Improving Energy Awareness Integrating Persuasive Game, Feedback, and Social Interaction into the Novel Ener-SCAPE Application

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Abstract— **Ener-SCAPE is a novel work in progress software framework made up of a persuasive game, a graphical interface to monitor energy usage and a tool for social interaction, which aims to improve the energy consumption awareness of its users at home as well as in the workplace. The game uses a common "escape room" game approach, tailoring the game archetype to focus on energy efficiency and energy consumption awareness. The monitoring interface allows the users to monitor some predefined energy efficiency indexes. The tool for social integration helps users to build social awareness. Users play the game by trying to exit from a virtual home or office by solving energy puzzles, working to improve their energy savings in their real environment, and sharing their acquired knowledge and experiences. Ener-SCAPE implements a unique feedback mechanism based on real energy consumption that leads consumers to apply what they have learned from the virtual reality of the game into their daily real lives. An important aspect of this work is that it merges different elements, which emerged as successful in achieving improved energy awareness, i.e., feedback mechanisms, serious games and social interaction.**

Keywords-energy awareness*; *serious game; educational game*; *escape room game; energy efficiency; feedback mechanism; social network interaction.

I. INTRODUCTION

This work is the extension of a study [1] that presents the design of a novel application and related underlying software framework whose main aim is to decrease the energy consumption levels both at home and in the office by increasing the consumption awareness of energy users. With respect to the previous study, this work presents an expanded literature review, the software framework is described in depth, the business model for the possible development of Ener-SCAPE as a product to market is showed, and suggestions for future works are presented. The main target of both works is reducing energy consumption caused through or careless energy use.

Energy consumption is steadily increasing worldwide, despite mitigation efforts, particularly in those countries that are experiencing a great economic growth. This is a global issue for environmental protection, as well as an economic and political issue, for countries that depend on foreign energy suppliers.

Many solutions are being proposed and implemented in order to address increasing energy consumption, such as incentives for renewable energy sources, new technologies for highly efficient buildings, new technologies for more efficient appliances, and more sustainable transportation.

People consume energy every day, not only for their basic needs, but also for making their lives more enjoyable, comfortable and improving their standard of living. Thus, if people are not driven to save energy and encouraged to improve their energy consumption behaviour in their everyday lives, lifestyle choices may frustrate savings coming from aforementioned engineering solutions [1][2][3]. Despite efforts to improve energy efficiency, the aggregate energy consumption behaviour in the transportation and residential sectors is responsible for a significant percentage of the overall energy consumption worldwide. Studies conducted in various countries have concluded that 26% to 36% of residential energy consumption is a result of household behaviour [2]. For example, behavioural change in the use of standby equipment can lead to energy saving up to 35% [4]. For this reason, the energy policy adopted by many countries is focused on Energy Consumption Awareness (ECA). The main factors that may influence energy consumption behaviours of citizens are environmental education, real time control of energy consumption, involvement of young people, and overall greater energy consumption awareness. Thus, ECA policies can be strategic for energy consumption reductions.

With the growing number of products and devices in homes and offices, keeping up-to-date with energy efficiency measures may be a difficult task. However, as more devices are able to communicate with each other, consumers will be able to look for more innovative and accessible ways to manage and learn about energy efficiency. Nevertheless, this kind of knowledge is a necessary but not sufficient condition for energy saving [5]. Indeed, studies generally demonstrate that information can increase knowledge, but has minimal effects on behaviour [6]. In order to reach significant savings, knowledge must be associated with energy awareness, motivational factors (such as curiosity), cost considerations, and willingness [7]. As a consequence, citizens should be "energy aware" in order to change their behaviour and save energy.

Behaviours improving energy efficiency are generally seen as factors reducing comfort. Actually, this is a misconception and people do not have to give up activities or their standard of living to save energy. On the contrary, new technologies and more effective behaviour will allow citizens to do more: improving their living conditions without compromising their standards. Furthermore, energy efficiency improvement can also lead to lower costs and greater sustainability, which is another important opportunity to stimulate economic growth.

This work aims to complement and build upon current initiatives. The goal of the novel proposed application is to improve the energy consumption awareness of people both at home and in the office, by employing three features: (i) a well-known and successful game model, (ii) a real-time intuitive feedback on consumption and (iii) a close collaboration with other players/consumers.

In Section II, the state of the art on feedback impacts, persuasive games, and social interaction on energy awareness is reported. In Section III, the different Ener-SCAPE applications are fully described. In Section IV, the scheduled experimentation plan is described. In Section V, the business model is explained. In Section VI, the conclusion and details of future works are given.

II. Literature Review

In the last few years several institutions, including the European Union (EU), have become increasingly committed to promoting a higher awareness of energy consumption. For this purpose, the EU has launched several initiatives and published several documents, especially directed at children and adolescents. Both in the EU and in the United States, labels reporting the energy consumption of household appliances have been introduced to inform consumers in a simple and direct way about energy efficiency of products [8][9]. In addition, information campaigns for raising awareness in energy consumption have spread. These actions produce long-term results, in particular, those focused on children [10].

But in order to obtain immediate results, feedback on consumption is frequently adopted to improve energy awareness. In the few last years, several studies have analysed the effectiveness of feedback as a tool for promoting energy savings at home. They generally report savings in a wide range (from 1.1% to over 20%) but usual savings are between 5% and 12% [11][12]. Fischer [11] lists the relevant features of feedback that may determine its effectiveness: frequency, duration, content, breakdown, medium and way of presentation, comparison, and combination with other instruments. The study shows that the most successful results come from feedback that is given frequently over a long period of time, provides an appliance-specific breakdown, is presented in a clear and appealing way, and uses computerised and interactive tools [11]. In order to promote energy savings, the consumers should first be made aware of the amount of energy they are consuming, so that they can then learn how they can improve their behaviour. Users should identify potential savings in their environment, by knowing how and where energy is actually used: this requires users to be aware not only of the overall energy consumption reported in their bills, but also at the appliance level. Reinhart et al. [13] have designed a system, called Ubiquitous Smart Energy Management (USEM), which is not only a simple automated solution to reduce electricity usage, but also provides detailed energy consumption information and incorporates mobile tools to assist and encourage users at improving their energy consumption behaviour. Some research projects, e.g., BeAware [14], or commercial products, e.g., Ecosphere [15], aim at motivating users to be more responsible in their use of electric appliances by showing real-time energy consumption feedback through intuitive user interfaces. Recent studies prove that this kind of feedback is enough, by itself, to reduce consumption by 15% [16]. Feedback can stimulate energy conservation only with the presence of motivational factors, cost considerations and altruistic or environmental concerns [12]. Some studies in the literature [17][18] show that the custom and real-time feedback on energy consumption is effective in consumption reduction.

Persuasive technologies have proven useful in modifying behaviours related to energy usage. A potential way to drive awareness is through the so called “serious games”, i.e., interactive virtual simulations whose main purpose is the development of user abilities and skills in a simulated environment with the aim of apply them in the real world. Recent studies suggest that the effectiveness of learning increases when it is active, experiential, situated, problem-based, and provides immediate feedback [19]. Indeed, literature proves that serious games can influence people change behaviours and attitudes in the areas of health, public policy, education and training [20], and notably for our purposes, energy [21]. Additionally, environmental awareness and attitudes toward environmental preservation can be promoted by simulation games [22]. Finally, simulation games can efficiently guide players with improving their environmental knowledge, attitudes, and behaviour [7].

Many serious games have been developed with the aim to increase knowledge and awareness about ecological and energy issues. Ecoville [23] is an interactive game, where the mission is to build a sustainable energy community constrained by resource, pollution and budget limits, by handling the energy balance, CO_2 emissions, garbage disposal, etc. EnerCities [24] further develops the concept: in this game, based on the Theory of Planned Behaviour [25], players have to balance three variables: population, planet, and profit. Power Agent [26] and Power Explorer [27] are two "pervasive games" that put family members in competition to reduce the domestic consumption as measured by sensors, pointing out the difference between player and non-player behaviours through an avatar helping to convey best practices in energy efficiency.

Even though there have been relatively good results, serious games still remain a "niche" field. The main limits to their popularity are their target audience (scholars and families, often very different from the average users and far from the gaming community), as well as the perception that educational games are boring, and also the lack of entertainment features that characterize traditional games. Moreover, the majority of serious games produced so far come from research projects, thus, there is not a large library of commercial games on the market, and the genre has not generated significant results in terms of revenue and profits.

In the recent years, some projects combining feedback mechanism and serious gaming have been developed with the purpose of promoting behavioural changes in energy consumption at home. As part of the EU funded project SOFIA [28], a product implementing game elements was designed for families with children with the aim of improving environmentally responsible behaviour in domestic energy consumption. Furthermore, Yang et al. [7] have developed a system called Energy COnservation PET (ECOPET): using a game-based learning strategy, with the help of a pet avatar, players are encouraged to use home-energy efficiently. The main distinctive feature of these last two products is the in-game implementation of a feedback mechanism, which helps learners to use electric appliances properly [7][28].

Finally, it is worth highlighting the social nature of this topic. Recent studies have showed that "energy consumption is a social and collective process rather than individual" [29]. A social debate, for example, by way of social network, can make people build common awareness. People, initially reluctant to change their behaviour, can be motivated to act in a more responsible way by interaction with other people. Several years ago, Mankoff et al. [30] already demonstrated a motivational effect for saving energy by integrating energy usage feedback to the MySpace social network. Similarly, Foster et al. [31], by means of a novel Facebook application, have demonstrated that energy consumption can be reduced through social encouragement and competition. Obviously, only exchanging ideas or opinions is not enough to raise awareness and change people behaviours. Real consumption measurements play a fundamental role in allowing people to change their behaviour in a more conscious way [29]. Petkov et al. [32] have expanded the idea of social comparison with their social application EnergyWiz, which allows users to compare their energy usage with their own history and the history of other users.

The goal of this work is to exploit the potentiality supplied by feedback, serious games, and social interaction in a novel software framework, named Ener-SCAPE, which integrates all these aspects to improve the ECA of its users.

III. Ener-SCAPE

Ener-SCAPE is a software framework composed of a persuasive game, a monitoring tool for energy consumption that processes and shows data coming from a sensing infrastructure, and a tool for social interaction. It mainly aims at improving the awareness of energy consumers both in their homes and in buildings where they usually work.

The core of Ener-SCAPE is the game. The name itself recalls the game genre since it is based on: the "room escape", or "escape games" [33], which is a subgenre of the well-known point-and-click adventure games. In the game, players are tasked with escaping from an apartment or an office by solving rebus puzzles, through the use of specific information and the implementation of strategies. The escape game paradigm has been chosen because it allows the game to be located in a place similar to the one where people should put into practice what they have learned. Moreover, making users explore the house while trying to escape allows them to face realistic situations. Most of the suggestions for a better ECA are related to common energy loads from devices that can be found in most houses and offices. Additionally, working with virtual environments allows game designers to make the game experience more exciting, emotionally compelling and to provide new elements. In this way, information and sensations experienced are remembered and allow the player to sharpen their perception, attention and memory by promoting behavioural changes through "learning by doing" [34].

A. Framework Architecture

The logical architecture is subdivided into four layers: the Security Layer, Business Layer, Data Layer, and Presentation Layer. A graphical representation is provided in Figure 1.

The Security Layer implements all checks needed to authenticate users and authorise access to resources. The application is accessible both from personal computers (PC) and mobile devices (tablets, smartphones), after user authentication. The OAuth v2.0 [35] protocol has been chosen to securely share user data with the Ener-SCAPE applications: monitoring data are exchanged anonymously with a token identifying the user.

The Business Layer implements the business logic of the whole system and the data processing that leads to the results that will be provided to the users through the dashboard. The logical components of the Business Layer are grouped by their functions:

- Notification Management, whose purpose is to provide a service for the exchange of real-time notifications between the various architectural components, according to the Publish/Subscribe pattern;
- User Management, which represents the logical group of software components in charge of managing the basic user information (creation, editing, profiling), as well as the interaction with the Social Community;

- Energy Management, which comprises the components that acquire data from sensors and the components that retrieve consumption data from a remote database for all requests from users through the monitoring dashboard;
- Game Management, which manages the logic of the Ener-SCAPE game and provides all the functional components, from loading the assets of the game, to the client-side components at Presentation Layer;
- Smart Advice Management, which groups all the infrastructure components that are responsible for the production of Smart Advice, i.e., personalised pieces of advice aiming at reducing energy consumption;
- CEP Management, which comprises the components that deal with the Complex Event Processing (CEP) in real-time, to increase the situation awareness of the users and to support their decisions.

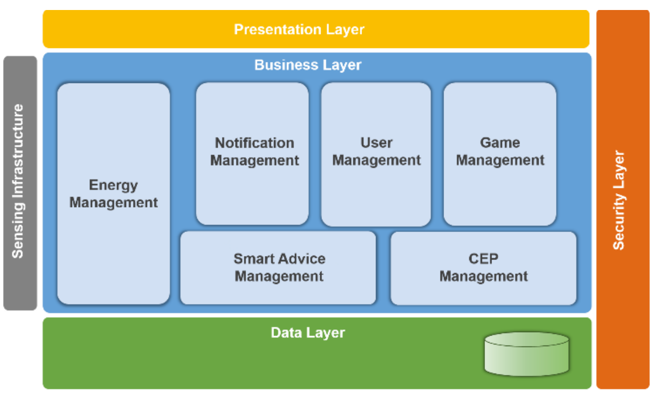

Figure 1. Ener-SCAPE high level architecture.

The Data Layer is the layer where interactions with the data storage are performed.

Finally, the Presentation Layer represents the application user interfaces (game, dashboard for monitoring energy performance, interface to interact with social networks).

All the taxonomic and non-taxonomic relationships between entities within the Ener-SCAPE application domain have been modelled in the Ener-SCAPE Ontology. This ontology is also at the basis of the feedback system to the end users aimed at increasing, in a personalised way, awareness of the impact of energy consumption actions. Feedback is made available to users on the monitoring dashboard in form of contextualised hints, or Smart Advice. The identification of the more appropriate piece of advice to be made available to the user is based on the real-time identification of contextual information: the advice is presented as one or more "hints" depending on user-specific factors, such as the type of dwelling and the consumption of electrical energy, as well as on environmental factors, such as climatic conditions during the period under observation. For example, in a region where the weather is warmer than expected, a user whose energy consumption during summer is higher than what has been forecasted, could be informed that the increase in consumption is probably because of the increased use of air conditioning in their home. In addition, a suggestion may be offered for improving the use of the air conditioning in order to reduce energy consumption. The production of personalised recommendations is done through semantic technologies. Circumstances relevant to users are described through Ontology Web Language (OWL) assertions. The different contexts that can be adapted to the user are logically organised according to a tree and each context is identified by a set of characteristics, such as type of dwelling where the user lives and the number of people living in the same house. The tips are then associated with one or more nodes in the tree. The task of determining what recommendations are appropriate for a given user is delegated to an ontological reasoner [18]. Hints proposed to the user have been gathered by seeking suggestions aiming at energy saving and efficiency on websites of institutions, government agencies, and consumer groups, as suggested in [3].

The CEP is a technology that enables processing and combining events from multiple sources to detect occurrences of special events that require a response from a system or from a human operator [36]. CEP is, therefore, a useful tool to increase the Situation Awareness, i.e., the awareness of the context. The use of CEP techniques in Ener-SCAPE, applied to consumption data and to the user profile, is a crucial step for the Energy Consumption Awareness. The CEP in Ener-SCAPE arises also as a valuable tool to report to end users (consumers, energy manager) criticalities and malfunctioning. Figure 2 shows the CEP architecture in Ener-SCAPE.

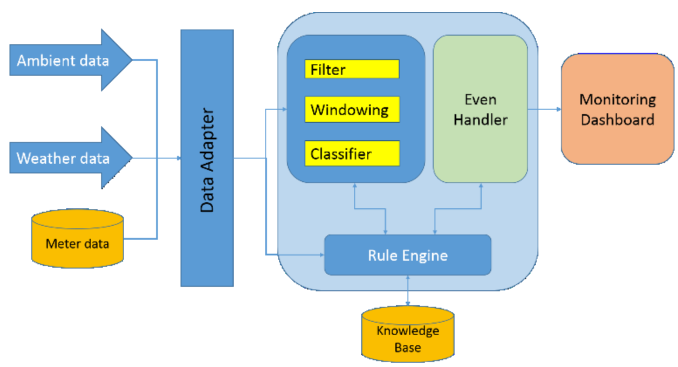

Figure 2. CEP architecture in Ener-SCAPE.

Two versions of the software framework are being developed: one related to a home environment and the other related to a building/campus environment. Both versions include and integrate the applications mentioned before: a dashboard for monitoring real energy consumption, which shows performance indicators and hints to improve performance; the escape game with two different approaches that will be described later; and the tool for integration with social networks (Facebook/Twitter/Google+) to allow collaboration between players/consumers.

The innovative aspect of the proposed approach is a simple but effective mechanism to integrate the three applications with the aim of converting existing successful models to an "edutainment" (education and entertainment) function.

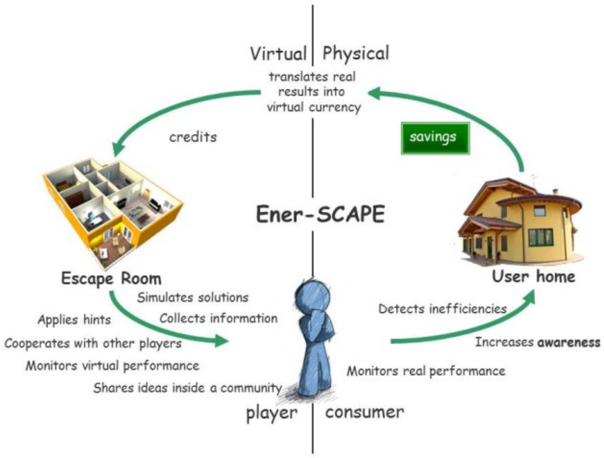

Figure 3. Ener-SCAPE approach to energy consumption awareness (home environment).

The cornerstone of the Ener-SCAPE game, as previously introduced, is essentially to escape from a house (or a building in the second version of the game) as in any escape room game. Escaping can only be achieved by solving a sequence of rebus puzzles (find items, combine them, use them, look for clues, piece together clues, gather information, find combinations, compose puzzles, solve riddles, etc.). The main feature of the game lies in the themes of each action: eco-sustainability, savings, efficiency, and energy-awareness. Moreover, effectiveness in acquiring ECA is given by the feedback from the real world. The game is integrated with a very simple and intuitive monitoring tool, which processes the data collected through a sensing infrastructure and allows consumers to see their real energy performance. The application allows the users to compare their current energy consumption with historical average values.

While playing, users acquire information (gained from the game or the social networks where they get useful tips for solving puzzles) that can also be used in the real world. The ultimate aim of the game is impacting consumer behaviour in their real lives. The monitoring dashboard provides a means to measure performance improvement, which is then translated into virtual currency that can be spent in the game to ease the escape. In order to facilitate the solution of a rebus puzzle, the users can utilise the virtual currency obtained from social network interactions. Indeed, users can cooperate with other consumers in specific social network groups: each consumer builds his or her own reputation by cooperating with the community in solving the escape room rebuses as well as in achieving better energy performance in the real world. A domain expert rewards the acquired reputation by assigning virtual currency to be spent in the game.

In this way, users at home will strive to improve their behaviour by trying to reach the optimal values of real performance indexes. Before addressing the optimal performance, the system proposes intermediate targets and rewards their achievements by assigning virtual currency to be spent in the game. In order to measure real performance, the user must install "off-the-shelf" sensors; solutions based on Non-Intrusive Appliance Load Monitoring (NIALM) are being taken into account as possible alternatives. Therefore, as can be seen in Figure 3, Ener-SCAPE implements a virtuous cycle that allows the consumer to learn how to efficiently use energy simply by playing the game. At home, the user can save or waste energy. Then, the dashboard graphically represents the real performances based on data coming from a sensing infrastructure installed in the home. The transition from the physical world to the virtual one corresponds to the translation of the real results into virtual currency, which in turn affects the consumer's ability to solve the rebuses in the virtual escape room. Finally, the beneficial cycle results in simulated solutions, information the user collects, applied hints, cooperation with other players, monitoring virtual performance, and sharing ideas inside a community. In this way, players may become consumers with increased energy consumption awareness that can help them to detect inefficiencies and improve their energy behaviour.

The game environment has been designed to be as graphically attractive as possible. In order to reach a good quality in architectural rendering, the free interior design software application Sweet Home 3D has been used [37].

Finally, the application was designed to be used on both PC and mobile devices, such as smartphones and tablets, in order to meet the requirements of usability and to avoid limiting the game to a single kind of device. Figure 4 shows a mock-up of the game in the tablet version in the home environment. On the right, there is a basket where discovered items are collected; at the bottom, there are some widgets where players can view their virtual and real performances, as well as their scores and hints. Figure 5. Mock-up of the dashboard (tablet version) in the home environment.

Figure 5 shows a mock-up of the dashboard in the tablet version in the home environment. The monitoring interface includes diagrams that give the users a representation of their consumption and performance. The user can select the time horizon, which can be daily, weekly, monthly or annually: the data will be temporally aggregated based on the selected time horizon. The user can also select the unit of energy consumption: kilowatt hours (kWh), EUR (€), grams of CO_2 (g CO_2), tonnes of oil equivalent (TOE). Users can compare their current consumption with the ideal average consumption for similar classes of consumers, previously profiled, and can check any possible abnormalities in their consumption caused by inefficiencies (see Figure 5). In the current version of the service platform, users are profiled on the basis of static information: e.g., in the home environment, size and type of the house, number, age and educational qualification of occupants, etc. This classification is probably not enough to catch the living style of users. Therefore, we are investigating how to model some aspects of the lifestyle that can be used as parameters, deduced dynamically from historical measurements, for user clustering.

Figure 4. Mock-up of the game (tablet version) in the home environment.

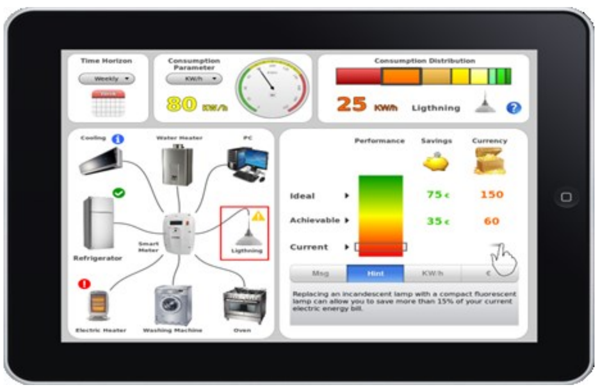

Figure 5. Mock-up of the dashboard (tablet version) in the home environment.

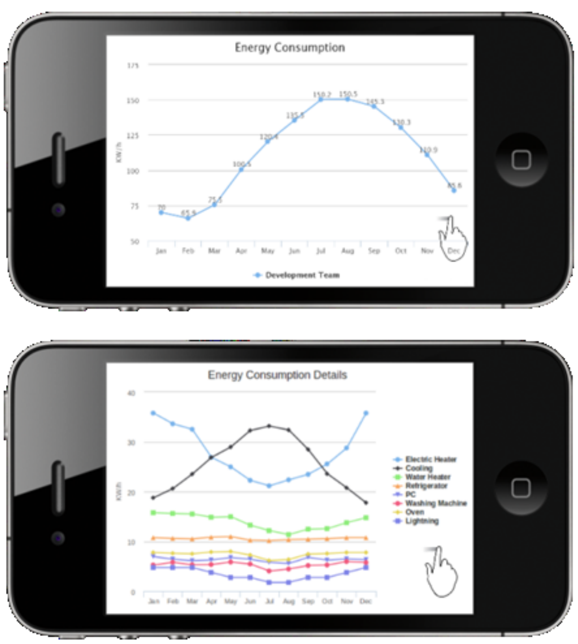

Figure 6. Energy consumption diagrams (smartphone version).

The access to energy consumption and performance values is enabled in multiple ways: by selecting household appliances in the star structure that represents the set of monitored devices (Figure 5), or by selecting a consumption category (e.g., heating, lighting, appliances, sockets, etc.).

Ener-SCAPE includes a feedback system to the end users, both in the home and in the building/campus contexts, in a personalised way to increase the awareness of the impact of their energy consumption actions. This approach is used in several ways and in a dedicated manner for the different actors in the system, e.g., suggesting:

- in the home environment, which appliance the user is using or has just used, and which device has exceeded a fixed threshold;
- inside the building/campus, the ineffective use of heating systems in relation to the outside temperature.

The feedback is made available to users on the dashboard in the form of “hints” (see Figure 5).

The monitoring dashboard shows the consumption trends, both cumulatively and per device. Users can also compare their current consumption with their historical consumption, as showed in Figure 6 and Figure 7 that depict the dashboard for smartphones.

The game version for an office environment (see Figure 8 for a mock-up of the PC version) has only one significant difference from the one for the home environment: it is an escape game played in teams. Thus, we had the chance to exploit the potentiality of collaborative learning in serious games [38]. Moreover, teams play against one another. In this way, we had also the chance to take advantage from recent studies results: Cagiltay et al. [39] have showed that creating a competition environment in a serious game makes motivation of learners improve significantly.

Figure 7. Energy consumption variation diagrams (smartphone version).

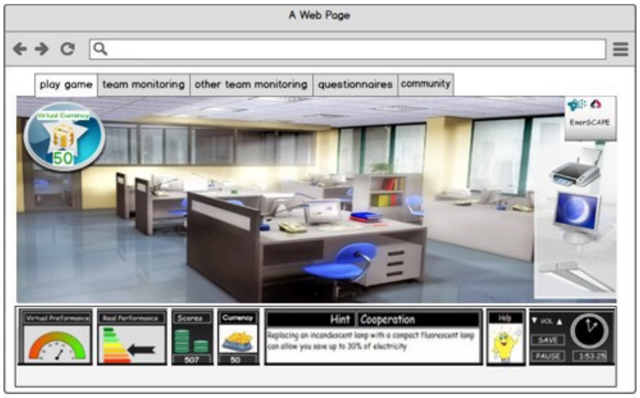

Figure 8. Mock-up of the game (PC version) in the building environment.

So, when motivation increases, learners tend to be more involved with the issue [40].

The basic idea of the game is identical to the one proposed for the home environment, but with the inclusion of other actors besides the previous single user/player: the energy manager (responsible for the coordination, management and efficient use of energy resources in the building/campus) and other users/players who live in the same environment and are energy consumers. In this case, as previously said, a mechanism for collaboration (among users belonging to the same team) and competition (with the other groups/teams of users) has been implemented. Members of the same team can exchange tips, information, and objects in the virtual world where they move. Every player can constantly see not only the results of his/her team but also the results of other teams. In order to improve the energy performance in the building(s), the energy manager will oversee the progress of the game, suggesting changes in behaviour, recommending precautions, or imposing guidelines. Furthermore, as in the home environment case, the user may take advantage of social networks as an important resource to acquire information and to earn virtual currency.

The beneficial cycle previously described for the office environment is represented in Figure 9.

Ener-SCAPE is currently in development but a complete and working prototype is already available for testers. Figure 10, Figure 11, Figure 12, and Figure 13 show some snapshots of the game and the monitoring tool for the PC version of Ener-SCAPE.

Figure 14 represents the Domain Expert interface: by accessing the application, a Domain Expert can interact with the Community through the major social networks (Twitter, Facebook, and Google+). When some members of the Community emerge by merit, for having provided useful pieces of advice and/or effective solutions, either for the game or for improving the performance in the real world, the Domain Expert can assign virtual currency to them.

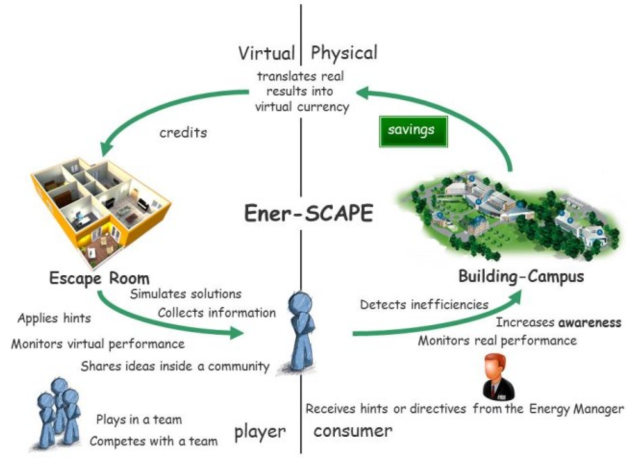

Figure 9. Ener-SCAPE approach to energy consumption awareness (building environment).

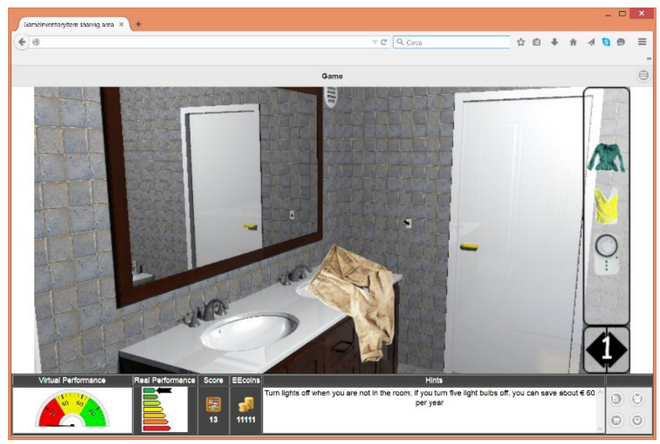

Figure 10. Snapshot of the game in the home environment for PC version

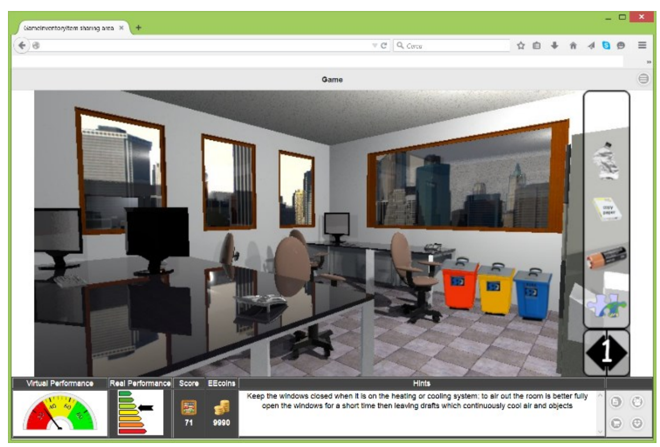

Figure 11. Snapshot of the game in the building environment for PC version.

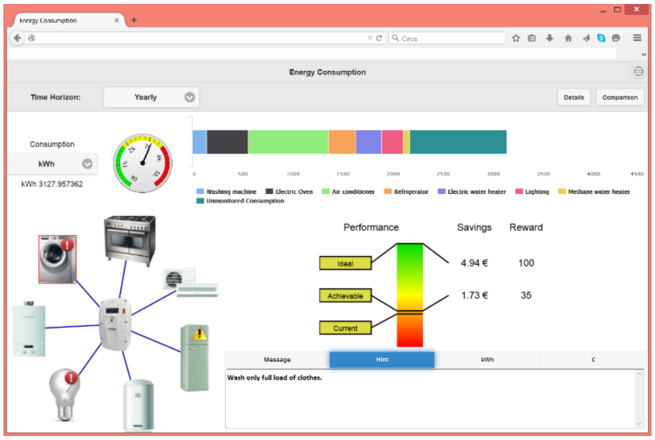

Figure 12. Snapshot of the monitoring dashboard for PC version.

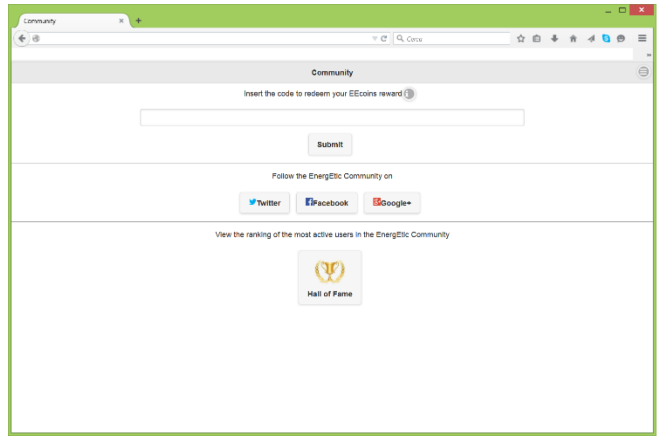

Figure 15. Player interface to redeem reward codes and to interact with the Community.

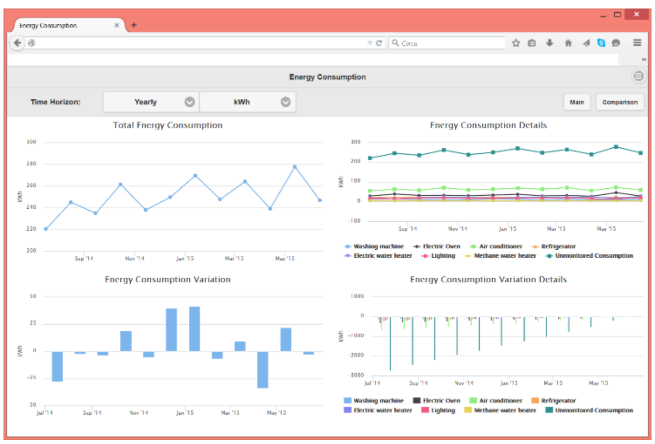

Figure 13. Energy consumption graphics in the version for PC.

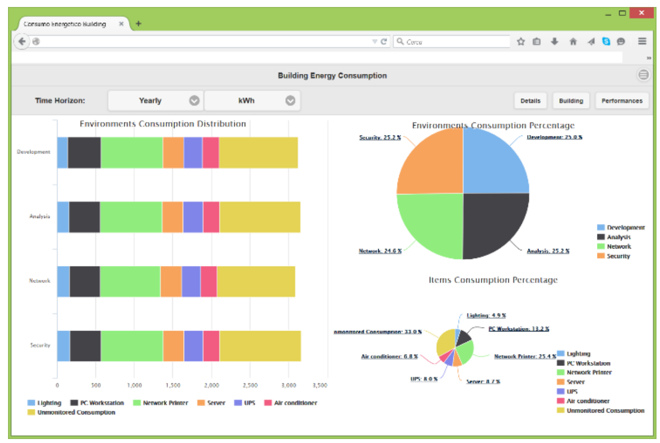

Figure 16. Energy Manager interface (PC version).

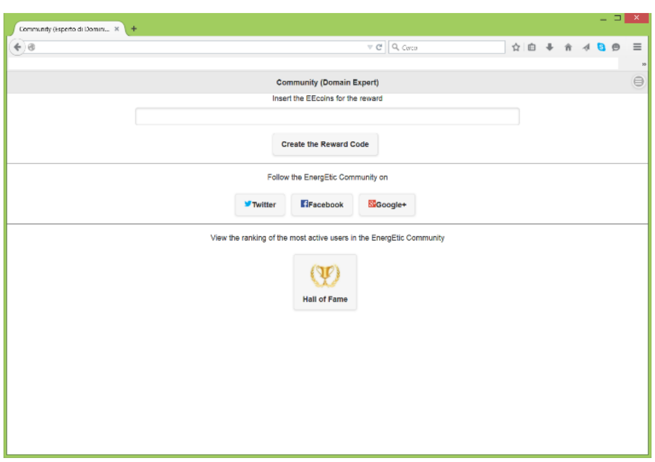

Figure 14. Domain Expert interface (PC version).

With this aim, the system generates the corresponding Reward Code (a string that is sent to the user through channels external to the application, e.g., via email, through the systems of internal chat on Facebook or Google+) for cashing in the virtual currency.

Figure 15 depicts the interface for the players to redeem the Reward Codes and to interact with the Community.

As the consumer user, the Energy Manager is provided with an interface that displays information to monitor consumption, cumulative or per device, from which he can deduce actions to induce improvements in energy efficiency, savings and economic sustainability (Figure 16).

IV. Experimentation Plan

In the light of a scientific validation of Ener-SCAPE, we intend to proceed with an experimentation phase aiming at gathering real data to evaluate the effectiveness of Ener-SCAPE. During the experimentation phase, we intend to evaluate both the home and the office version, adequately tailoring an experimentation plan. The home experimentation plan foresees the distribution of Ener-SCAPE and the sensing system to 20 users, chosen among the ones who will join the Ener-SCAPE public site and fill out the intention form for participating in the experimentation, including profiling data. The received applications will be then analysed and the users will be selected so as to have a statistical sample as diverse as possible. The office experimentation plan will be carried out at Engineering Ingegneria Informatica S.p.A. premises in Palermo, Italy.

In order to evaluate the results of this experimentation phase, a set of metrics has been identified and divided into quantitative metrics and qualitative metrics.

Quantitative metrics measure the effects of greater energy awareness. No preliminary consumption baseline is provided for the evaluation of the performance: users are clustered on the basis of a set of parameters (age, job, education, skills, etc.) provided during the preliminary registration phase. Their performance, both in home and in building/campus environment, are evaluated at a well-defined set of time slots (hour, day, week, month, etc.) and compared to their own past average values (starting from the beginning of the experimentation) or to the values of users belonging to the same cluster (e.g., the best user, the average one or the worst one). In order to have a greater persistence of the results, a massive amount of information must be acquired and assimilated slowly, so as to have a significant impact on the lifestyle of the consumer, rather than only on the performance recorded during the experimental period. The impact of Ener-SCAPE is expected to increase slowly with time, so that the comparison to the average performance, in the first part of the use of the application, can be considered as the comparison to the baseline.

TABLE I. INDIRECT QUALITATIVE METRICS

Application	Metrics
Feedback (monitoring)	Response to interaction Real-time perception Dashboard reliability Usefulness of shown information Completeness of shown information User-friendliness
Game (the escape room)	Conpliance to the Escape Room paradigm Perception of the entertaining aspect Appreciation of the entertaining aspect Perception of the educational aspect Appreciation of the educational aspect Appreciation of the graphical aspect *Appreciation of the team based Escape Room* *Appreciation of the competition mechanism* *Appreciation of the collaborative mechanism*
Social (community)	Usefulness of support to the community Reliability of information from the community Fairness of ranking mechanism

Qualitative metrics are subdivided into indirect metrics, aimed at assessing the user perception of the Ener-SCAPE application, and direct metrics, aimed at evaluating the effectiveness of Ener-SCAPE by evaluating the sensitivity acquired by the user in the field of eco-sustainability. In both cases, it has been decided to proceed by administering questionnaires to the users. In TABLE I, a list of indirect metrics are provided; specific metrics pertaining only to the business/campus case are reported in italic.

At the end of the experimentation phase, all the data collected will be analysed to evaluate the impact of Ener-SCAPE on the energy awareness.

V. Business Model

In recent years, big companies such as Google Inc. and Microsoft Corp. developed their own energy management tools. Both the initiatives have failed and their projects were closed after few years [41][42]. One reason can be found in the early stage of the market when the products were launched (2009). Indeed, very few smart meters and smart grid networks had been installed in those years. Additionally, Google and Microsoft probably did not follow the right distribution strategy, building only few partnerships with strategic partners. Starting from these two cases, and considering a possible launch of Ener-SCAPE into the market, we had the chance to develop new business models to avoid past mistakes.

Following the Business Model Canvas [43], we can analyse the possible development of Ener-SCAPE as a product to market. To do so, we have to consider separately the two versions of the software framework. The home version has individual users interested in energy and environmental issues, or interested in escape room games, as possible customers. Indeed, the game can be the driver to spread ECA even among people not directly interested in it. As a value proposition, Ener-SCAPE can increase ECA in an appealing and fresh way. Increasing the energy efficiency at home, users can save their money and respect the environment. We have identified two distribution channels: online selling in a dedicated web site or by partnership with a specialised third party as producers/sellers of energy sensing systems, energy retailers, energy service companies, consumers' associations, etc. We think that revenue could be produced after a year of software engineering and testing, during which the following resources will be utilised: software engineers, relational resources and technical resources. After this first phase, the promotion activity and a constant maintenance will be crucial. We have identified the following cost items: product realisation, promotion, maintenance, direct and indirect selling.

We have also done a business model of the building/campus version of Ener-SCAPE. Medium or large companies interested in their energy saving are possible customers of the product. The value proposition is the chance to save money consuming less energy. Distribution channels could include a direct sales force or selling by distributors/partners. The revenue plan is substantially the same as the plan seen for the Ener-SCAPE home version. Indeed, key resources, activities and cost structure are shared for both versions of the product. In the end, we can summarise that starting with relatively small investments, mostly concentrated in the first year, two marketable products may be obtained with good chance to generate incomes.

Finally, the reference market of Ener-SCAPE is in energy management software. Today, energy monitoring systems are offered by many big multinational companies such as

IBM Corporation, CISCO Systems, Inc., and the General Electric Company. However, this market is constantly developing, primarily due to the birth of the "Internet of Things" [44] and automation systems [45], and secondarily due to the great attention this market is calling. Despite the large amount of players, today there is no evidence that a product like Ener-SCAPE is already on the market. The distinctive feature is the simultaneous presence of a persuasive game in the form of an escape room game, a monitoring interface for the electric consumption and a tool for the integration with social networks. As a matter of fact, Ener-SCAPE strength lies in the cooperation of these three elements, to reach the same goal: providing the users with a greater ECA to get a better energy efficiency, save money and natural resources, and improve their lives.

VI. Conclusion and Future Work

This work proposes a pervasive and multi-platform application to improve energy consumption awareness. Following the results of a number of previous works found in the literature and analysed in depth, Ener-SCAPE has designed and developed an energy-aware application integrating successful elements for achieving energy consumption awareness: serious games, real time and detailed feedback on energy consumption and motivational factors coming from the social interaction in a community. In order to pave the way for possibly launching the application into the market, an experimentation phase has been scheduled inside the business plan. Corroborated by the use of elements that individually have been proven effective in increasing ECA, which have emerged as well known and widely utilized, we are confident on the effectiveness of this ongoing work.

Besides what is already planned, the monitoring tool can be extended and improved. Citizens consume not just electricity at their homes but also gas, water, and heat. Thus, the Ener-SCAPE monitoring interface could be enriched to evaluate all of these additional areas of consumption. In regards to the game, other exploratory works could be done with information and visualisation techniques. As an example, the home version could be expanded from a single player into a multiplayer game, by taking into consideration other households. The single user approach could be changed into a team-based one; trying to increase the ECA in all the household with a collaborative (and not only competitive) version of the game. This enhancement is supported by recent studies demonstrating that family relationships and dynamics have a lot of influence on ECA improvement [15]. Moreover, the age of the users and the contingent presence of children at home have been demonstrated as affecting the levels knowledge in energy related issues inside families [46].

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References

[1] D. Arnone, A. Rossi, E. G. Melodia, M. Mammina, and S. E. Jenkins, "Ener-SCAPE: A Novel Persuasive Game to Improve the Energy Consumption Awareness," The Fifth International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (Energy 2015), IARIA, May 2015, pp. 24-28, ISSN: 2308-412X.

[2] L. Adua, "To cool a sweltering earth: does energy efficiency improvement offset the climate impacts of lifestyle?" Energy Policy, Vol. 38 (10), pp. 5719–5732, Oct. 2010, doi: 10.1016/j.enpol.2010.05.021.

[3] C. Wilson, "Evaluating communication to optimise consumer-directed energy efficiency interventions," Energy Policy, Vol. 74, pp. 300–310, Sep. 2014, doi: 10.1016/j.enpol.2014.08.025.

[4] T. Dietz, G. T. Gardner, J. Gilligan, P. C. Stern, and M. P. Vandenbergh, "Household actions can provide a behavioural wedge to rapidly reduce US carbon emissions," Proc. Nat. Acad. Sci. USA, Vol. 106 (44), pp. 18452–18456, Oct. 2009, doi: 10.1073/pnas.0908738106.

[5] G. T. Gardner and P. C. Stern, "Environmental problems and human behaviour," (2nd ed.). Boston, 2002, MA: Pearson Custom.

[6] P. C. Stern, "Contributions of psychology to limiting climate change," Am. Psychol., Vol. 66 (4), pp. 303–314, Jun. 2011, doi: 10.1037/a0023235.

[7] J. C. Yang, K. H. Chien, and T. C. Liu, "A digital game-based learning system for energy education: an Energy COnservation PET," Turkish Online Journal of Educational Technology, Vol. 11 (2), pp. 27-37, Apr. 2012, Online ISSN: 1303-6521.

[8] New EU Energy Label, "Home page," [Online]. Available: http://www.newenergylabel.com/index.php/start/ [retrieved: July, 2015].

[9] Energy Star, "Home page," [Online]. Available: http://www.energystar.gov/ [retrieved: July, 2015].

[10] EUROPEAN COUNCIL - 25/26 MARCH 2010 - Europe 2020: a New European Strategy for Jobs and Growth. [Online]. Available: http://register.consilium.europa.eu/pdf/en/10/st00/st00007.en10.pdf [retrieved: July, 2015].

[11] C. Fischer, "Feedback on household electricity consumption: a tool for saving energy?," Energ. Effic., Vol. 1 (1), pp. 79-104, Feb. 2008, doi: 10.1007/s12053-008-9009-7.

[12] A. Nilsson, C. Jakobsson Bergstad, L. Thuvander, D. Andersson, K. Andersson, and P. Meiling, "Effects of continuous feedback on households' electricity consumption: potentials and barriers," Appl. Energ., Vol. 122, pp. 17–23, Feb. 2014, doi: 10.1016/j.apenergy.2014.01.060.

[13] F. Reinhart, K. Schlieper, M. Kugler, E. Andre, M. Masoodian, and B. Rogers, "Fostering Energy Awareness in Residential Homes Using Mobile Devices," The Fourth International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (Energy 2014), IARIA, Apr. 2014, pp. 35-43, ISSN: 2308-412X.

[14] BeAware, "Home page," [Online]. Available: http://www.energyawareness.eu/beaware/ [retrieved: July, 2015].

[15] S. Snow, D. Vyas, and M. Brereton, "When an eco-feedback system joins the family," Pers. Ubiquit. Comput., Online ISSN 1617-4917, Feb. 2015, doi: 10.1007/s00779-015-0839-y.

[16] S. D'Oca, S. P. Corgnati, and T. Buso, "Smart meters and energy savings in Italy: determining the effectiveness of persuasive communication in dwellings," Energy Res. Soc. Sci., Vol. 3, pp. 131–142, Sept. 2014, doi: 10.1016/j.erss.2014.07.015.

[17] S. Darby, "The effectiveness of feedback on energy consumption. A review for DEFRA of the literature on metering, billing and direct displays," Environmental Change Institute, University of Oxford, Apr. 2006, [Online]. Available: http://www.eci.ox.ac.uk/research/energy/electric-metering.php.

[18] P. Chaussecourte, B. Glimm, I. Horrocks, B. Motik, and L. Pierre, "The Energy Management Adviser at EDF," Proc. 12th International Semantic Web Conference (ISWC 2013), Oct. 2013, pp. 49-64, doi: 10.1007/978-3-642-41338-4_4.

[19] E. A. Boyle, T. M. Connolly, and T. Hainey, "The role of psychology in understanding the impact of computer games," Entertain. Comput., Vol. 2 (2), pp. 69–74. Jan. 2011, doi: 10.1016/j.entcom.2010.12.002.

[20] T. M. Connolly, E. A. Boyle, E. MacArthur, T. Hainey, and J. M. Boyle, "A systematic literature review of empirical evidence on computer games and serious games," Comput. Educ., Vol. 59, pp. 661–686, Sept. 2012, doi: 10.1016/j.compedu.2012.03.004.

[21] U. Dorji, P. Panjaburee, and N. Srisawasdi, "A learning cycle approach to developing educational computer game for improving students' learning and awareness in electric energy consumption and conservation," J. Educ. Techno. Soc., Vol. 18 (1), pp. 91–105, Jan. 2015, Online ISSN: 1436-4522.

[22] M. Torres and J. Macedo, "Learning sustainable development with a new simulation game," Simulat. Gaming, Vol. 31 (1), pp. 119-126, Mar. 2000, doi: 10.1177/104687810003100112.

[23] Ecoville, [Online]. Available: http://www.ecovillelejeu.com [retrieved: July, 2015].

[24] EnerCities, "Home page," [Online]. Available: http://www.enercities.eu [retrieved: July, 2015].

[25] I. Ajzen, "The theory of planned behavior," Organ. Behav. Hum. Dec. Proc., vol. 50 (2), pp. 179–211, Oct. 1991, doi: 10.1016/0749-5978(91)90020.

[26] A. Gustafsson, M. Bång, and C. Katzeff, "Evaluation of a Pervasive Game for Domestic Energy Engagement Among Teenagers," ACM CIE, vol. 7 (4), art. 54, Dec. 2009, doi: 10.1145/1658866.1658873.

[27] A. Gustafsson, M. Bång, and M. Svahn, "Power Explorer – a casual game style for encouraging long term behavior change among teenagers," Proc. The International Conference on Advances in Computer Enterntainment Technology (ACE '09), pp. 182-189, Oct. 2009, doi: 10.1145/1690388.1690419.

[28] W. Willemsen, J. Hu, G. Niezen, and B. van der Vlist, "Using game elements to motivate environmentally responsible behaviour," Game and Entertainment Technologies (GET 2011), IADIS.

[29] L. S. G. Piccolo, C. Baranauskas, M. Fernandez, H. Alani, and A. De Liddo, "Energy consumption awareness in the workplace: technical artefacts and practices," XIII Brazilian Symposium on Human Factors in Computer Systems (IHC 14), pp. 27-31, Oct. 2014.

[30] J. Mankoff, D. Matthews, S. R. Fussell, and M. Johnson, "Leveraging social networks to motivate individuals to reduce their ecological footprints," Proc. The 40th Hawaii International Conference on System Sciences (HICSS 2007), pp. 87–96, Jan. 2007.

[31] D. Foster, S. Lawson, M. Blythe, and P.Cairns, "Wattsup?: Motivating reductions in domestic energy consumption using social networks," Proc. The 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries (NordiCHI '10), pp. 178–187, Oct. 2010.

[32] P. Petkov, F. Ǩobler, M. Foth, and H. Krcmar, "Motivating domestic energy conservation through comparative, community-based feedback in mobile and social media," Proc. The 5th International Conference on Communities and Technologies (C&T '11), pp. 21–30, June 2011.

[33] H. T. Hou and Y. S. Chou, "Exploring the technology acceptance and flow state of a chamber escape game - Escape the Lab© for learning electromagnet concept," Proc. The 20th International Conference on Computer in Education (ICCE 2012), Asia-Pacific Society for Computers in Education, Nov. 2012, pp. 38-41.

[34] R. C. Schank, T. R. Berman, and K. A. Macpherson. "Learning by doing" Instructional-design theories and models: A new paradigm of instructional theory 2, 1999, pp. 161-181.

[35] OAuth 2.0, "About OAuth 2.0 page", [Online]. Available: http://oauth.net/2/ [retrieved: July, 2015].

[36] O. Etzion and P. Niblett, "Event Processing In Action," Manning Publications Co. Greenwich, CT, USA 2010, ISBN: 1935182218 9781935182214.

[37] Sweet Home 3D, "Home Page," [Online]. Available: http://www.sweethome3d.com/ [retrieved: July, 2015].

[38] J. Sánchez and R. Olivares, "Problem solving and collaboration using mobile serious games," Comput. Educ., Vol. 57, pp. 1943–1952, Apr. 2011, doi: 10.1016/j.compedu.2011.04.012.

[39] N. E. Cagiltay, E. Ozcelik, and N. S. Ozcelik, "The effect of competition on learning in games," Comput. Educ., Vol. 87, pp. 35-41, Apr. 2015, doi: 10.1016/j.compedu.2015.04.001.

[40] E. Ozcelik, N. E. Cagiltay, and N. S. Ozcelik, "The effect of uncertainty on learning in game-like environments," Comput. Educ., Vol. 67, pp. 12-20, Sept. 2013, doi: 10.1016/j.compedu.2013.02.009.

[41] C. Nuttall, "Google's mission falters on health, energy," The Financial Times, Financial Times Tech Blog, 25 Jun. 2011 [Online]. Available: http://blogs.ft.com/tech-blog/2011/06/googles-mission-falters-on-health-energy/ [retrieved: July, 2015].

[42] C. Nuttall, "Microsoft shutters Hohm," The Financial Times, Financial Times Tech Blog, 30 Jun. 2011 [Online]. Available: http://blogs.ft.com/tech-blog/2011/06/microsoft-shutters-hohm/? [retrieved: July, 2015].

[43] A. Osterwalder and Y. Pigneur, "Business model generation: a handbook for visionaries, game changers and challengers," John Wiley & Sons, Jul. 2010.

[44] J. Gubbia, R. Buyyab, S. Marusica, and M. Palaniswamia, "Internet of Things (IoT): A vision, architectural elements, and future directions," Future Gener. Comp. Sy., Vol. 29 (7), Sept. 2013, pp. 1645–1660, doi: 10.1016/j.future.2013.01.010.

[45] A. Alkar and U. Buhur, "An internet based wireless home automation system for multifunctional devices," IEEE Trans. Consumer Electronics, Vol. 51 (4), pp. 1169–1174, Nov. 2005, doi: 10.1109/TCE.2005.1561840.

[46] I. Vassileva and J. Campillo, "Increasing energy efficiency in low-income households through targeting awareness and behavioral change," Renew. Energ., Vol. 67, pp. 59-63, Dec. 2013, doi: 10.1016/j.renene.2013.11.046.