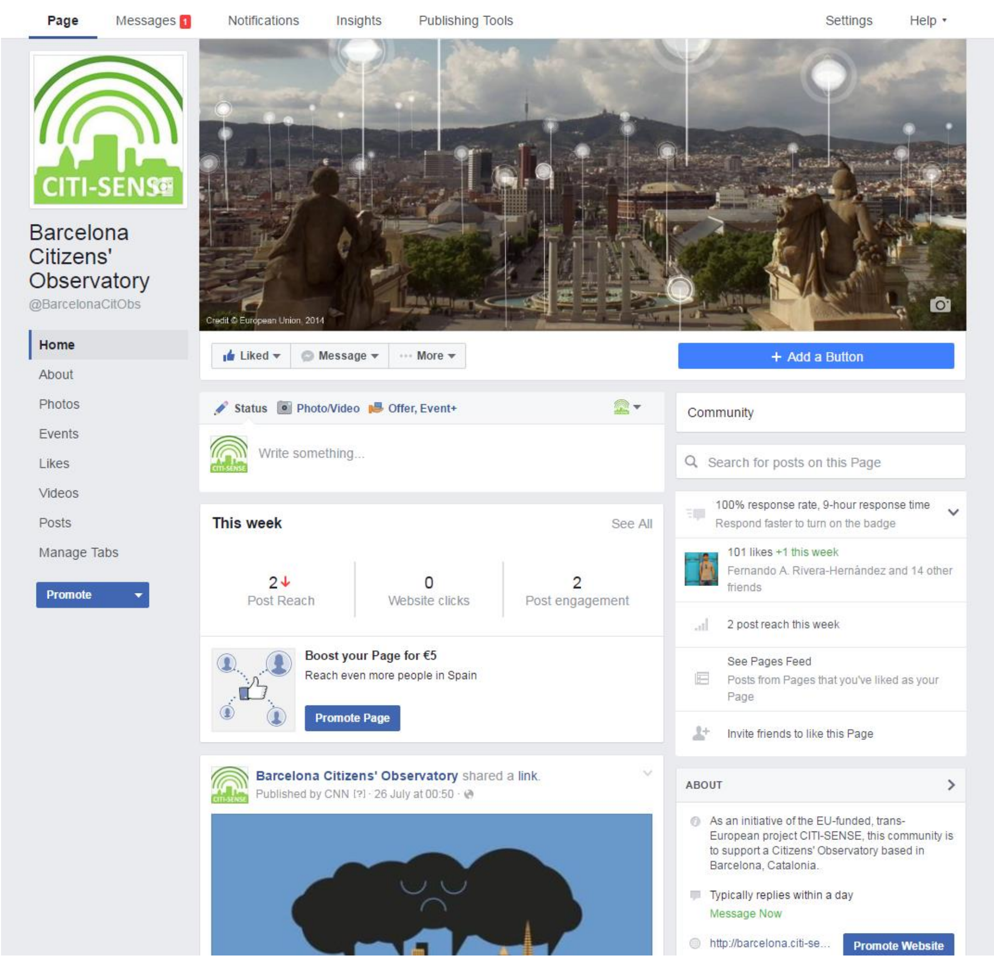


Figure 11a – Facebook account: example, CITI-SENSE Barcelona; profile home page, showing 101 'likes' (engaged users)

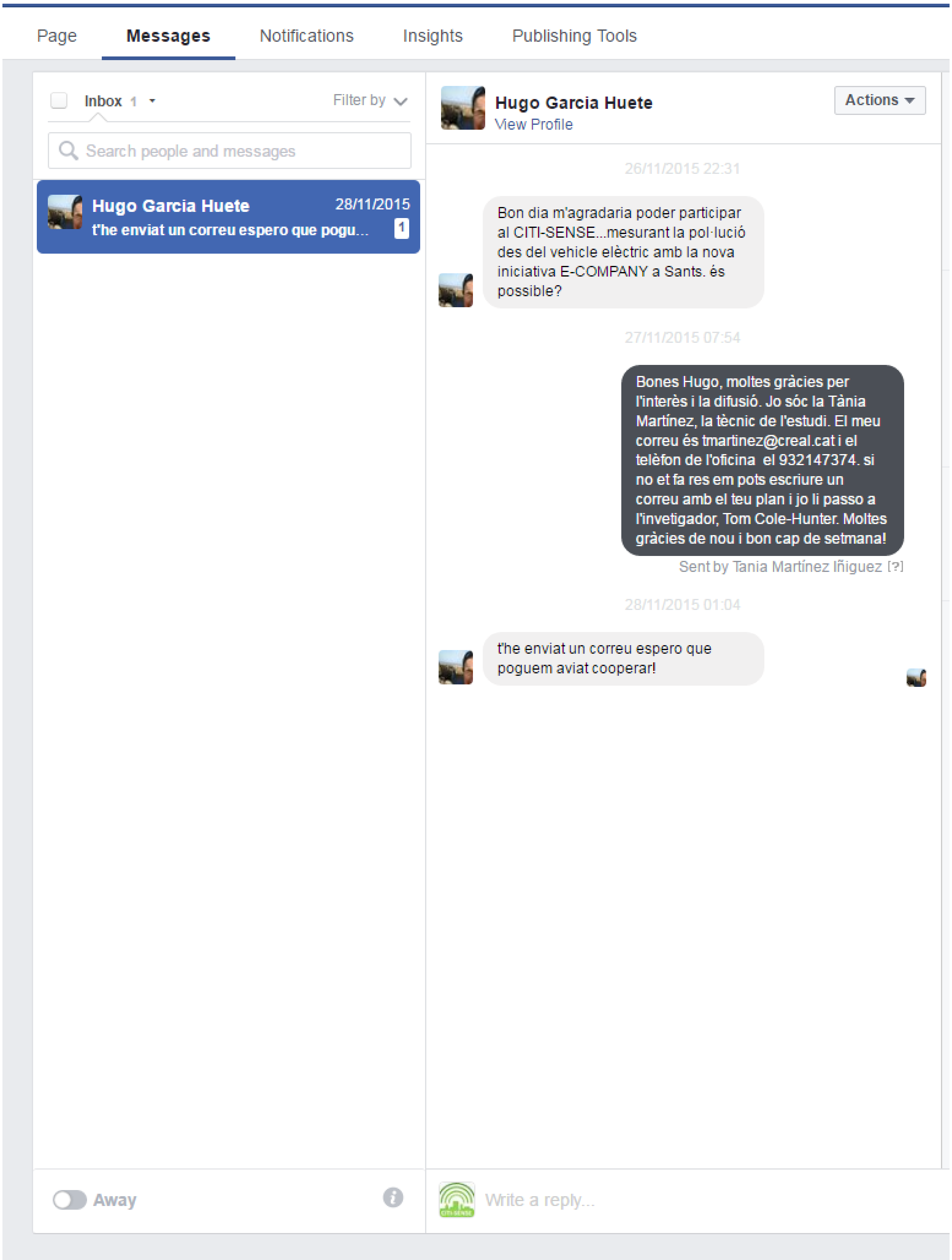


Figure 11b – Facebook account: example, CITI-SENSE Barcelona; message from user volunteering to host a physical sensor in an electric vehicle of the E-COMPANY initiative.

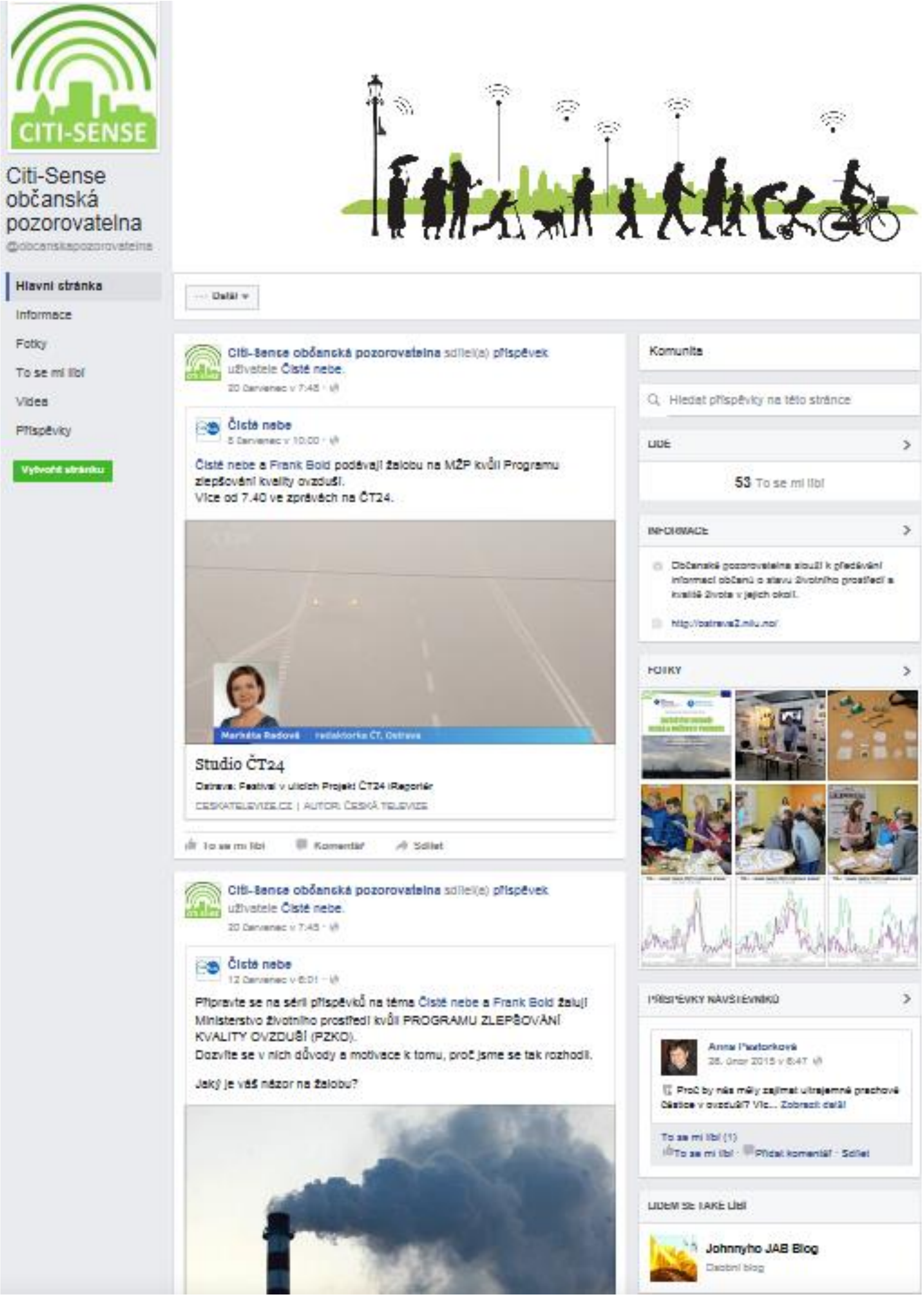


Figure 12 – Facebook account: example, CITI-SENSE Ostrava; profile of home page with 53 ´likes´

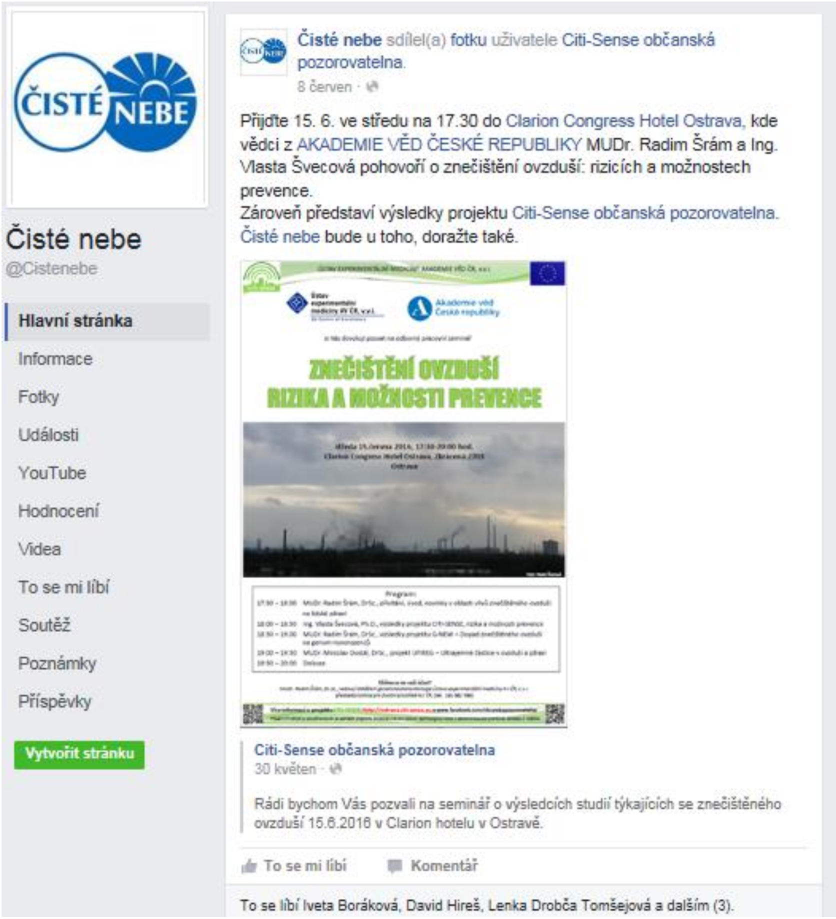


Figure 13 - Facebook account: example, CITI-SENSE Ostrava; facebook account of NGO Clear sky with the advertisement to CITI-SENSE workshop in Ostrava about the results of the project

b) Empowerment potential (evaluation of tools and products by users)

With reference to D5.5, here we give in brief the outcomes of the evaluations for user empowerment potential. This effort of evaluating the tools (as products) for empowerment potential by users was made to accomplish Task 2.5 [*Individual and (focus) group assessment of subject experience with the technology*; M30-46].

LOs worked closely with their assigned WP5 liaison officers in the previous months in preparation for the main deployment of the user tools for use and evaluation of potential to empower. LOs had at their disposal a list of key topics to be discussed during the individual and (focus) group interviews for assessing (subjective) user experience with the technological tools. LOs finalised the dates that user groups will be assessed either in an individual interview or a focus group. More important stakeholders, such as city authorities, were targeted for individual interviews. More populous stakeholders, such as commuter cyclists, were targeted for focus groups. To facilitate data (response) collation and analysis, LOs were responsible for translating verbatim local free-text responses into English for WP5 to categorise them. A method for reducing the burden of (translation) work on LOs was developed, by creating common categorisations from 10% of current responses. Yet, it was decided against use as it was later seen to risk introducing misclassification bias from multiple people/professions categorising rather than just the one.

Questionnaires, with the same content as the individual and (focus) group interviews, were also distributed to engage users that could not personally be identified such as the CityAir application users (which was disseminated via social and traditional media). For this, a Google Form was created for evaluation, however it is difficult to evaluate the results from it since there are forms in different languages and there is limited time and resources to translate the results and analyse them properly. The evaluation of the LAQP was for the results/outputs of the tool that are generated rather than the tool (questions, how it is made available) itself.

The following Table 3 shows a coordinated plan and timeline created for the execution of the evaluations. This table does not present results as it was decided that the most pragmatic thing to do is refer to D5.5.

Table 3 - Summary of evaluation activities performed for each tool; the who and when.
LAQPQ - Long air-quality perception questionnaire; CAA - CityAir smartphone application; LEO - Little Environmental Observatory; COP - Citizens' Observatory (web) portal; NGO - Non-governmental organisation

Tool	Evaluation type	Target groups	Timing
AQPQ-L	(1) Focus group (2) Individual interview	General public Advisory Committee members	Evaluation finalised in July
CityAir App	(1) Focus group (Edinburgh) for LEO users who also used the CityAir app (Ljubljana) (2) Individual interviews (Edinburgh) for LEO users who also used the CityAir app (Ljubljana)	General public Cyclists, patients, students, LEO users	Evaluation finalised in late May
LEO	(1) Focus group e.g. Ljubljana (2) Interview/de-brief, e.g. Barcelona, Edinburgh, Ljubljana	General public Cyclists, patients, students	Evaluation finalised in late May
COP	(1) Focus group/workshop, e.g. Oslo, Edinburgh (2) Individual interview e.g. Edinburgh	General public Local authority, NGO	Evaluation finalised in July

There are differences between the cities, however, which is why the following is a summary of evaluations performed in specific locations (extending from the location names given in the table above), as indicated by LOs:

- Feedback of the products and user experiences were gathered from the identified user groups through focus groups and individual interviews. The first task, which started in April 2016, was with the LEO and CityAir (AQPQ-S) app and more technically oriented stakeholders, such as from the Urbanistic Institute and the traffic department within the City Municipality of Ljubljana. Altogether three individual interviews and six focus group discussions were held to gain feedback on the user experience of CITI-SENSE tools.
- Volunteers carried the LEO and used the CityAir app during April and May 2016. Up to six volunteers were a part of the focus group/workshop to evaluate the LEOs, the CityAir app and the visualization portal (COP). It was initially undetermined if the focus group were also to evaluate the perception questionnaire (AQPQ-L), but both were eventually planned for early June. The COP was also evaluated by a focus group in the kindergartens hosting AQMesh pods. Interviews were held on the LEOs, CityAir app, perception survey and COP with interested NGOs, such as the NAAF (Norwegian Asthma and Allergy association) and authorities (Municipality of Oslo). A third major (biomonitoring) field campaign was held in February 2016; this campaign, or 'user case', was unique to Ostrava. The evaluation questionnaires were used, with the same content as the individual and (focus) group interviews, to catch the feedback from all participants. There were some additional field campaigns in April, where also other groups of volunteers were caught for their feedback. Some selected volunteers from citizens and other stakeholders were used for individual interviews. All work was planned in cooperation with WP5 liaison.
- In Edinburgh and Ljubljana, feedback of the products and user experiences were gathered from the identified user groups through focus groups and individual interviews. Individual interviews were undertaken for users of the LEO, who also evaluated with CityAir App and data visualization portal (as a package). Individual interviews and focus groups were also held with members of the local Advisory Committee to discuss the LAQP, City Air, COP products. In addition, some members of the Advisory committee also participated in individual interviews concerning the LEO.

c) Analysis of objective (physical sensor) data collected

This section will give an overview of the findings from data analysis performed by the LOs leading working groups.

Unpublished analysis: static sensors

The only formal analysis, proceeding for publication in a peer-reviewed journal (now accepted for publication), is that of the static sensors performance compared to government-run, reference instrumentation. An exhaustive evaluation of 24 identical units of a commercial low-cost sensor platform against CEN (European Standardization Organization) reference analyzers was conducted, evaluating their measurement capability over time and a range of environmental conditions. The results show that their performance varies spatially and temporally, as it depends on the atmospheric composition, the meteorological conditions and the platform and sensor degradation over time. The results also show that the performance varies from unit to unit, which makes it necessary to examine the data quality of each node before its use. In general, guidance is lacking on how to test such sensor nodes and ensure adequate performance prior to marketing these platforms. WP2 has implemented and tested diverse metrics in order to assess if the sensor can be employed for applications that require high accuracy (i.e. to meet the data quality objectives defined in the air quality legislation) or lower accuracy (i.e. to represent the pollution level on a coarse scale). Data quality is a pertinent concern, especially in citizen science applications, where citizens are collecting and interpreting the data by themselves.

The table below (Table 4) shows the results obtained in the test performed in the laboratory, under controlled conditions. The results show that the two platforms tested (688150 and 864150) showed good correlations with reference values ($r > 0.9$) for all the parameters analyzed. The slope is close to 1 and the intercept is close to 0 for all the sensors. We also analyzed the cross-sensitivity with other gases, i.e. the contribution of compounds other than the desired compound to the overall sensor response.

Table 4 - Summary of the calibration of AQMesh nodes 688150 and 864150 in the laboratory. The cross-sensitivity has been rated as N=No, L=Low and H= High.

Platform	Data Average Time (seconds)	Species/ parameter	Correlation (*r*)	Slope	Intercept [ppb]	Observed cross-sensitivity between gas species)*
688150	900	CO	0.99	0.86	0.07	NO_2:N, O_3:N, NO:N
		NO	0.99	0.97	-1.13	NO_2:N, O_3:N, CO:N
		NO_2	0.99	1.22	-1.02	O_3:N, NO:N, CO:N
		O_3	0.99	1.16	-1.27	NO_2:L, CO:N, NO:N
864150	900	CO	-	-	-	-
		NO	-	-	-	-
		NO_2	0.96	1.21	3.85	O_3:N
		O_3	0.99	0.99	3.25	NO_2:H

The next table (Table 5) summarizes the calibration results from both the laboratory and the field studies for two static sensor nodes (688150 and 864150). The results show a clear need for field calibration. For instance, field calibration of node 688150 reveal an offset of 166 ppb for CO, compared with an offset of 0.07 ppb obtained during the laboratory tests. The slope and intercept for NO were very similar in the laboratory and the field. The other gases, NO_2 and O_3, showed a large difference in both the slope and the intercept.

Correlations between node and reference data were also significantly lower in the field than in the laboratory. The highest correlation was obtained for the NO sensor, and was comparable to the one found in the laboratory.

Table 5 - Summary of calibration results of AQMesh nodes 688150 and 864150 in the laboratory and the field (collocation with AQM station).

AQMesh unit	Species/ parameter	Correlation (laboratory)	Correlation (field)	Slope (laboratory)	Slope (field)	Intercept (laboratory) [ppb]	Intercept (field) [ppb]
688150	CO	0.99	0.58	0.86	0.88	0.07	166
	NO	0.99	0.96	0.97	0.93	-1.13	-0.12
	NO_2	0.99	0.65	1.22	0.38	-1.02	3.8
	O_3	0.99	0.81	1.16	0.26	-1.27	7.2
864150	NO_2	0.96	0.30	1.21	0.2	3.85	16
	O_3	0.99	0.32	0.99	0.11	3.25	9

The following figure (Figure 14) shows the variation of the absolute bias with temperature for NO concentrations measured by co-located AQMesh nodes. It can be seen that the nodes' performance varies. For instance, node 688150 shows no significant bias, node 864150 shows increasing bias with temperature increase, and node 856150 shows higher bias when the temperature is below 5^{0}C or above 10^{0}C. This indicates that while the manufacturer adjustments work well for some nodes, they do not work as well for other nodes. Similar results were obtained for the other pollutants. Regarding relative humidity, the bias also varies from node to node. For example, some nodes show high bias when the relative humidity is below 40 %, while other (e.g. node 688150) show negligible bias.

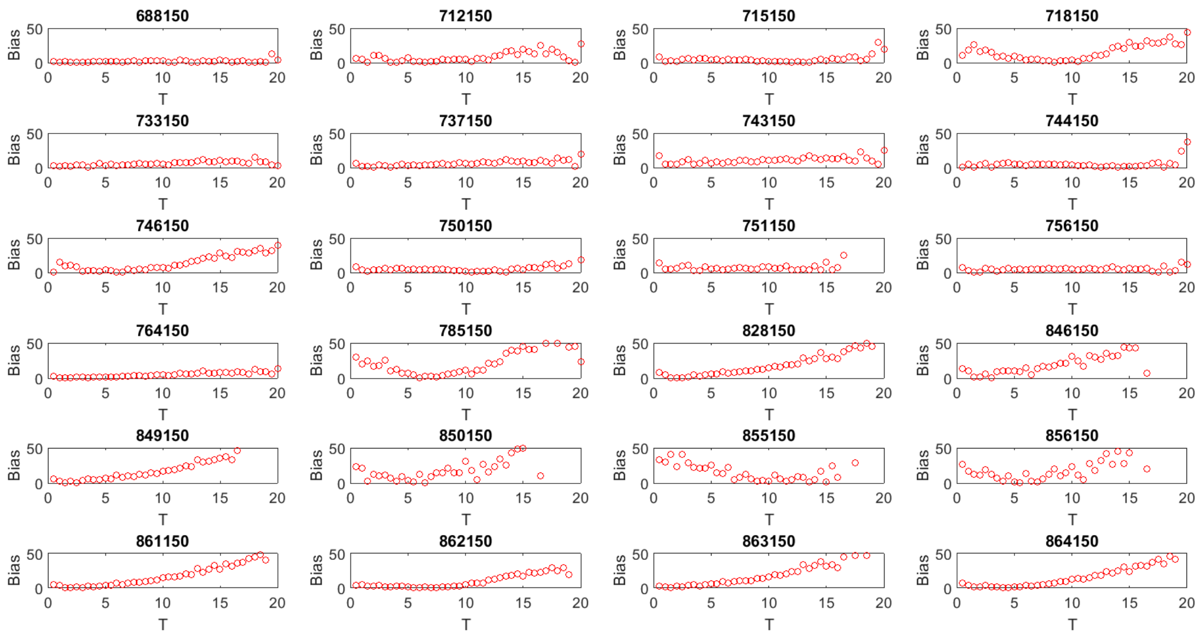


Figure 14 - Absolute bias (y-axis) for NO concentrations in relation to temperature (range: 0 – 20 °C) for AQMesh nodes co-located at Kirkeveien station, Oslo, NO.

The next figure (Figure 15) shows the daily variation for NO and PM_{10} concentrations. The sensor platform is capable of reproducing the time variation measured at the reference station. Thus, even if their data uncertainty is too high for use for legislative purposes, some sensors are still capable of offering interesting information to concerned citizens.

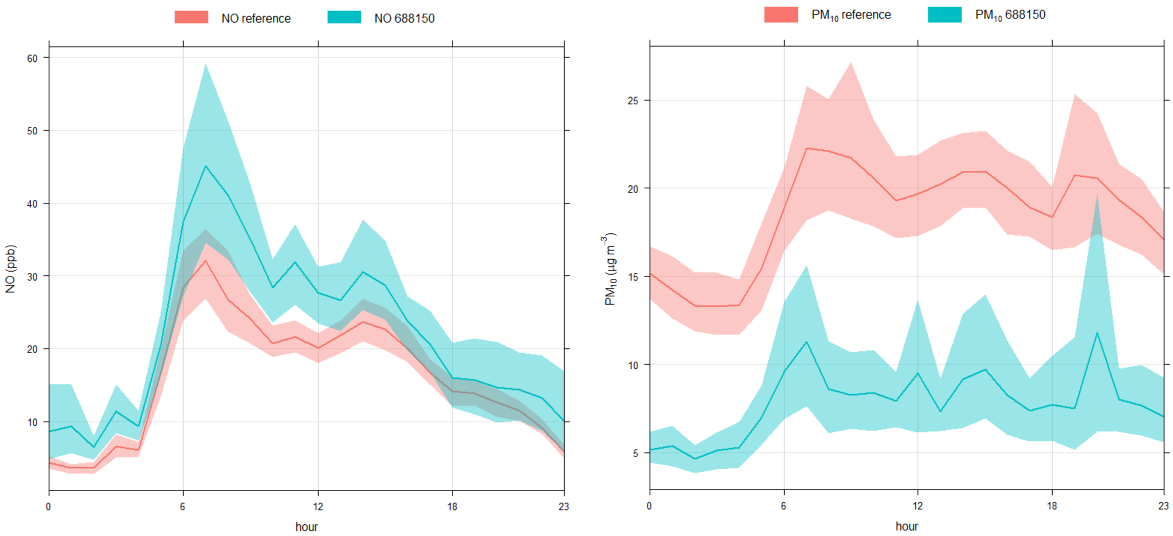


Figure 15 - Daily concentration cycle averaged during April - September, 2015, for NO (left) and PM10 (right) by sensor node 688150 (red) and the reference instrument (blue). The shaded areas represent the 95 % confidence interval.

The conclusion of this work is that, in general, while low-cost platforms provide an accuracy typically too low for regulatory purposes they can provide relative and aggregated information about the observed air quality.

Published analysis: static sensors

This work includes that by Barak Fishbain of WP2, which has been published; interested readers are directed to the online article[7]. The abstract is as follows:

Recent developments in sensory and communication technologies have made the development of portable air-quality (AQ) micro-sensing units (MSUs) feasible. These MSUs allow AQ measurements in many new applications, such as ambulatory exposure analyses and citizen science. Typically, the performance of these devices is assessed using the mean error or correlation coefficients with respect to a laboratory equipment. However, these criteria do not represent how such sensors perform outside of laboratory conditions in large-scale field applications, and do not cover all aspects of possible differences in performance between the sensor-based and standardized equipment, or changes in performance over time. This paper presents a comprehensive Sensor Evaluation Toolbox (SET) for evaluating AQ MSUs by a range of criteria, to better assess their performance in varied applications and environments. Within the SET are included four new schemes for evaluating sensors' capability to: locate pollution sources; represent the pollution level on a coarse scale; capture the high temporal variability of the observed pollutant and their reliability. Each of the evaluation criteria allows for

[7] Fishbain et al. 2016. An evaluation tool kit of air quality micro-sensing units. Science of the Total Environment. http://dx.doi.org/10.1016/j.scitotenv.2016.09.061

assessing sensors' performance in a different way, together constituting a holistic evaluation of the suitability and usability of the sensors in a wide range of applications. Application of the SET on measurements acquired by 25 MSUs deployed in eight cities across Europe showed that the suggested schemes facilitates a comprehensive cross platform analysis that can be used to determine and compare the sensors' performance. The SET was implemented in R and the code is available on the first author's website.

D. Contributions to Citizens' Observatories

In this section, we try to identify the critical elements for success or failure of similar future work such as continuation of the case studies in our empowerment initiative (EI), or initiatives that may use products from the Citizens' Observatory Toolbox (COT) in a similar way. In doing so, this section will list the contributions from WP2 to WP4, outlining the effort made to accomplish Task 2.6 [*Development of contributions to citizens' observatory*; M1-48].

Further to work reported to the European Commission in the a previous interim report ("IR5"), WP2 continued to support WP4 for developing the COT by providing feedback on content and lay-out of the COT web portal. More general feedback was collected from the (external) users on the COT as a product in itself, once the web portal (COP; see table in section Task 2.5, above) was completed and ready for public use, through user evaluations in some locations.

Identifying the critical elements for success or failure of future case studies or EIs came from such evaluations. These are detailed in WP5 deliverable D5.5. Here, however, the important knowledge and skills gained from the lessons learned during case study development as indicated by LOs are given first. Then, an assessment of the impact (i.e. as proposed in the DoW), will be provided following here.

a) Learned Lessons

Here we try to identify the critical elements for success or failure of future similar initiatives, as indicated by the LOs responsible for the case studies of this EI. They will be broken into the sections given in the Methods, to reflect the on-going nature of the work: Development of tools and services; Engagement of stakeholders and (recruitment of) users, and; Evaluation of users.

- Development of tools and services
    - Definition of case studies needed prior to development of products.
        - Partners developing technology assumed no creative control when producing tools, such as the functionality of the COP in terms of geographical and temporal extent of data visualization.
    - Existence of base maps for modelling purposes and consequences for choosing deployment location.
        - Vienna withdrew static node deployment prematurely due to lack of COP availability, or potential to show public users the information output for evaluation, and like Edinburgh shifted nodes to Ljubljana Oslo for the 'super-deployment'.
    - Continuous (iterative) interaction with the developers enables better (usable) end products
    - For the work with public, the products should be functional and verified with the pre-tested results. Public expected the quality products from scientists. Products need to be ready before planning designs of case studies. For example, Ostrava planned the biomonitoring campaigns in advance and due to delayed technology and products, not all products can be used and tested with public in the field.

- Recruitment and engagement of users and stakeholders
    - Despite stakeholders concerns and reservations, engagement can be effective – e.g. despite concerns about the use of novel sensor technology and the potential for 'low quality data being generated' which may then cause concerns amongst citizens and generate more work for LOs, LO was engaged and actively contributed to the project and deployment of GAPs across the city.
    - Limitation/volatility of microsensor technology
        - Edinburgh withdrew static node deployment prematurely due to microsensor hardware failure (from adverse weather conditions), with nodes shifted to Oslo for a 'super-deployment'.
        - Sensor failures due to adverse (but not atypical weather) in some of the locations proving challenging due to costs and time associated with (re)calibrating the pods and consequent data gaps, and having to re-visit deployment locations (which were sometimes difficult to access and required prior approval from stakeholders owning the property).
    - Consequences on having the data fed live to public users
        - Delayed COP availability to public meant short period of use and therefore limited ability for evaluation.
        - New algorithm applied to NO_2 data helped improve output.
        - Need for LO to continually have to manage and adjust stakeholders and others expectations on when products may become available on the project and what their capabilities are
        - The decision not to provide raw data to the citizens but an APIN instead.
    - Engaging with volunteers in public spaces/events can get them easily confused if you introduce too many products at the same sitting. (e.g., what we provide in CITI-SENSE is a variety of products, and in public events this is too much (for the listener) to comprehend. It is better to focus on one product during one event.
    - Limitation of battery life and consequences on deployment duration.
        - Limited financial resources to replace batteries for continued deployment meant modelling not tested 'live' (and therefore publically evaluated) in cities other than Oslo.
        - Inability to re-locate microsensors with reference stations to evaluate drift from initial colocation exercise.
    - Equipment failures – issues were encountered with LEOs during user trials. Whilst users were advised of the experimental nature of the products and care was taken to manage expectations, disappointment was encountered. This can have longer term consequences for other projects due to the negative experiences encountered.
    - Marketing of products

        - Across all locations, but perhaps particularly in Edinburgh, the existence of a similar application with the same name (CityAir)…
        - Barcelona ran a 'Colour Barcelona' campaign to increase use of the CityAir application. This was based upon the platform used in Berlin for the European Citizen Science Association conference.
        - Can be costly when making flyers, business cards, t-shirts, pens etc, as well as adverts in local press.
        - Simply carrying the product (e.g. LEO) in public raises interest and provides opportunities for discussion e.g. during shared rides while commuting.
    - Integrating the sensor technology into local school activities proved to be effective way to teach the youngest stakeholders about air quality. E.g. in Ljubljana
- Local advisory committees such as that convened in Edinburgh were very helpful in gaining advice, support and assistance on the urban air quality initiative from key local stakeholders, as well as allowing identification and linkage with other similar projects.
- Evaluation of products by users
    - LOs had limited previous experience (although this varied by location and user case) on performing interviews and focus groups, so a heavy reliance on WP5 was needed to know how to execute the task effectively and efficiently.
        - Internal training was necessary at the project consortium meeting preceding evaluation tasks.
    - Whether to invite the volunteers to visit the LOs institute or LOs visiting the volunteers will make a huge difference in the time consumed for the interviews the latter one being more time consuming.
    - Many volunteers feel uncomfortable with the idea of the interview being recorded, and even more uncomfortable if they are asked to give statements on video camera.
    - Due to the trans-European nature of the Empowerment Initiative, translation needed to be made at the tool-development stage (e.g. producing AQPQ-L question text) and at the tool-evaluation stage (e.g. transcribing AQPQ-L response recording).
        - Some locations, such as Barcelona, had two different non-English languages to transcribe.
        - Verbatim transcription is costly=time consuming and given the need for this may have limited the numbers of interviews held in some countries.

Perception of air quality – for some cities it was more challenging to engage with citizens than other cities where there is a perception that air quality is good, or certainly better than other cities. In cities where there are concerns, citizens may be more aware and likely to wish for change than action than other areas where it is perceived not to be an issue. Need to find out what citizens' concerns actually are, rather than what they are considered to be. The effort and time invested in trying to engage with citizens is not always reflected by the numbers actually engaged and participating in the project.

b) Assessment of Impact

Here we reflect upon how we expected to achieve/address the impacts as proposed in the DoW, and what impact we had (to our knowledge) in terms of contributions to a Citizens' Observatory.

The CITI-SENSE project is following the European Committee for Standardisation (CEN)'s geostandards (TC 287, TR 15449) and Global Earth Observation System of Systems (GEOSS) approach after due consideration of the different viewpoints of varied stakeholders, following the principles of the International Organisation for Standardisation (ISO)'s Reference Model of Open Distributed Processing (RM ODP) model.

As the CITI-SENSE project decided to follow the CEN/TC287 TR 15449 and GEOSS approach of describing the CITI-SENSE system and services according to the different viewpoints of different stakeholders, following the principles of the ISO RM ODP model, the first deliverable of WP2 (D2.1) described the required use of the CITI-SENSE systems in terms of user stories, use cases and information needs in the pilot case protocols. This is also done for the various pilots and social benefit areas in GEOSS and examples of such descriptions exist as examples to refer to.

Alongside CITI-SENSE, four other projects were funded by the European Commission under the same call for contributions. These projects include Citclops, COBWEB, Omniscientis and WeSenseIt. More information about them and their overall purpose can be found online here: http://www.citizen-obs.eu/.

These projects all aimed to impact society by "developing novel technologies and applications in the domain of Earth Observation, trying to exploit the capabilities offered by portable devices (smartphones, tablets, etc.), to enable an effective participation by citizens in environmental stewardship based on broad stakeholder and user involvement in support of both community and policy priorities." Now, to close, we will explore what may be next for CITI-SENSE and its products. The LOs will indicate how the products are seen to be picked-up and used beyond the project, and what needs to be in place to allow this, at each of the locations of this EI.

- Funding
    - Minimal finance may be necessary to maintain information-technology services (e.g. cloud computing).
    - A higher level of finance is necessary to expand existing networks, to acquire hardware and cover widened maintenance costs.
- Autonomous, funded/voluntary advisory board
    - Minimal (core) members needed to control, direct or delegate tasks or permission-giving to use limited resources.

    - A higher level of membership numbers are needed to expand reach (number) of case studies, to share burden of time demand.
    - A medium/high level of finance is necessary to maintain the CityAir app, so it can be updated and the data stored.
- Developer support for their product (service or tool)
    - Minimal support is needed by developers to troubleshoot issues encountered with use of their product, in conditions similar to the case studies of CITI-SENSE.
    - A higher level of support is needed by developers to adapt products to more varied case studies and reach into other fields of observation.
- Third parties must be able to access the raw data in order to develop their own applications and visualizations. E.g. in Ljubljana
- Local institutes in Ljubljana are interested in dense network of noise data. The Ljubljana team collaborated with the local institutes to explore the use of AQMesh for this purpose. Similarly interest towards the AQ data in Ljubljana was raised by various parties, however, the data quality was of concern for making a next step.
- Local schools will want to continue collaboration also after the life frame of the project.
- Products intended for public use need to be very easy to manipulate and understand with minimum support needed!

Annex

I. Executive Summaries of previouse Deliverables

This annex is given to allow the public to see, alongside this Deliverable, what previous Deliverables had dealt with and how the project had progressed and matured until the point of this document (i.e. Deliverable) being delivered.

i. D2.1.

This document details the protocol for multiple location pilot case studies within the four year CITI-SENSE Collaborative Project partly funded by the EU FP7-ENV-2012 under grant agreement 308524, which commenced in September 2012. Eight different locations (Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava and Vienna) will gather environmental sensor-enabled, health-relevant information on indoor and outdoor urban spaces. The overall aim of CITI-SENSE is to create a citizen observatory (CitObs) of which is used to empower citizens with the means to be informed and to communicate directly with authorities and policy-makers regarding contemporary urban environmental health issues.

In work package (WP) 2, we will focus on urban environmental health indicators including air pollution, and also to an extent noise and ultraviolet radiation, of outdoor urban spaces.

Initially, a pilot study will see a limited number of personal/mobile and geographical/static sensor nodes strategically deployed at the eight different locations to evaluate sensor technology and citizen participation. Using sensor-enabled data, methods will be tested for facilitating air pollution modeling, such as dynamic land-use regression (LUR) modeling, complemented by existing air monitoring networks to provide near-real-time map layers of urban environmental health indicators, including initially CO_2, NO_2, NOX (and then for the main study PM and noise), to produce an information service for citizens. Further afield, in some case studies with some special citizen groups, physiological responses to urban environmental health indicators may be monitored.

Progressively, feedback from different aspects (such as the technical and sociological methods) of the pilot studies will contribute towards the main study protocol and final products of the CITI-SENSE project. The final products or services will be developed and refined in consultation with relevant stakeholders such as local government, environmental advocates, and hospital outpatient groups.

Ultimately, the CITI-SENSE will contribute towards the development of CitObs and the improvement of the quality of life in urban environments, facilitating the detection and mitigation of environmental health indicator level limit breaches that may negatively impact citizens' health and quality of life on a daily basis.

ii. D2.2.

This document details the main study protocol for the location-based empowerment initiatives (EIs) within the four-year CITI-SENSE collaborative project partly funded by the European Union's Seventh Framework Programme for research, technological development and demonstration (EU FP7-ENV-2012, under grant agreement 308524). The fieldwork of the CITI-SENSE project, which commenced in September 2012, is based in nine different European locations (i.e., Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava, Vienna, and Vitoria-Gasteiz). These locations have started to gather environmental sensor-enabled, health-relevant information on indoor and outdoor habituated (urban) spaces. This information is intended to facilitate the creation of a location-based citizens' observatory (CO) to engage citizens, authorities and policy-makers (as stakeholders) and empower them to address contemporary urban environmental health issues.

In work package (WP) 2, we are focusing on such issues as elevated air pollution and noise of outdoor urban spaces. Initially, a pilot study saw a limited number of personal (mobile) and public (static) sensor nodes strategically deployed at eight different locations (being all but Vitoria-Gasteiz which pertains to another WP) to evaluate novel sensor network technology and initiate stakeholder engagement. The limited number of nodes meant consequential limitations in reach of engagement and testing opportunities of the entire network. For one, only the lead WP2 location (Barcelona) was able to handle and test the mobile nodes. For two, the quality of data coming from either type of node was not considered mature enough for using as a stakeholder engagement tool (except limited engagement with personnel of local air quality monitoring stations where nodes were co-located to obtain reference values). Despite these limitations, sensor-enabled information from the pilot study showed potential for personal and public exposure assessment, particularly with patterns of spatial and temporal variability.

The development of an application which collects smartphone-enabled information such as geolocation and accelerometry allows more accurate assesement of time-activity exposure profiles. The information, however, was not considered mature enough to be a standard of regulation for health-related exposure assessment. As such, this sensor-enabled information was decided to be used in a general advice service for the main study, shifting emphasis from technological to sociological tools of engagement and empowerment.

Besides quantitative data, qualitative data from user experience surveys administered with convenience samples in Barcelona showed that the technology can be interesting and practical to stakeholders. Some stakeholders (i.e. local authorities), however, have been hesitant to become involved with the project due to the potential of EIs and ultimately COs increasing public pressure to address complicated environmental issues such as deteriorating air quality. This hesitation and possible solutions are discussed with general communication methods in section 4.5 of this document.

Biannual feedback from the project's Technical Advisory Group (TAG) has highlighted that citizens should be involved at an earlier stage through a bottom-up co-design process of products and services (tools) to drive functionality of COs, prior to the start of the main study. Bottom-up co-design has also been supported by WP5 as a very important success-factor for the continued use of the project's tools beyond the life of the project. The extent of participation by the public in design of our tools, however, is limited due to technical aspects at an earlier stage of the project being quite fixed from an initial top-down decision-making process. Therefore, these limitations need to be transparent, to manage expectations, and focus on the aspects that still allow public-input-driven changes, for example the co-development of environmental quality perception questionnaires (trialled with citizens in Oslo by WP2), user-friendliness of tools (trialled with citizens in Barcelona by WP2), and visualizations of tools (trialled with schools in Ljubljana by WP3b). Towards the end of the main study, participatory evaluation will focus more on the research process, on what participants think of the quality of the participatory process, for example on their ability to influence the research design, data quality, on-going project decision-making, community interest group meetings, and so on.

Progressively, feedback also from both the technological and participatory trials of the pilot study has contributed towards this main study protocol (i.e., D2.2), its' products & services and ultimately the concept of a CO. As the main body of D2.2 will continue to detail, location EIs are to receive an increased number of both mobile (up to ten) and static (up to thirty) sensor nodes for a greater spatial distribution and reach, therefore impact on society throughout the location EI. Not only will the quantity of nodes substantially increase, but also the expected quality (functionality) of the nodes due to feedback for WP8 from the WP2 location piloting. For example, the mobile nodes now automatically, wirelessly and safely transmit data to a participating smartphone via Bluetooth technology, which then relays data to the project's dedicated web feature service for processing and visualising. Additionally, the static nodes now have optical particle counting and ambient noise monitoring capabilities, two very important environmental health considerations
Visualisations of the data collected are in different forms, suitable for different platforms, including smartphones, personal computers and even street art installations . Such visualisation services will later be evaluated in the project as part of a participatory evaluation process.

Satellite projects, such as an initiative facilitating the aforementioned street art installation in Barcelona and Oslo, will provide added-value to the project by exploring atypical medians for scientific dissemination. That is, popular and social media are being explored as a means to demystify the scientific process and significance behind environmental quality monitoring, boosting opportunities for engagement and empowerment among the general community of a location (and even between them) without technical training. Additionally, added-value methods such as dynamic data

fusion techniques and land-use regression modeling will provide near-real-time map layers of urban environmental health indicators, including gaseous, particulate and noise pollution, in multiple locations, allowing comparisons of exposure profiles to empower individuals in inequitable situations. Products and services will continue to be developed and refined in consultation with relevant work packages but also stakeholders such as participating citizens, local government(s) representatives, environmental advocates, and hospital outpatient groups towards the final set of tools. For that, participatory evaluation methods will be used in which are included questions on how to improve products and services.
Other important aspects such as CO branding and publication planning are touched upon in sections 4.6 and 4.7, respectively. In addition to D2.1, interested parties are referred to other deliverables produced by other WPs, including of the technological (WPs 6, 7, 8) and participatory (WPs 4, 5, 9) methods. Ultimately, CITI-SENSE will contribute towards the development of COs and the improvement of the quality of life in urban environments, empowering citizens and facilitating environmental health governance such as through the detection and mitigation of environmental health indicator and noise level limit breaches that may negatively affect citizens' health and quality of life on a daily basis.

iii. **D2.3.**
This document details the assessment of the CITI-SENSE Pilot Study while reporting the plan for the Full Implementation of the location-based Empowerment Initiatives (EIs) within the four-year collaborative CITI-SENSE project, funded by the European Union's Seventh Framework Programme for research, technological development and demonstration (EU FP7-ENV-2012, under grant agreement 308524).

The Pilot Studies of CITI-SENSE, based in nine different European locations (i.e., Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava, Vienna, and Vitoria-Gasteiz) commenced in September 2012. These locations gathered environmental sensor-enabled, health-relevant information on indoor and outdoor (urban) spaces. This information is intended to support location-based Citizens' Observatories (COs) for engaging citizens, authorities and policy-makers (as stakeholders or as having vested interest) and empowering them to address contemporary issues of urban environmental quality. In work package (WP) 2, elevated air pollution and noise of urban outdoor spaces are the issues being monitored. This document is the third deliverable of WP2, following the first (D2.1) as a Pilot Study protocol and the second (D2.2) as a limited Pilot Study evaluation.

Initially, the Pilot Study of WP2 evaluated novel sensor network technology and initiated stakeholder engagement with a limited number of personal (mobile) and public (static) sensor nodes trialled at eight different locations (being all but Vitoria-Gasteiz, a location pertaining only to WP3). Limitations from the small number of nodes available resulted in a reduced reach of engagement and testing opportunities of the entire network (demonstrating data flow). Firstly, only the lead WP2 location

(Barcelona) was able to deploy and co-evaluate the mobile nodes with hosts due to a limited number of prototypes made available by the manufacturer (also based in Barcelona). Secondly, the quality of data coming from either type of node was not considered accurate and thus not useful enough for engaging citizens and stakeholders, especially not the mobile nodes. The only engagement with data that occurred was limited to the personnel of local air quality monitoring stations (AQMs), where nodes were co-located to obtain reference values for applying offset and slope, as well as a peer group with collocated sensor nodes. Despite these limitations, sensor-enabled information from the pilot study showed potential in variability (i.e. changes in space and time, spatiotemporal) trends for personal and public exposure estimations.

An application which collects smartphone-enabled information such as geolocation and accelerometry, allowing more accurate assesement of time-activity exposure profiles, has been developed and will be trialed in the coming months. Previously, the information coming from personal sensing within the project was not considered mature enough to be at a standard for regulation of health-relevant exposure levels. As such, this sensor-enabled information was decided to be used only in a general advice service for the main study, shifting emphasis from technological to sociological tools of engagement and empowerment. The pre-established Common Air Quality Index (CAQI), for example used in previous projects , will be used to communicate general air pollutant levels in a simple, non-technical manner. Besides quantitative data, qualitative data from user experience surveys collected through convenience samples of volunteers in Barcelona showed that the sensor technology can be interesting and practical for stakeholders, defined as groups that will be affected directly from the outcomes of project work. Some stakeholders (i.e. local authorities), however, have been hesitant to become involved with the project due to the potential of EIs' and ultimately COs' increasing public pressure to address complicated environmental issues such as deteriorating air quality. This hesitation and possible solutions of how to engage these local authorities are discussed in section 3 of this document.

The Full Implementation will be publicized leading-up to a common public launch in all Case Study Cities (CSCs), where products and services from the project, and those of the peer groups (and collaborative outcomes) will be disseminated to the general public. Visualisations of the collected data are available in different forms, suitable for different platforms, including smartphones, personal computers and even potentially augmented reality within street art installations. Such visualisation services will later be evaluated in the project as part of a participatory evaluation process, performed by both the project partners and the public themselves. Satellite projects, such as an initiative facilitating the aforementioned street art installation in Barcelona and Oslo, will provide added-value to the project by exploring atypical ways for scientific dissemination. That is, popular and social media are being explored as a means to demystify the scientific process and significance behind environmental quality monitoring, boosting opportunities for engagement and empowerment among the general community of a location (and even between locations) without technical training. Public interest in environmental information and how to fine tune content for popular and social media will be analysed for scientific publication. Additionally, added-value methods such as dynamic data fusion techniques and land-use regression modeling will provide near-real-time map layers of urban air quality indicators, including gaseous, particulate and noise pollution, in multiple locations, allowing comparisons of exposure profiles to empower individuals in inequitable situations. The Common Air Quality Index specifically will be used for this purpose. Products and services will continue to be developed and refined in consultation with relevant work packages but also stakeholders such as participating citizens, local government(s) representatives, environmental advocates, and hospital outpatient groups towards the final set of tools. For that, participatory evaluation methods will be used, which include questions on how to improve products and services in a co-creative, co-design approach.

Now that the Pilot Study has established the technology and tools for a CO, the Full Implementation will be focused on two main activities:
1. Citizen/stakeholders observing the environment. Location Officers (LOs) have recruited citizen/stakeholders to participate actively in the collection of data and to be empowered for environmental issues.
2. Building a community of users and followers of the project interested in its outcomes ; using/following the information service to address environmental issues.

In summary, this deliverable (D2.3) will inform the reader on what has been learnt from the Pilot Study and what we plan to learn further through the Full Implementation in regards to citizen and stakeholder participation.
In the first section (as the Introduction), the reader is introduced to the document with a succinct summary of its content, introducing the four aspects of the Full Implementation process, including: citizens observing their environment; building a community of citizens that are participants ('Users') and followers ('Observers') of the project; participatory evaluation of the quality of citizen empowerment in the EI, and; comparative analysis.

Following the first section, the second section of this document summarises the main conclusions extracted from the final evaluation (as Key Performance Indicators, KPIs) of the pilot studies. The summary of these conclusions are focused on the recruitment of contributors, the people directly related to the data collected, and observations to be made in the Full Implementation. It describes and analyses the methods and results of the recruitment activities carried out so far, such as which users and stakeholders have been recruited and the foreseen assessment of their participation. This second chapter also collects any work done in the Pilot Study not previously reported. The chapter ends with a succinct summary of the main lessons learned from the Pilot Study for the purpose of planning the Full Implementation.

The third section describes the plan for the Full Implementation with the specificities needed to be implemented in each of the Empowerment Initiative (EI) cities. The aims and objectives (as a whole and by location), products and services, and KPIs for the Full Implementation are provided here. It includes the different components needed to be deployed for engaging citizens and stakeholders, being the products and services. Included in this chapter is a review of the KPIs to be used to evaluate the Full Implementation phase, based upon guidelines for context and construct of public participation in scientific research. It should be noted that WP5 will take the lead on engagement and empowerment issues, however WP2 will be an integral part of activities with WP5 at a local level.

Section 4 presents the coordination and learning among cities, explaining how different cities within the project, and even peer projects, can learn from each other through comparative analysis. As explained, this is expected to increase the value of the project outcomes and therefore attractiveness/longevity of the EIs and their COs. This chapter also includes the plan (timing) for the activities to be conducted in each CSC as a summarised table ('Chart 3. Activity plan coordination for the Full Implementation').

Section 5 reflects upon the expected impacts of the project products and services and how the Full Implemention plan will target these. It was said in the Description of Work (DoW) that CITI-SENSE will empower citizens in the EU and partner countries by enabling effective participation in local and the EU's environmental governance. To achieve this, it was stated that CITI-SENSE will realize the chain "sensors-platform-products-users", linking information users to information producers.

In Section 6, a conclusive summary is provided to summarise the main points from the plan for the Full Implementation.

Finally, as supplementary material, various key documents (in their English version) are provided for the reader, including the privacy policy, the user agreement (as informed consent) and the commodatum (property ownership) agreement which are to be used to protect the interests both of the project partners and the project product/service users. The participant work plan, provided to participants when inducted into the project by LOs to inform them of the protocol during their involvement, is also given here. The tools for "using" citizens as sensors, not just stakeholders, are provided for the reader's reference with the other documents/forms, all given in the final section, the Appendix. These are some of the key tools for establishing a CO in each EI during the Full Implementation.

Through the content within, this document describes the detailed plan for the Full Implementation of the first (i.e. outdoor urban quality) EI and specifically the assessment of the recruitment of involved end-users. Further, it assesses the potential for long-term sustainability including the up-scaling of activities, to create useful and viable COs.

II. Additional City-specific Description and Results

This Annex provides more detail on location-specific activities associated with recruitment, engagement and empowerment in those cities that wished to provide additional information to the main body of this report.

Edinburgh

Various user groups and location specific activities were undertaken in Edinburgh from an engagement and empowerment perspective in the main study, these being:

- Local Advisory Committee
- Citizens with a perceived interest in local air quality
- General public
- Local authority and installation of static air-quality monitor network.
- Stakeholders interested in the use of low cost sensor technology

These initiatives are discussed in more detail with particular reference to the extent of engagement and the local legacy (empowerment) as judged by the Edinburgh LO. The actual results of the empowerment potential are not discussed here as these are addressed elsewhere in this and other deliverables.

The specific aims/objectives of this special case are as follows:

- Edinburgh Case Study involved the following key components (amongst others):
  - Engagement with local authorities, researchers, NGOS, monitor manufacturers and citizens to explore the opportunities and challenges to the use of low cost sensor technology for monitoring air quality and engaging with citizens
  - Engagement with key stakeholders and citizens to obtain their perceptions on Edinburgh air quality via the LAQPQ and CityAir app
  - Conveying and running several Advisory Committee meetings to engage with key local stakeholders on the CITI-SENSE project and elicit their views and opinions for inclusion
  - Exploring usability and empowerment potential of key tools such as the LEO, CityAir App and the data visualization webpage
  - Engagement with local stakeholders to install a network of static GAPS across the city of Edinburgh to allow the testing of these devices

In conjunction with WP3, engaging with a local secondary schools to explore how novel sensor technologies may be used by the school children.

Local Advisory Committee

It was clear that engagement with key stakeholder groups was of great value to the project and the decision was taken to convene an Edinburgh Advisory Committee focused on the WP2 element of the work. The remit of the Advisory Committee was to provide an independent forum for the IOM research team to meet with local experts on urban air quality in Edinburgh to discuss project progress.

The role of the committee was to provide advice and guidance on:
- the sensor deployment in the Edinburgh area
- spatial variation modelling in the Edinburgh area
- the engagement and communication of air quality information to interested citizens and stakeholders
- exploring synergies and linkages between the CITI-SENSE project and other air quality initiatives in Edinburgh.

The Advisory Committee comprised of representatives of the local authority, Scottish Environmental Protection agency, Friends of the Earth (NGO) and an air quality research for another local research organization. The committee met formally on five occasions over the course of the project and valuable contributions were provided which helped the local team focus project efforts (although it should be noted that not all members were able to participate on each occasion). It was clear from the Advisory Committee members that there were a range of opinions and views on the use of novel air quality sensors.

In additional the local advisory committee participated in the empowerment potential of the interim results of the LAQP questionnaire, the CityAir App, the web portal and data visualization webpage. In addition, two members of the advisory committee also trialed and provided feedback on the personal LEOs.

Overall it was considered that engagement between the Advisory Committee and local CITI-SENSE team was good and productive, primarily because there was investment in the initiative from all participants. The contributions that the Advisory Committee made was very much appreciated. Overviews of the focus group and interviews held with these stakeholders will be provided in the WP5 deliverable. A legacy from the Advisory Committee initiative is that links have been established with these stakeholders and it is hoped that this will foster joint working on other local air quality research projects.

Citizens with a perceived interest in local air quality
The target here was primarily cyclists who were perceived would have a greater interest in air quality. During the main study the following methods were employed to engage with such groups (those used during the pilot phases of the project are not discussed):

Pedal on parliament, http://pedalonparliament.org – This is a grass-roots group of people who want to see Scotland become a place where active travel is safe and enjoyable for everyone, whether they cycle or not. On an annual basis there is a mass rally of people who cycle to the Scottish Parliament to make their voices heard. At this event, engagement was via direct contact with cyclist, approaching them to complete the LAQP whilst they waited for the rally to begin which proved to be very effective with the majority, if not all of those approached completing the questionnaire. Flyers were also distributed to encourage participation in the LAQP however it is considered that this is ineffective as people are likely to discard or forget about them.

SPOKES bike breakfast, Edinburgh festival of cycling – this was a relatively small scale event (200-400 persons, dropping in during the 3 hour period) organised as part of the festival of cycling. The CITI-SENSE project had a stand to promote the project and to encourage interested persons to sign up for further information and express an interest in participating in the CITI-SENSE initiatives. 17 people signed up for further information, some of which taking more flyers for colleagues / students. Some comments concerning the CITI-SENSE project were that it was a 'worthwhile initiative' and 'it would be great if you could come into the office and give a short talk/presentation on the work you are doing. Perhaps some of the work will sink in and help us better inform master planners of new cities!'

Given the issues presented concerning the personal sensors cyclists were not approached (who were originally intended to trial these). All those who expressed an interest in the study and who left contact details were contacted and encouraged to participate in the LAQP and use the CityAir App. As these are both anonymous tools it is unknown whether this request was acted upon. It is also unclear what longevity these engagement efforts have on those engaged with however it is considered to be low.

General public

The focus of the engagement with the general public was to encourage participation in the LAQP and the use of the CityAir App. Various strategies were employed as part of this campaign including:

- Posters / flyers displayed in local businesses, community centres, libraries, leisure centres
- Adverts in local press for three consecutive weeks and also on-line – this local press is made available free at all local train stations, buses, park and rides.
- Distribution of flyers around research park and university, park and rides and also at main train station during rush hour.

A significant amount of effort was invested to disseminate and encourage participation in these tools however the return on this was low. It is possible that this reflects more widely the effectiveness of these more passive engagement methods and that other more active strategies (such as those used at the Pedal on Parliament event) may be more effective. It is highly unlikely that there is any longevity in these approaches or the continued use of the CityAir App. Uptake in Edinburgh was low and continued use was lower. However, steps can be taken on monitor use of this tool which will help inform the longevity potential of this product

In addition direct contact was made with IOM colleagues and their friends and family to participate in the empowerment potential of the LEO, City Air App and data visualization webpages of the COP. It was decided to limit the evaluation of the LEOs to a group of people where it was considered more achievable to manage their expectations on what the tools current capabilities were. Due to financial limitations the evaluation was limited to 8 individuals, seven of which having their interviews recorded. These were transcribed and then sent to WP5 representatives for analysis. Had other resources been available, it is likely that more participants would have been included in this empowerment evaluation.

Local authority and installation of network of static air quality sensors
A key element of the planned main study was the setting up of a network of static air quality sensors (GAPs) around key locations in Edinburgh. Successful engagement with members of the local authority was required to achieve this as the GAPS needed to be installed on lampposts and permission was required to do so and this was achieved.

Due to previous experience with using low cost sensor devices (manufactured by other developers) our key contact with the LA was very skeptical concerning the reliability and usefulness of data obtained from such tools. Concerns were expressed that the data did not accurately reflect that generated from the official reference monitoring equipment and that the provision of this information to relatively uninformed citizens may cause unnecessary worry and alarm. The development and reliability of models using data from such devices was also raised as a concern. Despite these issues being raised, the LA was very accommodating in facilitating the provision of the GAP network in Edinburgh. There was engagement in the selection of lampposts across Edinburgh and also access to the reference air quality monitoring stations to allow comparisons to be undertaken, which was time consuming for all those involved. This engagement was possibly successful due to the inclusion of the LA in the Advisory Committee thus allowing transparency in the issues and otherwise presented during the use of the GAPs. In addition, during the time of the network deployment, no data was made publically available.

The decision was taken to remove the GAP network in Edinburgh in March 2016. This was partly due to issues with the provision of base maps to allow for the mapping exercise envisaged for the project. More crucially (and the main issue), widespread sensor failures occurred in Edinburgh due to the atypical winter weather conditions (similar issues were encountered in the pilot study) which led to significant costs being incurred in the replacement and recalibration of these pods. Also the limited battery life of the pods meant that the batteries had stopped working before all the other cities had fully deployed and no funds were available for these to all be replaced on a second occasion. It is unfortunate that the engagement and longevity potential of a fully functioning sensor network with publically available data was unable to be evaluated in Edinburgh during the course of the project. However it is hoped that through the engagement and open discussions that took place during this work that such opportunities may be welcomed in the future.

Stakeholders interested in the use of low cost sensor technology
The Edinburgh CITI-SENSE team, in conjunction with the Scottish ResearcH partnership for Air Pollution health Effects (SHAPE), organised a workshop focused on the 'Use of low-cost sensor technology to monitor air quality & engage citizens". This was also funded by the EPSRC Network SECURE. The workshop brought together 44 participants including researchers, local authorities & public bodies, sensor developers & consultancies and citizens & civil society groups, both from the Lothian locality but also from the wider Central Belt for Scotland and Northern England. To facilitate the discussions an overview of current sensor technologies was provided which included an overview of the key findings from the CITI-SENSE project. The workshop participants then addressed key questions; these being the current capabilities and needs ("Current sensor capabilities & applications", "What data do citizens need/want?" and "Low-cost sensing for local authorities") as well as looking to the future needs and considerations ("Research needs for next-generation sensors", "How to safeguard data quality from CS projects?" and "Stakeholder roles for next generation low-cost sensors").

The workshop concluded that *"in order to overcome key barriers in the development and use of low-cost sensors, there is a clear need to improve sensor performance and implement standards. However, there is currently no clear funding model for this, and different stakeholders (government, regulatory agencies, academia and research institutes, private companies) could have a role to play".*

Activities such as this workshop were viewed as being important to facilitate and engage different groups and stakeholders, and to foster an ongoing dialogue. In addition to providing information, it was viewed that this dialogue can help to shape the policy and governance landscape, for instance creating platforms and initiatives where scientists, citizens and civil society groups, regulars and policy makers (and others) can co-produce solutions to improve public health and well-being in the cities of tomorrow".

Whilst the CITI-SENSE products were not evaluated for their empowerment potential within the workshop it is considered that the contribution that CITI-SENSE made to this workshop is valuable and is one of the key contributions produced by Edinburgh. The learning from CITI-SENSE helped inform, facilitate and focus the discussions, which themselves will then inform the planning and execution of future air quality / citizen engagement projects. It was clear from the discussions that there was a 'buzz' and a need to move forward and ensure ongoing dialogue between the involved stakeholders continued as this may help shape policy and local governance.

Future initiatives which were mentioned and for which there seemed a clear impetus to move forward were the drafting of a publication to help foster dialogues as well as engagement with the Scottish Government and others not represented to establish and maintain initiatives so that solutions to improve public health and well-being in the cities can be produced via a collaborative platform.

Summary

Various strategies were implemented to engage with citizens and stakeholders in Edinburgh with varying degrees of success. It is considered that active rather than passive means of project dissemination and engagement were more effective. It is considered that engagement with citizens and other stakeholders can be challenging due to the need to carefully manage expectations. The Edinburgh CITI-SENSE team considered there was a need to 'hold back' on more active recruitment due to, fro example, concerns about the actual delivery date of the LEOs and other products as well as how they would actually perform on arrival.

It is one view that the longevity of the CITI-SENSE project is unclear at this stage. Dissemination of the overall project findings is still ongoing, discussions are still taking place and so the full implications of the work may not be realized until a period of time following the official end date of the project. It is however clear that there is a building interest in this area with other local researchers undertaking similar or related projects, being keen to explore the potential for some of the CITI-SENSE tools in their work. For example, ongoing links and engagement during the project has resulted in students from the University of Strathclyde deploying the LEO sensors, alongside other sensors at an urban background monitoring site in Glasgow to allow for data comparisons. It may also be hypothesized that future campaigns encouraging citizens to participate in the LAQP may be run, particularly following any local initiatives to reduce air quality. One member of the Advisory Committee did state that they could see value in the LAQP in helping inform future campaigns and it will be interesting to see if this is indeed the case.

Haifa

In Haifa we used a "User centered design" for building a local internet site and data presentation platform. This approach is based on active involvement of users, to improve the understanding of platform requirements, while conducting multiple iterations of design and evaluation. This process was done through Semi-structured interviews with residents hosting the sensors in their homes, focus groups, using comments on the project website and utilizing information from the CITISENSE perception questionnaire.
While assessing the needs of the community, we presented interviewees 3 levels of data presentation:

- An overview map of the neighborhood with sensors marked by color according to air quality measurements, on a 1-5 qualitative scale.
- Comparative pollutant distributions graphs.
- Raw measurement data, presented with a table.

We asked participants to explain what they understood from each presentation, and in general which presentation they preferred. The results were very conclusive, participants understood and preferred the general map, and they did not understand or think it was helpful to see the raw data. The distribution graph was clear to some participants, not all. This information served as the basis for building our platform and included a number of iterations for improving data presentation and adding information.

Lessons that were learned about participants needs: participants requests can be divided into a number of categories:

- Factual information- Understanding basic facts, such as air pollutants and sensor distribution.
- Putting things in context- relating data to Israeli law, and to the world.
- Bottom line- is the neighborhood polluted?
- Practical and health implications of the data presented

Ljubljana

Various stakeholders were involved throughout the case study in Ljubljana. The local authorities were kept informed about the progress of the project thru emails, phone calls and face-to-face meetings during which their views were listened and implemented where feasible. More technically experienced volunteers provided the main pool for LEO volunteers in the main study. This strategy was adapted after assessment of the limitations of the current status of the device, it being too complex for a regular citizen. Host of the AQMesh were chosen both considering a spatial distribution of the pods throughout the city (originally having mind the LUR modelling needs) as well as the interest of the general public. Activities with the local public included outdoor stands during various open day events as well as a campaign in the streets of Ljubljana together with high school students (see D.3.4). The Ljubljana EI focused on engaging with local schools not only in indoor air quality (D3.1-D3.4, but mainly on outdoor activities. This included organizing nature days to primary school children (1st, 3rd and 4th graders) as well as walks around the school (with 8th graders) where portable sensors were used together with other interesting and equipment with educational potential. Three schools were also provided with outdoor sensors (AQMesh), which led to student's research assignments. In addition two high school students developed a mobile application displaying air quality in cities, which they also presented in various international competitions (e.g. Genius Olympiad in Houston, US) receiving awards for their accomplishments. The phone app enables inclusion of measurements from any amateur air quality monitoring product, CITI-SENSE data and cities being just one of many global sources of data. The municipality of Ljubljana acknowledged their success both by meeting with the mayor as well as including them in the green capital activities in 2016.

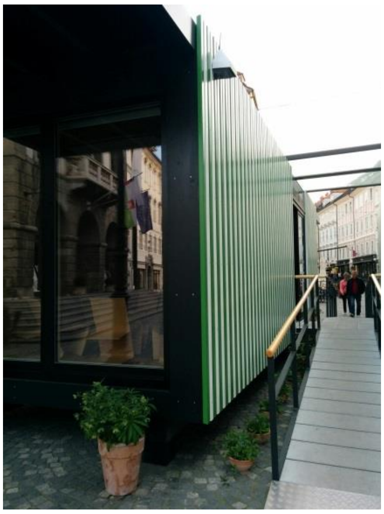


Figure 15 - AQMesh in front of mayors' office

Figure 16 - Recruitment material for questionnaires

Figure 17 - Installing AQMesh at local stakeholders

Figure 18 - High school boys phone app leaflet

Figure 19 - LEO volunteer

Oslo

Authorities in Oslo were involved from the beginning of the study. Their contribution was essential to plan the collection of air pollution data with low-cost sensors. For example, parking guards tested the first prototype of the portable sensor. Meetings previous to the sensor deployment were also maintained with the neighborhood authorities responsible of environmental health in the kindergartens. These meetings allow us to better design a deployment strategy for the static sensors (AQMesh).
For the final deployment, we involved more than 30 citizens carrying the portable units (LEO) for one week. After their participation, the volunteers filled in an evaluation form. A focus group was also organized after the LEO campaign.
The static sensors were deployed in 17 kindergartens in Oslo. This number was increased to 50 kindergartens during the "super-deployment". All the kindergartens responsible received a brochure explaining the goals of the project and the description of the deployment. A

focus group was organized with parents and authorities to evaluate the usefulness of monitoring air quality in the kindergartens and the visualization portal.
The questionnaire and CityAir app were promoted using mailing list, participations in events, leaflets, social media, etc. For the CityAir app a dedicated campaign “Colour the air in Oslo” was performed with the aim to get as much participants as possible in the period of 4 days (Friday to Monday). A total of 300 air quality perceptions were collected with the CityAir app. The questionnaire was answered by more than 300 citizens. A report summarizing the results from the questionnaire and the CityAir app was made available to the authorities previous to an interview with them. We are currently working in a public report summarizing all the results from the Oslo Citizens’ Observatory.

Ostrava

Different user groups were involved in the study. We have contacted NGOs from the beginning of the project to help us set the design of the work in the chosen locality. We have contacted also the Majors of the chosen localities to plan the study for biggest impact in the locations. Local citizens were included in the biomonitoring campaigns, who were tested all the technology, which were used in the monitoring. Also, people from NGOs participated on monitoring. The NGOs cooperated on advertisements posted on the internet and in media about prepared campaign and recruitment of volunteers. Advertisements were also published in local newspapers. Promotion of project activities were published in Ostrava schools and health centers. NGOs made promotion on their web pages and during their campaigns and events. The strategic partners in Ostrava were contacted before the monitoring campaigns helping spreading the information through the Ostrava city.

III. Key Performance Indicators (pilot phase)

i. Questions (KPI as used for the evaluation of pilot phase)

KPI type	KPI	Successful level description	Successful level or evaluation scoring
1. Sensors indicators	1) Was the 'real-world' deployment of mobile and static sensor nodes successful? For example, was deployment of static and personal sensors with target stakeholders feedback obtained?	Yes No Partly	Score 5 Score 1 Score 3
	2) Were sensors successfully validated and calibrated? Were special methods/protocols developed for QA/QC sensor readings? Was real-life deployment of sensor units demonstrated?	Yes No Partly	Score 5 Score 1 Score 3
	3) Are readings of the sensors comparable to data obtained from standard sensors/devices? Could sensor data be algorithmically corrected to follow records from standard units (this may not relevant to all pilot case studies)? For example: ☐ Side by side comparison of static and personal monitor sensors ☐ Comparison of static sensors with DEFRA and local authority standard air monitoring instruments ☐ Comparison of personal sensors with standard air monitoring instruments	Yes No Partly	Score 5 Score 1 Score 3
	4) Were methods and visualisation tools developed to demonstrate the quality of the comparison between static sensor unit network and personal/mobile units (this is not relevant to WP3b)?	Yes No Partly	Score 5 Score 1 Score 3
2. Platform indicators	**1)** Does the pilot end-to-end prototype or architecture function (e.g., can the measured pollutant concentrations be viewed on the web or smart phone)? (Arne will provide more indicators)	Yes No To some extent	Score 5 Score 1 Score 3

	2) Is it support for the creation of users, groups and other resource management (i.e. sensors)?	Yes No To some extent	Score 5 Score 1 Score 3
	3) Can all observations be supported - for static, mobile and citizens sensors (questionnaires)?	Yes No To some extent	Score 5 Score 1 Score 3
	4) Can all observations be published and discovered?	Yes No To some extent	Score 5 Score 1 Score 3
	5) Can all relevant observations be processed and analysed?	Yes No To some extent	Score 5 Score 1 Score 3
	6) Can all observations be visualised - for both mobile and web platforms?	Yes No To some extent	Score 5 Score 1 Score 3
	7) Can all relevant situations be recognised for notification/alarm if required?	Yes No To some extent	Score 5 Score 1 Score 3
	8) Does the platform handle security and privacy concerns, with right management, according to the needs?	Yes No To some extent	Score 5 Score 1 Score 3
3. Products indicators	1) Are tools developed within the use cases easy to use, attractive and enjoyable to use?	Yes No Partly	Score 5 Score 1 Score 3
	2) Is usability assessment of products/services completed with stakeholder groups?	Yes No Partly	Score 5 Score 1 Score 3

Table 1. (*Cont.*)

KPIs type	KPIs	Successful level description	Successful level or evaluation scoring
3. Products and services	3) What is the satisfaction level or useful level of the feedback from users for the pilot products and services?	Very satisfied Satisfied Not satisfied Not measured	Score 5 Score 3 Score 1 No score needed
	4) Is assessment of the products/services used to assess the level of satisfaction with users of the pilot study products and services? Or have we asked users if they are satisfied with products and services in the pilot?	Yes No Partly	Score 5 Score 1 Score 3
	5) Are stakeholders (e.g., local authority, scientists, schools, citizens) involved in the tools design process (e.g., web portal, data acquisition and visualization)?	Yes No Partly	Score 5 Score 1 Score 3
	6) Does the pilot increase air quality awareness and understanding of related issues in the population (this is ambitious and hard to track, but at some point we can track how many people aware of various citizens' observatories in different cities within CITI-SENSE through its social media platforms)?	Yes No Partly	Score 5 Score 1 Score 3
	7) What is the pilot products and services access level (e.g., how easy to access the project product and service)?	High Medium Low	Score 5 Score 3 Score 1
	8) What is the quality of products (e.g., personalized air quality data from WP2, real-time indoor AQ data in schools from WP3b, etc.) that are meaningful and could be presented to the public for cooperation?	High Medium Low	Score 5 Score 3 Score 1
	9) Can the pilot exercise developed products be applied to the main study?	Yes No Partly	Score 5 Score 1 Score 3

4. Users indicators	1)	Is the work relationship with the stakeholders (e.g. local authorities, scientists, schools, citizens, etc.) established?	Yes No Partly	Score 5 Score 1 Score 3
	2)	Is the work relationship with the stakeholders (e.g. local authorities, scientists, schools, citizens, etc.) effective?	Yes No Partly	Score 5 Score 1 Score 3
	3)	Are citizens motivated in the pilot and want to participate in observing their environment in the case study full implementation?	Yes No Partly	Score 5 Score 1 Score 3
	4)	Is engagement concerning pilot study and CITI-SENSE initiative with local authorities/scientists/schools/citizens documented?	Yes No Partly	Score 5 Score 1 Score 3
	5)	Is stakeholders' response and satisfaction measured?	Yes No Partly	Score 5 Score 1 Score 3
	6)	Is assessment of public engagement tools (e.g., by the use of questionnaires) used to document engagement with stakeholders?	Yes No Partly	Score 5 Score 1 Score 3
	7)	What is the quality of communication and interaction with those involved (scientists/citizen groups/citizens/administrators)?	Good Fair Poor	Score 5 Score 3 Score 1
	8)	Has organized open lectures to the public, outreach activities, engagement of different stakeholder groups, dissemination material, etc.?	Yes No Partly	Score 5 Score 1 Score 3
5. Others	1)	Do location officers have thorough and clear understanding of the refinements required to the use of the sensors and other tools?	Yes No Partly	Score 5 Score 1 Score 3

2)	Were lessons learned, potential issues addressed, recommendations for improvement and refinement implemented in the full case study, and the objectives scope and remit of the full case study achieved (e.g., could use the Confluence WPs 2 and 3 pilot study log to help evaluate this KPI)?	Yes No Partly	Score 5 Score 1 Score 3

ii. Summary of responses - pilot phase

City/Location	Preliminary KPI type (# of sub-KPIs/questions)	Preliminary KPI score (%)	Comments
Barcelona	Sensors (4)	90	Good
	Platforms (1)	60	Fair
	Products (9)	64	Relatively good
	Users (8)	75	Relatively good
	Others (2)	100	Excellent
	Location Total (24)	**75**	**Good**
Belgrade	Sensors (4)	80	Relatively good
	Platforms (1)	60	Fair
	Products (9)	38	Fair or poor
	Users (8)	65	Relatively good
	Others (2)	80	Good
	Location Total (24)	**58**	**Fair**
Edinburgh	Sensors (4)	50	Fair or poor
	Platforms (1)	20	Poor
	Products (9)	20	Poor
	Users (8)	50	Fair or poor
	Others (2)	20	Poor
	Location Total (24)	**35**	**Fair**
Haifa	Sensors (4)	90	Good
	Platforms (1)	80	Good
	Products (9)	69	Relatively good
	Users (8)	65	Relatively good
	Others (2)	100	Excellent
	Location Total (24)	**74**	**Good**
Ljubljana	Sensors (4)	50	Fair or poor
	Platforms (1)	100	Excellent
	Products (9)	56	Fair or poor

	Users (8)	85	Good
	Others (2)	80	Good
	Location Total (24)	**68**	**Fair or good**
Oslo	Sensors (4)	80	Relatively good
	Platforms (1)	20	Poor
	Products (9)	44	Fair or poor
	Users (8)	70	Relatively good
	Others (2)	40	Fair or poor
	Location Total (24)	**57**	**Fair**
Ostrava	Sensors (4)	20	Poor
	Platforms (1)	20	Poor
	Products (9)	73	Relatively good
	Users (8)	85	Good
	Others (2)	100	Excellent
	Location Total (24)	**68**	**Fair or good**
Vienna	Sensors (4)	80	Relatively good
	Platforms (1)	100	Excellent
	Products (9)	64	Relatively good
	Users (8)	60	Relatively good
	Others (2)	80	Good
	Location Total (24)	**53**	**Fair**