MOBISTYLE

Motivating end-users behavioral change by combined ICT based modular Information on energy use, indoor environment, health and lifestyle

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Summary (abstract):

The main goal of this deliverable is to evaluate the effectiveness the campaigns within the project had on the people using MOBISTYLE products and being exposed to them. Results of this deliverable can be therefore used for future planning of activities aimed at improving human building interaction with the aim of improving indoor environment quality (IEQ) and consequently better health and productivity while lowering energy use. This report is based on the work done in WP2 during the development process that used the people-centred methodology where we used findings from focus groups, interviews and information received from users in five countries to prepare the solution for the people. Engagement of users was instrumental for designing solutions which will have a long-lasting effect on energy consumption as observed in at least SI demo, and wellbeing. In previous tasks and deliverables, we have already confirmed that technologies (e.g. smartphone apps) can influence behaviours and beliefs of people and help shaping their long-term habits and practices. Later in the project the ten general and country specific recommendations for solution development were elaborated and used in the development of ICT solutions and tailored campaigns in very different demo sites.

Cost effective multichannel campaigns taking in to account demo site micro cultural and building specific were deployed with goal of improving human-building interactions. All developments followed people centered iterative approach where solutions users are kept in the development loop. Measured improvements were observed in some but not all demo cases e.g. SI demo where cooling energy was decreased (13-25%) even though cooling needs were increased by 21%. Similar with heat, where heat use decrease (7-12%) while needs decreased by 5%. Other cases, such as DK, showed significant decrease of CO_2 concentration in homes and decrease of average temperature for 0,5K due to solutions used.

In the MOBISTYLE project, we shifted our focus from buildings and technologies to people and their behaviour, habits, and practices. We tried to understand how people interact with buildings, tools and devices at home and at work, how do they consume energy throughout the day, and how we can change and influence their practices and habits by using technologies and utilising non-technological means. Due to nature of demo sites, we use in situ methods, surveys and ethnography as a type of research that investigates daily lifestyles, habits, and practices through qualitative approaches (e.g. participant observation, interviews, focus groups, etc.). These mixed approaches enabled us to gain an in-depth understanding of human behaviour and penetrate beyond quantified behaviour of "big data", collected by technological solutions.

Not all project objectives were fully reached, but all of them were well addressed and targeted values were missed by a margin. Behaviour was changed to certain extend, the exact reasons are difficult to pinpoint. The variations can be observed/ understood when taking in to account people with their specifics and contexts.

The experiment shows how the MOBISTYLE approach could be monetarized and used to reach more people. The Cost benefit Analysis (CBA) is provided in the closing chapter, in terms of methodology adjusted to each demo case and results achieved in the months of ICT-tools deployment.

The lessons learned and recommendation for future development of socio-technical solutions improving human-building interaction are presented in the closing chapter in the form of 10 recommendation.

Lessons learned and recommendations:

- **Moving people** – Basic campaigns can be effective. MOBISTYLE moved people: in mind sets and on staircases.
- **Multi-channel campaigns** – Cost-effective and simple multi-channel campaigns can be very effective.
- **Minimalistic solutions** – IAQ state communicated via changing RGB LED seems to work (people declared and we measured more window opening). The more information people get, the more they seem to hate the solution and vice versa: minimalistic solutions seem to work better.
- **Hearing other people** – People listen to other people. It is important to target decision makers. When communicating, we need concrete individual stories.
- **Micro-cultures and facility management** – Various site specific (established) communication channels need to be exploited for campaigns. Location associated micro cultural specifics need to be taken in to account when designing campaigns. The later should be part of regular **facility management** to ensure sustainability.
- **Tipping points** – Small steps are needed in modifying behaviour. People want to manage/interact with buildings. Behaviour in groups seems to follow tipping point effect (phase change): first a few, then almost all. Activities should be designed by **approach focused on communities**.
- **Contextual information** – Information provided to the room users' needs to be contextual; **you must get them when you can do something**. Getting phone notification of e.g. poor IAQ in the office and you are at home, makes you to stop using the solution.
- **Technology must be reliable**. If it tricks you or you find out it does not work as it supposed to, it is the end of trust. It makes one mistake, and it is over. We could "humanize" or "anthropomorphize" the technologies, e.g. devices could "confess" that there was an error.
- **Transparency and clarity** – If people will have the feeling they are being **manipulated** to achieve savings (not due to care for health), there will be resistance. Everything must be **transparent** and clear.

Key words:

Human-building interactions, anthropological study, people-centred development, user needs, changing behaviour and habits, cost benefits analysis (CBA), campaigns evaluation.

Revision and history chart:

VERSION	DATE	EDITORS	COMMENT
Version 0	25.5.2020	IRI UL	First version provided to partners
Version 1	04.06.2020	IRI UL, DMO, WHR	Integrated contributions and suggestions from CM8
Version 2	11.06.20	TAU, IRI UL	Added detail about PL case, improved conclusions
Version 3	15.06.20	POLITO	IT case inputs, improved introduction
Version 4	17.06.20	POLITO, IRI UL	CBA chapter added
Version 5	29.06.20	POLITO, IRI UL	Internal reviewer: Giulia Vergerio. Remarks addressed.
Version 6	30.06.20		Submitted

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Executive Summary

Deliverable D6.3 is aimed at evaluating the campaigns of MOBISTYLE project in various settings. Due to the different nature of each demo case, the approaches were not uniform as diverse solutions were deployed. This deliverable needs to be read together with D6.2 where impact on the energy use and other case specific goals are show and with D6.4 where developed and deployed IT tools are evaluated in detail. This is necessary in order to get the wider understanding of interdisciplinary approach and complexity of indoor environment – health and energy nexus.

The outcome of the deliverable shows the possible ways forward and lessons learned in the form of recommendations. We try to show why looking at the raw measured data from various sensors does not provide a big picture and it does not give us full understanding of human-building interactions in different contexts. It is shown that even simple activities adopted by people in buildings can have significant effects.

Impacts of MOBISTYLE activities are diverse in type and not necessary always in the desired direction (e.g. indoor environment could get worse). Ideal situation would be, that all impacts for everyone would be positive. In "real" life, it is rarely the case, especially when targeting larger numbers of people as we did in this project. Impacts reached are for most positive, but for some they are negative.

The use of multi-channel party sublime campaign should not be underestimated, because it creates awareness step by step, and this gives the ground for new behaviours.

SI: Because heating needs (HDD) decrease (5%) was lower than heat use decrease (7-12%), we conclude, the project had some positive impacts on the demo case buildings heat use. Cooling was decreased (EF 13%, FRI 25%) even when cooling needs were increased (21%). Electricity use was increased in all SI demo sites. For cooling it is safely to assume, that the goal of 16% saving was reached. Main reason might be, that people *figured out, that the cooling stops working when the window is open*. Lecturers *started opening the windows frequently, so that the students wouldn't get cold* [1]. We found out that the state-of-the-art highly automated building, does not necessarily guarantee the well-being and satisfaction of its occupants. On the contrary, "smartness" of the building has often proven to be a source of discontent and disappointment, especially when it tries to appropriate agency from the people and make independent choices regarding their needs and wants. In such cases, people tend to find innovative solutions for outsmarting the building and taking back control [1]. A desired feature of automated building is to support the lives of the people and other beings in an unobtrusive way.

PL: In order to enable the Mobistyle system to affect the users' behaviour and habits, it is recommended to introduce the following changes:

- introduction of a system of weekly, monthly, periodic reports;
- introduction of communications and push-type notifications as well as the ability to manage these notifications;
- the system's learning of user behaviour and habits;
- ability to remotely activate / de-activate selected devices / outlets at times specified earlier.

It is recommended to refine the gamification elements of the Mobistyle application, this would make it possible to generate the desirable changes in habits – both short-term and long-term. It is proposed

to engage greater technical support to solve problems related to the installation of devices and aid in connecting and configuring devices as well as the support's more effective work in terms of solving current technical problems.

IT: Campaign was based on ICT and non-ICT tools. The receptionists do not have a strong position in saying that they would be willing to use the ICT solutions. However, they show a stronger position in terms of good integration of functionalities, confidence in the use and no need for technical support in the usage. Indeed, they agree on the people's ability to quickly learn how to use the tools. In line with customized-demand-based solutions, it is possible that different preferences and needs occur among users of a same space, requiring even more detailed customization of the ICT-tools. Preferences about advices are diverse. However, lack of time and no integration of the solutions with other services used in the hotel are the issues that are still preventing them from using the solutions more actively. They commented that the project made them pay attention to some factors (e.g. dry air) and small actions (unplug the laptop cable) that otherwise they would have not care about, making them become an habits on a longer term. Limitations (especially when guests are targeted) of MOBISTYLE strategy in this particular context are outlined.

DK: The MOBISTYLE Game was developed to combine information regarding IEQ and energy in a way to be cognitively comprehendible for occupants and giving them a possibility to act. This resulted in a clear improvement of indoor air quality in a large majority of rooms. Same tendency was observed for temperature but with much less effect. A similar effect was not seen on energy use for heating. In average, a temperature decrease of 0,5°C, (decrease in 68% out of rooms), In average reduction in CO_2 concentration of 400 ppm (decrease in 85% of the rooms) and energy use for heating increased in average 6% (increase in 55% and, decrease in 20% of the apartments. The solutions applied had too many limitations, leading to frustrations and loss of interest. It had been noted that the main improvement would be achieved through a reduction of data flow latency, from the current 15 to 30 minutes to 30 sec to 1 min, in order to allow the user to receive immediate feedback from their actions, and in ensuring a stable data flow.

NL: Dutch case provided three studies to test whether dynamic temperatures are acceptable for people as stable indoor temperatures. The hypothesis was that the dynamic temperatures can lead not only to improved metabolic and cardiac health but also lead to users acceptance and comfort. People found dynamic temperature profiles comfortable and was not significantly different from the comfort levels of the stable temperatures. Despite the change in thermal sensation from slightly cool to slightly warm, the thermal comfort stayed within the limits of just comfortable and comfortable. Such dynamic conditions lead in average to 21 % energy savings compared to stable indoor temperature settings. The MOBISTYLE subjects found the Office App appealing where it educated the colleagues as office guests about the indoor conditions in the different meeting rooms as also provided feedback about potential benefits of the dynamic conditions. However, main advantage for future would be to scale across the studies done so far on a small sample.

1. Introduction

In the MOBISTYLE project, we **shifted our focus from buildings and technologies to people and their behaviour, habits, and practices.** We tried to understand how people interact with buildings, tools and devices at home and at work, how do they consume energy throughout the day, and how we can change and influence their practices and habits by using technologies and utilising non-technological means. According to literature [8], there are four "traditional" methods for building occupant research: in situ, laboratory, survey, and virtual reality. Due to nature of demo sites, we use in situ methods, surveys and ethnography as a type of research that investigates daily lifestyles, habits, and practices through qualitative approaches (e.g. participant observation, interviews, focus groups, etc.). These mixed approaches enabled us to gain an in-depth understanding of human behaviour and penetrate beyond quantified behaviour of "big data", collected by technological solutions. In this task, we evaluated impact and usefulness of combined monitoring and motivation methods. The impact is compared with a "traditional" information supply, based only on energy use. The traditional is in this context understood as looking at monthly energy bills for residential buildings and hotel. In SI demo the information regarding energy use of public buildings is traditionally understood only looking at yearly and maybe monthly costs. There is a challenge of correlating the results to various (soft) factors. We addressed this via several approaches (e.g. looking to statistics of use as reported in D6.4 or keeping close communication with users to be aware of their reasoning as reported in this deliverable). We evaluated campaigns in five MOBISTYLE demo cases: a neighbourhood in Denmark, "smart city" residents in Poland, university buildings in Slovenia, a hotel in Italy, and an office building in the Netherlands. The findings from initial ethnographic research were summarized in recommendations for developers who tailored and adapted them in collaboration with engineers and other experts to different scenarios, specifics of buildings, and their users. As explained above, we put people in the centre of the MOBISTYLE project by the people-centered development approach. Therefore, we prepared solutions in collaboration with people (sometimes referred to as "users", "consumers", "customers" and "clients") and took into account their needs, requirements, specifics, wishes and desires, socio-cultural and economic backgrounds, etc.

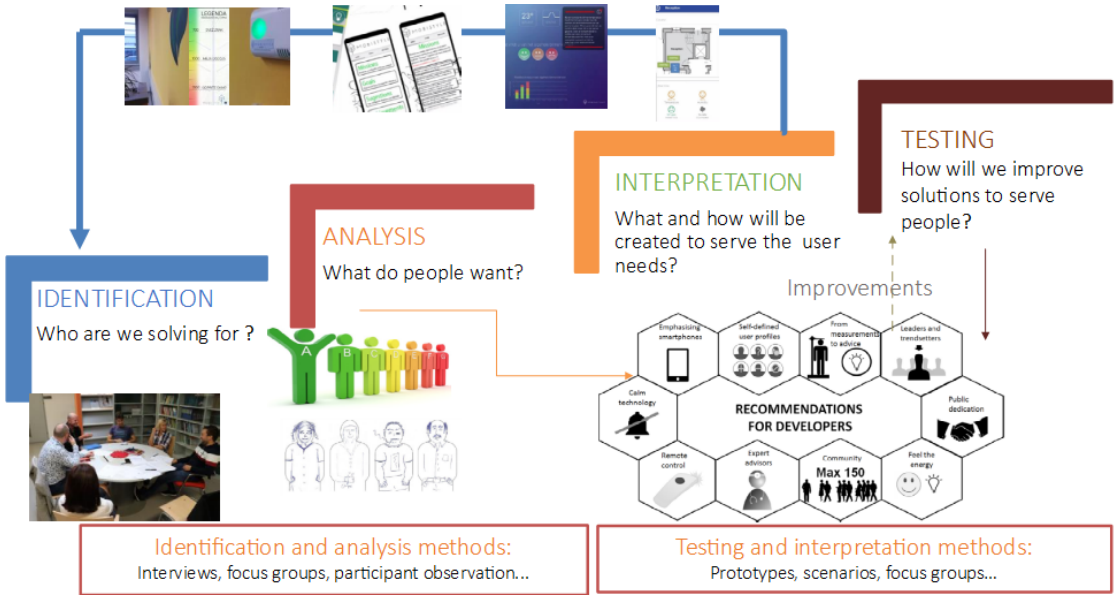


Image: MOBISTYLE people-centered development

2. Evaluation of feedback campaigns

In the frame of the project many activities directed toward improving human-building interaction were carried out. In order to obtain lessons learned and to find out what works and might be worth for further elaboration, we need to understand if the activities (i.e. ICT-tools deployment, awareness campaign, communication, etc.) made some impact in the desired direction. In particular an evaluation must be carefully planned and carried out. As mentioned in D3.3, it should be based on outcomes, process, and impacts evaluation. Outcomes (related to energy, IEQ, behavioural patterns, etc.) were assessed computing relevant KPIs starting from measured physical quantitates e.g. temperatures, CO_2 concentrations, window opening, etc. in baseline and MOBISTYLE periods for comparison. These factors are described in D6.2. This deliverable (D6.3) collects results of the work done to integrate outcomes adding a layer of knowledge coming from qualitative investigations, contributing to the process evaluation (i.e. evaluation of provided feedbacks) and observing impacts of MOBISTYLE strategy on people habits and perception. To do so, a set of methods was adopted (as described in the followings and deepened in chapter 4).

Since all human behaviours cannot be measured, we relied on qualitative (ethnographic) research methods to get insight into observed and self-reported behaviour and perception. This was conducted mainly by focus groups and open questions in questionnaires, partly also by individual interviews and long-term participant observation in case studies. In our study, we also tried to investigate how the sensors and other available technologies help people control their indoor environment, how effective they are in decreasing energy consumption, and whether they indeed provide the optimal environment for the building occupants. Combining the qualitative and quantitative methods expanded our perception of the behaviors, values, practices and habits "thickened" the "big data", and "softened" the "hard data". Going back and forth, from quantitative to qualitative and *vice versa*, enabled us to establish a research problem as suggested by the data, gauge new perspectives on the known problems, and account for outliers and patterns in the data [1].

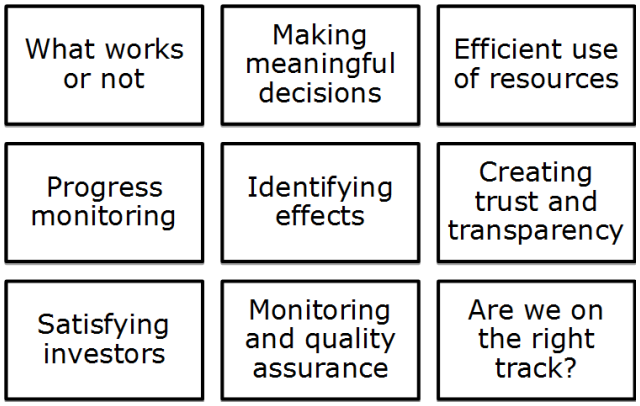


Image: Why evaluations?

Impacts evaluated campaigns had can have several dimensions and levels, as presented in the image below. They (combined info campaigns) can shift individuals' perspectives and thus actions, but via individuals they can change wider organization or even the whole system, as did the current epidemics (i.e. COVID-19). As we saw also in MOBISTYLE, not all impacts in all cases and circumstances are in the

desired direction (e.g. less energy use) nor are all expected (e.g. keen adoption and further promotion of temperature training).

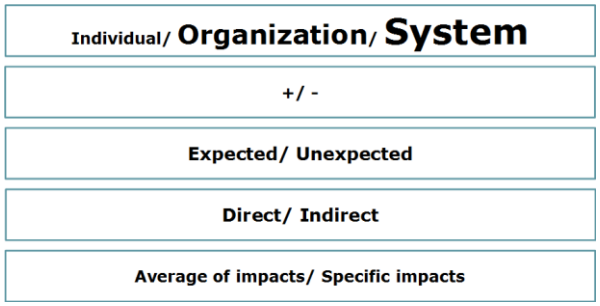


Image: Impacts of the campaigns

In this deliverable we analyse impact on several levels, from the user perceptions, to get the understanding of their solutions acceptability, to investigating the changed behaviour by measuring buildings parameters (e.g. window opening) and, based on data collected at each demo side level, trying to monetarize the impacts by applying the Cost Benefits Analysis (CBA) taking in to account occupants/employer and society viewpoint, as presented in the chapter CBA.

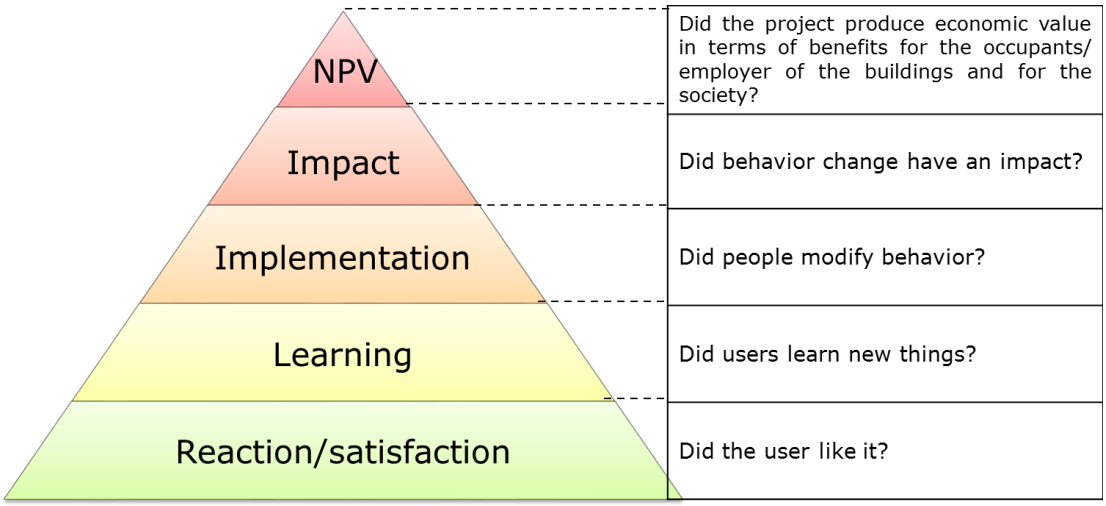


Image: 5 levels of impacts of a campaign

Graphics show the motivation to do the evaluation and the levels addressed and potentially evaluated by the MOBISTYLE campaigns. Several “hard” and “soft” data categories can be used to do the evaluations. Under hard there are costs (operational, overhead, penalties…), we can measure outputs, time (e.g. over, down, sick), quality and energy (fossil, land use, pollutions, waste…). Under soft we understand creativity (e.g. ideas, innovations, suggestions, partnerships), development (e.g. capability, performance, potential) and culture where we can count absenteeism, engagements, loyalty etc.

+ for all	**YES**	NO	NO	NO
+ for some	**YES**	**YES**	**YES**	NO
- for some	NO	NO	**YES**	**YES**
- for all	NO	NO	NO	**YES**
SYNTHEZIS	GOOD	?	?	BAD

Image: Positive and negative impacts for some vs all

As presented in the graphics above, we should keep in mind that impacts of MOBISTYLE activities can be diverse in type and directions. Ideal situation would be that all impacts for everyone would be positive. In "real life" this is rarely the case, especially when targeting larger numbers of people as we did in this project and when dealing with potentially divergent impacts (e.g. energy savings vs comfort), where MOBISTYLE goal was to keep them together. Impacts reached are for most positive, but for some they are negative.

3. Combined information and feedback campaigns

In the project several channels for providing relevant contextual information have been used. The following ICT based tools were deployed: game in Danish and Polish demo cases, dashboard in Italy and Slovenia and office app for the Dutch demo case. Following also the recommendations from the ethnographic research, the ICT tools based activities were enhanced with multi-channel campaigns tailored to the demo sites. Awareness and information campaigns for the five cases were proposed in D6.1. [5] The actual implementation varies due to project execution dynamics. Each demo has a specific objective and employed various methods to provide feedback to users about their energy use and indoor environment and guiding them to change their practices.

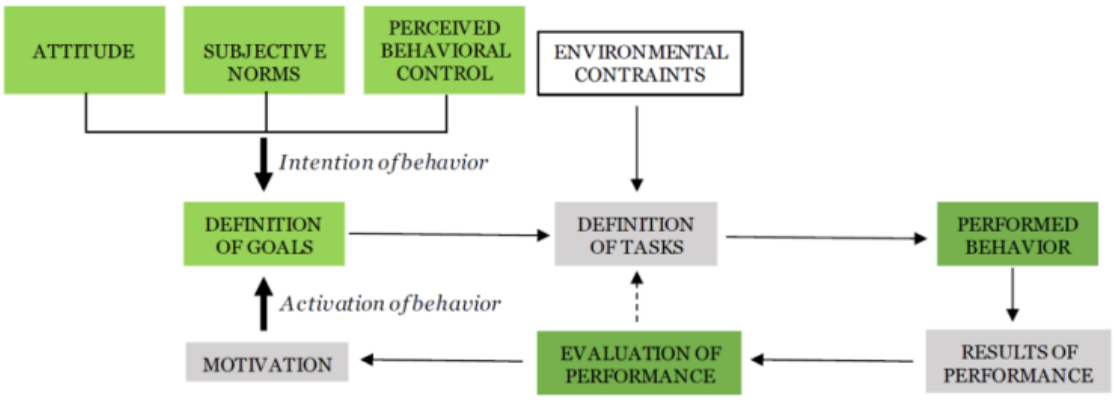


Image: Flow Diagram of Behavioural Action Plan from D3.2 [7]

The general approach is shown in the graphics above. Each demo case adopted different strategies to implement it, based on the local circumstances, user needs and expectations [3], practical possibilities of data acquisition as described *in D2.5 Composition of specific sets of data acquisition* [2] and recommendations from ethnographic research as presented in D2.3 [4]. The details about the combined feedback about energy, IEQ and health campaigns parameters are presented in D3.1 [6]. For each demo case, gathered data was translated into meaningful information for the users and actions to stimulate a behavioural change according to a specific behavioural action plan which was developed per each demo case (as presented in D3.2 [7]). The concept is shown in the graphic below.

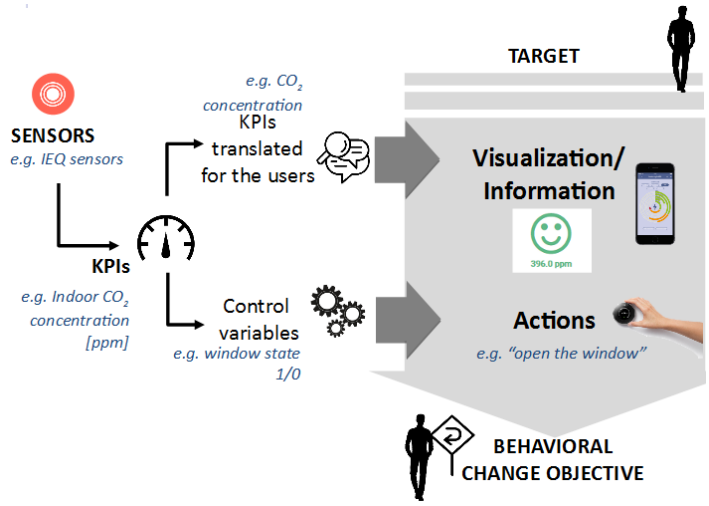


Image: Concept of data based information campaigns from WP3

Specific campaigns activities are presented in subchapters below.

3.1. Slovenian case campaigns

The specific case objective (from D6.1 [5]) was to provide users with information regarding IEQ in order to influence their short term behaviour and change in long term habits leading towards improved IEQ and energy reduction.

Demonstration case of University of Ljubljana (UL) consists of 4 faculty buildings located in Ljubljana:

- Faculty of Computer and Information Science (FRI) – upper right
- Faculty of Chemistry and Chemical Technology (FKKT) – upper left
- Faculty of Economics (EF) – lower left
- Faculty of Arts (FF) – lower right

Image: SI demo buildings

Since all four buildings have a similar room typology and users, we focused on the FRI FKKT facility for in-depth measurements and complex analysis. Other buildings will be used for verification and generalisation of findings and further implementation of the solution. As for the UL demonstration case, the main objective is to observe relation between the changing indoor environment conditions as a result of users' interactions based on the increased awareness. Therefore, energy consumption monitoring is not the main objective, but it was carried out nevertheless.

Dashboard and app

The dashboard is a tool that allows different user types to visualise data (energy usage, IEQ, health, appliances, etc.) and derive information about the buildings they interact with. Information is given through simple data monitoring, historical trend analysis, specific widgets and ad hoc suggestions. These advices were prepared in the frame of T3.4.

The purpose of the dashboard is to raise awareness on energy consumption, motivate change in the behaviour and stimulate reduction of energy usage and IEQ improvement by providing intuitive and customised presentation of relevant information.

The app and dashboard functionalities can be seen here LINK.

Image: Screenshots from the app on mobile phone of the room user

Images above show how the app used by room user functions in practice: when certain trigger is reached (e.g. high CO_2 concentration) a push notification is shown on screen. If the phone user presses on the notification, the MOBISTYLE app is opened with additional advises on images. These were regularly changed in order to keep the app interesting. Right hand side of image with graphs show how CO_2 concertation in one room were decreased after the app deployment at least for short time, while the occupancy reported from room users, did not change in this period. This shows an example, that people start to behave differently the question is just the duration of this new behaviour.

Video testimonials

of MOBISTLYE energy-health-IEQ nexus services satisfied user being shared across various platforms LINK.

Image: Video of MOBISTYLE services user Email footers

Email footers (signature) with 8 different regularly changed advices, from MOBISTYLE in every sent email from the IRI UL MOBISTYLE team.

Image: Examples of email signatures used

Non-IT gamification of behaviour

Several tests were carried out to gamify desired behaviour, including employees competing with the boss in stairs use. At the end, a small reward was granted to the winners.

Image: Tests of non ICT behaviour modification via gamification

Indirect micro-donations (EF): If room user leaves light on, the co-worker from the office next door reminds the room user to pay 1€ and the budget is used for a common activity.

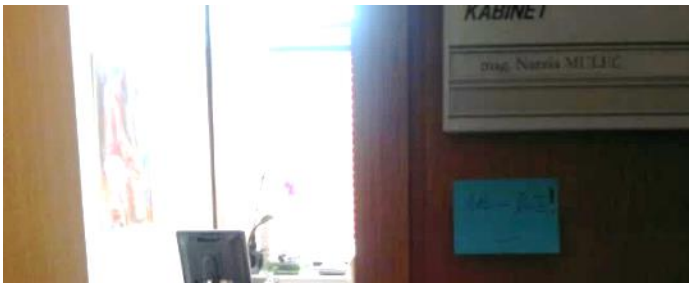


Image: Note on the micro-donation to stimulate better building use

The use of such multi-channel, party sublime campaign should not be underestimated, because it creates awareness step by step, and this gives the ground for new behaviours.

Sensors with non-intrusive notification about the IAQ

These, together with scales letting the people know what light means were deployed it the test room at FRI (Faculty of Computer and Information Science) and FKKT (Faculty of Chemistry and Chemical Technology). The measurements and the analysis are detailed described in D6.2.

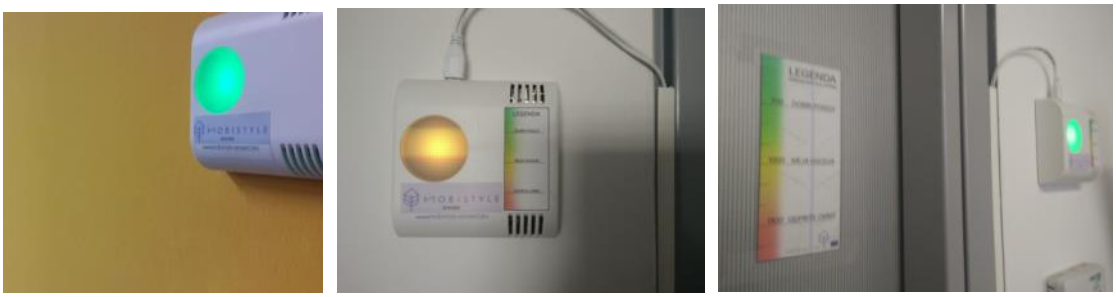


Image: Rewarded sensor deployed in Slovenian demo case

Image: Scales for letting the people know what light means and possible effects on they cognition

Campaigns based on the people-centred approach

Targeted audience was asked several times about the most suitable texts formulations and design of the campaigns. Several versions were designed prior to the deployment. Focus groups were organized where people from the demo buildings could express they views and suggest the design, text formulations and channels where to deploy the massages within the building. The latter is of great importance, to actually reach the occupants.

Image: Designs of campaign from the development process

Campaigns were tailored to different buildings and communication channels

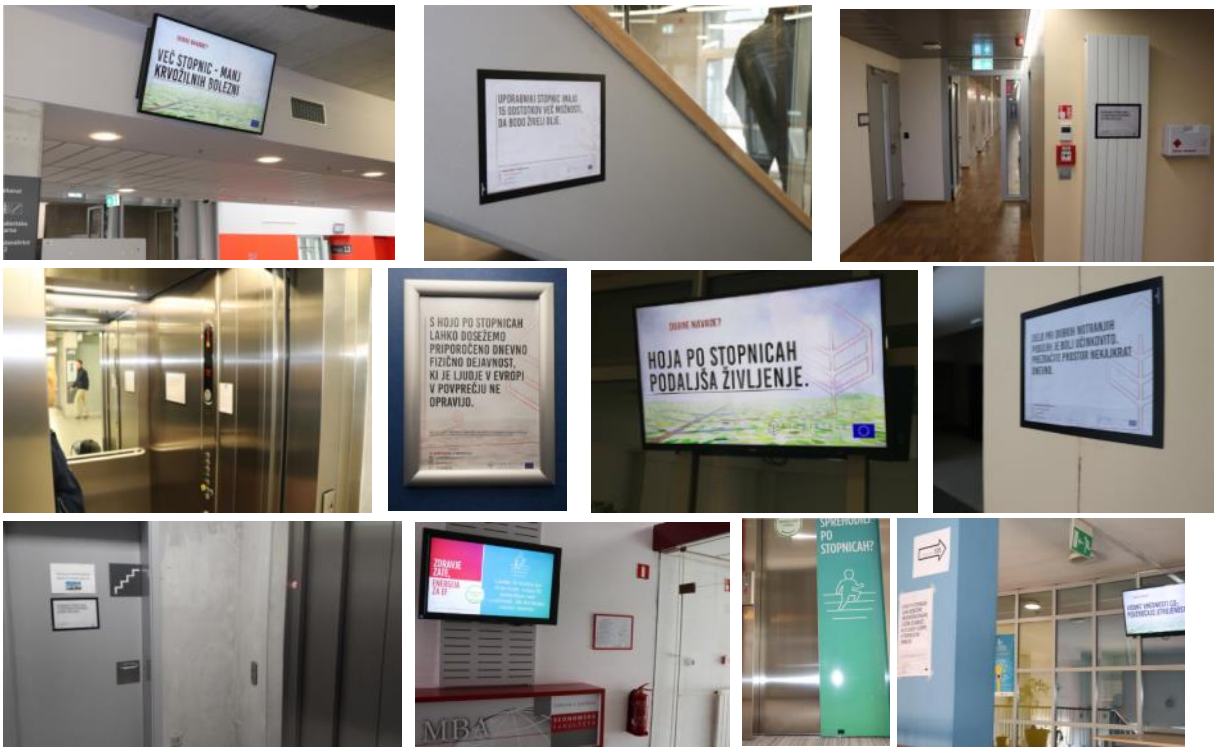


Image: Few channels and locations of campaign posters from SI demo buildings (FRI, FKKT, FF and EF)

Energy use in SI demo case

As an example of impacts complexity, analysis was carried out enlarging the boundaries to the whole demo building level to see impacts of the campaign that took place not only in the demo rooms, but through the demo buildings. Baseline period February 2018-January 2019 and Monitoring from February 2019-January 2020

Table: Energy use by serves in SI demo buildings

	2/18-1/19	2/19-1/20			
	Baseline	Monitoring			
	In MWh				
FRI	616,4	548,5	89,0%	heating	measurement
	202,1	151,01	74,7%	cooling	measurement
	948,4	985,3	103,9%	electricity	bill
FKKT	2665,7	2574,2	96,6%	heating	measurement
	1053,8	1048,4	99,5%	cooling	manual input
	2248,3	2607	116,0%	electricity	bill
X	616,4	494	80,1%	heating	measurement
	1146,7	1155,9	100,8%	electricity	bill
FRI FKKT X complex					
Heat	3898,58	3616,74	92,8%		measurement
Gas	4446,4	4139,343	93,1%		bill
Electricity	4343,6	4748,2	109,3%		bill
EF	1098,7	962,8	87,6%	heating	bill
	75	65,3	87,0%	cooling	measurement
	815,8	864,5	106,0%	electricity	bill
FF	910,1	827,1	90,9%	heating	bill
	681,7	705,7	103,5%	electricity	bill
HDD	2662,3	2531,7	95,1%	In Kday	Meteo office
CDD	173,6	210,7	121,4%	In Kday	Meteo office

Because heating needs (HDD) decrease (5%) was lower than heat use decrease (7-12%), we conclude, the project had some positive impacts on the demo case buildings heat use. Cooling was decreased (EF 13%, FRI 25%) even when cooling needs were increased (21%)! For cooling it is safely to assume, that the goal of 16% saving was reached. One of the reasons might be, that people *figured out, that the cooling stops* ***working when the window is open***. Lecturers *started opening the windows frequently, so that the students wouldn't get cold* [1]. Electricity use was increased in all SI demo sites, and this is associated with basic process in the buildings.

Looking at the data for 25 faculties (44 buildings with 310.334 m^2) and academies of UL in the same periods (Feb18-Jan19 and Feb19-Jan20) total heat use fell from 34,5 to 32,9 (4,8% - in correlation with decreased HDD), while electricity use grew from 26,5 to 27,3 GWh (~3%).

3.2. Polish case campaigns

The specific case objective (from D6.1) was *to monitor the electricity consumption of users and motivate their behaviour change towards more energy efficient building usage by giving users attractive information about their daily activity (healthy tips), IEQ and energy (recommendations for actions and measured data). Moreover, the goal is to obtain real household profiles mapping internal needs of customers to understand and communicate potential benefits for both parties – the service providers and building owners. The goal is also to observe daily activities of the residents combining information regarding lifestyle and energy consumption as this is the difference of MOBISTYLE in comparison to the existing projects only concentrating on providing info solely about energy*.

For the needs of the campaign supporting the recruitment of pilot participants as well as during the demonstration, marketing materials were prepared: push messages, banners, and video materials.

Image: marketing materials - banners, push massages

A video material containing the user story has been prepared https://youtu.be/LbXdYR0o3QM

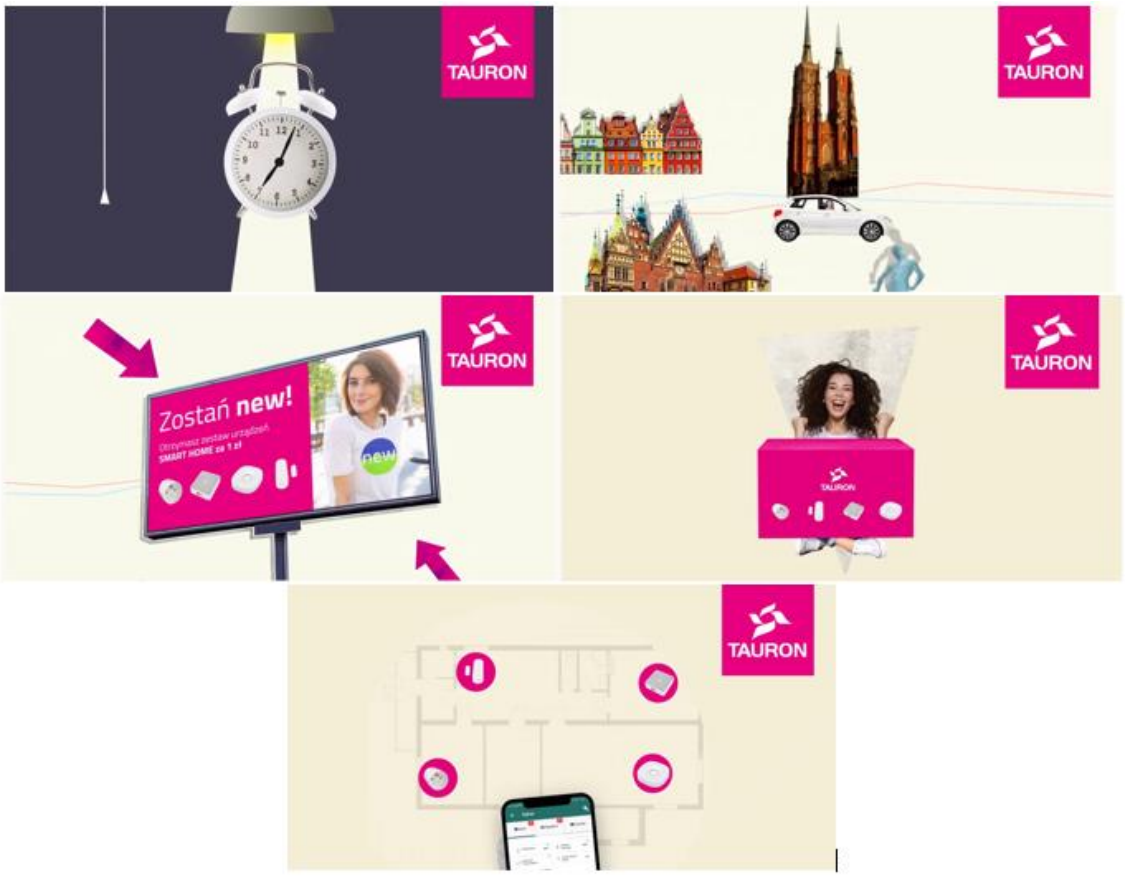


Image: Marketing materials - screen shots from the video

The game is described here LINK and available on Google play.

How game works for home user in practice:

To get access to the Mobistyle Game you had to first connect the received devices and configure them accordingly by specifying in which room they are located. All instructions regarding the launch of the devices and their configuration were available on the TAURON website and forwarded to participants by email.

Image: Launched devices in the home of one of the users

Then, if all devices were correctly connected and configured, an individual House Code was generated, which the user received by email with a link to Google Play to download the MobistyleGame app.

The application presented measurement data measured by connected devices in individual rooms:

- Temperature;
- Relative humidity;
- Total energy produced;
- Electrical power;
- Electrical consumption;
- Window state;
- Power switch state;

The Main Screen of the App displays an array of information on the status of the house:

- The collected “MobiPoints” in the last day and last week;
- The ranking of the house on the last day and last week;
- Historical view of the MobiPoints achieved in the last 7 days

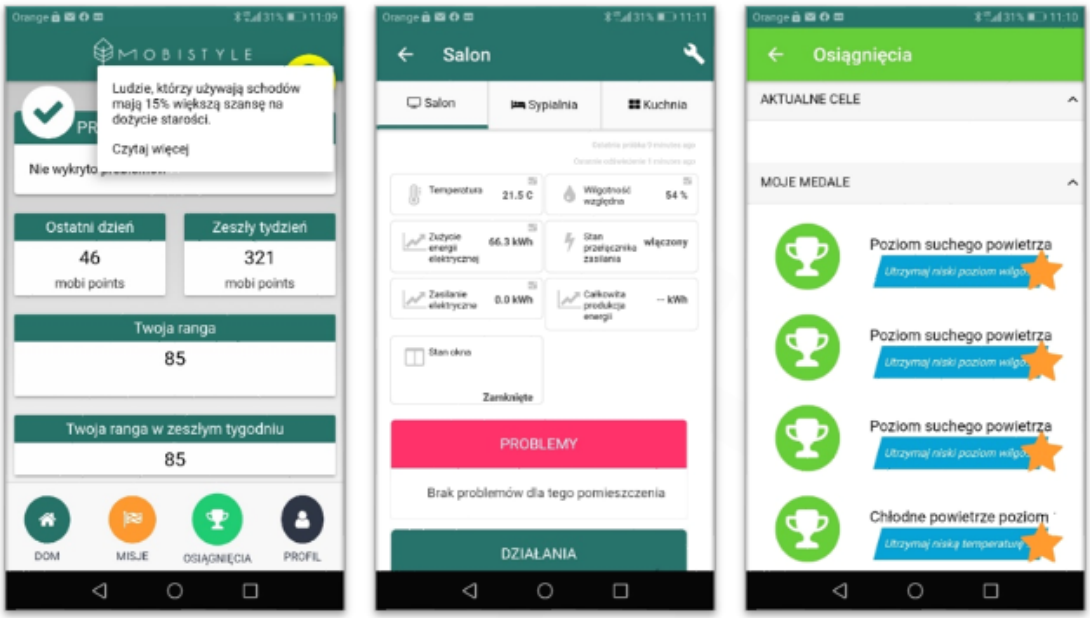


Image: Mobistyle Game application

For maintaining appropriate conditions and performing missions related to displayed Problems at home, each user received points (MobiPoints), on the basis of which the ranking was created. The yellow light bulb symbol on the main screen, when clicked, reveals information aimed at awareness creation on associated health benefits. Graphical charts were available for the user when clicking on the displayed values: temperature and relative humidity.

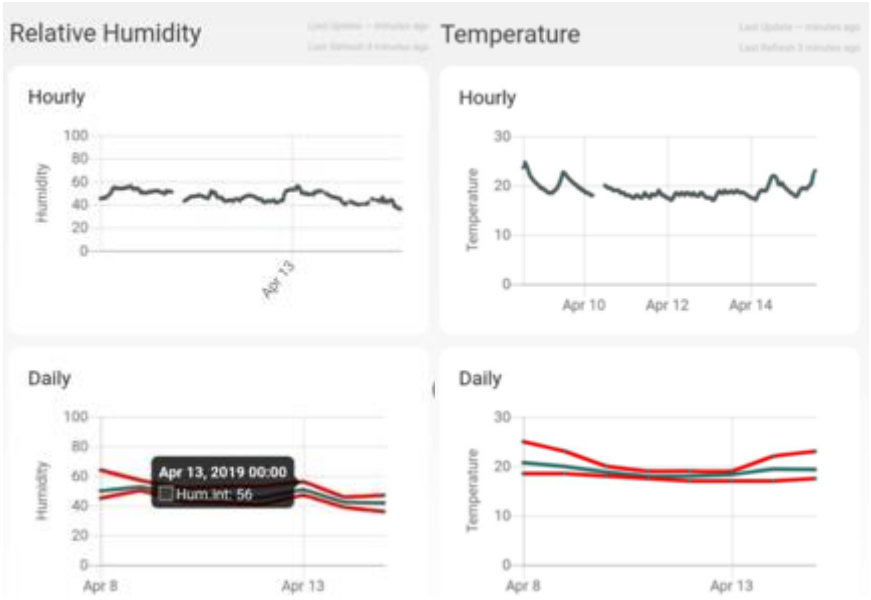


Image: Humidity and temperature charts

The Main Screen is where the notifications regarding possible issues were displayed. The user receives a brief message with information on the room where the issue is detected and a short description of the issue itself.

The designed missions related to air temperature and humidity.

Actions that the user could take were to close or to open the window. If an issue was identified in any room, it was described in the 'Problems' section. The user could check for problems in the rooms either by choosing the room from the Home Data Screens or directly from the notifications in the Main Screen.

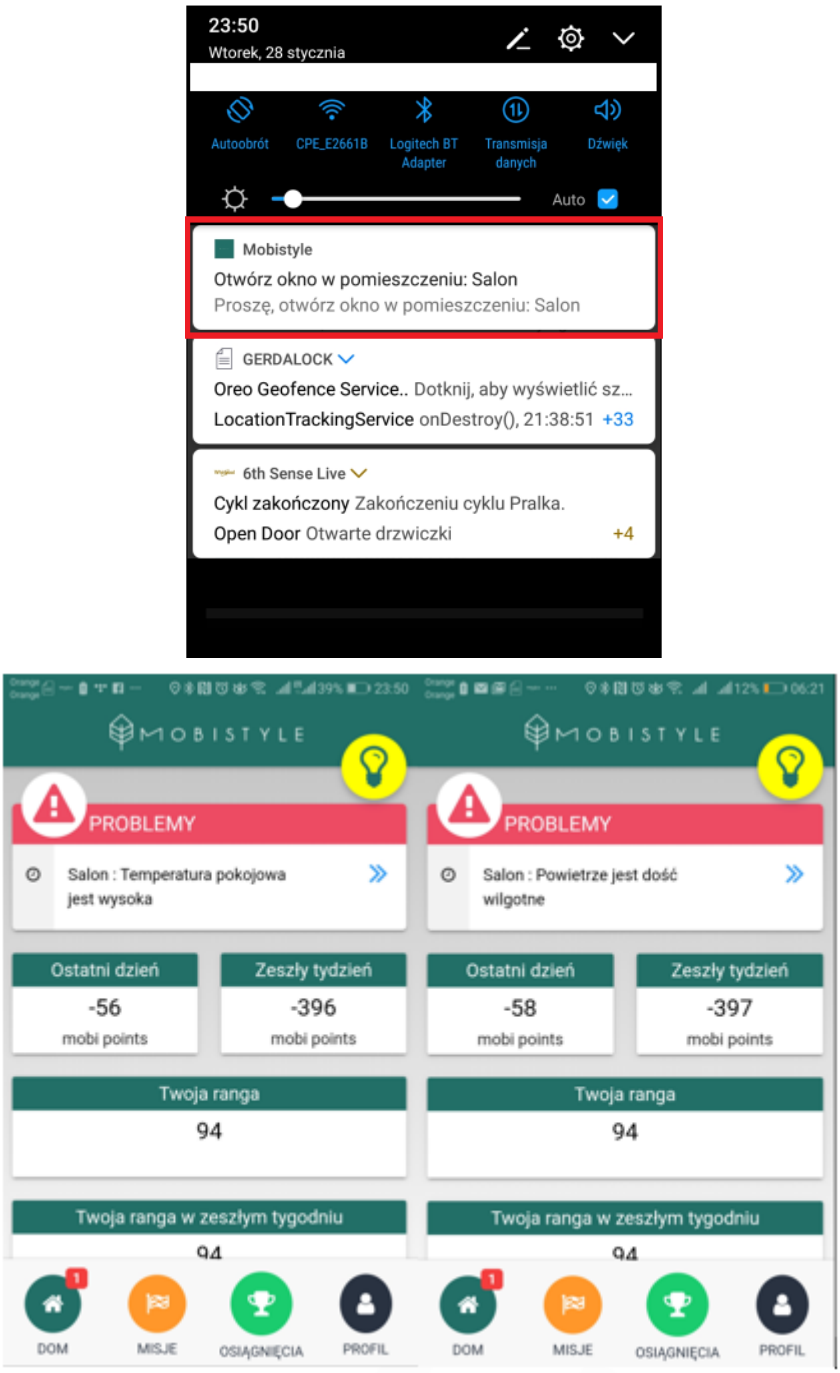


Image: Notification of a problem in a given room and mission to accomplish

Keeping these parameters at a level not exceeding the set limits, the user did not receive a mission to complete, and his/her result was 100%.

For maintaining an appropriate level of humidity and temperature, the user gained achievements on the achievements screen.

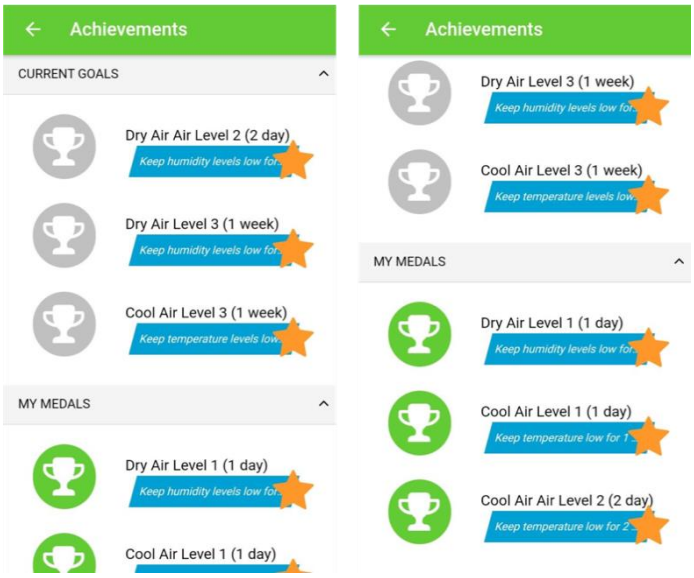
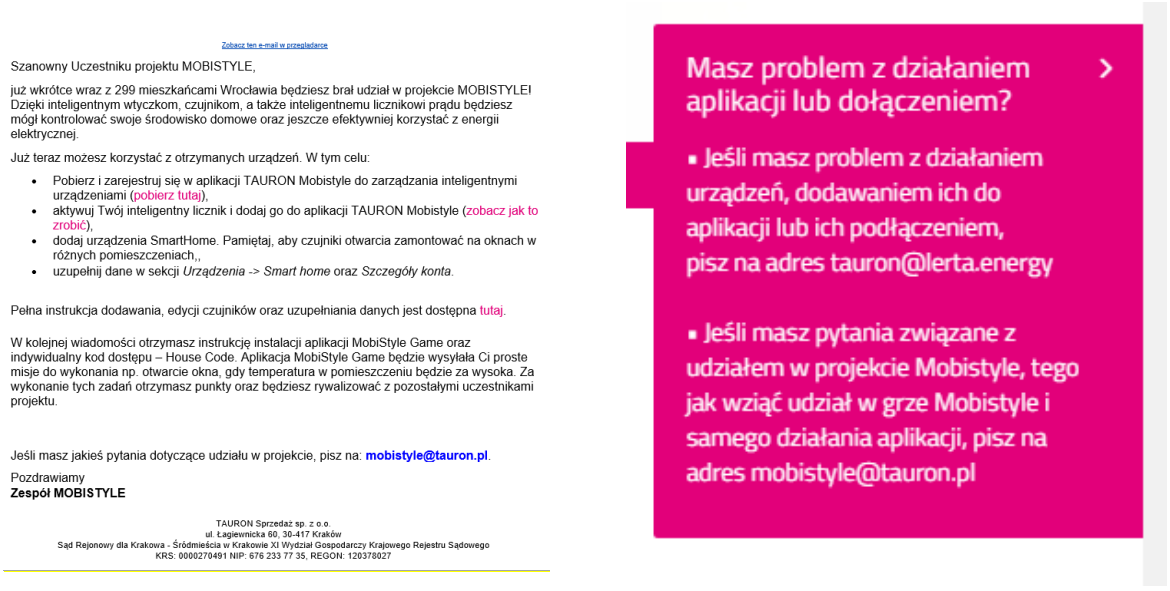


Image: Achievement screen in the application

Ongoing contact with project participants

Throughout the project, Tauron's customers had technical support available for connecting devices and the AMI meter. To date, there is also an email address where customers can ask questions about the project, the operation of the Mobistyle application and other related topics. An additional hotline has been launched, contacting selected people to indicate to participants exactly what they should do to get access to the mobistyle game. The hotline noted missing data regarding the location of the sensor or the need to connect the missing device.



Zobacz ten e-mail w przeglądarce

Szanowny Uczestniku projektu MOBISTYLE,

już wkrótce wraz z 299 mieszkańcami Wrocławia będziesz brał udział w projekcie MOBISTYLE! Dzięki inteligentnym wtyczkom, czujnikom, a także inteligentnemu licznikowi prądu będziesz mógł kontrolować swoje środowisko domowe oraz jeszcze efektywniej korzystać z energii elektrycznej.

Już teraz możesz korzystać z otrzymanych urządzeń. W tym celu:

- Pobierz i zarejestruj się w aplikacji TAURON Mobistyle do zarządzania inteligentnymi urządzeniami (pobierz tutaj),
- aktywuj Twój inteligentny licznik i dodaj go do aplikacji TAURON Mobistyle (zobacz jak to zrobić),
- dodaj urządzenia SmartHome. Pamiętaj, aby czujniki otwarcia zamontować na oknach w różnych pomieszczeniach,,
- uzupełnij dane w sekcji *Urządzenia -> Smart home* oraz *Szczegóły konta*.

Pełna instrukcja dodawania, edycji czujników oraz uzupełniania danych jest dostępna tutaj.

W kolejnej wiadomości otrzymasz instrukcję instalacji aplikacji MobiStyle Game oraz indywidualny kod dostępu – House Code. Aplikacja MobiStyle Game będzie wysyłała Ci proste misje do wykonania np. otwarcie okna, gdy temperatura w pomieszczeniu będzie za wysoka. Za wykonanie tych zadań otrzymasz punkty oraz będziesz rywalizować z pozostałymi uczestnikami projektu.

Jeśli masz jakieś pytania dotyczące udziału w projekcie, pisz na: **mobistyle@tauron.pl**.

Pozdrawiamy
Zespół MOBISTYLE

TAURON Sprzedaż sp. z o.o.
ul. Łagiewnicka 60, 30-417 Kraków
Sąd Rejonowy dla Krakowa - Śródmieścia w Krakowie XI Wydział Gospodarczy Krajowego Rejestru Sądowego
KRS: 0000270491 NIP: 676 233 77 35, REGON: 120378027

Image: Sample email sent to a participant

More details regarding IEQ and energy parameters in D6.2.

3.3. Danish case campaigns

The specific case objective (from D6.1 [5]) *was to combine information regarding IEQ (Indoor Environmental Quality), hot and cold water use as well as heating energy in order to establish how tailoring information according to different use types helps increase awareness and leads to energy efficient behaviour change and improved indoor environmental quality.*

The MOBISTYLE Game is a mobile application that uses "nudges", complemented by "tips", to change user behaviour based on the sensors available in the residence. Residential users are the key target users as they have most control of their environment.

The MOBISTYLE game consists of a gamified app aiming at behavioural change regarding energy use and also at creating awareness on the associated health benefits. The acquisition of the desired MOBISTYLE behaviours is achieved through a series of gamified challenges, which were designed following the project's people centric approach. The game relies on the operationalisation of the MOBISTYLE behaviours in measurable actions that can be captured by sensors within the environment. The game identifies different behaviours within the home based on data collected from the sensors available. Then, based on the analysis of the data, the game provides incentives in the form of recognition, achievements and suggestions with the ultimate goal to encourage the users to adopt and sustain particular behaviours towards better energy efficiency and also provide useful health tips. The MOBISTYLE game provides users with attractive, personalized information on their energy usage, indoor environment & health. This way, we boost their positive intentions and help them to reach their self-determined goals!

The users can browse through the different rooms in their house, check their state and suggestions on how to improve their indoor environment. The game makes it easy for them to adjust their behaviour: Save energy and be healthier!

The game is described here LINK.

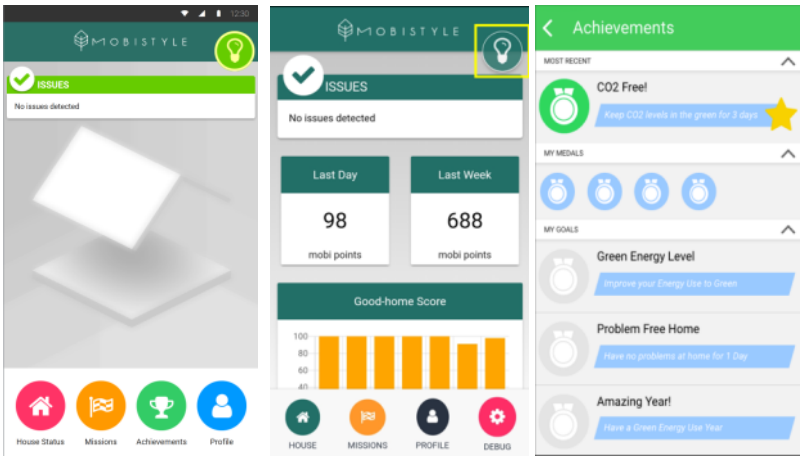


Image: Screens of the game

Same game was deployed in DK and PL case, therefore please take a look at PL case for the description. The application presented the following measurement data:

- Temperature

- CO_2 concentration
- Relative humidity
- Window state;
- Total number of openings
- Heat Consumption (heating is supplied via hot water)
- Cold Domestic Water
- Hot Domestic Water
- Total Energy Consumption

In the Danish case the information was related to heating energy use, hot water use, indoor temperature, indoor air quality represented by CO_2 level and relative humidity and the state of window opening. User could see the immediate conditions (with a 45 minutes delay) as well as the historic development during the last week. Colours (green, yellow and red) indicated if the present and historic conditions were acceptable, problematic or critical giving users an overview of the past conditions and a possibility to identify critical incidents in the near past.

For the heating energy use a heating profile based on HDD was developed for each apartment based on the heating energy use during the reference year. By calculating a 7-day moving average of the heating consumption, it could be compared to the expected use for the apartment according to the running number of HDD. If the consumption were 10% higher than expected user were given a warning.

A similar approach was used for the hot water use although the expected use was considered to be constant during the year. The expected level was calculated for each apartment based on the use during the reference period.

For the temperature level different feedbacks were given. During the heating season a warming was given (reduce set point), if the minimum temperature during night was above a critical level, as it was assumed that the minimum temperature level during night was a good proxy for the heating set point temperature. During the summer period guidance was given, if the temperature in the bedroom was high in the evening (open window before going to bed) or during the last night (open window more during sleeping) to reduce the temperature level in the bedroom and improve sleeping quality.

For air quality, recommendations were given, if the CO_2 level in bedrooms during night was higher than a critical level. Then users were recommended to increase window opening during night to improve conditions.

3.4. Italian case campaigns

The specific case objective (from D6.1 [5]) *was to monitor IEQ and electricity consumptions in order to provide the hotel guests with feedback on energy use and guidance on how to save energy, use smart control of heating, lighting and appliances. This could be combined with suggestions regarding healthy daily activities and encouraging energy efficient usage of whitegoods as additional information to increase user awareness, though these are not directly measured.*

As also described as part of D6.2, specific ICT and non-ICT tools were deployed in the Italian demo case to achieve MOBIYSTLE goals.

Dashboard and app

The Dashboard developed by Holonix (HLX) is a tool whose aim is to visualize data to rise people awareness about energy consumptions and IEQ in buildings. Data are gathered from monitoring systems and translated into meaningful information for the occupants in terms of easy-to-understand KPIs in order to support IT demo case objective (i.e. provide the hotel guests and staff members with feedback on energy use with guidance on how to save energy while creating a healthy and adequate indoor environment). Being the same tools deployed in SL demo case, the app and dashboard functionalities can be seen here LINK. Specificity of its deployment in IT demo case are described in the followings.

MOBISTYLE Dashboard (in its web and mobile version) developed by company HOLONIX (HLX) was deployed in IT demo case in three difference interfaces:

- Dashboard for the guests (displaying information about their own apartment).
- Dashboard for the receptionists (displaying information about the reception).
- Dashboard for the manager (displaying information about all the MOBISTYLE apartments and the reception).

To give access to ICT-tools to the **guests**, HLX developed a specific procedure called “handover”. It consists in a functionality of the Dashboard which allows to associate a new user to a specific apartment and for a specific period of time (from the day the procedure is initialized to the check-out date) using only his email address. Once the staff members do that (via the manager interface of the Dashboard), the new user receives an email with a link to finalize the handover procedure and create his account. Once the account is activated, the new guest can access the Dashboard online from any browser (http://mobistyle.demo.holonix.biz/#!/login) or download the App from Google Play Store on his personal smartphone. In the interface that it is so offered to the guest, the following KPIs (in relation to his apartment) were provided:

- Daily energy consumptions (i.e. consumptions per each appliance and total consumption per apartment) in kWh or Wh and represented as smiles with different colours (red, yellow, green) based on thresholds.
- Number of trees necessary to absorb CO_2 due to energy consumptions.
- Temperature, Relative Humidity and CO_2 concentration with smiles with different colours (red, yellow, green) based on thresholds.
- Temperature, Relative Humidity and CO_2 concentration trends.

- Active suggestions (with activation and deactivation based on thresholds of measured parameters).

Unfortunately, only one guest over the duration of the project accessed the ICT-tools by finalizing the handover procedure and creating his account.

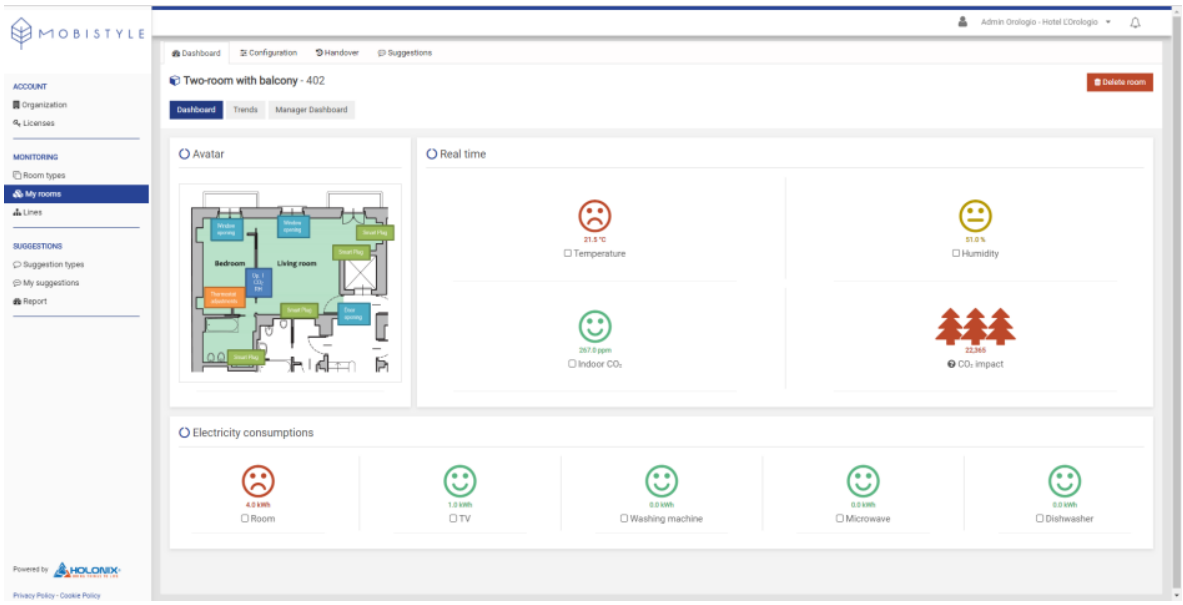


Image: The hotel dashboard for one apartment

Targeting **staff members**, they were provided with two accounts (username and password) to access the ICT-tools from their laptop or smartphone and see relevant information related to the reception space. In particular, they could see KPIs (in relation to the reception space) for:

- Daily energy consumptions (i.e. consumptions per laptop and printer) in Wh and represented as smile with different colours (red, yellow, green) based on thresholds.
- Temperature, Relative Humidity and CO_2 concentration with smile with different colours (red, yellow, green) based on thresholds.
- Temperature, Relative Humidity and CO_2 concentration trends.
- Active suggestions (with activation and deactivation based on thresholds of measured parameters).

Two staff members used the tools between November 2019 and end of February 2020. Defined suggestions were in Italian and automatically provided to the users based on start and end rules (i.e. thresholds on temperature, relative humidity, CO_2 concentration and active power of the printer). Action suggested were related to ventilate the room, avoid overheating and avoid waste of energy by switching off the printer.

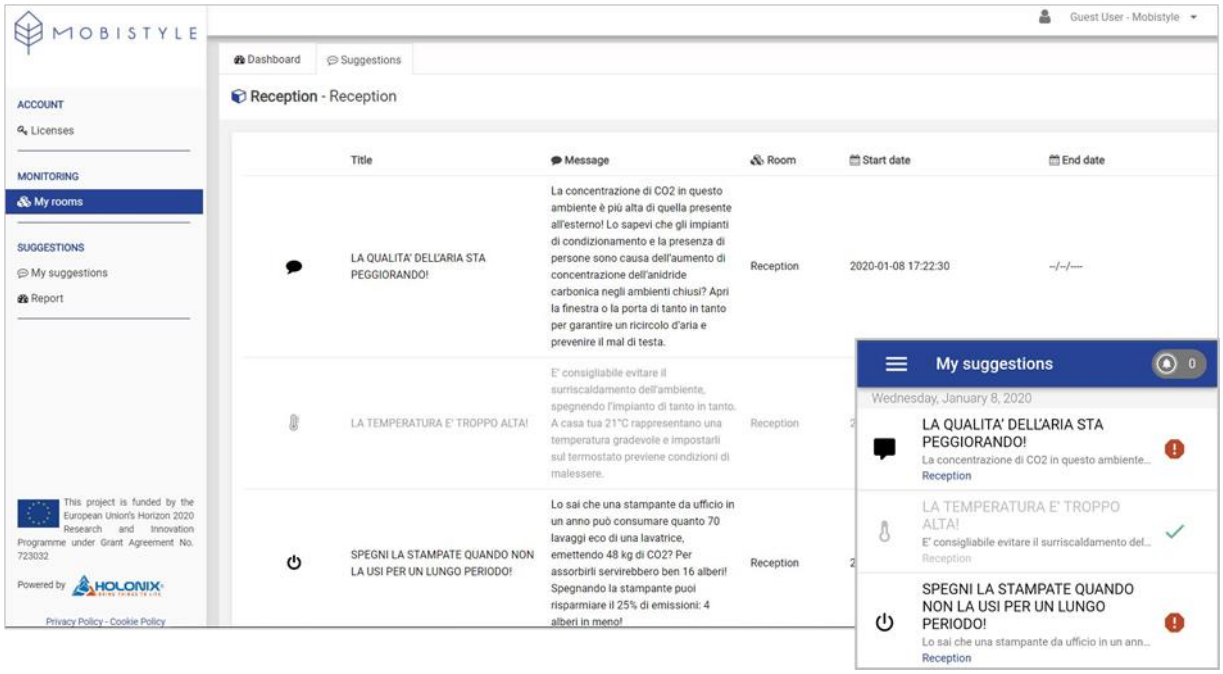


Image: active suggestions in the Dashboard (web and app version).

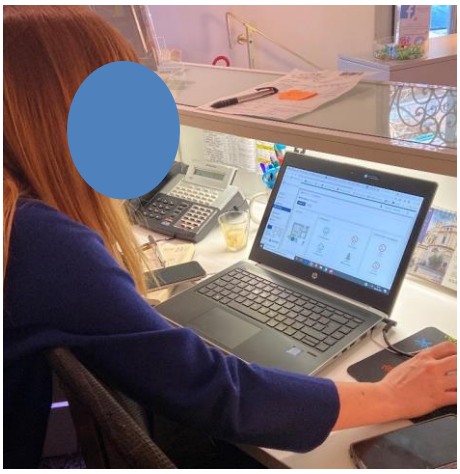


Image: staff member using the Dashboard.

Interface for manager allowed to see same information (plus energy costs and energy consumptions trends) for all the spaces involved in the project at once and offered access to handover procedure and creation of new suggestions. Despite manager interface was tested with users during the focus group to collect their feedback, it was mostly used by PoliTo team as project manager (e.g. to create new suggestions for staff), and staff members used it only to access the handover procedure and register new guests.

Non-ICT tools and information

To target both guests are staff members, also non-ICT tools were deployed in the rooms and in the reception space, both in Italian and English. The main topics addressed by the MOBISTYLE stickers were:

- Impacts on health of too high setpoint temperature

- Impacts on health (i.e. headache) of poor ventilation
- Waste of energy due to standby
- Healthy lifestyle (i.e. use of the stair to be healthy and save energy and protect the quality of your sleep avoiding use of smartphone before sleeping)

The stickers also aimed at informing guests of the presence of the project and at engaging them in checking the MOBISTYLE ICT-tools.

Image: Element of the IT hotel campaigns – MOBISTYLE stickers in apartment space (from D6.2).

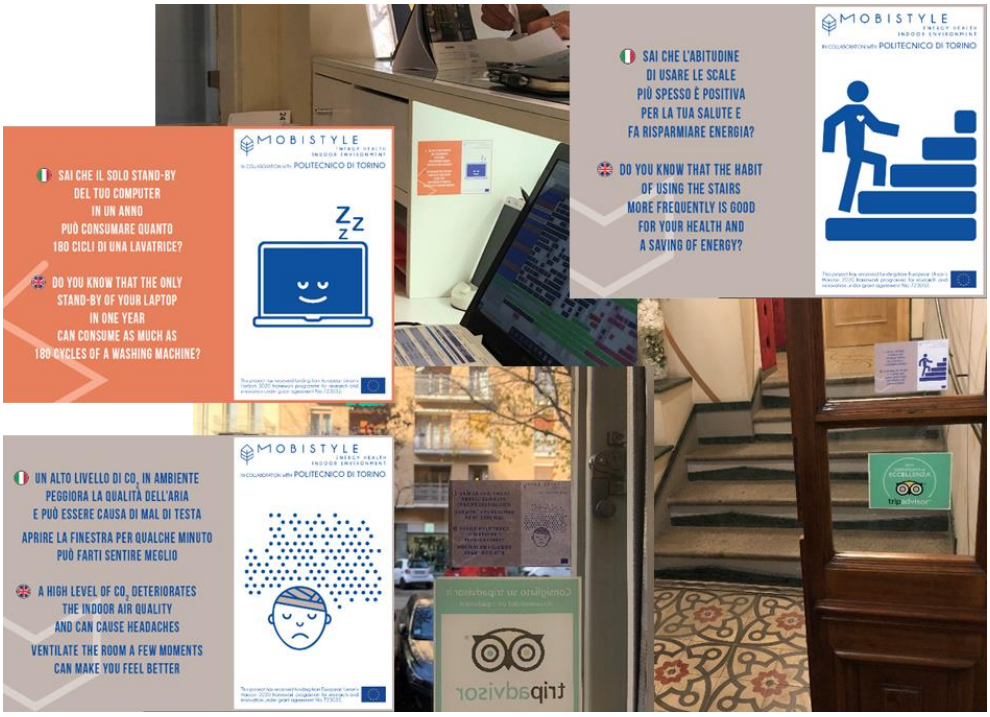


Image: Element of the IT hotel campaigns – MOBISTYLE stickers in reception space (from D6.2).

With the same aim of making people informed and interested in the project, informative materials were also displayed. Staff members also shared online MOBISTYLE promoting it like a new service for their guests (https://www.orologio-residence.com/2019/12/06/8301/).

Image: Element of the IT hotel campaigns – informative materials in reception space.

Image: Element of the IT hotel campaigns – marketing communication by hotel staff.

Energy and IEQ in IT demo case

Data analysis performed during the MOBISTYLE solutions deployment in RECEPTION space showed benefits in terms of **electricity energy savings** (9.14%) and **reduction of average CO_2 concentration** (7.6%), if compared to same period of the previous winter. Both topics were addressed by MOBISTYLE stickers suggesting switching off the printer before leaving the office and opening the window sometimes, stressing on negative impact of high CO_2 concentration on health and well-being. Information on consumptions and CO_2 concentration were provided also via the Dashboard. **No benefits were measured in terms of thermal quality of the indoor environment** (topic addressed only via the Dashboard). The stickers (easily visible without the necessity to open an App) were more effective than the ICT-tools.

Targeting GUESTS, only one guest accessed the Dashboard over the duration of the project. Consequently, it's quite impossible to make some considerations about effectiveness of feedbacks given via ICT-tools. MOBISTYLE stickers deployed in guests' apartments were stressing on two topics in particular:

- Keeping proper setpoints ("*Do you know that excessive indoor temperatures could negatively affect your health? 21°C is a pleasant temperature*")
- Ventilate the room ("*A high level of CO_2 deteriorates the indoor air quality and can cause headache. Ventilate the room a few minutes can make you feel better*")

Comparison of relevant KPIs computed before and after MOBISTYLE stickers deployment allowed to observe that overheating phenomenon was slightly reduced improving IEQ in terms of temperature for some types of guests. During sticker deployment the **time spent in comfort category I and II in terms of CO_2 concentration was increased** (25-70% time instead of 14-59%) for some of the analysed types of guests.

More details in D6.2.

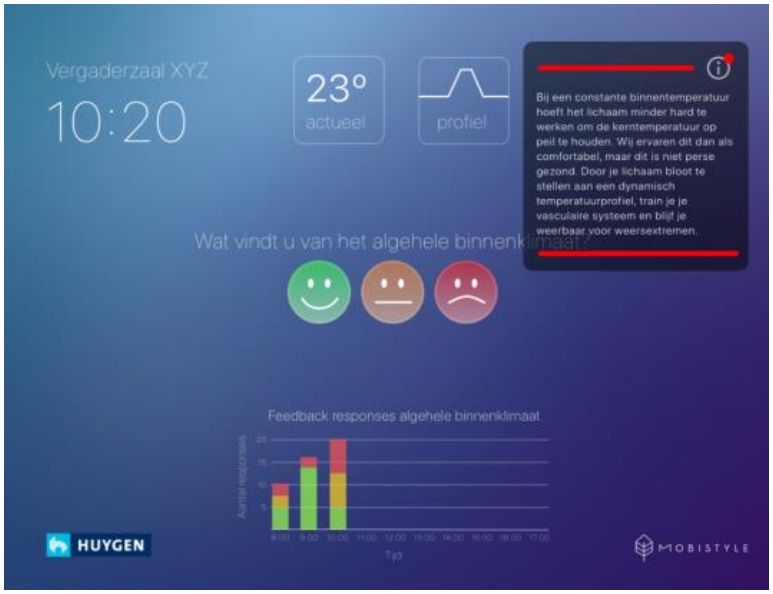
3.5. Dutch case campaigns

The specific case objective (from D6.1 [5]) *was to establish a correlation between different indoor environment situations (dynamic temperature profile in comparison to traditional constant temperature setting) affect occupant's health (physiological) response and also how occupants perceive such conditions (psychological). Moreover, to support the main MOBISTYLE objective, an investigation of whether lowered indoor temperatures in the winter season could lead to not only energy savings, but also improved wellbeing, will be conducted.* The Dutch case was divided into the three investigations:

a) Lab studies to show the correlation between physiological response of the body (human biology) and strict imposed controlled indoor conditions;
b) Correlation between physiological response of the body (human biology) and real life indoor conditions for the Qeske building;
c) Awareness raising with the dynamic conditions in Brightlands building.

More about these studies can be found in D6.2. Feedback and awareness raising was only introduced once the Qeske studies proved there is a positive body response to the imposed dynamic conditions. So primarily were awareness campaigns focused on the Brightlands building with some simple evaluation questionnaire and VR video for Qeske.

For the Qeske building, the VR glasses were used as a gadget to show the possibilities of the dynamic conditions. The 360° movie is available online: LINK. The Office app introduced for the Brightlands building is described here LINK where the app is intended for employees & company managers and used primarily to increase awareness of users with the surrounding conditions, encourage dynamic indoor conditions and evaluate their perception. See the MOBISTYLE Office App video: LINK.



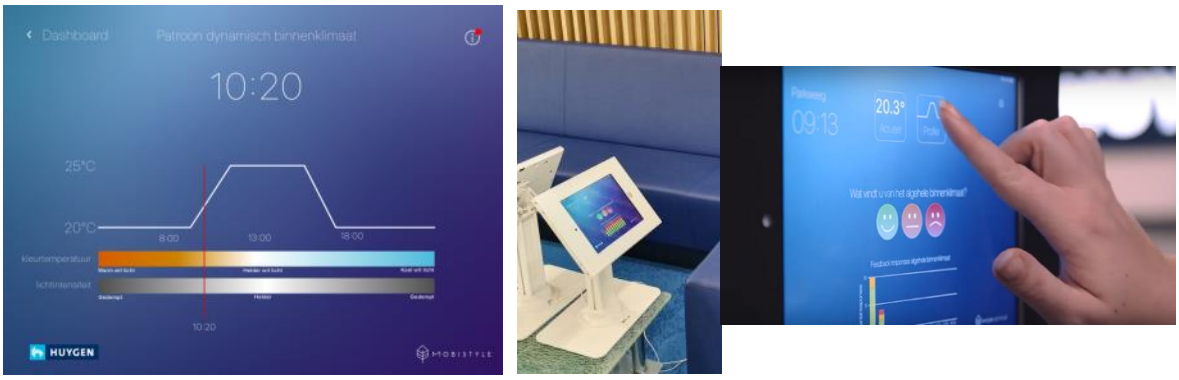


Image: The Office App user interface.

The application was available via a dashboard installed on the wall (close to the doors) of an office/meeting room. When the occupant arrives to the office, he/she can see sees the status of the indoor climate. The interaction works via touch-screen where user is asked to give feedback on the indoor climate and can leave feedback on their own satisfaction with the given conditions. Furthermore, when dynamic conditions are introduced he/she can see at which point at the temperature pyramid the setting is (see left image above). By visiting Tips section, short ideas conveying facts on health, energy use or indoor air quality are given. Besides the ICT solution, also awareness campaigns were organized where Huygen internal newsletter channel was used for circulating weekly/monthly MOBISTYLE reports.

Uitnodiging luchtbijeenkomst 8 oktober 12:00 uur

MOBISTYLE

Team,

Huygen krijgt de kans om naar een nieuw kantoor te verhuizen dat in een research-omgeving ligt (community).

Aanvullend op onze lopende onderzoeken over terugdringing energieverbruik/CO2-uitstoot, relatie gezondheid en comfort van binnenklimaat en gebruikersgedrag, willen wij de mogelijkheid aangrijpen om in deze nieuwe omgeving ook zelf experimenten te doen.

De eerste experimenten die wij gaan doen hebben betrekking op productiviteit in kantoren. Samen met TUe en UM ontwikkelen we een methodologie voor het meten van zelf-beoordeelde productiviteit door kantoormedewerkers. Volgens het huidige inzicht is een enquête (survey) het voornaamste instrument om veranderingen in productiviteit vast te stellen. Periodiek (twee á driemaal per jaar) een uitgebreidere enquête en dagelijks tweemaal het scoren van een zeer beperkt aantal vragen. Het traject begint met een nulmeting.

Deelname is vrijwillig en anoniem voor zowel onderzoekers als directie. De enquête-data is dubbel gecodeerd, eerst door de onderzoekers en vervolgens door een vertrouwenspersoon [redacted] Wij hopen dat iedereen meedoet.

Image: NL dissemination event

Furthermore, Brightlands lunch meetings were organized to spread the concept of MOBISTYLE among a broader public, see below.

Image: NL dissemination event

Along the office spaces and on hallways, MOBISTYLE stickers have been posted promoting MOBISTYLE temperature trainings (see below).

Image: Sticker example used in NL case

4. MOBISTYLE solutions testing, users understanding and feedback

Methodology for this report was laid down in the "Feedback_evaluation_protocol" that was prepared based on Slovenian demo tests by IRI UL and used by demo case holders. In the MOBISTYLE project, we focus on human interactions with buildings, technologies, tools, and devices at home and work. We are interested how people consume energy throughout the day, which daily activities of the people are connected to health, wellbeing, and energy consumption, and how we can change and improve their health and energy related practices and habits by different IT-based solutions. The research approach and methodology used is described more in details in D2.2. Inventory of user needs and expectations [3].

Different user groups were initially identified by an online survey, filled in by users in five case studies. We identified 5-7 individuals per case in participating countries with dedicated demonstration cases, who were willing to be engaged. In the next phase, we focused on health, wellbeing and energy related habits in these groups by ethnographic approach (participant observation, interviews, surveys and focus groups). Later we prepared a list of general and case-specific recommendations for development of technological solutions which will influence short-term behaviour of the people and support establishing the long-term habits connected to health, wellbeing and sustainable energy use.

Developers followed these recommendations in the reasonable way. Later we introduced in the WP4 developed solutions to users, involved in the project, and carry out usability testing with them and provided feedback to the developers once more for fine tuning. The evaluation of solutions from user perspective is presented below. Several research methods were used such as focus groups, standard and specific questionnaires and participant observation.

4.1 Focus groups

For each demo case, a focus group (FG) with the existing or future users were carried out several times during the project duration. The selection of participants was carried out by the project partners, following the Recruitment of participants in the ethnographic study Instructions as described in D2.2 [3]. Before each group discussion, the participants were informed and gave consent regarding the data collection (recording and analysis) as described in Report on Ethics and expressed their interest to participate in the project. Questions for participants were in one part unified for all groups, and partly adapted to specific cases and their ICT solutions.

In this document the focus groups results are shown in the context of achieving objectives (O1,2,3,5) set in the DoA. Results from FG user testing of ICT solutions are described in D4.3 [10],
Purpose of FG, i.e. collecting user feedback about the following:

- Understandable information related to energy use
- GUI usable and attractive
- Understandable and useful personalized information for users by combining energy monitoring with monitoring of IEQ, behaviour parameters and daily habits
- Prolonged behaviour change due to combined modular information on energy, IEQ and health
- Solution attractive and willingness to use the services in future
- Self-reported behavioural change and reduction of energy use in different real environments by deploying and validating for the demo cases

- Involved end users show structural behavioural changes and embed the tools in daily routines

In the FG execution the focus was on the following (associated with MOBISTYLE objectives):

1. Understandable information related to energy use
   - data managed and presented
   - users understand the presented information
   - redemption of end users, once they start using the tools
   - users find the GUI usable and attractive

2. Understandable and useful personalized information for users by combining energy monitoring with monitoring of IEQ, behaviour parameters and daily habits
   - users understand information on IEQ
   - users find this useful information

3. Prolonged behaviour change due to combined modular information on energy, IEQ, health
   - users find the modular information services usable and attractive and are willing to use the services in future
   - users actually use the modular structure in an active way

5. Behavioural change and reduction of energy use in different real environments by deploying and validating for the demo cases
   - involved end users show structural behavioural changes and embed the tools in daily routines

4.2 Quantitative measurement by System Usability Scale

Standard System Usability Scale (as described in D3.3 [9].) tests were done in various times for developed ICT solution. Results are described in D4.3 [10], and D6.4. *In the DK and PL case usability testing was performed on a prototype of the Game. This was useful to give input for the further development of the App version of the Game itself.*

4.3 Questionnaires about perception

The DK and PL intermediate evaluations of the game were done in 2020 just before the restriction measures were put in place all around Europe due to the COVID-19 situation.

Questionnaires about perception were deployed in different moments at each demo site level. Some specific contexts require having a shorter and faster evaluation tool, to get users' attention and to keep them interested. For this reason, a significantly shortened and more understandable questionnaire was prepared. Questionnaires were presented in national languages using the double translation to keep the translations as similar as possible. The aim of the questionnaire is to understand changes in terms of perception by the participants related to comfort, energy health, and the MOBISTYLE project. The questionnaire consisted in 5 sections with a set of specific questions related to old/new perception of comfort; old/new perception of energy and related costs; old/new perception of health; perception of feedback provision and MOBISTYLE project and intention to change the own behaviour in a long-lasting manner. This questionnaire was developed as part *of D3.3. Evaluation method to test the effectiveness of the combined feedback campaigns* [9]. After testing on the users it was modified to be more understandable and to fit better to the demo case specific.

O1-5 – objectives, Q- question or statement in the questionnaire referring to the objectives. Relation to the objectives/its achievement:

- O1: 90 % of end users understand information (on energy)
  - Q: I understand how my actions affect building energy use.
- O2: 75% of end users understand information on IEQ
  - Q: The MOBISTYLE services provided understandable information and feedback
  - Q: I want to know how my behaviour affects building energy use/costs/indoor environment/my health.
- O3: 90% of end users find the modular information services usable and attractive and are willing to use the services in future
  - Q: The MOBISTYLE services gave me useful advises on how my behaviour affects energy use and the quality of indoor environment.
  - Q: I will keep new habits in the future.
- O5: 90% of involved end users show structural behavioural changes and embed the tools in daily routines
  - Q: The MOBISTYLE services helped me to change my habits.
  - Q: I think that the MOBISTYLE services helped me to adopt a healthier lifestyle.
  - Q: The MOBISTYLE services helped me to improve the thermal environment in my home/office.
  - Q: The MOBISTYLE services helped me to improve the indoor air quality in my home/office.

Results for each case are presented in following chapters by countries, here the table with summary.

Table: Objectives reached based on questionnaires:

achieved				
not achieved	PL	SI	DK	IT
O1: 90 % of end users understand information (on energy):	96%	100%	80%	/
O2: 75% of end users understand information on IEQ	80%, 97%	100%, 100%	60%,100%	/
O3: 90% of end users find the modular information services usable and attractive and are willing to use the services in future:	77%, 92%	89%,100%	40%	100%,100%
O5: 90% of involved end users show structural behavioural changes and embed the tools in daily routines:	68%,66%, 64%,68%	89%,89%, 67%, 100%	60%,60%	100%,100%, 100
n	99	9	5	2

Natural counted under positive.

Some particular contexts (e.g. hotels or offices) require shorter questionnaires to keep people attention and interest, therefore not all questions were addressed in all cases. Details available below.

5. Polish demo case: smart city Wroclaw

The first FG with 6 participants (plus 2 researchers) took place on 12th April 2017 via teleconference. Another one took place on 10th of March 2020, the results were send to IRI UL in presentation and questionnaires results in a table. The questionnaire was sent to around 150 users who had received house code for Mobistyle Game and we had 99 responses.

Conclusions from the FG:

- The Mobistyle system affects the respondents' knowledge and awareness, which is indirectly translated into changes in behaviour / habits. The related changes are mainly aimed at achieving savings in energy consumption.
- The Mobistyle system allows for controlling utility media consumption and internal environment elements as well as moderately contributes to savings. However, Mobistyle does not directly affect health-promoting of environmentally-friendly attitudes.
- Mobistyle has insufficient impact on the creation of short-term and long-term behaviour, because it is underdeveloped. Despite the fact that the respondents point to changes in their behaviour, the changes are incidental. The respondents treat Mobistyle as an innovative gadget and not a system that actually generates real changes in the use of particular devices and utility media consumption control.
- Mobistyle enables internal environment monitoring, but does not cause regular behaviour focused on making progress in the given area. It does not demonstrate any substantial dependency between the changes in behaviour / habits motivated by ecological factors.
- Lack of notifications and gamification elements makes the Mobistyle system become not functional.

Recommendations from the FG:

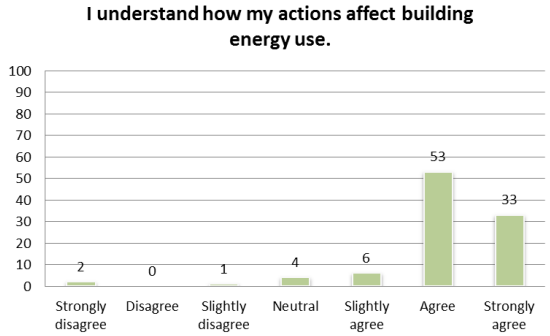
- In order to enable the Mobistyle system to affect the users' behaviour and habits, it is recommended to introduce the following changes:
    - introduction of a system of weekly, monthly, periodic reports;
    - introduction of communications and push-type notifications as well as the ability to manage these notifications;
    - the system's learning of user behaviour and habits;
    - ability to remotely activate / de-activate selected devices / outlets at times specified earlier.
- It is recommended to refine the gamification elements of the Mobistyle application, this would make it possible to generate the desirable changes in habits – both short-term and long-term.
- It is proposed to engage greater technical support to solve problems related to the installation of devices and aid in connecting and configuring devices as well as the support's more effective work in terms of solving current technical problems.

Questionnaires

Results from the PL questionnaire are presented below in respect to achieving MOBITYLE objectives.

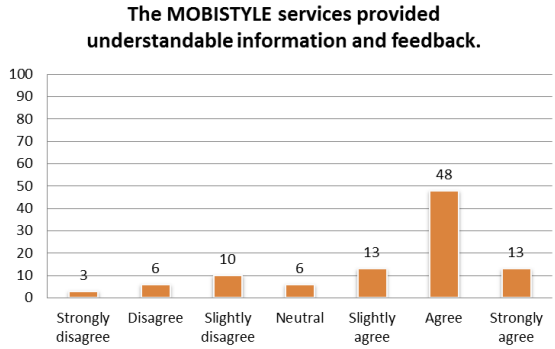
N=99

O1: 90 % of end users understand information (on energy): PL case achieved

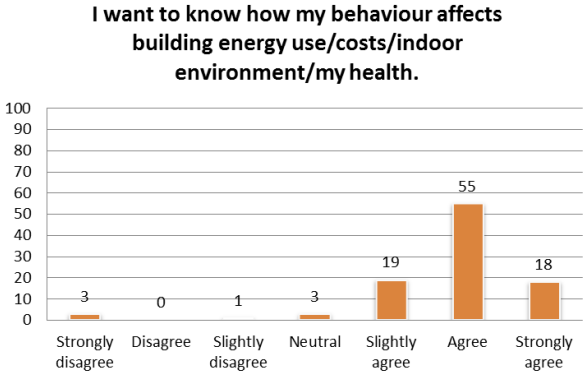


96% agree or neutral

O2: 75% of end users understand information on IEQ: PL case achieved

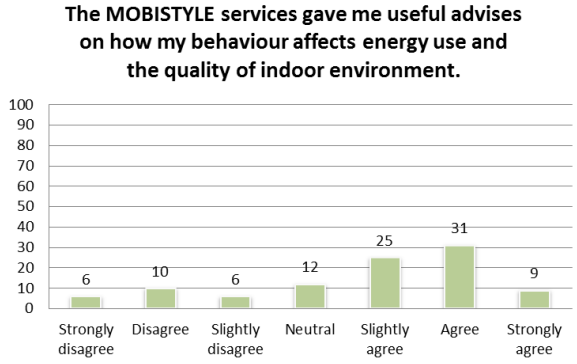


80% agree or neutral

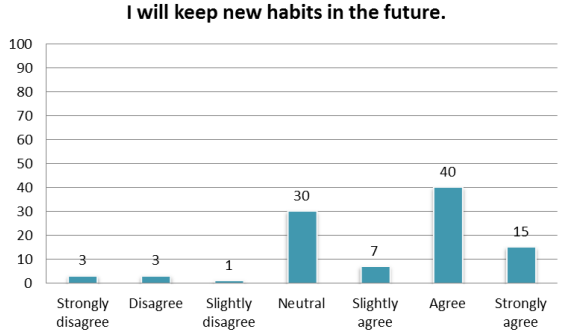


97 % agree or neutral

O3: 90% of end users find the modular information services usable and attractive and are willing to use the services in future: PL case not achieved

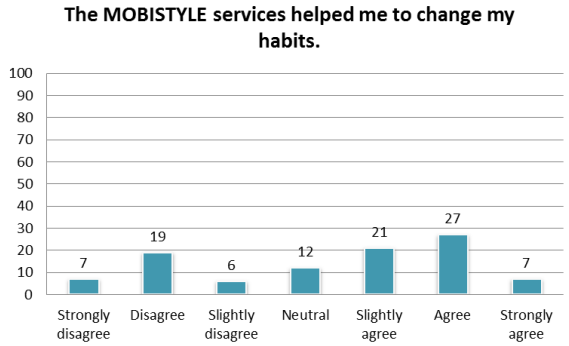


77% agree or neutral

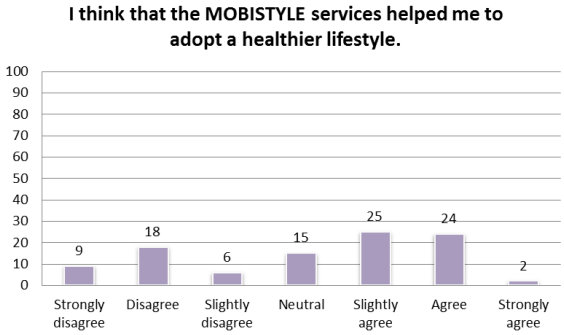


92% agree or neutral

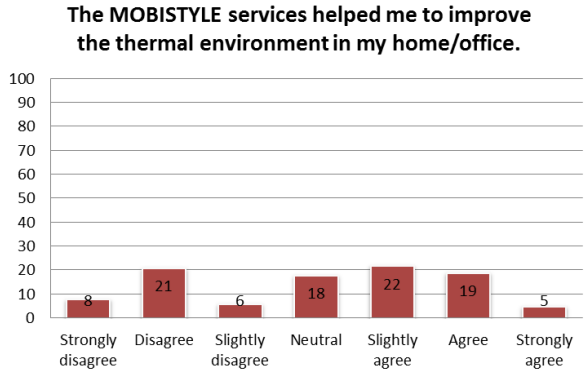
O5: 90% of involved end users show structural behavioural changes and embed the tools in daily routines: PL case not achieved



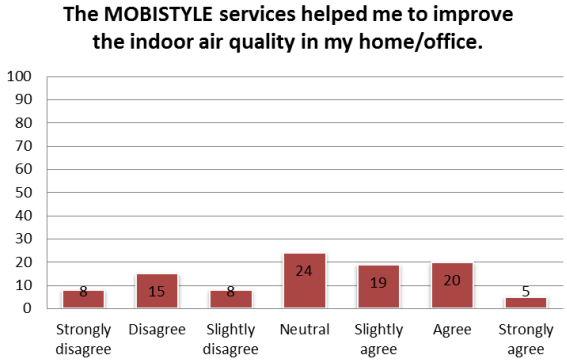
68 % agree or neutral



66 % agree or neutral



64 % agree or neutral



68 % agree or neutral

As it can be observed from questionnaires and text people provided next to them, some experience campaigns positively (+) and some negatively (-). There was an option of free text in the questionnaires. Here below some examples.

I think that the MOBISTYLE services helped me to adopt a healthier lifestyle

- The system itself doesn't motivate me to anything

+ Mobistyle motivates me to check the air humidity so I can have the air quality in my apartment under control.

- The programme has not likely caused a change in behaviour and habits

+ I started to take more care of the humidity in my rooms.

- the application has not yet informed me about the wrong temperature/humidity

+ I'm taking care to maintain the optimum temperature

- Nothing has changed in my behaviour regarding the temperature/humidity control in the apartment. It is still at the same good level.

+ I pay more attention to energy consumption and its impact on climate conditions at home

- It doesn't motivate in any way, it's just an information system.

+ Using Mobistyle has made me aware of where the highest energy consumption occurs

Please let us know what you think about the Mobistyle.

- The device application works and is great. However, after logging in, Mobistyle Game does not give me any points, nor does it have any actions to perform. I'm waiting maybe it's a matter of time ?
+ Generally speaking its great, however, more devices would be useful.
- Unfortunately, I have repeatedly reported a problem with the Mobistyle application - it does not receive any tasks to perform. The problem has not been solved
- The project could have made sense. It could. But I got a pack of products that are poorly designed…
+ Very cool and interesting project, I'm happy to use. Email with access to the application got into spam so I started using it with a delay. It is worth to make sure that this information reaches the participants earlier :)
+I am very pleased to be able to use the equipment provided
- It would be good to work on a game application.
- I don't know if in my case this application works properly. It seems to work, but I don't feel like I'm running a game or achieving any goals.
+ I am pleased to be able to take part in the program because it allowed me to learn practical possibilities of using new technologies at home, saved energy and improved the comfort of living environment.
- Very inconvenient is the lack of notification from the application. I lack the possibility to view weekly data, etc. There is no possibility of statistical analysis of data/reports.

The answer is that solutions need to be adapted to individuals, and not just various contexts or buildings.

The insight regarding behaviour from industrial partner addressing Polish demo case:

From experience and the consumer analysis we have done, people want to reduce energy consumption but they need to see an economic return in order to change habits. The economic benefits doesn't have to be big though, but it has to be visible. Gamification is a way to engage people at the very beginning and make them explore the system, but interest would fade away in few weeks if they cannot see a practical return. Despite Mobistyle pilot for Poland is underdeveloped, as reported in the document, it confirmed the observations I just reported.

6. Slovenian demo case: university buildings

We carried out in-depth ethnographic research to investigate how the sensors, in all their numerousness, and other available technologies help people control their working space, how effective they are in decreasing energy consumption, and whether they indeed provide the optimal environment for the building occupants[1].

We looked into quantitative data the sensors were recording and used findings from survey, carried out in spring 2018. In addition to the survey, we selected 14 different rooms, among which there were six offices, four laboratories (common offices) and three administrative offices.

Then, we observed the rooms' occupancy, window opening, temperature settings, energy consumption and air quality in a longitudinal study spanning from 2016 to 2019. At the same time, we conducted a three-year ethnographic fieldwork in the building, lasting from 2016 to 2019. We interviewed the inhabitants, shared their offices with them, browsed through institutional fora, and performed focus studies for designing monitoring apps. These methods expanded our perception of the behaviours, values, practices, habits and hacks people used in the building and "thickened" our "big data". The measured data is presented in D6.2.

Quantitative data, acquired with sensors, helped us identify behaviour patterns for each room individually and for the building as a whole. One such "typical" pattern that emerged was that ***people mostly open windows between late spring and early autumn****. There were very few instances where people would open the windows in the winter, even though almost all of them said in the interviews that the first thing that they do upon coming to work, was open the window. This was not the case, as sensors showed. Most occupants forgot to mention that they open the window exclusively when it is sufficiently warm outside. Moreover, people grossly overestimated their habits of opening windows. This is a typical case of "attitudinal fallacy", where people either intentionally misrepresent their behaviour to make them look like they're adhering to the desired behaviour or their actions are simply too subconscious to report them accurately.*

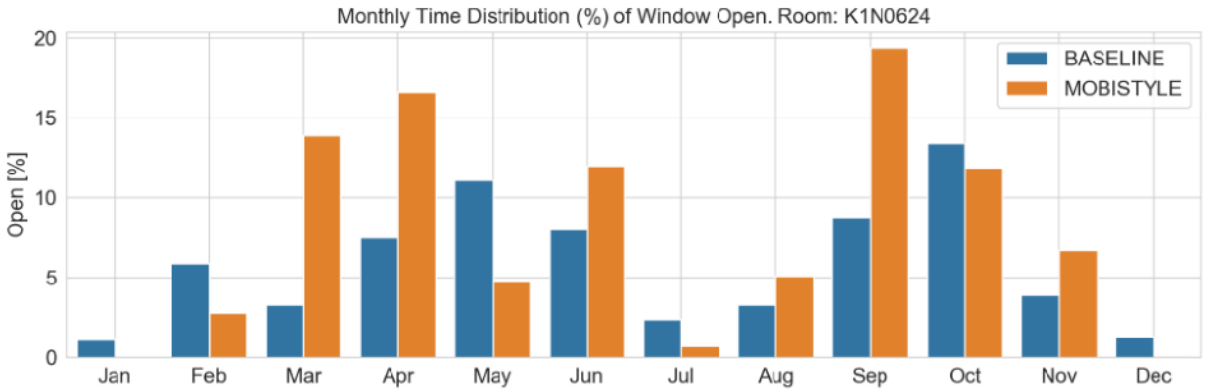


Image: Example of monthly window opening distribution - D6.2

Another behaviour we noticed by sensor data analysis was that people ***frequently*** *open windows when they come into their office (normally around 8 am or 9 am),* ***but rarely in the afternoon****, even though the air gets quite bad by the end of the day.*

There was a slight increase in opening windows at 1 pm, because a lot of the occupants returned from lunch and noticed the bad air. ***This changed significantly when the sensor started showing CO_2 levels with a coloured light*** *(green representing good and red bad air quality). Once the light was activated, the frequency of window opening in the afternoon increased.*

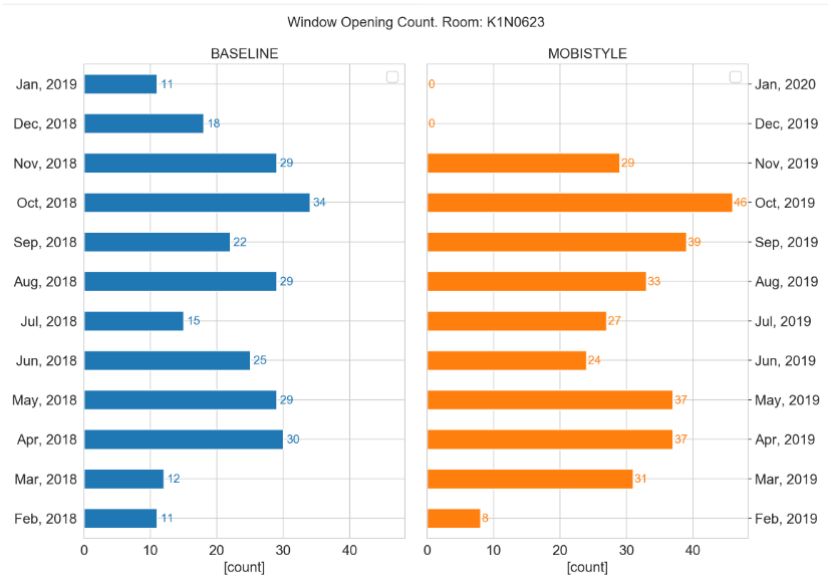


Image: Example of room where important increase of counted window opening was measured - D6.2

Another trick, which they figured out, was that the cooling stops ***working when the window is open (not to waste energy, of course).*** *Concurrently, lecturers started opening the windows frequently, so that the students wouldn't get cold in cooling season.*

Elevators use FRI FKKT

By showing elevator use date we focus on specific habits/practices that were changed due to MOBISTYLE campaigns. More granular analyses were done to see impacts of MOBISTYLE on people practices. There are 5 elevators in the complex with flowing names: X kitchen, FKKT large, FKKT small, X panoramic and FRI. Every movement is recorded on the elevator system and they are read monthly as part of regular preventive maintenance checks. For the baseline period we used data from 12/4-2017 – 30/4-2019. There were 748 days, of which 535 working days (only weekends excluded).

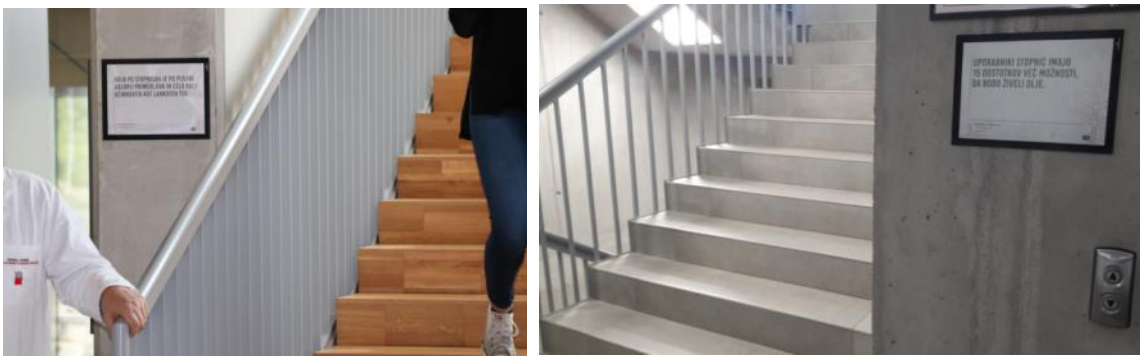


Image: Part of the campaign stimulating stair use at FRI FKKT

The MOBISTYLE campaigns stimulating stairs use were started on 16/4-2019. The test period was from 31/5-2019 to 29/1-2020 (243 days, 174 working).

Table: Elevators use at FRI FKKT complex in baseline and MOBISTYLE period

Elevator	X kitchen	FKKT large	FKKT small	X panoramic	FRI
Nr. of moves in baseline period	73130	133940	232436	106483	181290
Nr. of moves in baseline period per working day	137	250	434	199	339
Nr. of moves in the test period	24752	40577	66798	31442	51455
Nr. of moves in test period per working day	142	233	384	181	296
Change of moves per day in %	**+4**	**-7,4**	**-13,2**	**-10,1**	**-14,6**

The only elevator showing increase is the one used for staff and goods for supply of the kitchen serving cantina in 2nd floor of building X. The large elevator in FKKT is used primary for goods transport. Only ones serving exclusively personnel are FRI and FKK small and these 2 show the largest decrease (13 and 15%) thus we can conclude that the campaign combining health and building use, was successful.

Elevators use EF

We manged to get data for only 2 (out of 3) elevators in the building: RCU and Library. Every movement is recorded on the elevator system and they are read monthly as part of regular preventive maintenance checks. For the baseline period of RCU we used data from 1/9-2005 – 1/6-2019, and for Library (newer elevator) from 1/12-2018-1/6-2019

Image: Part of the campaign stimulating stair use at EF

The MOBISTYLE campaigns stimulating stairs use at EF were started on 30/5-2019. The test period was from 1/6-2019 to 4/11-2019

Table: Elevators use at EF

Elevator	RCU	Library
Nr. of moves in baseline period	788.800	13.222
Nr. of moves in baseline period per working day	220	102
Nr. of moves in the test period	16.700	10.802
Nr. of moves in test period per working day	150	97
Change of moves per day in %	**-32,6**	**-4,3**

More insights from SI demo deep ethnographic research available in [1].

Final tools evaluation focus group for SI demo took place on 3/10-19. Below some insights

- Frames with campaign noticed
- Nobody used elevator
- Opening windows based on new knowledge
- Context info
- Objective information coming from the sensor was used by room occupants as an excuse for opening window in rooms with more people (before LED no window ventilation in winter)
- One forgets the password, url…
- Same trends every day
- Too much info
- Deleted the app after getting info in the afternoon.
- Morning cleaning causes red LED
- Colors ok
- All visitors see the sensor on the wall

Example report from SI focus group

Example of what kind of understanding we can get from ethnography: „LED red often, I don't trust it…

"

Image: Lab gown used in organic chemistry lab emissions from which can affect the sensor.

General recommendations from the FG:

- It seems that ICT tools are present too much of a cognitive burden to the room users. They look at them in the beginning and later they tend to lose interest.
- Information needs to be presented in the context; one should be aware of poor air quality when he or she is in the room and not somewhere else.
- Communicating IAQ via wall mounted LED changing color seems to be well accepted.
- Sensors should be regularly checked and calibrated in order to make trustworthy measurements, since equipment can always fail.
- Appropriate decision making in rooms with more people should be facilitated, so that the room conditions are not based on individuals' mood; instead, they can be collectively decided. -Push notifications should not be sent too often –only when urgent or necessary.
- IAQ parameters are mostly constant, thus not so interesting.
- Parameters, such as temperature, humidity and CO_2/VOC concentrations could be shown on the sensor itself.

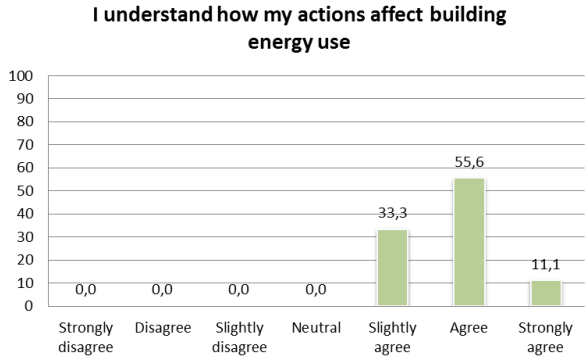
- Micro-location of campaign boards in the building and sensor in the room is essential, so they are taken in to account.
- Identifying the right reason for poor air quality is critical so that the measures are effective (robes, shoes, cleaning chemicals, ...).
- Colors from green to red are suitable.

Questionnaires

Results from the SI questionnaire are presented below in respect to achieving MOBITYLE objectives.

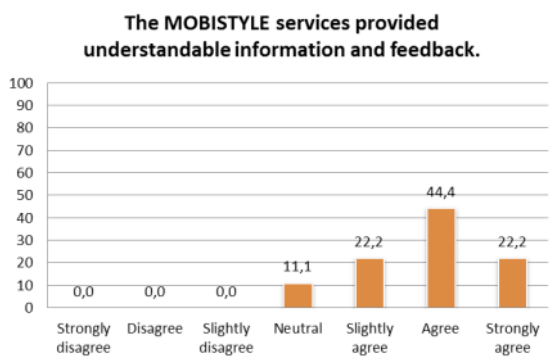
N=9

O1: 90 % of end users understand information (on energy): SI case achieved

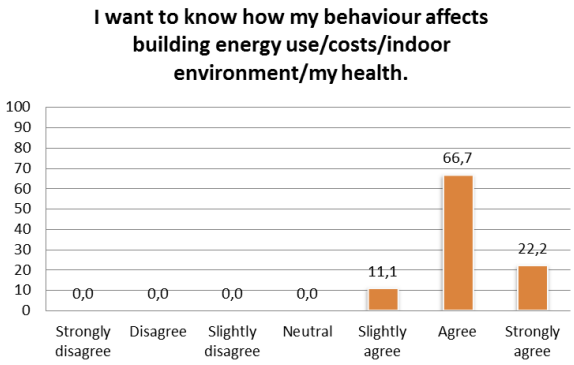


100 % agree

O2: 75% of end users understand information on IEQ: SI case achieved

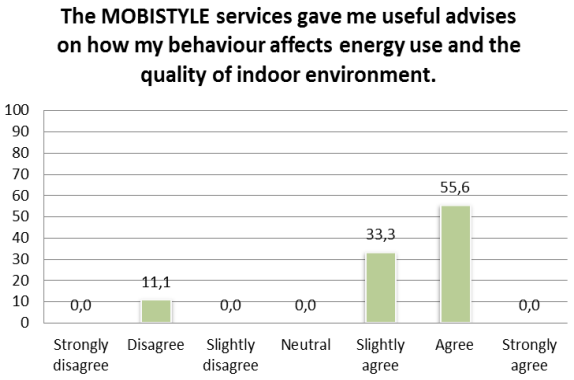


100 % agree or neutral

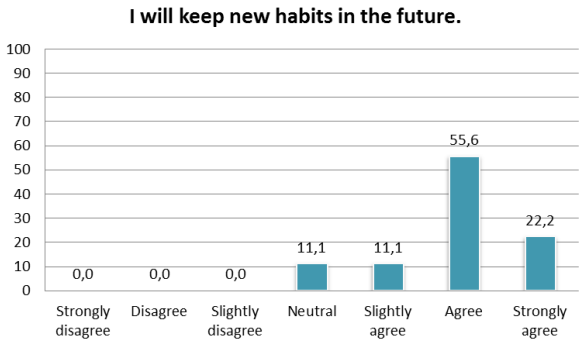


100 % agree

O3: 90% of end users find the modular information services usable and attractive and are willing to use the services in future: SI case achieved

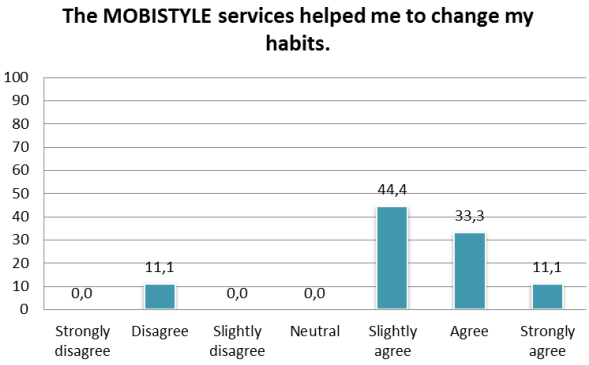


89 % agree

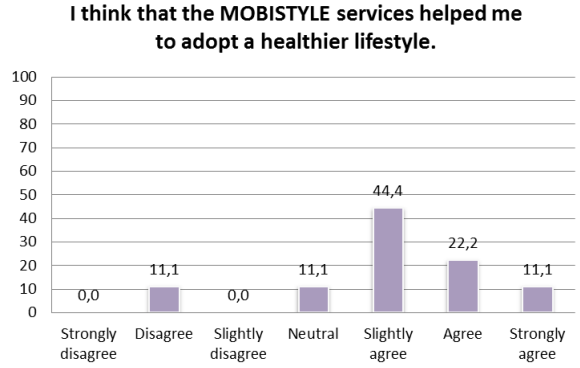


100 % agree or neutral

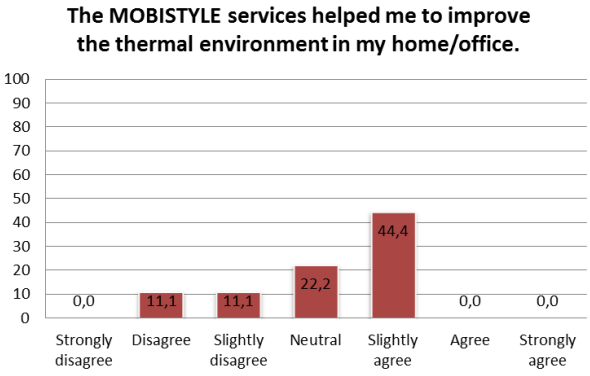
O5: 90% of involved end users show structural behavioural changes and embed the tools in daily routines: SI case not achieved



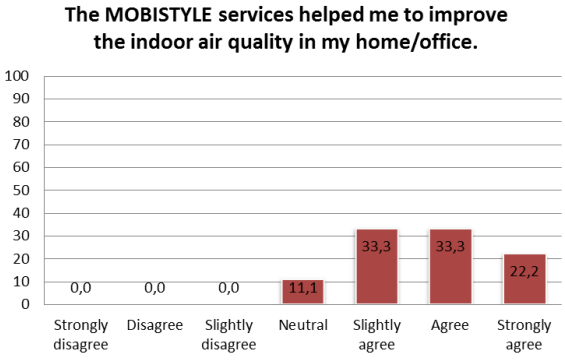
89 % agree



89 % agree or neutral



67 % agree or neutral



100 % agree or neutral

7. Danish demo case: neighbourhood Kildeparken

In the DK and PL case usability testing was performed on a prototype of the Game. This was useful to give input for the further development of the App version of the Game itself. The DK and PL intermediate evaluations of the game were done in 2020 just before the restriction measures were put in place all around Europe due to the COVID-19 situation.

FG findings

The technical stability of the solution is very critical for users and they quickly **lose** confidence in the system, if it does not work for a period or it is difficult to understand **what** was is going on. For a number of apartments, data were lost in periods resulting in the situation that the historical data did not work properly, so it has been difficult for them to evaluate the situation. The 45 minutes delay from **moment** actions are carried out until **change** it is displayed on the App is also too long for many users. They expect much faster response on their actions. Finally, they did not get a warning, if the data-transmission was temporary down and as the app always showed the last data received it led to confusion for many users.

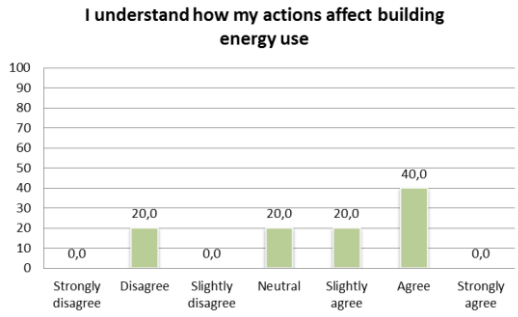
The recommendations given in the app was based on general limits established from standards and experience. However, several users wanted the possibility to define their own limits. For example, they wanted different temperatures in bedrooms and living room and wanted this to be reflected in the feedback in the App. For other the limits/targets and numbers did not mean anything and found them difficult to understand and only related to the color codes given. Probably, a solution with the possibility of different levels of use could improve experience, i.e. a "user-level" without numbers and based on default values and an "expert level", where numbers are given and possibilities to adapt to personal preferences are possible.

The possibility to view the historic data was valued by most users. Some of them established new habits as for example looking at the app in the evening to see how the conditions had been during the day and relate this to the activities. Others found the gamification option very useful and was closely following the status compared to their neighbor's.

Questionnaires

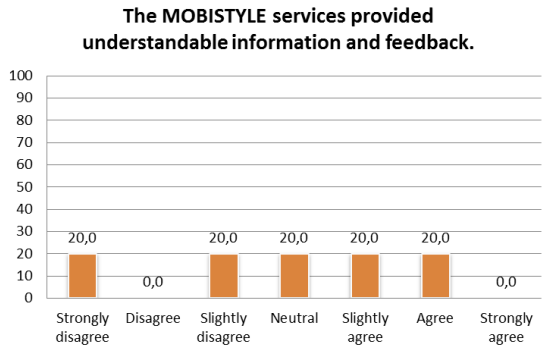
N=5

O1: 90 % of end users understand information (on energy): DK case not achieved

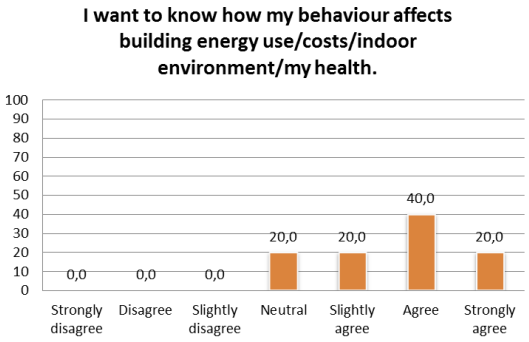


80 % agree or neutral

O2: 75% of end users understand information on IEQ: DK case not achieved

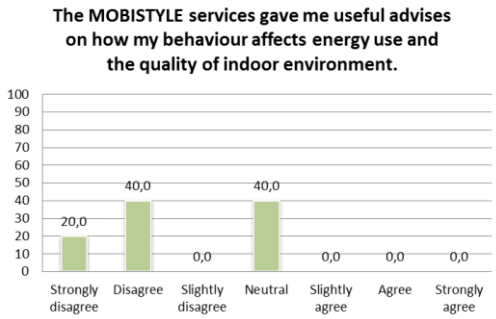


60 % agree or neutral



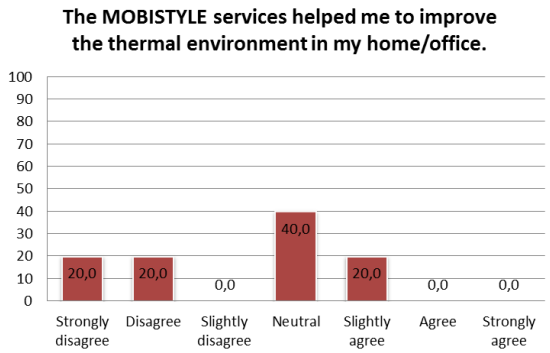
all agree or neutral

O3: 90% of end users find the modular information services usable and attractive and are willing to use the services in future: DK case not achieved

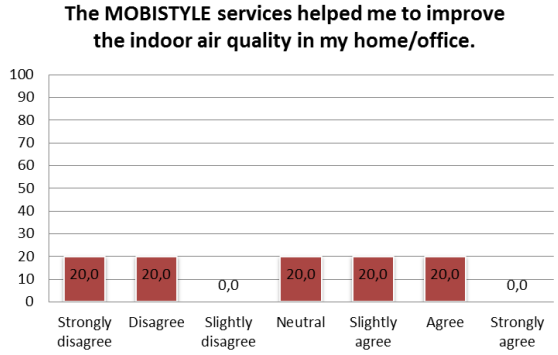


40 % neutral, 60% disagree

O5: 90% of involved end users show structural behavioural changes and embed the tools in daily routines: DK case not achieved



60 % agree or neutral



60 % agree or neutral

8. Italian demo case: a hotel

Focus groups findings

The first focus group with 6 participants (plus 2 researchers) took place on 31st May 2017 via teleconference. In late January 2020 there was a third FG with the hotel staff (after the one held in September 2018 about usability testing of mock-up ICT-tools with staff members and 3 dummy guests). In accordance with the evaluation protocol prepared as part of T6.4, we collected feedback on the usability of the ICT-tools in their latest versions and on the effectiveness of advices. Key finding from usability testing (both in mock-up and latest versions of the tools) are reported as part of D6.4.

Focus group IT demo 23/1-2020

The main target groups in the Italian demo case are guests and hotel staff. The meeting was aimed only at the reception staff (R1, R2), where one of them, covering the managerial tasks on a daily basis, took also the role of hotel manager (R1). The focus group (FG) was carried out in Italian language. 4 researchers (energetics) from PoliTo team (PT) were present at the FG. Various graphical user interfaces (GUIs) were assessed in the FG: the Dashboard (both manager's and receptionists' interface) and the Mobile App (as receptionists' interface). They are assessed both from the usability and content point of view. During the discussion, more attention was paid to the usability of the Dashboard, being the tool that the receptionists are more likely to use during their working hours, both as end-users of the receptions' and of the manager's interface. Feedback about provided information are collected also pointing out to the non-ICT solutions deployed at the hotel, mainly MOBISTYLE stickers. Questionnaires about perception were deployed to support outlining the conclusions about the general view on the MOBISTYLE solutions as seen by the users, namely staff members. Conclusions are enriched by the feedback directly and indirectly collected during the weekly visits at the hotel of PT. Also, an open discussion aimed at trying to give some figures and motivations about the scarce interests that the guests manifested for the project and the ICT-tools in particular.

Accordingly to the objectives, the FG was divided into three parts:

- **Collection of feedback about GUI**: deployment of SUS and discussion
- **Collection of feedback about advices and provided information**: open discussion supported by the game of choosing best and worst advices
- **Questionnaire about perception**: filling of the questionnaire and discussion to assess the effectiveness of MOBISTYLE in changing users' perception

Below, key findings from Italian case and limitations are summarized.

General recommendations on advices

As Occupants

- While asking the receptionists to choose between the advices, PT underlined to think as they are receiving them thought the Dashboard and the Mobile App on an daily basis, when they are occupying the reception room (as it is already the case for some of them). R1 and R2 show very different opinions about the worst advices.
- R1 considers the advices that provide too much information to be the worst; she suggests that it is necessary to be brief using the minimum number of information in order to achieve the goal.
- On the contrary, R2 is interested in improving her knowledge, therefore she expresses her interest in the advices that provide more information. She thinks that she would not pay attention to a suggestion which is giving her a trivial information.
- R1 and R2 agree on the choice of the best advices concerning the electricity consumption and its impacts on costs, because they reflect this knowledge on their own houses.
- Both of them have chosen as best advices those that have long-term health consequences. R1 prefers advices with cause-effect relationship distant in time because it has a greater impact than the ones related to immediate health effects; instead, R2 argues that advices pointing to long-term consequences are in general less trivial, then more informative.
- Advices related to energy field are the choicest among the best advice.
- Advices related to environment and IEQ represent the majority of the worst advices, especially for R1, because they provide too much information.

As Manager

When it was asked to R1 to think of receiving the same advices while using the managers' Dashboard interface, she reported the same comments and needs previously presented. In addition, she agrees that it is interesting to have, through the manager account, the possibility to set new suggestions, for example: "Please remember to unplug the TV when you are not using it!". However, setting them based on recorded variables is not easy for a non-expert. Instead, using the platform to have the possibility to send direct messages to the guests would be very appreciated.

Conclusions of the FG

Based on results from FG, it is interesting to study the changes between the usability test responses provided in this workshop and those gathered during the first one (September 2018). The receptionists still do not have a strong position in saying that they would be willing to use the solutions. However, they show a stronger position in terms of good integration of functionalities, confidence in the use and no need for technical support in the usage. Indeed, they agree on the people's ability to quickly learn how to use the tools. Regarding the feedbacks on tested advices, it is useful to highlight the opposite views of the two receptionists. While R1 considers the advices that provide too much information the worst, suggesting using minimum number of words to achieve the goal, R2 is interested in improving her knowledge about the topic, expressing her interest in advices that supply more information.

In line with customized-demand-based solutions, it is possible that different preferences and needs occur among users of a same space, requiring even more detailed customization of the ICT-tools.

However, lack of time and no integration of the solutions with other services used in the hotel are the issues that are still preventing them from using the solutions more actively.

Outlining FG conclusions (as integrated also by analysis of questionnaires and weekly meeting with the staff members), considering the receptionists as targets, it is possible to affirm that:

- MOBISTYLE ICT-tools are not perceived enough as something which help them to handle their daily tasks, which are the only reason they are spending time in that environment. In their opinion it could work better in an office environment more structured in terms of roles and responsibilities.
- While checking the Dashboard under Polito supervision they were interested in understanding if the way they perceived the environment was motivated by indoor parameters trends, but they think they do not have munch control on the room. So, displayed information seem relevant.
- In their managerial role, they would probably be considering using MOBISTYLE in future if it was integrated with other services (e.g. direct communication on check-in, request for reviews, etc.) that could make their job faster.
- In terms of perception of health impact of indoor environment, they both significantly changed their mind, agreeing in saying that “indoor environment has a negative impact on my health”.
- Despite the quantitative results achieve in the demo case, it seems they were interested in understanding how much energy costs, to reproduce more responsible behaviour also in their houses. They also learnt something about the use of devices (e.g. to recognize the standby mode).
- Even if they did not use MOBISTYLE services as much as expected, they commented that the project made them pay attention to some factors (e.g. dry air) and small actions (unplug the laptop cable) that otherwise they would have not care about, making them become an habits on a longer term.
- Despite the quantitative results achieve in the demo case, they do not think to have already developed new habits. Indeed, in the hotel, convenience in the use of devices is prioritized over energy-friendliness.

Main limitation in evaluating MOBISTYLE strategy in the Italian demo case was that for all the project duration guests did not expressed interests for the project. Indeed, only one guest completed the registration to the system to use the ICT-tools. Some of the informative flyers were taken by curious guests, but none asked information to the staff. They also refused to be engaged in the feedback loop that MOBISTYLE was supposed to build with the final users. This was proved also by the fact that only 4 initial questionnaires out of 13 deployed were returned with full consent for data treatment by guests, and only 1 of these guests returned also the final questionnaire, allowing to assess what is his perception on MOBISTYLE.

From the only filled questionnaire and thanks to the feedback collected from the staff members, it is possible to draft some conclusions about MOBISTYLE goals as seen by the guests.

- A guest travelling for work expressed a strong opinion against the project saying that he does not have time.
- Some usual guests recognize the importance of the message brought by MOBISTYLE but they do not want to be bothered while they are staying at the hotel and they do not want to have interruption in the way they use the room (e.g. keeping the smart plug where it is).
- A guest travelling for work expressed the opinion that the hotel environment is not appropriate for such a project because it requires more time than the mean duration of a stay.
- A guest travelling for leisure was willing to try MOBISTYLE as a way to have more control on the room because he was not happy with the temperature. Unfortunately, as most of the leisure stay, it was too short to catch his collaboration in the project.
- In general guests do not use to check their mailbox while travelling (action needed to complete the access to the ICT-tools).
- Having another App on mobile phone is not interesting.
- Despite provided information are useful, the guest who filled the questionnaire thinks that MOBISTYLE is exploring a path which requires long time to have an impact. Contents and graphics should be updated accordingly.

From the receptionists' point of view, when targeting guests, MOBISTYLE strategy have limitation in different reasons.

- There are some barriers in the engagement phase on the use of ICT-tools that would be easier to overcome if they had a different kind of services infrastructure encouraging the use of personal devices (e.g. access to hotel wi-fi with landing page where also a link to online services as MOBISTYLE could be integrated).
- Guests in general are not willing to have too much information, neither at the reception desk or in the rooms. They already have some difficulties in sorting out the needed actions to handle the booking.
- Most of the guests are really demanding, and hotel staff is not open to talk to them about MOBISTYLE.
- Elderly people would have more time to pay attention to MOBISTYLE, but they are automatically excluded as target group for the deployment of ICT-tools because some of them do not have smartphones.

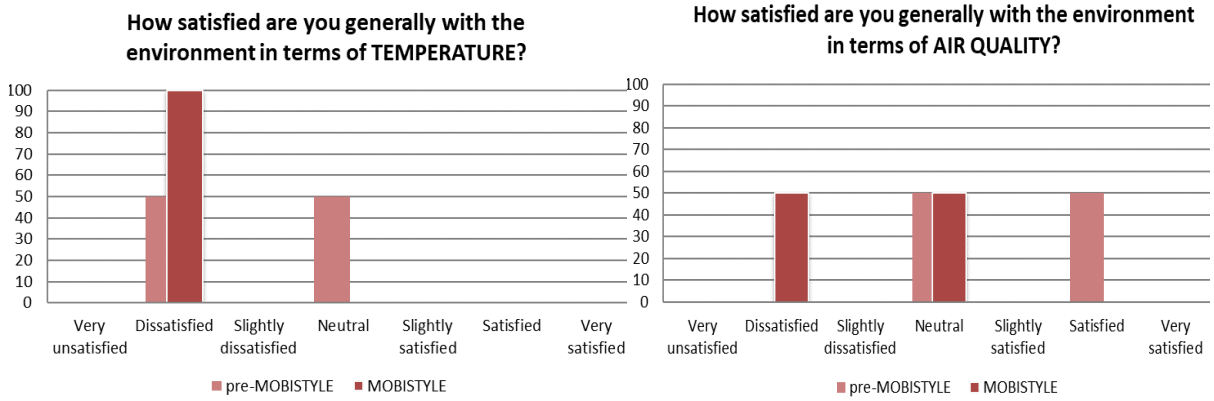
Questionnaires

During the last session of the focus group in IT demo case (23/01-2020) addressed to staff members, questionnaires were submitted to them. The aim was to assess users' level of satisfaction with the indoor environment and their perception about how it influences their health, understanding what they think about MOBISTYLE services helping them in improving their satisfaction, awareness, knowledge and habits. To do so questionnaires about perception were deployed to receptionists (previously translated in Italian). Three topics are covered:

- Comfort perception
- Understanding of energy consumptions
- Understanding impacts on health

Results of the questionnaires are reported in the following graphs and compared to the answers given by the same users at the beginning of MOBISTYLE solutions deployment (pre-MOBISTYLE) to observe if the users changed their perception. Questions related to MOBISTYLE services helped to assess what users' opinion about the project is. Since their usage was not as active as expected (mainly because of time-constraints at work), PT encouraged them to think of having the possibility to keep using them and commenting on their usefulness. Results are commented and integrated with opinions which the receptionists gave during the weekly meeting which happened over the duration of the project.

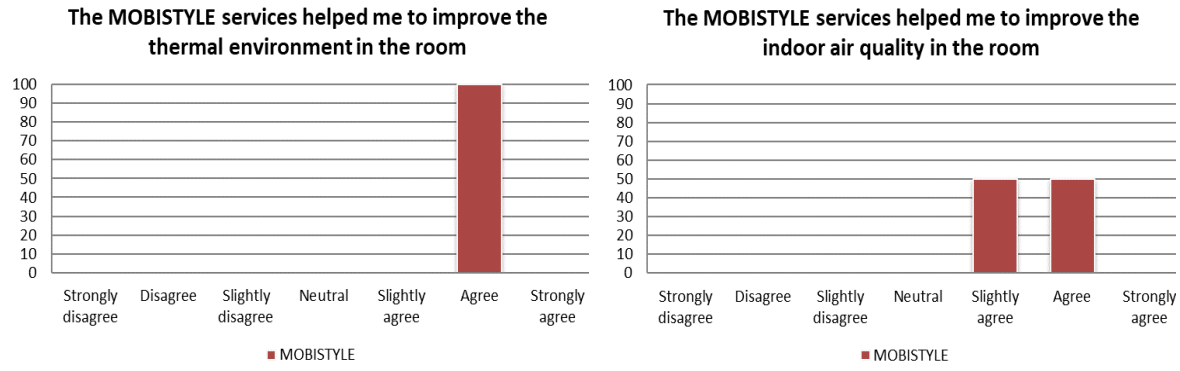
Comfort perception



Perception about temperature: percentage share of answers left and Perception about Air quality: percentage share of answers right

Before MOBISTYLE solution deployment, one receptionist was dissatisfied with the indoor temperature, and the other one neutral. They are both dissatisfied after MOBISTYLE deployment (maybe because they are more aware of it), but they are arguing that this is due to something which is out of their control. Indeed, the external door is opening often and automatically because of the arrival of guests, and this bring a non-comfort perception in wintertime (when the questionnaires were deployed).

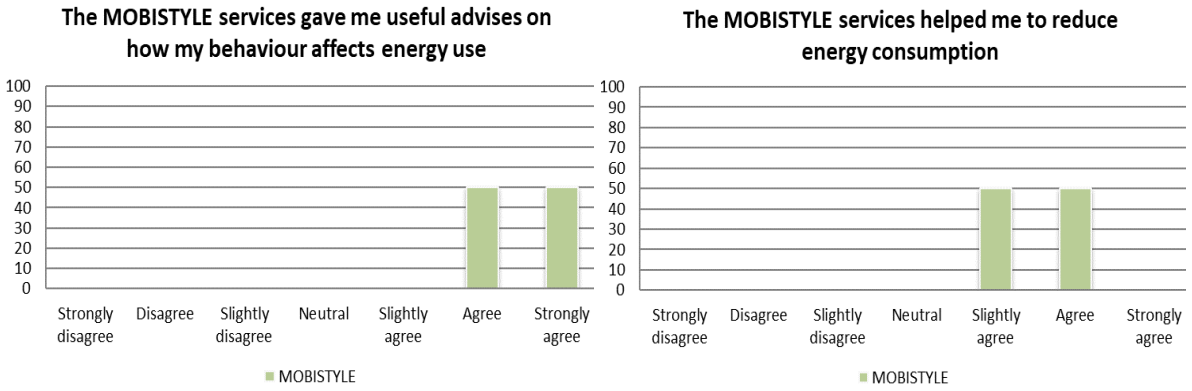
50% of the staff members remains neutral about the perceived quality of indoor air, while the other 50% strongly changes her opinion; she is arguing that she learnt to understand and notice how dry the air can became when the heating system is on.



Opinion about MOBITYLE helping to improve thermal environment: percentage share of answers left and Opinion about MOBITYLE helping to improve air quality: percentage share of answers right

In figures above it is possible to observe that receptionists agree or slightly agree in affirming that MOBISTYLE can help them improving the indoor environment in terms of temperature and air quality, although they keep thinking that a physical intervention to improve temperature regulation is needed, going beyond MOBISTYLE scope. However, feedbacks from MOBISTYLE ICT-tools can play as reminder to keep proper indoor conditions.

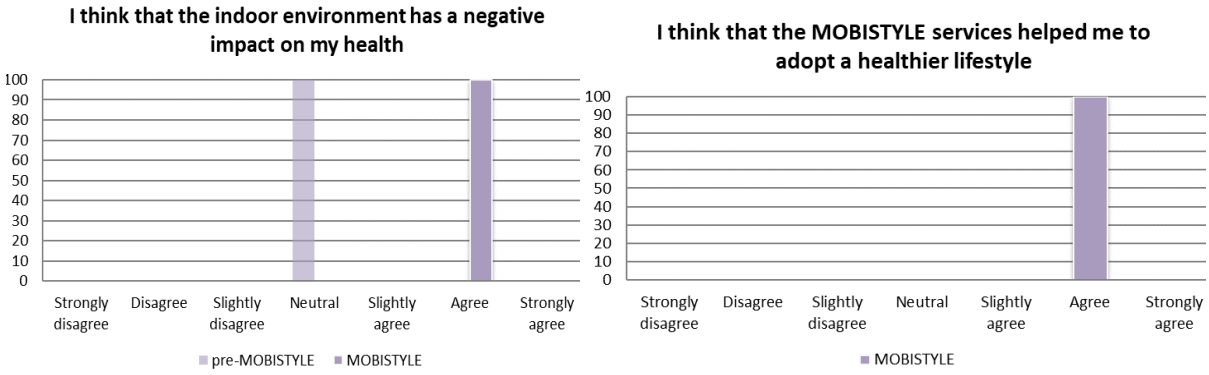
Understanding of energy consumptions



Opinion about MOBITYLE helping to improve awareness on how behaviour affects energy consumptions: percentage share of answers left and Opinion about MOBITYLE helping to reduce energy consumptions: percentage share of answers right

In figures above it is possible to observe that receptionists agree in affirming that MOBISTYLE helps them to reduced consumptions and to be aware of the impact of their behaviour on them. It seems they are interested in understanding how much energy is consumed (especially in relation to costs), to reproduce more responsible behaviour also in their houses thanks to new knowledge. For example, they did not have a clear idea about what the standby is (they thought that the red light of rooms TVs means the TVs were completely switched off) and they learnt that leaving the cable of the laptop plugged can cause consumptions. They also learnt that their printer is consuming a lot of energy during the night. However, being in an office space, they keep prioritizing convenience in the way they use devices (e.g. they do not always want to switch off the printer because the switching on would take too long in the morning).

Understanding impacts on health



Perception about health impact: percentage share of answers left and Opinion about MOBITYLE helping to adopt healthier lifestyle: percentage share of answers right

It is particularly interesting to see that 100% of the staff members had a neutral position about thinking that the indoor environment has a negative impact on health. They both significantly changed their mind, agreeing in saying that "indoor environment has a negative impact on my health". One of the two staff members comments that she learnt that there is not correspondence between what she was perceiving as a comfortable indoor environment and what it is good for her health.

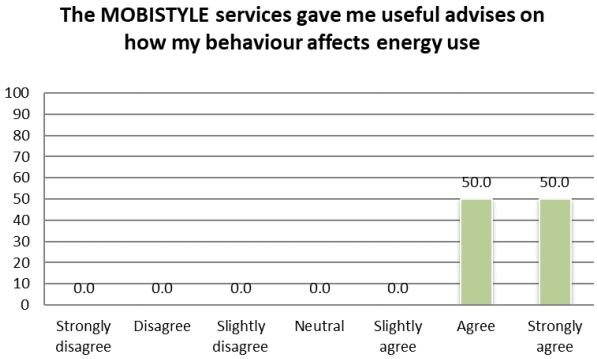
Both the receptionists agree in saying that MOBISTYLE can help in adopting a healthier lifestyle (e.g. taking the elevator less often). Although they did not use MOBISTYLE services as active as was expected, it is interesting to notice that they are commenting that the project stressed on some factors and small actions that otherwise they would have not thought about, making them become a habits on a longer term.

Thanks to questionnaires deployment, achievement in regard to O3 and O5 for staff member were assessed.

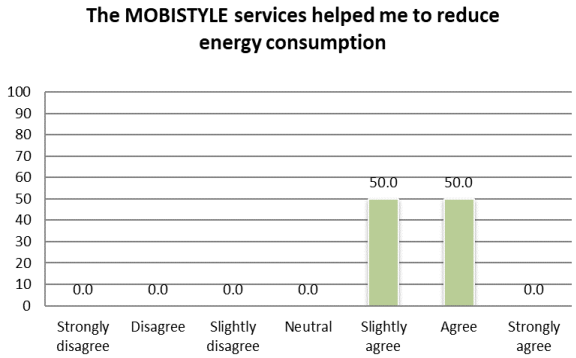
As defined before (section "**Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.**"), some specific context (as hotels) requires to deploy a short version of questionnaire to keep users interested. Results from the IT shortened questionnaire are presented below in respect to achieving MOBITYLE objectives.

N=2

O3: 90% of end users find the modular information services usable and attractive and are willing to use the services in future: IT case achieved (in relation to staff members)

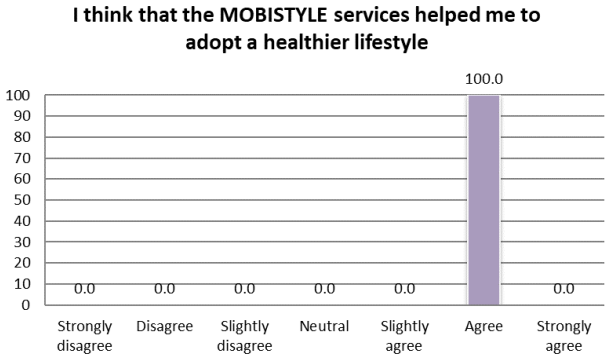


100 % agree or strongly agree

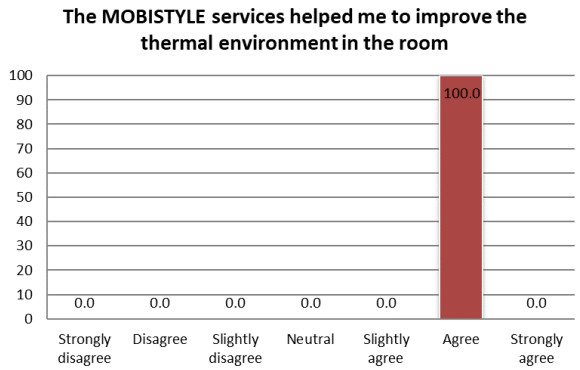


100 % agree or slightly agree

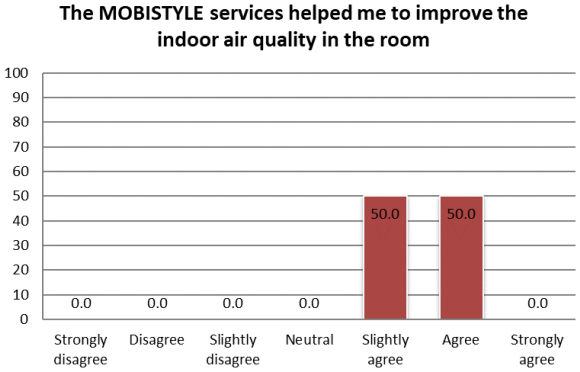
O5: 90% of involved end users show structural behavioural changes and embed the tools in daily routines: IT case achieved (in relation to staff members)



100 % agree or strongly agree



100 % agree



100 % agree or slightly agree

Although objectives were achieved, it is important to keep in mind that they are based on questionnaires deployed with staff members, to whom the focus group was addressed. Only 4 initial questionnaires out of 13 deployed were returned with full consent for data treatment by guests, and only 1 of these guests returned also the final questionnaire, allowing to assess what is his perception on MOBISTYLE. Qualitative feedback collected were discussed as part of conclusions from FG.

9. Dutch demo case

At Brightlands, MOBISTYLE awareness campaigns and information feedback is provided for employees to further increase people's perception and acceptance with dynamic indoor conditions. The first focus groups were organized to discuss the first version (prototype) of the solution and see how to improve the solution. The evaluation questionnaire and another focus groups was done to see the intermediate evaluation. Focus group to discuss what could be the relevant features (12.10.2018, Qeske), Focus group on first version of the solution (24.6.2019, Brightlands) & Intermediate Usability testing of the Office App (28.10.2019, Brightlands).

Focus groups at Qeske

The first focus group with 8 participants (plus 1 researcher) took place on 12th October 2018 at the Qeske location at the participants everyday workspace. This was not yet dedicated to the setup of the awareness campaigns but to map an overall understanding of the building occupant's satisfaction with the stable and dynamic conditions. These results are reported in D6.2 (results of three different questionnaires for evaluation of the perception of the thermal environment). The Qeske studies confirmed the acceptability of the building occupants with the dynamic indoor climate. Furthermore, the VR video proved to be a useful tool to explain the dynamic indoor conditions possibilities to the different occupants in an easy to use and attractive way.

Focus group at Brightlands

The first focus groups at Brightlands were organized to get feedback on the solution design and features proposed. This focus groups outcomes are reported in D4.3 as they shaped the development of the ICT tools.

Focus group at Brightlands

From 1 Sep to 27 Oct 2019 (two months) the first version of the application was available at the entrance of the different meeting rooms. This was done to evaluate the usefulness and attractiveness of the tool where the application informed room occupants about the current status of the room (CO_2, relative humidity, temperature). This was done to see whether the application is being used and what are users first impressions. Furthermore, it was detected if there is any bug or error in the application.

On 28 Oct, 17 employees of Huygen gathered during the lunch meeting (12.00-13.30) to facilitate an overall discussion around the experience with the Office App application that was installed in several meeting rooms to inform office employees about the room indoor conditions. The researcher explained the MOBISTYLE purpose and scope of the Dutch case study. Overall, the occupants were enthusiastic about the new gadget. During this session, the MOBISTYLE scope and the Dutch case MOBISTYLE objectives were introduced to them in depth.

They were also asked to give some overall impressions about the applications. General recommendations on MOBISTYLE Office App were:

- ''*After a while, the tips started repeating itself*.'' – Recommendation: Add more tips.
- *''It is a useful to get some understanding in the long-term effect of these conditions. If I talk with a client about our experiments, this is their first question.*'' – Recommendation: Provide some weekly/monthly reports.

- *''It would be nice to see whether the room is booked or not in the application*.'' – Recommendation: Add office agenda integration.
- ''I *expected to get some information about the comparison of energy costs when having static and dynamic conditions*.'' – Recommendation: Provide some weekly/monthly reports also with practical economic results.
- *''It was funny to get a recommendation to do a meeting outdoors when it was raining*.'' – Recommendation: Combine outdoor weather data into the application.
- *''I was mostly cold in the morning so I always clicked a sad face, but nothing changed. I did not understand if something should change?*'' – Recommendation: Beside ICT solution, provide also some interactive lunch sessions where you explain the application to a broader community (in simple to understand terminology – e.g. also for non-engineering colleagues).

This focus groups were organized before any MOBISTYLE real interventions (dynamic conditions combined with feedback provision) was introduced, to find few volunteers who will participate daily for the coming 4 weeks for the MOBISTYLE Experiments (see D6.2 – Third case: Brightlands). 7 volunteers were identified to whom it was explained the intention of the experiments. They were explained the coming 1-month of experiments where the following schedule was introduced:

- 4.11.-8.11.2019: Static conditions
- 11.11.-15.11.2019: Dynamic conditions
- 18.11-22.11.2019: Static conditions + MOBISTYLE Office App
- 25.11-29.11.2019: Dynamic conditions + MOBISTYLE Office App

The results of these studies are available in D6.2. In this D6.3 are presented only parts related to the MOBISTYLE feedback campaigns & MOBISTYLE Office App solution.

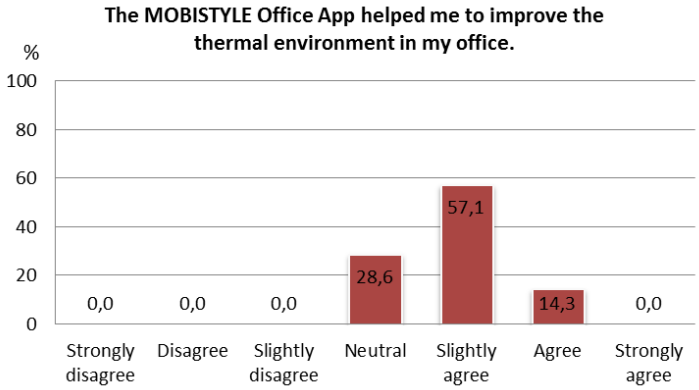
Final evaluation at Brightlands, 29.11.2019

At the end of the 4-week experiment, the 7 subjects were given beside the thermal evaluation questionnaires also a questionnaire to assess their satisfaction with the app and their overall acceptance and satisfaction with the app that they were having at hand for the last two weeks. Besides the results of the different questionnaires for evaluation of the perception of thermal acceptance, comfort, sensation and alertness also a questionnaire to assess the impact of the ICT tool & feedback campaigns were given. It was assessed whether the objective of the application to make people aware of the dynamic conditions and stimulate these was achieved.

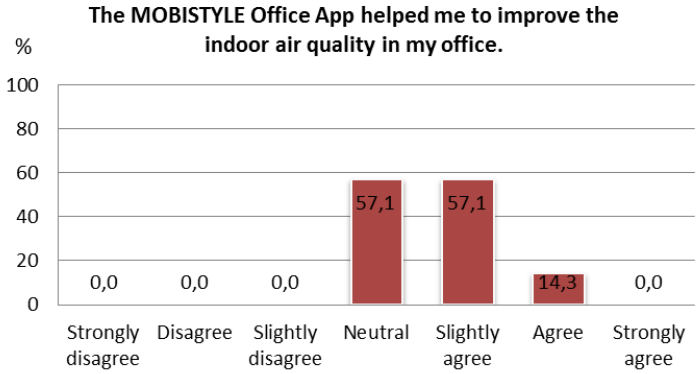
The participants were asked to assess how much they are agreeing with the following statements where the scale below was used to evaluate their responses.

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree

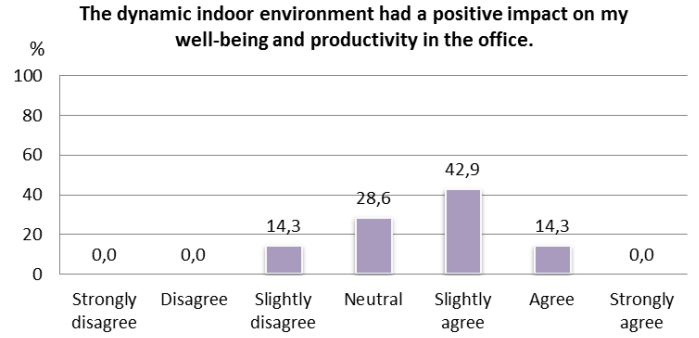
1. The MOBISTYLE Office App helped me to improve the thermal environment in my office.



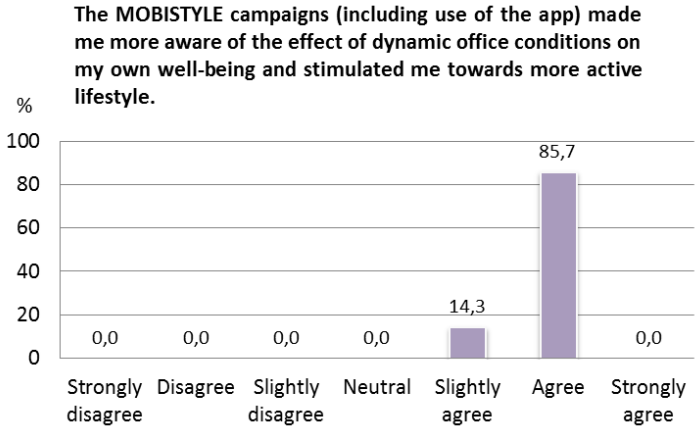
2. The MOBISTYLE Office App helped me to improve the indoor air quality in my office.



3. The dynamic indoor environment had a positive impact on my well-being and productivity in the office.



4. The MOBISTYLE campaigns (including use of the app) made me more aware of the effect of dynamic office conditions on my own well-being and stimulated me towards more active lifestyle.



Conclusions based on the Brightlands focus groups

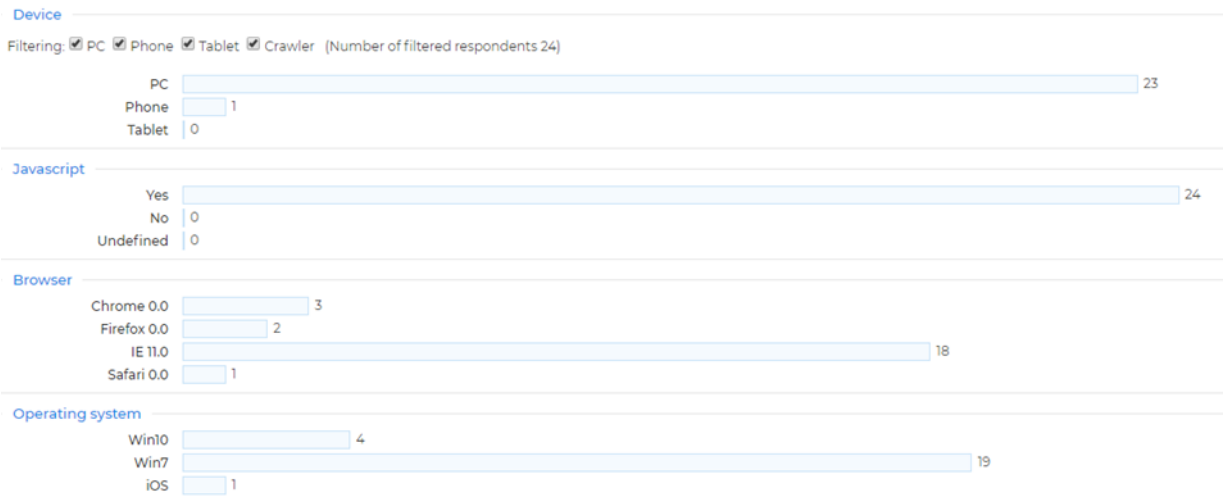
Following the outcomes of the two focus groups it was clear that the Brightlands occupants engaged in the study were satisfied and happy with the new dynamic conditions. Overall, they were happy with what the application had to offer, nevertheless, they hoped for some more in-depth report based on long-term analysis to understand dynamic conditions long-term effect. The short experiment showed there is a potential for such customized Office App solution when introducing the dynamic conditions. Nevertheless, it should be noted that this experiment was done on a small scale and in limited time. It was difficult to ensure that the same occupants were sitting at the same room for a month (9.00-17.00) as the work of the project engineers is dynamic (e.g. external business meetings, visits of the construction sites). Furthermore, for the Dutch case the 7 volunteers had to fill in quite some questionnaires (see D6.2) and were wearing wearables (iButtons, FitBits). Therefore, the study was not a longer than a month in order to not interfere and disturb employees daily work too much or for too long.

To conclude, there is a great potential for combination of the MOBISTYLE Office App and dynamic conditions continuation at the Brightlands Huygen Office as also to replicate it to the other office spaces at the campus.

Final SUS testing – online

Experiments with the variable indoor conditions were concluded in 2019 as reported in D6.2. The Office App application was still available during the first months of spring 2020, however, only in combination with stable conditions. The final focus groups were planned to be done 23 Mar 2020. However, COVID-19 restrictions were put in place in the Netherlands as of 15 Mar 2020 and therefore the physical focus groups have been postponed to a new date: 24 Apr 2020. Nevertheless, work from home is still an active norm at the time of writing this report (June 2020), therefore for the Dutch case it was decided to suspend all the final MOBISTYLE office physical activities including the final physical focus groups. For this reason, SUS testing introduced in D4.3 was given online (via https://www.1ka.si/d/en). It should be noted at the time of filling the questionnaire, the employees have not been in the office for 2.5 months. The long version of the survey has been circulated on Monday 01.06.2020, in an email exchange with 30 Huygen employees. The response rate was of 80%, with 24 valid responses collected. 21 employees replied to the survey during the same day, while 3 responded completed the survey in the coming two days.

Almost all participants completed the survey through the desktop version (n=23). The on-line survey has been successful completed by using Internet Explorer (n=18), Chrome (n=3), as well as Firefox (n=2) and Safari (n=1) in the mobile application. Window 7 and Window 10 both supported the on-line survey, as well as the iOS operating system.



Participant	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	SUS Score
p1	3	2	5	1	3	2	5	4	4	2	**72.5**
p2	5	1	5	1	5	1	5	1	5	1	**100.0**
p3	5	1	5	1	3	1	5	1	4	2	**90.0**
p4	4	2	4	1	3	3	4	1	4	1	**77.5**
p5	5	1	5	2	5	2	5	1	5	2	**92.5**
p6	5	1	5	2	2	3	5	2	4	1	**80.0**
p7	4	3	4	2	3	5	4	4	3	3	**52.5**
p8	5	1	5	2	5	3	5	1	5	1	**92.5**
p9	5	2	3	1	3	3	4	2	3	2	**70.0**
p10	5	3	3	2	4	2	3	3	2	2	**62.5**
p11	4	4	4	1	3	3	4	1	3	3	**65.0**
p12	4	3	4	2	4	4	4	4	4	2	**62.5**
p13	5	2	5	1	4	3	5	1	5	1	**90.0**
p14	5	1	4	2	4	3	5	1	5	1	**87.5**
p15	3	2	4	3	3	4	2	4	2	4	**42.5**
p16	5	2	3	1	3	3	4	2	3	2	**70.0**
p17	5	1	4	1	5	1	4	1	5	1	**95.0**
p18	5	2	5	1	5	1	5	1	4	4	**87.5**
p19	5	1	5	3	4	3	4	1	4	1	**82.5**
p20	5	3	5	2	3	4	4	1	4	2	**72.5**
p21	3	3	4	1	4	1	4	1	5	1	**82.5**
p22	5	1	5	3	4	3	4	1	4	1	**82.5**
p23	3	1	4	1	4	2	5	2	5	1	**85.0**
p24	5	2	4	1	3	3	4	2	3	2	**72.5**
Average SUS score											**77.8**

The overall Average SUS Score was 77.8% which corresponds to a result of **Good**.

10.Cost-benefit analysis

The evaluation strategy for MOBISTYLE included the adoption of the so-called Cost-Benefit Analysis (CBA). The specificity of the methodology consists in the possibility to assess the economic advantage or disadvantage of a project, taking into account not only direct market impacts (costs or benefits strictly monetary), but also non-market ones (not strictly monetary), both direct (i.e. affecting the main beneficiary of the project) and external (i.e. affecting the whole society).

As described in detail in D3.3 [1], the main steps composing the CBA methodology are (Figure 1):

1 - Objectives and context definition
2 - Time horizon setting
3 - Future costs and benefits definition and monetization
4 - Discount rate setting
5 - Economic performance evaluation
6 - Sensitivity analyses

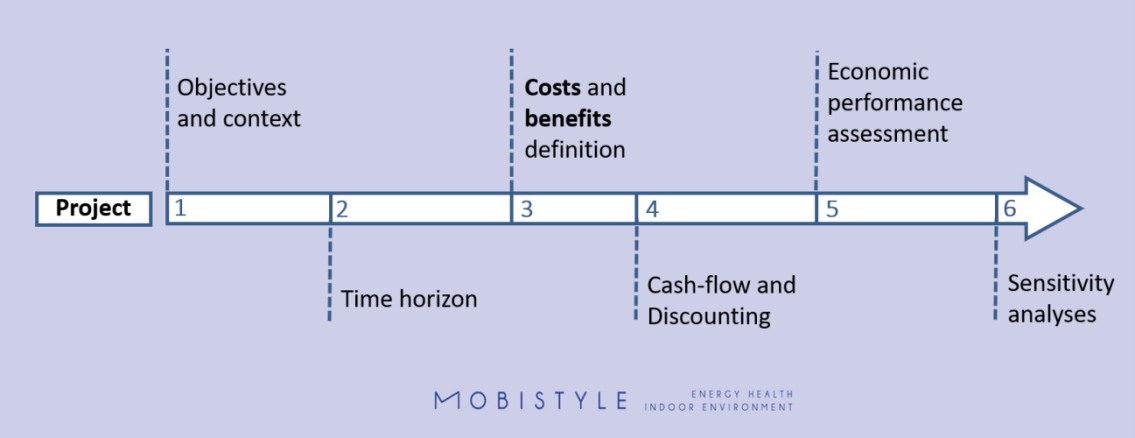


Figure 1 – Cost-Benefit Analysis methodological steps. Source: [1] (references in the end of this chapter)

Since the application of a CBA is strictly dependent on the scope and on the objectives, the methodology for MOBISTYLE project was adjusted to each demo case. Adjusted methodology and results for each case study are described in the following. General conclusions are provided in the end.

Methodology

The methodology was adjusted to the MOBISTYLE demo cases as shown below.

1 - Objective and context definition: objective, context and beneficiaries of the project under analysis were identified per each demo case.

Objective

The project under evaluation involved the provision of ICT-tools with the aim to drive a behavioural chance in buildings occupants according to a specific behavioural action plan per each demo case. Thus, the aim of this evaluation was to assess the effectiveness of the deployment of MOBISTYLE ICT-solutions in producing impacts that can be translated in economic value in terms of benefits, not only for the occupants/owners/employer of the buildings (the so-called direct impacts), but also for the society (the so-called externalities).

Context

The context identification consists in the description of two scenarios. One called “with-the-project scenario”, in which the MOBISTYLE ICT-tools were provided to the occupants of the different demo cases; the other one called “without-the-project scenario”. Indeed, as defined in D3.3, the method adopts an incremental approach; it means that the with-the-project scenario had to be assessed upon a counterfactual scenario (“without-the-project scenario”) referred to the conditions before ICT-tools provision. The CBA considers the difference between the cash flow in the with-the-project and the without-the-project scenario. In particular, the focus is on the operational phase of the project, so no-investment cost is taken into account for ICT-solutions production and for the installation of a new monitoring system or for the integration with new sensors of the pre-existing monitoring system in the different demo cases.

Four demo cases were involved in the evaluation:

- Residential building complex Kildeparken, Aalborg, Denmark (DK)
- Smart City Wroclaw, Poland (PL)
- Faculty buildings of University of Ljubljana, Slovenia (SLO)
- Hotel L'Orologio Living Apartment, Turin, Italy (IT)

It’s worth noting that in Italian demo case only the reception space, where staff members used the HLX Dashboard, was involved in the CBA assessment. This is because, over the duration of the project, only one guest downloaded and used the ICT-tools. Being the effectiveness in ICT-tools deployment the objective of the evaluation, it seemed reasonable to ignore the guests’ use of the dashboard in the CBA.

The Dutch demo case was not involved in the assessment because there are no models in literature that permit to monetize the monitored parameters.

For each demo case, the description of the scenarios for the analyses are summarized in the following table.

Table 1: Scenarios description for each demo case

	without-the-project scenario Counterfactual	*with-the-project scenario MOBISTYLE*
SLO	8 offices. Monitoring ongoing.	8 offices. Monitoring ongoing. Dashboard distributed to users.
DK	17 households. Monitoring ongoing.	17 households. Monitoring ongoing. Game distributed to users.
PL	150 households. Monitoring ongoing.	150 households. Monitoring ongoing. Game distributed to users.
IT	Hotel reception space. Monitoring ongoing.	Hotel reception space. Monitoring ongoing. Dashboard distributed to users.

The parameters involved in the monitoring (gathered both thanks to pre-existing and new monitoring systems), the different demo cases and the timing of ICT-tools deployment are described in D2.5, D6.1 and D6.2, respectively.

The context definition deals also with the collection of the context-dependent data (e.g. energy prices, emissions factors, current market values, etc.) that were collected in accordance with the computational needs for each demo case. They are reported with results per each demo case (Table 7, Table 11, Table 15, Table 21).

Beneficiaries

The identification of the beneficiaries for the different demo cases fixed the perspectives of the analysis, clarifying the viewpoint of the assessment depending on the final use of the buildings. Two perspectives for the analysis were identified:

- I layer: beneficiaries are employers/occupants/owners of the buildings. Impacts to be assessed were selected taking into account their perspective and, in particular, who, in a real market application, would burden the investment costs of MOBISTYLE ICT-solutions.
- II layer: beneficiary is the whole society. This layer included impacts of I layer, to which externalities were added.

Beneficiaries for the two layers of the analyses are summarized in the following table for each demo case.

Table 2: Description of beneficiaries for each demo case according to the two layers of the analysis.

		I layer	*II layer*
Residential	DK	Occupants. They benefit from possible direct impacts of MOBISTYLE (e.g. cheaper energy bills, …).	Whole society. It benefits from external impacts (e.g. smaller GHG and PM emissions, …).
	PL	Occupants. They benefit from possible direct impacts of MOBISTYLE (e.g. cheaper energy bills, better IEQ, …).	Whole society. It benefits from external impacts (e.g. smaller GHG and PM emissions, …).
Non-reside	SLO	Employer. He benefits from possible direct impacts of MOBISTYLE (e.g. more productive employees, …).	Whole society. It benefits from external impacts (e.g. less health care costs, …).

	IT	Employer. He benefits from possible direct impacts of MOBISTYLE (e.g. more productive employees, cheaper energy bills, …).	Whole society. It benefits from external impacts (e.g. smaller GHG and PM emissions, less health care costs, …).

2 - Time horizon setting

The timespan of the analysis, called "time horizon", was set proportionally to the project economically useful life. Moreover, given the incremental approach of the CBA, it's fundamental to assure that the overall timespan could be compared with a period equally long and homogeneous in terms of boundary conditions, when monitoring was running but ICT-tools were not distributed. Consequently, a different timespan was chosen per each demo case; counterfactual scenarios were defined as same months of the previous year, as reported in Table 3.

Table 3: Timespan for each demo case

	without-the-project scenario Counterfactual	*with-the-project scenario MOBISTYLE*
DK	Dec2018-Feb2019*	Dec2019-Feb2020*
PL	Feb2019-Mar2019*	Feb2020-Mar2020*
SLO	Feb2018-Dec2018	Feb2019-Dec2019
IT	Nov2018-Feb2019*	Nov2019-Feb2020*

* end date was adjusted because of Covid-19 situation.

Due to the COVID-19 situation, with-the-project scenarios (and without-the-project scenario accordingly) for IT, PL and DK demo cases (the ones were monitoring period with ICT-tools deployment was still running when the virus spread in Europe) were shortened, ending in February or March 2020. Performing the analyses on a situation, which showed atypical use of building due to the lockdown, was judged as not meaningful, since results would not be relevant for future exploitation of MOBISTYLE solutions.

3 - Identification of the relevant impacts

Once objective, context, beneficiaries and timespan were selected, impacts were identified according to the different two layers of the analysis. Direct market (strictly monetary) and non-market (not strictly monetary) impacts were included as part of layer I, representing occupants/employer viewpoint. Externalities were identified as part of II layer of the evaluation to capture the society viewpoint.

Impacts were identified based on monitored parameters and specificities of each demo case. Beside to the relevant impacts, specific physical indicators and appraisal methods were selected for their quantification and monetization, as summarized in Table 4.

Table 4: Impacts of the deployment of MOBISTYLE ICT-tools in each demo case

Impact	Context	Aim	Beneficiaries		Evaluation		
	MOBITYLE demo case		Owner-occupant	Society	Physical indicator	Quantification	Appraisal method
Energy Consumption	DK, PL, IT	Min	x		Energy consumption	kWh	Energy price (with taxes)
Water consumption	DK	Min	x		Water consumption	m^3	Water price (with taxes)
Productivity	SLO, IT	Max	x		Indoor air temperature	%	Labour cost
IEQ improvement	PL	Max	x		Self-reported IEQ	Qualitative (in field surveys)	Hedonic price
GHG emissions	DK, PL, IT	Min	x	x	Energy consumption	kWh * emission coeff.	GHG cost
PM emissions	DK, PL, IT	Min	x	x	Energy consumption	kWh * emission coeff.	PM cost
Headache cases	SLO, IT	Min	x	x	Indoor air temperature	Degree hours above 23°C	Cost of illness (direct + indirect)

In Table 4, "aim" column specifies if each impact must be minimized (being lower in with-the-project than in counterfactual scenario) or maximized (being higher in with-the-project than in counterfactual scenario) to be considered as benefit brought by MOBISTYLE solutions deployment.

Concerning impacts, monetized **energy** and **water consumptions** accounted for market impacts on employer/owner/occupants, representing costs for fuels/electricity and water provision. **Productivity** accounted for a gain or loss in workers' efficiency. It is a non-market impact; it was monetized by multiplying percentage productivity times the labour cost (which, being the amount of money that an employer is supposed to pay per each employee, represents the economic value of employees' efficiency). **Indoor Environmental Quality (IEQ) improvement** was the only impact included in the analysis which was assessed not based on measurements but on self-reporting from users. It accounted for users' perception about MOBISTYLE ICT-tools success in improving thermal comfort and indoor air quality in their houses. IEQ improvement is a non-market impact; it was monetized by assessing people willingness-to-pay (WTP) for IEQ improvement in buildings. WTP was assessed as a marginal cost in overall selling and rental prices of houses were IEQ improvement was self-reported, estimated as a percentage of their current prices (percentage value was gathered from literature). **Green House Gas (GHG)** and **Particulate Matter (PM) emissions**, as well as **headache cases**, are

external impacts, meaning that their impacts involve as beneficiary the whole society. Indeed, they were accounting for costs (or benefits, depending if they were increased or reduced by the project) burdening on the whole society in terms of monetary value of environmental damage caused by CO_2 (as estimated by the European commission [5]), value of reducing harmful effect of air pollution in terms PM emissions (as estimated by Copenhagen Economics [6]) and healthcare costs of headaches (as estimated by Linde et al. (2012) [10], including direct and indirect costs as absenteeism from work, diagnostic investigations, hospitalization, outpatient health care, prophylactic medications and acute medications, paid out-of-pocket from people but also by government or insurance companies).

Further methodological insights about techniques for the assessment of each impact are provided in a separate section below ("Methodological insight on impacts quantification and monetization"). The described methods were used to quantify and monetize the identified impacts month by month in both without-the-project and with-the-project scenarios.

4 - Cash flow and discounting

Once impacts were computed both in with-the-project and without-the-project scenarios month by month (monthly timestep), they were subtracted and, depending on the sign of their differences, they were defined as costs (negative cash flows) or benefits (positive cash flows). The monetary costs (with sign "-") and benefits (with sign "+") distributed over the timespan of the analysis were summed to compute the monthly cash flows, which were then discounted. Before doing that, the annual discount rate (assumed equal to 3%, in accordance with the benchmark value recommended by the European Commission) was translated in a monthly value i according to the following formula.

$$i = (1 + r)^{\frac{1}{12}} - 1 \qquad (1)$$

Where:

r: annual discounting rate, assumed equal to 3%

5 - Economic evaluation

Starting from the discounted monthly cash flows, Net Present Value (NPV) was finally computed according to equation (2).

$$NPV = \sum_{t=1}^{n} a_t S_t = \frac{S_1}{(1+i)^1} + \frac{S_2}{(1+i)^2} + \cdots + \frac{S_n}{(1+i)^n} \qquad (2)$$

Where:

$a_t = \frac{1}{(1+i)^t}$ represents the discounting formula

S_t is the balance of cash flows at time t

i is the monthly discount rate

n is the number of analysed months

If NPV is major than zero, the benefits (defined as positive impacts of MOBISTYLE ICT-tools deployment) overcome the relative costs.

The whole methodology is depicted in Figure .

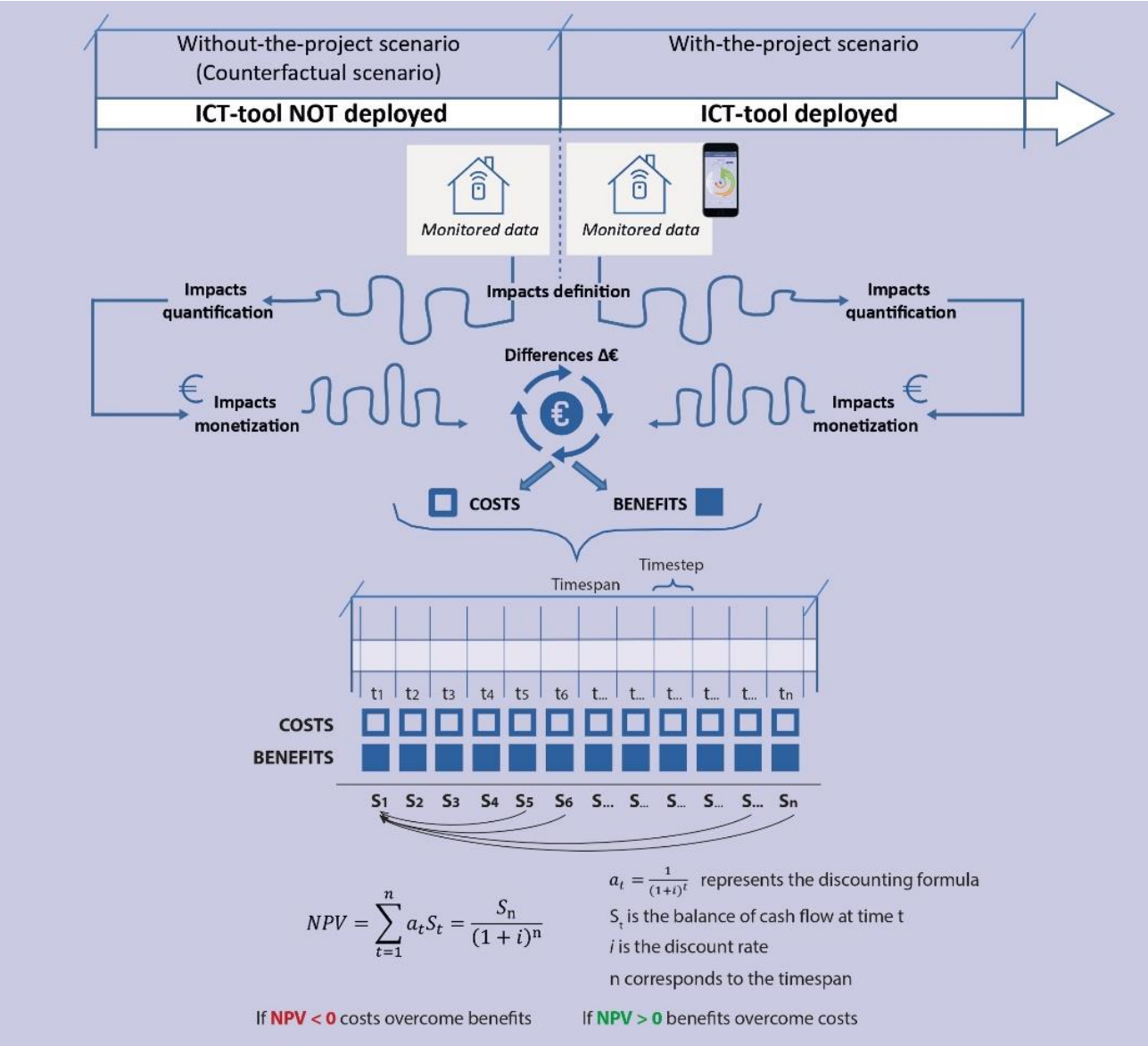


Figure 2 – Application of CBA to MOBISTYLE for each demo case

Methodological insight on impacts quantification and monetization

This section represents an insight on the quantification and appraisal methods that were applied to compute monthly impacts in without-the-project and with-the-project scenarios for each demo case. In the following, the data from demo case holders are highlighted in **red** and the data from literature or coming from previous computations are in **purple**.

Energy consumption

Control variable: final energy consumptions for energy carrier (monitored).

Involved demo cases: DK (district heating), PL (electricity), IT (electricity).

Energy consumption impact was related to district heating (DK) or electricity (PL, IT) consumptions, depending on the demo case, and quantified in terms of monitored consumptions. They were monetized by multiplying the monthly consumptions time the energy tariff (VAT and taxes included), as defined in equation (3).

$$\boldsymbol{Energy_{€} = Cons \cdot En\ price_{€}}[€/\boldsymbol{month}] \quad \textbf{(3)}$$

Where:

Energy$_{€}$: Monetized energy consumption [€/month]
Cons: Monthly consumption of the energy carrier [kWh/month]
En price$_{€}$: energy price for the energy carrier (VAT and taxes included) [€/kWh]

En price$_{€}$ was defined previously in the national currency and translated in €.

Water consumption

Control variable: cold water consumption (monitored).

Involved demo cases: DK.

Water consumption impact was related to cold water usage and quantified as monitored monthly consumptions. They were monetized by multiplying the monthly water consumptions time the water price (taxes included), as expressed in equation (4).

$$\boldsymbol{Water_{€} = W\ Cons \cdot W\ price_{€}}[€/\boldsymbol{month}] \quad \textbf{(4)}$$

Where:

Water$_{€}$: Monetized water consumption [€/month]
W Cons: Monthly cold-water consumption [m^3/month]
W price$_{€}$: Water price (taxes included) [€/ m^3]

W price$_{€}$ was defined previously in the national currency and translated in €.

Productivity

Control variable: Indoor air temperature (monitored).

Involved demo cases: SLO, IT

According to the model defined by Seppanen et al. (2004) [3], productivity impact was quantified in percentage based on monitored indoor air temperature (with the 100% of performance around 22°C). The model is expressed by equation (5).

$$p = (0.1647524 \cdot T - 0.0058274 \cdot T^2 + 0.0000623 \cdot T^3 + 0.4685328)\ [\%] \quad (5)$$

Where:

p: productivity level [%]

T: hourly/monthly indoor air temperature in working hours [°C]

The computation was performed having as input the hourly (in IT demo case) or monthly (in SLO demo case) mean indoor air temperature in occupied hours. Only working days were considered per each month involved in the evaluation, because of the office use of the demo cases. The monetization consisted in multiplying the obtained percentage times employee the labour cost[1] for all the working hours of the month. More in detail, computation for Italian demo case is summarized in equation (6), when values of hourly mean of indoor air temperature were available:

$$\boldsymbol{Prod_{€} = \sum_{i=1}^{h} [p \cdot L \cdot occ_i]\ [€/month]} \quad \textbf{(6)}$$

Where:

$Prod_{€}$: Monetized productivity [€/month]

p: productivity level [%]

L: hourly labour cost as defined by Eurostat [2] [€/hour · pers]

occ_i: number of employees in working hour i [pers]

h: number of working hours in a month

In equation (7), computation for Slovenian demo case is reported, when values of monthly mean of indoor air temperature were adopted:

$$\boldsymbol{Prod_{€} = p \cdot L \cdot occ \cdot h \cdot d\ [€/month]} \quad \textbf{(7)}$$

Where:

$Prod_{€}$: Monetized productivity [€/month]

L: hourly labour cost as defined by Eurostat [2] [€/ hour · pers]

occ: number of employees in working hour [pers]

h: number of working hours in a day [hours/day]

d: number of working days in a month [day/month]

Hourly labour cost (L) was defined in €.

[1] Being the viewpoint for the analysis the one of employer, labour cost (including all the costs an employer must face for his personals) was considered.

IEQ improvement

Control variable: usefulness of MOBISTYLE ICT-solutions in improving thermal comfort and indoor air quality (self-reported from surveys).

Involved demo cases: PL.

IEQ improvement was assessed thanks to self-reporting from MOBISTYLE users. In particular, the quantification involved the estimation of the total square meters of owner-occupied and rented apartments where users self-reported an improvement in IEQ due to MOBISTYLE services.

Monetization of improved IEQ was performed according to the hedonic price method[2], looking to the real estate market. Indeed, it was found in literature that selling and rental prices of houses with excellent IEQ is 6% and 5% higher than the standard one (Table 5). This marginal price is called hedonic price and can be read as the occupants' willingness-to-pay (WTP) for better IEQ.

Table 5: impact of IEQ on residential real estate market in terms of percentage increase in selling and rental prices (s). Source: Asmma' et al. (2015) [4]

Case study	s	Reference in literature
Rented houses	6%	Asmma' et al. (2015) [4]
Owner-occupied houses	5%	Asmma' et al. (2015) [4]

So, total market value and total rental income of the residential demo case (PL) was computed accounting for economic value of IEQ improvement in terms of WTP (quantified thanks to literature as 5% or 6% of current market value or rental income).

To do so, equations (8) and (9) were used, for, respectively, owner-occupied and rented apartments.

$$M(IEQ)_{€} = M_{€} \cdot \left(A_{tot,o} - A_{IEQ+,o}\right) + \left[(100\% + s) \cdot M_{€} \cdot A_{IEQ+,o}\right] [€] \quad (8)$$

Where:

$M(IEQ)_{€}$: Total stock market value accounting for IEQ improvement [€]

$M_{€}$: current market value per square meter [€/m^2]

$A_{tot,o}$: total owner-occupied square meters [m^2]

$A_{IEQ+,o}$: owner-occupied square meters where improvement in IEQ was self-reported, from eq. (11-12) [m^2]

s: percentage increase according to literature [4] as reported in Table 5 [%]

$$R(IEQ)_{€} = R_{€} \cdot \left(A_{tot,r} - A_{IEQ+,r}\right) + \left[(100\% + s) \cdot R_{€} \cdot A_{IEQ+,r}\right] [€/month] \quad (9)$$

[2] The hedonic price method measures the implicit price of a non-market good by observing the value of a surrogate good for which a market exists. For example, the change in a house price resulting from the marginal change in one of its characteristics is called hedonic price and it can be interpreted as the willingness-to-pay of households for a marginal increase in that particular feature. In this application, hedonic price for improved IEQ is assumed from previous studies as percentage increase on current prices.

Where:

$R(IEQ)_€$: Total stock rental income accounting for IEQ improvement [€/month]
$R_€$: current monthly rental income per square meter [€/month · m^2]
$A_{tot,r}$: total rented square meters [m^2]
$A_{IEQ+,r}$: rented square meters where improvement in IEQ was self-reported, from eq. (11-12) [m^2]
s: percentage increase according to literature [4] as reported in Table 5 [%]

$M_€$ and $R_€$ were defined previously in the national currency and then translated in €.

Current market value and rental income were increased according to literature [4] for the square meters of houses where IEQ improvement was self-reported, in order to take into account WTP for better IEQ. In particular, results from questionnaires deployed with MOBISTYLE users were used to assess $A_{IEQ+,o}$ and $A_{IEQ+,r}$ (Eq. 10-11).

$$A_{IEQ+,o} = A_{tot,o} \cdot \%Answ\ [m^2] \qquad (10)$$

$$A_{IEQ+,r} = A_{tot,r} \cdot \%Answ\ [m^2] \qquad (11)$$

Where:

$A_{IEQ+,o}$: owner-occupied square meters where improvement in IEQ was self-reported [m^2]
$A_{IEQ+,r}$: rented square meters where improvement in IEQ was self-reported [m^2]
%Answ: Percentage of users who agreed or strongly agreed in affirming that MOBISTYLE services helped them improving thermal comfort and indoor air quality [%]

Before summing the two components of equation (8) and (9) a temporal mismatching had to be addressed. While $R(IEQ)_€$ was a monthly value, $M(IEQ)_€$ is a *una tantum* value. It was necessary to scale down $M(IEQ)_€$ to be able to assume it as a monthly value to compute monthly cash flows. To do it, the capitalization income approach was used. In particular, the Gross Operating Income (GOI) of the owner-occupied house was calculated as:

$$GOI_€ = M(IEQ)_€ \cdot r\ [€/year] \qquad (12)$$

Where:

$GOI_€$: Annual Gross Operating income [€/year]
$M(IEQ)_€$: Total stock market value accounting for IEQ improvement, from eq. (8) [€]
r: capitalization rate that is defined at local level for a specific use of the building (i.e. residential) depending on market dynamics [-]

The monthly value was calculated dividing $GOI_€$ times 12 (months of a year). Being computed starting from $M(IEQ)_€$, it accounts for IEQ improvement.

$$GOI(IEQ)_€ = \frac{GOI_€}{12}\ [€/month] \qquad (13)$$

Where:

$GOI(IEQ)_€$: Monthly Gross Operating income accounting for IEQ [€/month]
$GOI_€$: Annual gross operating income [€/year]

In summary, the impact called "IEQ improvement" was assessed in monetary terms as total stock market values (of owner-occupied and rented apartments) accounting for IEQ improvement in terms of WTP as:

$$\boldsymbol{IEQ_{€} = R(IEQ)_{€} + GOI(IEQ)_{€}[€/month]} \qquad \textbf{(14)}$$

Where:

$IEQ_{€}$: Monetized IEQ improvement [€/month]

$R(IEQ)_{€}$: Total stock rental income accounting for IEQ improvement, from eq. (9) [€/month]

$GOI(IEQ)_{€}$: Monthly gross operating income accounting for IEQ improvement, from eq. (13) [€/month]

GHG emissions

Control variable: energy consumption (monitored).

Involved demo cases: DK (district heating), PL (electricity), IT (electricity).

The GHG emissions were quantified by multiplying the final consumption supply by a specific energy carrier (district heating in DK and electricity in PL and IT) by its correspondent emission factor. Their monetization was performed multiplying the estimated emissions (expressed in $kgCO_{2eq}$) by the parametric cost of GHG as defined by the European Commission (2012) [5].

$$\boldsymbol{GHG_{€} = Cons \cdot Coeff_{GHG} \cdot C_{GHG}\ [€/month]} \qquad \textbf{(15)}$$

Where:

$GHG_{€}$: Monetized GHG emissions [€/month]

Cons: Monthly consumption supply by a specific energy carrier [kWh/month]

$Coeff_{GHG}$: Emission factor for the specific energy carrier [$kgCO_{2eq}$/kWh]

C_{GHG}: cost of GHG emissions, as defined by the European Commission (2012) [5] [€/$kgCO_{2e}$]

PM emissions

Control variable: energy consumption (monitored).

Involved demo cases: DK (district heating), PL (electricity), IT (electricity).

The PM emissions were quantified by multiplying the final consumption (district heating in DK and electricity in PL and IT) by correspondent emission factor for the specific energy carrier. Their monetization was performed by multiplying the estimated emissions (expressed in gPM) by the parametric cost of PM as defined by the Copenhagen Economics (2012) [6].

$$\boldsymbol{PM_{€} = Cons \cdot Coeff_{PM} \cdot C_{PM}[€/month]} \qquad \textbf{(16)}$$

Where:

$PM_{€}$: Monetized PM emissions [€/month]

Cons: Monthly consumption supply by a specific energy carrier [kWh/month]

$Coeff_{PM}$: Emission factor for the specific energy carrier [gPM/kWh]

C_{PM}: cost of PM emissions, as defined by the Copenhagen Economics (2012) [6] [€/gPM]

Headache cases (due to overheating)

Control variable: indoor air temperature (monitored).

Involved demo cases: SLO, IT.

Some studies demonstrate that there is a correlation between indoor parameters and Sick Building Syndrome (SBS) occurrence. In particular, a study developed by Mendel et al. (2009) [7] found that SBS prevalence rates in winter increased as temperatures increased above 23°C and provided adjusted odds ratios (ORs) for the symptom prevalence increases for each 9 degree hours above 23°C. The adjusted (based on genders and other variables) odds ratio is equal to 1.19 per each 9 degree-hours above 23°C in winter conditions.

In this application, extra cases of headache due to the risk factor of overheating in winter were quantified and monetized. Monetization was performed according to the Cost of Illness approach, by multiplying cases times the daily cost for headaches. Costs of headache were gathered from a study according to which in Europe the annual cost pro capita is equal to 1778 €[3] (including reduced productivity at work, absenteeism from work, diagnostic investigations, hospitalization, outpatient health care, prophylactic medications and acute medications [10]), 648 € if reduced productivity at work is excluded (to avoid double accounting), it means 1.8 € per day.

In detail, the impact was calculated according the following equation:

$$\boldsymbol{Headache}_{€} = \sum_{i=1}^{d}\left[\boldsymbol{P_{headache}}\,(\boldsymbol{RR}-\mathbf{1})\cdot \boldsymbol{occ_{exposed,i}}\cdot \boldsymbol{cost_{headache}}\right][€/\boldsymbol{month}] \quad \textbf{(17)}$$

Where:

Headache$_{€}$: Monetized headache cases [€/month]
$P_{headache,d}$: current daily prevalence of headache, assumed by [7] [cases/pers]
RR: relative risk factor of overheating, assumed by [7] [-]
$occ_{exposed,i}$: number of occupants exposed to the risk factor in working day I [pers]
$cost_{headache}$: daily costs of treatment, assumed by [10] [€/case]
d: number of working days of the month

In this analysis, current daily prevalence (P) was assumed from Mendel et al. (2009) [7] as 0.152 over a working week, consequently 0.0304 per day. Since for prevalence below 0.20 RR can be considered equal to OR [8], RR was assumed equal to the OR provided by Mendel et al. (2009) [7] for each 9 degree-hours > 23°C, as reported in the formula:

$$RR = OR^{\frac{D}{9}} \qquad (18)$$

Where:

RR: relative risk of the risk factor of overheating, assumed by [7] [-]
D: are degree-hours per each working day of the month

[3] If cases due to medication overuse are excluded

Computation of D is summarized in equation (19) for Italian demo case, when values of mean hourly indoor air temperature were available, and in equation (20) for Slovenian demo case, when values of mean monthly indoor air temperature were adopted.

$$T_i > 23°C \rightarrow D = \sum_{i=1}^{h}(T_i - 23°C) \qquad (19)$$

Where:

D: degree hours [degree hours/day]

T_i: hourly mean indoor air temperature in working hour i [°C]

h: working hours in a day [hours]

$$T > 23°C \rightarrow D = (T - 23°C) \cdot h \qquad (20)$$

Where:

D: degree hours [degree hours/day]

T: monthly mean indoor air temperature in occupied hours [°C]

h: working hours in a day [hours]

It was evaluated that assumption of performing the assessment based on monthly means could bring to both overestimations and underestimation, so to their balancing, with good level of estimation of this impact.

Input data and results for demo cases

DK demo case

In DK demo case the timespan for the evaluation corresponded to the time when users had access to HLZ Game, namely December 2019, January 2020 and February 2020 (with-the-project-scenario). Indeed, March, April and May 2020 were excluded from the analysis because affected by the COVID-19 lockdown. Counterfactual scenario was defined accordingly, as the same months of the previous year.

To summarize, **impacts** for DK demo case were:

- Energy consumption (I and II layer)
- Water consumption (I and II layer)
- GHG emissions (II layer)
- PM emissions (II layer)

They all had to be minimized (being lower in with-the-project than in counterfactual scenario) to be considered as benefits brought by MOBISTYLE. In the followings, input data and results are reported.

Input data (Table 6) coming from measurements and surveys in DK demo case were:

- Monthly district heating consumptions of all the 17 households.
- Monthly water consumptions of all the 17 households.
- Monthly heating degree days (HDD_m). They were used before computing the relevant impact (i.e. energy consumptions, GHG and PM emissions) to adjust district heating consumptions and make comparable the ones from winter 2018-2019 and winter 2019-2020. This was done, for district heating (DH) consumptions data of each month, according to the following equation:

$$DH\ consumption_{w2018-2019,adj} = DH\ consumption_{w2018-2019} \cdot \frac{HDD_{m2019-2020}}{HDD_{m2018-2019}}$$

[kWh/month] (23)

Table 6: Input data gathered from DK demo case measurements and surveys

		District heating consumptions [kWh/month]*	*Water consumptions* [m^3/month]*	*HDD_m [HDD]*
without-the-project-scenario	Dec2018	11'856	60.09	352
	Jan2019	22'180	49.01	432
	Feb2019	15'097	92.04	315
with-the-project-scenario	Dec2019	15'407	64.32	346.9
	Jan2020	14'222	61.06	307.8
	Feb2020	13'841	50.83	316.1

* sum of the consumptions of all 17 apartments included in the analysis

Fixed data needed for the computation, both provided by demo case holder and coming from literature, are summarized in the following.

Table 7: Fixed data for DK demo case

	Value	*Unit*	*Source*
GHG emission factor for district heating	0.2408	[$kgCO_{2eq}$/kWh]	Reported by demo case holder as national value
PM (2.5 and 10) emission factor for district heating	0.02	[gPM/kWh]	Reported by demo case holder as national value
Energy price (all taxes included) for district heating	0.54	[DKK/kWh]	Reported by demo case holder
Water price (all taxes included)	43.54	[DKK/m^3]	Reported by demo case holder
GHG price	20	[€/ton]	European commission [5]
PM price	10'805	[€/ton]	Copenhagen Economics [6]

Based on these input data, all impacts were quantified and monetized month by month. Differences of impacts between without-the-project and with-the-project scenario were computed month by month to define whether each impact could be considered a cost or a benefit (Table 8). Costs (in red) are negative cash flows, while benefits (in green) are positive cash flows produced by monetized impacts.

Table 8: Costs (in red) and benefits (in green) in € for DK demo case

Viewpoint:		*II layer (society)*			
		I layer (occupants)			
Impacts:		***Energy consumptions [€]***	***Water consumptions [€]***	***GHG emissions [€]***	***PM emissions [€]***
MOBISTYLE results	Dec (2019/2018)	**-261.34**	**-23.91**	**-17.93**	**-0.80449**
	Jan (2020/2019)	**+111.00**	**-68.18**	**+7.62**	**+0.34171**

	Feb (2020/2019)	+91.87	+233.28	+6.30	+0.28281

Finally, monthly cash flows, putting together different impacts, were computed according to I and II layer and NPV was provided (Table 9).

Table 9: Total monthly cash flows in € for DK demo case

Viewpoint:		*II layer (society)*	
		I layer (occupants)	
Total monthly cash flows		***[€]***	***[€]***
MOBISTYLE results	Dec (2019/2018)	-285.25	-303.99
	Jan (2020/2019)	+42.82	+50.78
	Feb (2020/2019)	+325.15	+331.74

NPV (I layer)	**+81 €**
NPV (II layer)	**+77 €**

MOBISTYLE for DK demo case produced negative cash flows in December, but on 3 months of evaluation resulted in a positive NPV, meaning that benefits overcame costs. Further comments are provided in conclusions.

PL demo case

In PL demo case the timespan for the evaluation corresponded to the time when users had access to HLZ Game, namely February and March 2020 (with-the-project-scenario). Indeed, April and May 2020 were excluded from the analysis because affected by the COVID-19 lockdown. Counterfactual scenario was defined accordingly as the same months of the previous year.

To summarize, **impacts** for PL demo case were:

- Energy consumption (I and II layer)
- IEQ improvement (I and II layer)
- GHG emissions (II layer)
- PM emissions (II layer)

Consumptions and emissions had to be minimized (being lower in with-the-project than in counterfactual scenario) to be considered as benefits brought by MOBISTYLE, while IEQ improvement had to be maximized. In the followings, input data and results are reported.

Input data (Table 10) coming from measurements and surveys in PL demo case were:

- Monthly electricity consumptions at apartment level for the 150 households where the Game was distributed. They included all electrical uses.
- Percentage of users who agreed or strongly agreed in affirming that MOBISTYLE services helped them in improving thermal comfort and indoor air quality in their apartment.

Table 10: Input data gathered from PL demo case measurements and surveys.

		Electricity consumptions [kWh/month]*	*Percentage of users self-reporting IEQ improvement thanks to MOBISTYLE – owner-occupied apartments [%]*	*Percentage of users self-reporting IEQ improvement thanks to MOBISTYLE – rented apartments [%]*
without-the-project-scenario	Feb2019	25'566.9	0	0
	Mar2019	26'001.7		
with-the-project-scenario	Feb2020	27'906.2	16.2**	16.2**
	Mar2020	32'295.1		

* sum of the consumptions of all 150 apartments involved in the analysis
** based on 99 respondents

Fixed data needed for the computation, both provided by demo case holder and coming from literature, are summarized in Table 11.

Table 11: Fixed data for PL demo case

	Value	*Unit*	*Source*
GHG emission factor for electricity	0.792	[$kgCO_{2eq}$/kWh]	Reported by demo case holder
PM (2.5 and 10) emission factor for electricity	0.037	[gPM/kWh]	Reported by demo case holder
Energy price (all taxes included) for electricity	0.5920	[PLN/kWh]	Eurostat [2]
GHG price	20	[€/ton]	European commission [5]
PM price	10'805	[€/ton]	Copenhagen Economics [6]
Renting fee per month per square meter	29.6	[PLN/m^2]	Reported by demo case holder for 2019
Market price per square meter	7'795	[PLN/m^2]	Reported by demo case holder for 2019
Total square meters of owner-occupied apartments	9'535.7	[m^2]	Reported by demo case holder
Total square meters of rented apartments	1'789.4	[m^2]	Reported by demo case holder
Capitalization rate	0.068	[-]	Reported by demo case holder for 2019

Based on these input data, all impacts were quantified and monetized month by month. Differences of impacts between without-the-project and with-the-project scenario were computed month by month to define whether each impact could be considered a cost or a benefit (Table 12). Costs (in red) are negative cash flows, while benefits (in green) are positive cash flows produced by monetized impacts.

Table 12: Costs (red) and benefits (green) in € for PL demo case

Viewpoint:		II layer (society)			
		I layer (occupants)			
Impacts:		Energy consumptions [€]	IEQ improvement [€]	GHG emissions [€]	PM emissions [€]
MOBISTYLE results	Feb (2020/2019)	-318.51	+ 885.24	-37.05	-0.9352
	Mar (2020/2019)	-856.91	+ 885.24	-99.69	-2.51601

Finally, monthly cash flows, putting together different impacts, were computed according to I and II layer and NPV was provided (Table 13).

Table 13: Total monthly cash flows in € for PL demo case

Viewpoint:		II layer (society)	
		I layer (occupants)	
Total monthly cash flows		[€]	[€]
MOBISTYLE results	Feb (2020/2019)	+566.73	+528.74
	Mar (2020/2019)	+28.33	-73.88

NPV (I layer)	+594 €
NPV (II layer)	+454 €

MOBISTYLE for PL demo case always produced costs in terms of energy and GHG and PM emissions. However, self-reported IEQ improvement thanks to MOBISTYLE services resulted in positive cash flow. NPV values are positive, meaning that benefits overcame costs in both I and II layer. Further comments are provided in conclusions.

SLO demo case

In SLO demo case the timespan for the evaluation corresponded to the time when users had access to HLX Dashboard and to the period between February 2019 and December 2019, both included. Counterfactual scenario was defined accordingly, as the same months of the previous year. A particular attention was in the definition of vacations and working days; to have equal number of workdays in the two compared months, specific dates were excluded and a slight shift in calendar days for counterfactual scenario was adopted.

To summarize, **impacts** for SLO demo case were:

- Productivity (I and II layer)
- Headache cases due to overheating (II layer)

Productivity had to be maximized (being higher in with-the-project than in counterfactual scenario) to be considered as benefits brought by MOBISTYLE, while headache cases to be minimized. In the followings, input data and results are reported.

Input data (Table 14) coming from measurements and surveys in SLO demo case were:

- Monthly mean indoor air temperature per each office.

Table 14: Input data gathered from SLO demo case measurements and surveys

		Indoor air temperature [°C]							
		Of1	***Of2***	***Of3***	***Of4***	***Of5***	***Of6***	***Of7***	***Of8***
without-the-project-scenario	Feb2018	21.4	21.2	22.0	23.9	24.8	23.2	21.9	22.9
	Mar2018	21.8	22.0	22.4	23.8	25.0	23.8	22.9	23.3
	Apr2018	22.7	22.0	23.2	24.5	26.4	25.4	25.1	24.0
	May2018	22.5	22.7	23.8	25.4	26.1	26.4	25.3	25.1
	Jun2018	24.0	24.7	24.0	26.2	26.7	25.8	26.2	25.9
	Jul2018	23.9	24.0	23.6	26.1	26.2	26.7	26.1	26.2
	Aug2018	24.4	25.0	24.4	26.1	25.7	26.7	27.0	26.2
	Sept2018	23.1	23.6	23.1	25.2	26.4	25.4	25.7	24.9
	Oct2018	21.9	22.2	22.6	24.3	25.9	24.5	23.7	23.3
	Nov2018	22.6	22.9	22.5	23.8	25.0	23.8	22.9	22.9
	Dec2018	22.7	22.0	23.3	23.6	24.1	23.4	22.7	23.1
with-the-project-scenario	Feb2019	22.4	21.4	23.1	24.1	24.5	23.9	23.1	22.8
	Mar2019	22.4	21.5	23.2	24.3	25.6	24.4	23.6	23.3
	Apr2019	22.5	21.9	23.5	24.8	26.3	24.9	24.1	23.6
	May2019	22.4	21.8	23.2	24.8	26.0	24.8	23.9	23.3
	Jun2019	23.9	25.1	23.5	26.8	26.1	26.4	26.3	26.2
	Jul2019	24.1	25.2	23.6	26.7	26.0	27.0	26.7	26.7
	Aug2019	24.1	25.1	23.2	26.5	26.0	25.9	26.2	26.6
	Sept2019	22.7	24.4	23.0	24.8	26.4	25.7	25.4	25.2
	Oct2019	22.2	20.9	22.9	23.8	25.8	24.7	24.3	23.6
	Nov2019	21.5	20.3	22.2	23.0	25.1	24.0	23.7	23.8
	Dec2019	21.6	19.9	21.9	21.5	24.2	23.6	23.2	22.6

Of1: K1N0623; *Of2*: K1N0624; *Of3*: K3N0605; *Of4*: K3N0618; *Of5*: R2N0805; *Of6*: R2N0634; *Of7*: R3N0644; *Of8*: R3N0808

Fixed data needed for the computation, both provided by demo case holder and coming from literature, are summarized in Table 15.

Table 15: Fixed data for SLO demo case

	Value	*Unit*	*Source*
N. of occupants	21*	[-]	Reported by demo case holder
Current daily prevalence	0.0304	[-]	Literature [7]
Relative risk	1.19	[-]	Literature [7]
Working hours in a day	11	[-]	Assumed as 8am-6pm
Working days in a month	various	[-]	Defined based on vacations, weekends and adjusted to have equal number between the two scenarios
Cost of headache per day	1.8	[€/day · pers]	Literature [10]

Labour cost per hour	18.1	[€/hour · pers]	Eurostat [2]

* occupants are distributed in 8 offices; 21 is the total number

More in detail, occupants were distributed in different offices as in Table 16.

Table 16: Number of occupants in SLO demo case per each office

	Of1	*Of2*	*Of3*	*Of4*	*Of5*	*Of6*	*Of7*	*Of8*
N. of occupants	2	1	2	1	6	2	1	6

Of1: K1N0623; *Of2*: K1N0624; *Of3*: K3N0605; *Of4*: K3N0618; *Of5*: R2N0805; *Of6*: R2N0634; *Of7*: R3N0644; *Of8*: R3N0808

Based on these input data, all impacts were quantified and monetized month by month and summed across the 8 offices included in the evaluation. Differences of impacts between without-the-project and with-the-project scenario were computed month by month to define whether each impact could be considered a cost or a benefit (Table 17). Costs (in red) are negative cash flows, while benefits (in green) are positive cash flows produced by monetized impacts.

Table 17: Costs (red) and benefits (green) in € for SLO demo case

Viewpoint:		*II layer (society)*	
		I layer (employer)	
Impacts:		***Productivity [€]***	***Headache cases [€]***
MOBISTYLE results	Feb (2019/2018)	**-10.14**	**+0.09**
	Mar (2019/2018)	**-258.86**	**-2.21**
	Apr (2019/2018)	**106.34**	**+0.97**
	May (2019/2018)	**615.66**	**+5.82**
	Jun (2019/2018)	**15.93**	NA
	Jul (2019/2018)	**-277.09**	NA
	Aug (2019/2018)	**-23.86**	NA
	Sept (2019/2018)	**-78.84**	**-0.80**
	Oct (2019/2018)	**-46.70**	**-0.38**
	Nov (2019/2018)	**-137.45**	**-1.52**
	Dec (2019/2018)	**53.79**	**+0.09**

Finally, monthly cash flows, putting together different impacts, were computed according to I and II layer and NPV was provided (Table 18).

Table 18: Total monthly cash flows in € for SLO demo case

Viewpoint:		*II layer (society)*	
		I layer (employer)	
Total monthly cash flows		***[€]***	***[€]***
MOBISTYLE results	Feb (2019/2018)	**-10.14**	**-10.05**
	Mar (2019/2018)	**-258.86**	**-261.07**
	Apr (2019/2018)	**+106.34**	**+107.32**
	May (2019/2018)	**+615.66**	**+621.48**
	Jun (2019/2018)	**+15.93**	**+15.93**
	Jul (2019/2018)	**-277.09**	**-277.09**
	Aug (2019/2018)	**-23.86**	**-23.86**
	Sept (2019/2018)	**-78.84**	**-79.64**
	Oct (2019/2018)	**-46.70**	**-47.09**
	Nov (2019/2018)	**-137.45**	**-138.97**
	Dec (2019/2018)	**+53.79**	**+53.88**

NPV (I layer)	**-38 €**
NPV (II layer)	**-35.9 €**

The same analysis was performed keeping separated each one of the 8 offices involved in the project. NPV for the 8 offices separately are provided in Table 19.

Table 19: NPV for SLO demo case per each office

	NPV [€]							
	Of1	***Of2***	***Of3***	***Of4***	***Of5***	***Of6***	***Of7***	***Of8***
I layer	+36.29	-103.29	+84.76	-14.83	+76.48	+32.69	+20.19	-170.28
II layer	+36.33	-103.53	+84.99	-14.27	+75.96	+32.96	+20.43	-168.80

Of1: K1N0623; *Of2*: K1N0624; *Of3*: K3N0605; *Of4*: K3N0618; *Of5*: R2N0805; *Of6*: R2N0634; *Of7*: R3N0644; *Of8*: R3N0808.

MOBISTYLE for SLO demo case always produced negative NPV over 11 months of evaluation, both from owner and society viewpoint, meaning that costs overcame benefits. However, the situation is diversified in the different offices, with positive results in terms of NPV for some offices. Further comments are provided in conclusions.

IT demo case

In IT demo case the timespan for the evaluation corresponds to the time when users started to use HLX Dashboard, namely November 2019, December 2019, January 2020 and February 2020 (with-the-project-scenario). March 2020 was excluded from the analysis because affected by the COVID-19 lockdown. Counterfactual scenario (without-the-project) was defined accordingly, as the same months of the previous year. A particular attention was in the definition of vacations and working days; to have equal number of workdays in the two compared months, specific dates were excluded and a slight shift in calendar days for counterfactual scenario was adopted.

To summarize, **impacts** for IT demo case were:

- Energy consumption (in terms of electricity consumptions for printer[4]) (I and II layer)
- Productivity (I and II layer)
- GHG emissions (II layer)
- PM emissions (II layer)
- Headache cases due to overheating (II layer)

All of them had to be minimized (being lower in with-the-project than in counterfactual scenario) to be considered as benefits brought by MOBISTYLE, apart for productivity that had to be maximized. In the followings, input data and results are reported.

Input data (Table 20) coming from measurements and surveys in IT demo case were:

- Monthly electricity consumptions for printer.
- Hourly mean indoor air temperature.

Table 20: Input data gathered from IT demo case measurements and surveys

		Electricity consumptions [kWh/month]*	*Indoor air temperature ** [°C/month]*
without-the-project-scenario	Nov2018	13.0	23.09
	Dec2018	16.0	24.17
	Jan2019	18.0	23.92
	Feb2019	16.1	23.40
with-the-project-scenario	Nov2019	10.0	24.51
	Dec2019	12.6	24.26
	Jan2020	16.7	23.79
	Feb2020	18.1	23.31

* related to printer in reception space.
**monthly mean values in occupied hours (from 8am to 7pm in weekdays and from 8am to 12am on Saturday). In the computation hourly mean temperature were used.

Fixed data needed for the computation, both provided by demo case holder and coming from literature, are summarized in Table 21.

Table 21: Fixed data for IT demo case

	Value	*Unit*	*Source*
GHG emission factor for electricity	0.4332	[$kgCO_{2eq}$/kWh]	Reported by demo case holder
PM (2.5 and 10) emission factor for electricity	0.0076	[gPM/kWh]	Reported by demo case holder
N. of occupants	2	[-]	Reported by demo case holder
Current daily prevalence	0.0304	[-]	Literature [7]
Relative risk	1.19	[-]	Literature [7]

[4] Laptop consumptions was excluded from the analysis in accordance with data analysis reported in D6.2 because it was considered not significant.

Working hours in a day	12 in weekdays 5 on Saturday	[-]	Assumed as 8am-7pm (weekdays) and 8am-12am (Saturday)
Working days in a month	various	[-]	Defined based on vacations and adjusted to have equal number between the two scenarios
Energy price (all taxes included) for electricity	0.21	[€/kWh]	Reported by by demo case holder from bills
GHG price	20	[€/ton]	European commission [5]
PM price	10'805	[€/ton]	Copenhagen Economics [6]
Cost of headache per day	1.8	[€/day · pers]	Literature [10]
Labour cost per hour	28.2	[€/hour · pers]	Eurostat [2]

Based on these input data, all impacts were quantified and monetized month by month. Differences of impacts between without-the-project and with-the-project scenario were computed month by month to define whether each impact could be considered a cost or a benefit (Table 22). Costs (in red) are negative cash flows, while benefits (in green) are positive cash flows produced by monetized impacts.

Table 22: Costs (red) and benefits (green) in € for IT demo case

Viewpoint:		*II layer (society)*				
		I layer (employer)				
Impacts:		***Energy consumptions [€]***	***Productivity [€]***	***Headache cases [€]***	***GHG emissions [€]***	***PM emissions [€]***
MOBISTYLE results	Nov (2019/2018)	**+0.63**	**-106.91**	**-0.58**	**+0.026**	**+0.00025**
	Dec (2019/2018)	**+0.71**	**-2.14**	**-0.02**	**+0.029**	**+0.00028**
	Jan (2020/2019)	**+0.28**	**-1.20**	**+0.01**	**+0.012**	**+0.00011**
	Feb (2020/2019)	**-0.41**	**-4.97**	**-0.03**	**-0.017**	**-0.00016**

Finally, monthly cash flows, putting together different impacts, were computed according to I and II layer and NPV was provided (Table 23).

Table 23: Monthly cash flows in € for IT demo case

Viewpoint:		*II layer (society)*	
		I layer (employer)	
Total monthly cash flows		***[€]***	***[€]***
MOBISTYLE results	Nov (2019/2018)	**-106.28**	**-106.84**
	Dec (2019/2018)	**-1.42**	**-1.42**
	Jan (2020/2019)	**-0.92**	**-0.90**

	Feb (2020/2019)	**-5.38**	**-5.43**

NPV (I layer)	**-113.7 €**
NPV (II layer)	**-114.3 €**

MOBISTYLE for IT demo case produced negative NPV over 4 months of evaluation, both from owner and society viewpoint, meaning that costs overcame benefits. Despite benefits (positive cash flows) in terms of energy consumption (meaning lower financial burdens for the owner due to energy savings), they are still too little to balance costs (negative cash flows) in terms of productivity. Indeed, monetized productivity was smaller in with-the-project scenario than in counterfactual one, resulting a cost for the owner. Further comments are provided in conclusions.

Conclusions about CBA

Results from different demo cases in terms of NVP computed according to the two layers are summarized in the Table 24.

Table 24: Results (NPV) from different demo cases according to the two layers of analysis

Demo case	Net Present Value (NPV) [€]	
	I layer	II layer
DK	+81 €	+77 €
PL	+594 €	+454 €
SLO	-38 €	-35.9 €
IT	-113.7 €	-114.3 €

DK: The NPV equals **+81 €**, if the occupants' viewpoint is considered (I layer). It means that over 3 months of evaluation benefits overcome costs when direct impacts (namely, financial burdens for district heating and water provision) are considered. Highest benefit is related to water consumption impact during last month of the evaluation. When externalities are added to the evaluation, accounting for impacts on the whole society (namely, monetized GHG and PM emissions), NPV is a bit lower (**+77 €**). Indeed, emissions are related to district heating consumptions, and high energy consumptions in December brought further costs in term of GHG and PM emissions. Because of high water price, pushing on water consumption savings is judged particularly valuable in Danish context.

PL: The NPV equals **+594 €**, if the occupants' viewpoint is considered (I layer). In this demo case, energy consumption impact produces costs during MOBISTYLE ICT-tools deployment. However, monetized improvement in IEQ produces benefits, balancing and overcoming outflows. This results in positive NPV over 2 months of evaluation, meaning that globally benefits overcome costs. Since II layer include emissions, which are dependent on energy consumptions, when the society viewpoint is considered, further costs happens and NVP get lower, being equal to **+454 €**.

It is important to keep in mind that quantification of IEQ improvement was based on self-reporting from users, thus, thanks to qualitative assessments.

SLO: over 11 months of evaluation, deployment of MOBISTYLE ICT-tools produces a negative NPV, meaning that costs overcome benefits, both from employer (I layer) and society (II layer) viewpoint. NPV equals **-38 €** when productivity is considered while it is higher (**-35.9 €** so costs are overcome benefits to a less extent) in II layer perspective. However, the situation is diversified in the different offices (Table 19).

IT: over 4 months of evaluation, deployment of MOBISTYLE ICT-tools produces a negative NPV, meaning that costs overcome benefits, both from employer (I layer) and society (II layer) viewpoint. NPV equals **-113.7 €** when monetized productivity and energy consumptions are considered, and it is even lower (**-114.3 €**) when burdens on the whole society, in terms of environmental costs for GHG emissions, PM emissions, expenses for headache cases due to overheating, are added to the

evaluation. Despite benefits guaranteed by savings in energy consumptions for three out of four months of the evaluation, costs for productivity have a high impact on results.

To summarize results in **residential demo cases**:

- Benefits overcome costs, producing positive NPV.
- In DK demo case, over **3 months** of evaluation with ICT-tools deployed, MOBISTYLE produced **+4.8 €** and **+4.5 €** of NPV per apartment, if I and II layer are respectively considered.
- In PL demo case, over **2 months** of evaluation with ICT-tools deployed, MOBISTYLE produced **+3.96 €** and **+3.03 €** of NPV per apartment, if I and II layer are respectively considered.
- Water consumption has high impact on results in Danish context.
- Results for monetized IEQ improvement suggests it as an interesting impact to explore further in the residential context.

To summarize results in **non-residential demo cases**:

- Costs overcome benefits, producing negative NPV.
- In SLO demo case, over **11 months** of evaluation with ICT-tools deployed, MOBISTYLE produced **-4.75 €** and **-4.49 €** of NPV per office, if I and II layer are respectively considered.
- In IT demo case, over **4 months** of evaluation with ICT-tools deployed, MOBISTYLE produced **-56.85 €** and **-57.15 €** of NPV per employee, if I and II layer are respectively considered.
- Productivity has a high impact on results.
- Despite various monetization techniques, further infield research providing for new models for productivity and health impact quantification based on indoor parameters are an open research filed.

References CBA chapter

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11. Conclusion and recommendations

In the frame of this project several research activities were carried out to understand the human-building interactions in the context of MOBISTLYE project needs. Most of the previous findings are described in D2.2. [3] and D2.3. [4] such as the use of calm technology principles. It will be difficult to justify changes only due to technological interventions (ICT). In this sense, the project is a "trend setter" – MOBISTYLE made a change by combining IEQ, energy, health and wellbeing.

The main goal of this deliverable is to evaluate effectiveness of various campaigns on people involved or being exposed to them and to provide meaningful lessons arising from multi-disciplinary approach. The reader should bear in mind that the project started in 2016 an ICT related techniques and available options are changing rapidly. Therefore, some solutions developed in the project might be today different because of the recent developments.

Here are the main findings and recommendations with relation to the project activities that facilitated the findings:

Moving people: Stairs campaign had measurable improvements. Effect on health was not stressed enough. Basic campaigns can be efficient. **MOBISTYLE moved people – in mind sets and on staircases**.

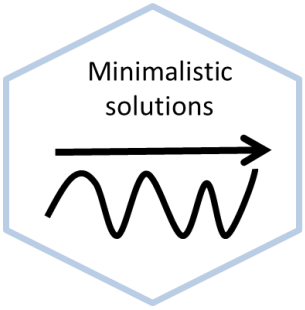
Where: SI demo 7-15% less elevators use due to campaigns (chapter 6 of this report). We can assume the changed mind-set from the focus groups results and texts provided next to questionnaires (D4.3 [10], and this report for at least SI, PL and IT case).

"I think that they [the habits] can have an impact, because if we see that we consume a lot of electricity and we have a habit of leaving the lights on everywhere, then we automatically start thinking that maybe we should turn the light off."
"I had a 5.1 speaker system which I was connecting to the phone to listen to music and it turned out that the speakers consume 34 watts on stand-by within a couple of hours, so I stopped using them."
"I pay more attention to energy consumption and its impact on climate conditions at home."

Multi-channel campaigns: Cost-effective and simple multi-channel campaigns can be very effective. We observed that simple but persistent approach is relevant and complex data gathering is not necessary in all cases and circumstances.

Where: SI and IT demo (chapter 6 and 8 of this report). SI demo **decreased energy use**: The Heating needs decrease (5%) was lower than heat use decrease (7-12%). Cooling was decreased (EF 13%, FRI 25%) even when cooling needs were increased (21%) - chapter 3.1 of this report). 9.14% electricity energy saving is observed in reception space of IT demo case (D6.2). Stickers with tips were effective in IT hotel (D6.2).

"In the past I would unplug the charger and when it turned out that it doesn't consume [electricity] when it isn't connected to the phone, I stopped unplugging it. Mainly the awareness on consumption. I once thought that the laptop charger consumes a lot, but it turned out that it doesn't."



Minimalistic solutions: IAQ state communicated via changing colour based on air quality seems to work (people declared and we measured more window opening). **The more information people get, the more they seem to reject the solution and vice versa**. Minimalistic solutions seem to work better.

Where: Feedbacks from the final focus groups (D4.3 [10]) and SI, IT demo, room to room analysis in D6.2.

"I find this light ok, I see when it goes toward red."
After being asked if she does something when the light turns red, U says: "I do it, I open the window."

Hearing other people: People tend to listen other people (like SI video Klementina or Huygen CEO Corne). Dean of FF said, he will use the stairs – it is important to target decision makers. When communicating, we need concrete individual stories. Storytelling approach in producing informative materials to engage people in different demo cases was developed and use.

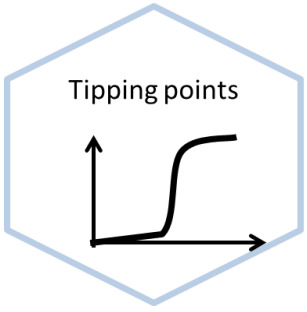
Where: SI demo video of satisfied user.

"In the time without heating and cooling, I have window open all the time with the tilt turn. In summer and winter in the way you taught me, I open the window and the door for short time."

Micro-cultures and facility management: Various site specific (**established) communication channels** can be used for campaigns. Location associated **micro-cultural specifics** need to be taken into account when designing campaigns. The later should be part of regular **facility management** to ensure sustainability.

Where: D2.2. [3] Inventory of user needs and expectations and D2.3. [4] - Recommendations for improvement and further development of solutions. The need to integrate it in regular facility management came from SI demo, and the need to integrate other (hotel) services came from IT demo focus groups (chapter 8 of this report and D6.4).

"No one is looking at large screens."
"When someone came to the room at 1 pm, it smelled really bad, but if you were in it, you did not notice". In that specific room they don't like to ventilate the room in the winter. "Light is one excuse to … open the window. They know before that they have to ventilate, but now they have objective information. For



Tipping points: Small steps are needed to modify behaviour. People want to manage/interact with buildings. **Smart people in smart buildings.** Behaviour in groups seems to follow tipping point effect (phase change): first a few, then almost all. We need more "Feel the energy" activities as described in D2.3. [4] Activities should be designed by **approach focused on communities**.

Contextual information: Information provided to the room users' needs to be contextual; you must get them **when you can do something**. Getting phone notification of e.g. poor IAQ in the office and you are at home, makes you to stop using the solution. Time delay from physical event associated with human - building interaction and information presented in the ICT solution is crucial. If this is more than e.g. 30 minutes, the actual use and perceived value of provided information is questionable. Time delay still acceptable by the people is important topic to be investigated in the future in relation to acceptability and system costs.

Where: Reported at least in SI and PL demo cases focus groups (D4.3 [10]) the actual use of gamification and dashboard depend on the real time or no real time data. User test the systems by e.g. opening the window and observing what happens in the ICT solution. If there is a too long delay, the trust is lost.

"I come early in the morning when the cleaning lady wipes the floor and I could see there was red light on."
"I was looking at the light all the time."
"I noticed it makes a difference when there are more people in the room"
"It is interesting to see the parameters when in the room, if I get notification to ventilate the office and I'm at home, it makes no sense, I just feel guilty."

Transparency and clarity: If people will have the feeling they are being **manipulated** to achieve savings (not due to care for health), there will be resistance. Everything must be **transparent** and clear.

Technology must be reliable. If it tricks you or you find out it does not work as it supposed to, it is the end of trust. It makes one mistake, and it is over. We deploy them too early. We could "humanize" or "anthropomorphize" the technologies, e.g. devices could "confess" that there was an error. The compliance with GDPR complicates the processes a bit, but is not a barrier for such solutions. It forces the developers to address and understand ethics and privacy implications of the activities.

Where: Demo case experiences.

"I did not like it (the LED light sensor) because I did not know what the sensor is showing."

Figure: Visualized recommendations

It is recommended to refine the gamification elements of the MOBISTYLE game, this would make it possible to generate the desirable changes in habits – both short-term and long-term. It is proposed to engage greater technical support to solve problems related to the installation of devices and aid in connecting and configuring devices as well as the support's more effective work in terms of solving technical problems. It is recommended to look for integration of MOBISTYLE dashboard with other services in non-residential context (hotel). For some (residential) users monetization of benefits is necessary to be shown on the long run to keep people motivated.

The use of low cost sensory equipment was stimulated, but what has been learned, that there is a trade off when one wishes to ensure stable data flow (which is apparently hard to achieve – D6.2 missing data by cases). Here important costs can occur and in the end of the day data from low cost sensors could no longer be that cheap. When designing solutions as in this project, one must bare in min what exactly is the purpose of data collection: the feedback to the users, or data available to be analysed by domain experts. This significantly influences the boundary conditions set when design the appropriate solution.

MOBISTYLE project had very different demo cases with important differences among them in terms of building type, users and contexts. One could state, that each demo case was a project by itself this some trade-offs between generic and specific approach in terms of performance and security must be taken, otherwise no solutions would be developed and deployed. We found out (IT, PL an SI demo) that solutions need to be adapted to individuals, and not just various contexts or buildings.

There are indications, that behaviour was changed e.g elevators use in SI demo, reduced CO_2 concentrations in DK and IT case. variations can be observed/ understood when taking in to account people with their specifics and contexts combining self-reporting, observations and measurements where possible. Self-reporting can differ to what we measure. We had certain conclusions presented

in this repot thanks to measured results enriched with qualitative investigations. As shown in CBA, we quantified some of the impacts, that are traditionally not expressed with numbers.

We learned, that one needs to deal with people regularly. The People want a feeling of being in control. It is frustrating, when the sensor instructs you to take action, but you simply cannot. Sensors, when giving feedback to the people, have to be understandable and related to an action people can very easily do [1].

Habits and long-lasting practices are formed in communities, neighbourhoods and circles of friends through peer pressure in offline and online social networks, and in families and educational institutions by “top-down” supervision and control [11].

The application of the CBA, where impacts of the project were monetized, allowed to make potential benefits tangible (thus, more understandable by users). Although the application did not show always positive results (i.e. benefits do not always overcome costs), it allowed to identify relevant impacts to leverage on to engage people in changing their habits in different environments (i.e. residential and non-residential buildings) and given certain available data.

These are lessons learned that should encourage us to further develop appropriate solutions together with the people to apply the right technologies to serve their needs.

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