

Behavioral Change towards EE by Utilizing ICT Tools †

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Abstract: Due to end-users' habit being one of the prominent factors influencing building performance, changing user behavior to encourage energy efficient habits has tremendous potential to facilitate energy savings. Four ongoing European projects, eTeacher, FEEdBACK, InBetween, and UtilitEE, developed ICT solutions achieve this change through triggering mechanisms, informative feedback, gamification, and automation services within a human-centric and context aware framework. This paper provides each project's methodology to enhance end-user engagement of their respective approach, methodology to assess the expected results, technical and legal challenges, and the preliminary results of their ICT solutions, which have also been presented at Sustainable Places 2020 conference.

Keywords: behavioral change; energy efficiency; ICT

1. Introduction

As the energy consumption habits of end-users have been identified as one of the parameters influencing building performance the most, a behavioral change towards more energy-efficient activities and lifestyles promises a significant potential for energy savings.

Four ongoing European projects, eTeacher, FEEdBACK, InBetween, and UtilitEE, focus on creating innovative ICT tools aiming at raising awareness towards energy efficiency, motivating end-users to adapt more sustainable routines, helping them identify energy waste and fostering the transition to overall more efficient behaviors. The developed solutions are designed to achieve a change in user mentality and establish more efficient usage habits through triggering mechanisms, informative feedback, gamification, and automation services within a human-centric and context-aware framework.

In this workshop, part of the Sustainable Places conference, a platform for the dissemination of research of Horizon 2020 EU projects and networking between stakeholders of all types, these four

projects joined forces in order to present and discuss their work and preliminary results. The latest advancements of the developed ICT tools were presented through interactive sessions, and the major opportunities and challenges arising were discussed.

2. Proposed Methodologies for Enhancement of End-User Engagement

This section was dedicated to the different approaches adopted within the four projects towards achieving maximum user acceptance and optimizing impact through interactive services.

2.1. UtilitEE

The goal of the UtilitEE project is to support the transformation of traditional utility business models towards concepts that are compatible with the energy transition in Europe. This is achieved by developing a universal behavioral change framework that relies on the use of innovative ICT solutions. To ensure a high level of end-user engagement, UtilitEE applies the approach of Living Labs (LL), which "(...) are defined as user-centered, open innovation ecosystems based on a systematic user co-creation approach integrating research and innovation processes in real-life communities and settings" [1]. The aim of the UtilitEE LL is to identify the users' needs and preferences regarding the ICT-based behavioral change framework and to directly incorporate their feedback during the development phase. To maintain the high level of user-centricity throughout the entire project period, the initial setup of the LL is followed-up by three more rounds of intensified end-user engagement at each of UtilitEE's five pilot sites across Europe. These business-to-customer LL activities are complemented by business-to-business LL activities to ensure that the needs and experiences of potential adopters of the UtilitEE solution are taken into account as well.

2.2. eTEACHER

For eTEACHER, energy end-user engagement is key for the project's success. Therefore, eTEACHER sought to develop and tailor effective behavior change intervention, based upon research evidence, consultation with energy end-users, and a pre-chosen structured framework for designing behavioral change initiatives, the "Enabling Change framework" [1]. "Enabling Change" is an evidence-based approach which advocates a participatory approach to project development, at both whole-programme level and with relation to specific interventions on the ground. As part of this approach, Feedback Forums, a group of key building stakeholders and actors who could provide feedback on key ideas and concepts for the development of the eTEACHER tool, were formed in each of the 12 pilot buildings that eTEACHER is being trialled in. The Feedback Forums acted as a means of co-creation during the tool planning and development phase and allowed for user experience feedback during the implementation and demonstration phase of the project.

eTEACHER has incorporated end-user engagement across all phases of the project duration, allowing for end-user feedback to not only help steer the tool design but also tailor the intervention roll-out and subsequent engagement activities throughout the demonstration phase. This approach, we believe, will maximize the end-user acceptance of our eTEACHER tool and optimize its impact on improving energy efficiency across a wide range of building types and building user groups.

2.3. InBetween

Inducing a behavioral change towards EE represents an unsolved societal challenge with potentially enormous environmental impact, but it is still difficult to get people to adopt a more energy-efficient lifestyle due to several reasons, among which the low capability to change energy demand patterns and energy use practices of individuals. The InBetween solutions is a platform with two interfaces for the different types of "digital users": a mobile application (SEM app) and a web browser application (WiTMo). They were both designed to tackle barriers related to Users agency (e.g., low motivation to save energy, and lack of knowledge of how to save energy) and capacity (difficulty or inability to act in order to save energy). At the initial stage of the project, it was envisioned that the web platform would be mainly targeted to building/facility managers, providing

more advanced functionalities for data analysis than the SEM mobile app. However, during the baseline period it was decided that the web interface would be also made available to the end-users that for different reasons would not have access to the SEM mobile app, either because they did not own/use smartphones, or because they preferred to use their PC to access the services of the InBetween platform, or because they only own devices with iOS operating system, and therefore could not install the app. The InBetween platform has been used by two demo sites in the project. The first demo site is located in a rural region of Austria and offers both non-residential and residential buildings, while the second demo site is located in an urban area in France, and presents social housing dwellings.

The process of engaging end-user could be summarized in three macro-phases: (1) enrolling them in the project, (2) installing the sensors, and (3) engage them with the InBetween platform. An initial survey was prepared and submitted at the beginning of the project (2018). It aimed at collecting information about the technical characterization of the buildings, socio-economic information of the participants and their expectations about the project. It consisted of face-to-face interviews in local language, accompanied by an information sheet. For the installation of sensors, use-cases were prepared for and together with the non-residential building owners and landlords. For the residential houses, different equipment versions have been tested: from very basic installations with the most essential equipment only up to very well-equipped apartments with added comfort and safety features. During the baselining phase (end 2018–end 2019) the aim was to avoid influencing participants' behavior (technical visits only). In April 2019, the first version of the app was released for early users and feedbacks collected through phone calls and visits and implemented. The validation phase started on 4th October 2019. In this phase, a survey was designed and executed for the potential consumers at the deployment test sites to identify (a) the barriers for technology acceptance; and (b) appropriate, trustworthy, and socially accepted agent/actor to introduce the technology. Initially planned as desk analysis, phone calls, and home visits were finally the preferred option for running this and the following surveys. Positive feedbacks were received. Insights on end-user engagement are reported in the conclusive deliverables of the project.

2.4. FEEdBACK

The goal of FEEdBACK is to bring about energy reduction in buildings through behavior change; from the beginning of the project, it was identified that user engagement and commitment to change were integral to success.

FEEdBACK developed an interactive app platform that combines gamification with real-time data feedback and personalized messages based on sensor data and in-game activity. The gamification content was developed using feedback from users in early-stage engagement events and activities including workshops, interviews, and a comprehensive user profiling survey. The app collects users' gameplay data, monitors logins, and level of progression. Players gain badges for interaction and receive reminders in the form of video or text messages.

The project combined user profiles and player feedback with social cognitive theory and spaced learning methodologies, to develop TV Novella style drama and character-based games which show players their own behaviors through relatable characters. These characters grow and develop to become more engaged in positive energy reduction behavior in a way that users would recognize and engage with.

Within the 12-part campaign game, players are encouraged to interact with the building's energy consumption and are guided to address their own energy bad habits through tasks, challenges and quizzes.

FEEdBACK's combination of gamification and learning with an emphasis on ownership of one's own energy behavior through an immersive campaign game is designed to keep users engaged throughout the competition and to maintain behavior change after completion.

3. Validation and Impact Assessment Methodologies

This section was focused on the design of effective methodologies for the evaluation of the results expected from the different ICT solutions presented, and the assessment of their impact on the consumption behavior of the end-users such as their comfort or acceptance.

3.1. UtilitEE

UtilitEE attempts to define the optimum point or in other words the trade-off between three main pillars of the project by answering, through the validation process, the three fundamentals to the project objectives/questions:

1. Energy Efficiency—How much energy can be saved?
2. User Acceptance—What's the tolerance of the end-users with regards to their energy usage habits and comfort preferences to achieve energy consumption reduction?
3. Degree of Automation—How automated an energy management system should be to fulfil the user's requirements?

The validation plan must take into account the evaluation criteria defined within the project, in line with the three assessment categories defined to evaluate whether the project objectives are fulfilled: (1) Technical assessment of the UTILITEE framework: focusing on the UTILITEE requirements defined within the project, this evaluation pillar aims at the system performance assessment from the perspective of the final users as well as from technical developers and pilot leaders in the consortium. (2) Impact assessment of the UTILITEE framework: the impact analysis must be defined so that all the critical aspects of the UTILITEE framework performance reflecting the achievement of the project objectives are examined. In this context, the evaluation criteria are categorized into four domains: the Energy, the (Indoor) Environmental, the Behavioral, and the Business impact of the UTILITEE framework; and (3) User acceptance assessment of the UTILITEE framework: referring to the acceptance, reliability, learnability, and attractiveness achieved by the UTILITEE system with regards to its users and to other people affected by its use.

3.2. eTEACHER

eTEACHER validation and impact assessment aim at (1) identifying behavior changes of building users towards energy efficiency and better indoor conditions encouraged by the project tools and (2) evaluating the impact and effects of those behavior changes regarding energy savings and improvement of indoor conditions.

For that purpose, eTEACHER has defined a methodology that uses measured and self-reported evidences and is based on three methods: (a) monitoring to collect data on energy consumption, outdoor and indoor conditions; (b) eTEACHER app to collect information related to users interaction (number of users registered, number of active users, etc.) and (c) feedback forum & surveys to gather the opinion of the building users. In addition, key performance indicators (KPIs) that represent project impact and success are calculated. An important aspect of the methodology is the experimental design which consists of comparing control environments (environments without eTEACHER) with study environments (environments with eTEACHER) before and after the deployment of eTEACHER to draw conclusions regarding behavior change caused by the project tools.

3.3. InBetween

InBetween overarching objective was to engage end-users to identify energy wastes, teach them how they can avoid wastes and conserve energy, motivate them to act and, finally, assist them to carry out energy efficiency practices. For this purpose, an IoT-enabled cloud platform was established and advance energy services were developed yielding an affordable solution that offers added value without significant disruption of end-users' every day activities and comfort. Such ambitious goals required a sophisticated validation and impact assessment methodology.

The cornerstone of employed validation methodology was the widely adopted International Performance Measurement and Verification Protocol (IPMVP), where the “Option C” was selected since the savings were quantified by continuously measuring energy use, using smart meters and heat meters, on the household level over the entire reporting period. Moreover, for specific demand types (e.g., heating, DHW etc.), additional sub-metering was employed. To be able to validate the platform effectiveness, a range of KPIs was derived, which can be divided into three main categories: (1) energy use (e.g., total consumption per energy carrier, normalized consumption per are, number of inhabitants, CO₂ emissions, peak load indicator, load match index, etc.); (2) comfort (e.g., indicators such thermal discomfort, stale air, volatile organic compounds, etc.); and (3) user engagement (platform usage, number of interactions etc.). Nevertheless, a tailored subset of KPIs was offered to each of the three stakeholder groups, i.e., platform end-users, demo site owners and supervisors, and platform maintenance and R&D teams, according to their requirements.

Finally, in some cases, the adopted validation methodology was customised to overcome unavoidable factors, influencing reliability of results, such as data availability, combination of invoice and monitored data, precision of HDD corrections, change of habits during COVID-19 lockdown, and ability to associate the cause of energy savings.

The impact assessment on end-user behavior was based on several user engagement and technology acceptance indicators. Namely, engagement with the platform was assessed from the intensity of interactions between end-users and the platform (e.g., number of sessions in a mobile app, most frequently used features etc.) and usage of control functions of the platform (e.g., remote appliance control, appliance working hours scheduling etc.). Moreover, end-user engagement was also analyzed by measuring their level of compliance to recommendations issued by the platform. In other words, we were able to track and associate end-user actions with a specific energy conservation recommendation (via notification within the InBetween mobile App), within a given timeframe. Finally, end-user satisfaction was monitored via a built-in feedback mechanism (5-star rating) within platform user interfaces.

4. Technical and Legal Challenges

This section was dedicated to the discussion of the different challenges identified during the development phase of the four projects. Such challenges include monitoring technology implementation, data quality, personal data protection, system interoperability, data analysis, application, and gamification development issues.

4.1. UtilitEE

The behavioral change framework developed in the UtilitEE project is a modular solution combining a locally installed IoT network, cutting edge data analysis, UIs for both utilities and prosumers, and a remote control and automation service. Due to the solution complexity, several challenges occurred during its implementation, including, the challenges related to the physical equipment deployment and maintenance and the challenges related to the integration and seamless interoperability of the system components, each developed by a different partner.

From the first perspective, various challenges were encountered, related to the disperse locality of the pilot sites all over Europe that complicated the installation and commissioning process of the equipment, resulted in communication issues that also threatened the collected data quality and the raised considerations related to personal data handling. From the second perspective, the main challenges faced were related to the fact that several partners contributed to the development of the system components. In both cases, a number of strategic solutions contributed to overcoming these challenges relying on the establishment of continuous communication between the pilots and the technical partners, the clear responsibility definitions and the open error reporting which allowed a swift and effective troubleshooting process. Furthermore, a robust data management system was established to ensure the quality of the collected information, and also General Data Protection Regulation (GDPR) compliance throughout the project. Last but not least, support materials

including manuals and instructions translated in the native language of all pilot partners, were produced to develop a local, first level of technical support.

4.2. FEEdBACK

In the course of the FEEdBACK project, we developed an ICT-based platform that encompasses various applications meant to aid the end-user and the facility manager to realize energy savings through behavioral change. The main technical challenges faced in the development process can be separated into the following groups: the seamless integration of applications, the interaction with gamification, and the creation of the multisensor solution. The development of applications by several partners posed a challenge to code compatibility and management of inputs and outputs, which was resolved by implementing specific API and deployment of container environments to execute scripts. Moreover, running the project in three demonstration sites required a particular management strategy of multiple different databases. The applied gamification technique had to encourage the user to engage regularly. We resolved it by introducing a scoring system, progression by levels, and various learning objects, such as games and videos, embedded using special data structures. In addition, the multi-platform availability for Android and iOS was enabled using the Unity 3D game engine. To efficiently collect on-site measurements, we developed a multisensor solution capable of recording humidity, temperature, CO₂ concentration, and luminosity in the indoor space. The custom-created PCB-based device enables real-time communication through existing Wi-Fi networks and allows information storage. The low cost and low energy consumption respond to the challenge of mass-installation in large demonstration sites.

4.3. eTEACHER

The main technical challenges addressed by eTEACHER project are related to the monitoring technology and data quality; the system interoperability and the data processing. The project has identified that wireless technology is not ready for big buildings and that many monitoring devices do not meet commercial specifications. The main problems experienced with wireless monitoring devices are lack of signal coverage and short duration of devices batteries. In addition, the manipulations of devices by the building users have caused important problems. In consequence, the project had to address a number of data quality challenges such as lack of measurements, data gaps and sensors sending the same value. The solutions adopted by the project are based on the implementation of algorithms for automatic data validation and a continuous supervision and maintenance of monitoring devices and data quality by project partners.

Another important challenge is the interoperability with the building systems and in between the different eTEACHER tools. The solution developed consists of using the Internet for technical interoperability; using a new data format specified as eTEACHER API for synthetical interoperability, and a set of tools including a common relational database (Cloud SQL-DB); a synchronization tool; an API and an OPC server (open platform communication unified architecture). Finally, some challenges addressed by the data processing services to be highlighted are its applicability regardless of data available; continuous and real-time availability during building operation; versatility or flexibility to be applied to any kind of building, and scalability.

4.4. InBetween

During the course of InBetween project, a number of technical challenges were faced ranging from monitoring platform implementation, underlying interoperability issues, quality of assessed data, personal data protection, and development of specific energy services.

The monitoring and automation platform was overall set-up using a single IoT vendor, offering a vast majority of sensors and actuators (except smart radiator thermostats), and the communication interoperability was inherently solved. However, the utilized wireless technology was not suitable in some cases (e.g., large and detached houses) due to the range issues, which were resolved with signal corresponding repeaters. Expected issues such as loss of internet connection and wasted

batteries on sensors were significantly influencing data quality since the data collection was based “on change” and it was hard to distinguish the case when there was no real change in measurement or something is wrong with the connection or sensor itself. This was solved by improving gateway firmware and adding features allowing the detection of such cases. The sensors generally provided accurate data (except from some outliers) apart from the external meter interface (opto-electric device) for smart meters, which in some cases was hard to set correctly. Moreover, in some cases, where on-site renewables (i.e., PV plant) were connected via smart meters to the grid, it was not possible to use such metering interface due to mixing of energy import and export. The semantic interoperability was solved with the introduction of a custom canonical data model and messaging format as well as an ontology-based repository. Personal data protection was tackled from the platform design and end-user data were pseudonymized across the entire platform, i.e., a correlation between physical persons and user IDs was known only to demo site owners.

When it comes to the development of InBetween advanced energy services, the main technical issue was to acquire complete datasets for analytical services. For example, for the non-intrusive load monitoring (NILM), in some cases, there were issues to gather representative training datasets (with labelled data) and suitable open datasets were used instead. However, there were also technical challenges, e.g., to operate a real-time notification service. This service represents a rule-based engine that simultaneously assesses sensor measurements from all end-users and cross-correlate them with the contextual knowledge stored in an ontology to deliver suitable energy conservation measures to end-users in close to real-time (2–3 s).

Finally, all the legal challenges were mainly related to the GDPR and they were systematically treated from the project beginning using the corresponding end-user consent forms and consortium agreement among key service providers.

5. Preliminary Results Presentation

In this section, participating projects would have presented their preliminary results concerning energy change and their conclusions to best practices and lessons learnt. However, due to the COVID-19 pandemic, some phases within projects were affected and delayed. As such, only UtilitEE presented their preliminary results.

UtilitEE

The validation of the UtilitEE system is conducted through launching a series of behavioral change campaigns based on personalized and context-aware recommendations, defined by the project’s pilot partners (utilities and energy providers) based on their business strategy and the end-users’ segmentation according to their beliefs and values. The outcomes of the campaigns are evaluated under a set of Key Performance Indicators assessing indoor comfort, energy efficiency, cost-effectiveness of the system, and end-user acceptance. The ongoing validation activities of UtilitEE have been significantly delayed by the COVID-19 pandemic, which has posed a number of challenges to the project. These challenges include difficulties in the local installations maintenance when on-site visits are required, and inability to validate the solution in commercial buildings which remain unoccupied due to the remote work strategies adopted within the social distancing policies of most EU countries. The overall situation further influences the validation procedure as the baseline defined in the project is no longer representative of the energy consumption patterns of the end-users. Nevertheless, the UtilitEE partners have also identified new opportunities in this extraordinary situation as residential users get to interact with the system for a longer period. On top of that, valuable information related to the energy usage of end-users in times of crisis can be extracted. In this context, and in addition to its validation activities, UtilitEE is currently investigating the emerging consumption patterns of the pilot users and how they are influenced by different demographic factors, aiming to better understand the behavioral aspects of energy consumption.

6. Concluding Remarks

Four ongoing European projects, eTeacher, FEEdBACK, InBetween, and UtilitEE, under the same call, have been discussed during the workshop with valuable outcomes derived that showcase some uniformity on the implementation approach to achieve objectives and some differentiation driven by the specific objectives of each project.

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