Promoting energy users' behavioural change in social housing through a serious game

M. Casals, M. Gangolells & M. Macarulla
Technical University of Catalonia, Department of Project and Construction Engineering, Group of Construction Research and Innovation, C/ Colom 11, Ed TR5, 08222 Terrassa, Barcelona, Spain

A. Fuertes, R. Jones & S. Pahl
Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA, United Kingdom

M. Ruiz
Fremen Corp, Rue des Bas Trevois, Troyes 10000, France

ABSTRACT: Housing represents about 29% of the total energy consumption in Europe and contributes with around 20% of emissions (European Commission 2013). Social housing represents about 12% of the total European housing stock and therefore is a significant target for energy efficiency measures by governments of EU member states. This paper is aimed at exploring how an innovative serious game could contribute to energy consumption and carbon emissions reduction in social housing by increasing the social tenants' understanding and engagement in energy efficiency. The proposed solution is being developed under the auspices of the EnerGAware project (Energy Game for Awareness of energy efficiency in social housing communities), funded by the European Commission under the Horizon 2020 programme.

1 INTRODUCTION

The housing sector is one of the priority areas in Europe with regard to energy efficiency – not only because it consumes a great amount of energy, but also because it remains greatly inefficient. Housing represents about 29% of the total energy consumption in Europe and contributes with around 20% of emissions (European Commission 2013). Social housing represents about 12% of the total European housing stock and therefore is a significant target for energy efficiency measures by governments of EU member states. The proportion of social housing does however vary significantly between countries; the Netherlands has the highest share of social housing in Europe, accounting for 32% of the total housing stock, followed by Austria (23%) and Denmark (19%). The UK (18%), Sweden (18%), France (17%) and Finland (16%) also have a relatively large social housing sector (CECODHAS 2011). Increased cost of fuel, the liberalisation of energy markets and decreased levels of welfare provision in Europe since the 1970s, has also resulted in an increasing number of households living in social housing that cannot afford the energy bills. In 2011, 9.8% of households in the EU could not afford to heat their home adequately, whilst 8.8% of households were in arrears on their utility bills (Thomson & Snell 2013).

One of the ways of addressing this challenge is though social tenants' behavioural change. This paper is aimed at exploring how an innovative serious game could contribute to energy consumption and carbon emissions reduction in social housing by increasing the social tenants' understanding and engagement in energy efficiency. The proposed solution is being developed under the auspices of the EnerGAware project (Energy Game for Awareness of energy efficiency in social housing communities), funded by the European Commission under the Horizon 2020 programme.

2 THE ENERGAWARE SERIOUS GAME

Serious games are a simulation environment, based on social interaction and scenario experimentation, designed to highlight, although virtually, potential realistic outcomes. Therefore, the main objective of serious games is to change human behaviour through education and training.

The EnerGAware project aims to bridge the gap in people's understanding and awareness of energy consumption by developing a serious game linked to the real energy consumption of the users' homes. The following subsection describes the process of eliciting specific user, building and game requirements necessary to design the EnerGAware integrated serious game and metering system solution. Subsection 2.2 introduces the concept behind the EnerGAware serious game whereas subsection 2.3 describes the game mechanics. The methodology used to assess the impact of the EnerGAware serious game in terms of energy saving and peak demand but also in terms of perceived physical comfort, self-reported energy consumption behaviours and awareness, energy knowledge, social media activity, IT-literacy and socio-economic status and health is also described.

2.1 *Eliciting requirements*

A comprehensive identification and analysis of the specific user, building and game requirements that are necessary to design the EnerGAware integrated serious game and metering system solution was carried out. Requirements were defined using a range of different datasets and methods including (1) literature review; (2) a large-scale, city-wide survey, undertaken in Plymouth, UK, during 2015, which was administered to all the 2,772 social houses managed by the social housing provider partaking in the EnerGAware project; (3) three game-play scenarios focus groups undertaken with social housing tenants in Plymouth, UK, during 2015 and (4) asocial housing building stock database gathered and managed by project partner DCH (Building Stock Condition Database).

2.1.1 *User requirements*

Results suggested that the EnerGAware serious game virtual world should be based on a domestic environment (e.g. virtual home), so as to help the players to relate to. Results revealed the existence of a large group of older people, high presence of retired people and a large group with low educational level, suggesting that the EnerGAware game should put special attention when designing the visual aspects of the game to those requirements derived from human aging process and novice users. In relation to the didactic approach of the game, the game should adapt to different learning levels and provide clear and easy to understand goals. Regarding the educational content, the game should allow users to learn how to balance the energy consumption, comfort and financial cost of a house; gain knowledge on how much energy is used by the typical end-uses existing in a domestic environment, poor practices of use that might increase the energy consumption, as well as the most efficient ways to use them to save energy. The game should also help the player to assess the potential energy savings from different behaviour actions and energy-efficient changes to the virtual house. From the game functionalities point of view, the link to social media platforms to enhance communication and information sharing amongst players was found relevant.

2.1.2 *Building requirements*

The most common building characteristics, building envelope, building services and controls and renewable energy generation were analysed and transformed into the ‘typical’ social dwelling which was used to influence the design the virtual home contained in the EnerGAware serious game. Data related to the energy metering and monitoring systems existing in social homes (e.g. smart meters, end-use metering, etc.), internet availability and coverage was used to design the energy metering and data communication infrastructure.

2.1.3 *Game requirements*

Results validated that a significant part of the social tenants have a good IT-literacy, Internet and social networks habits, and experience in playing video games. Therefore, the results suggest that the online serious game approach adopted for the EnerGAware serious game should not be a barrier for the targeted audience. Both the focus group and the Social Housing Survey results suggested that the EnerGAware serious game should be an energy management game (home management, resources management) focused on a virtual house customization game. Regarding the graphical aspect and the setting of the EnerGAware serious game, the results of the Social Housing Survey suggested that this is not a major criterion of game choice for the targeted players. However, the focus groups concluded that a pseudo-realistic game setting would be better than a fantasy world (or sci-fi, or cartoon) and better than a fully-realistic simulation. A tactile tablet was identified as the most suitable IT device (both technically and cost-effectively) for the deployment of the EnerGAware serious game.

2.2 *The EnerGAware concept*

The serious game will allow users to design their own virtual home using a simple drag-and-drop interface. The users will have an initial limited financial budget (in-game currency) available to construct their house and choose domestic appliances, lighting and furniture. Users will be able to earn in-game rewards to upgrade their home and buy more in-game objects by improving the energy efficiency of the house (e.g. increase insulation) or change the game characters energy efficiency behavior.

A building energy consumption simulation engine (Figure 1) will calculate the current energy consumption of the virtual house and provide the potential options for improving its energy efficiency. The options provided will demonstrate the potential energy savings from (1) upgrading buildings’ envelopes (i.e. no insulation vs. cavity wall insulation or solid wall insulation, etc.); (2) replacing the existing domestic appliances and lighting (i.e. incandescent bulbs vs. CFL bulbs or LED bulbs, etc.); and (3) user behaviour change (i.e. reducing heating and cooling temperatures or durations; leaving appliances in standby mode, etc.). Users will be able to click on appliances and HVAC devices in the game and receive feedback about the energy consumption in different modes (e.g. active, standby, off; set-point temperatures; heating/cooling periods).

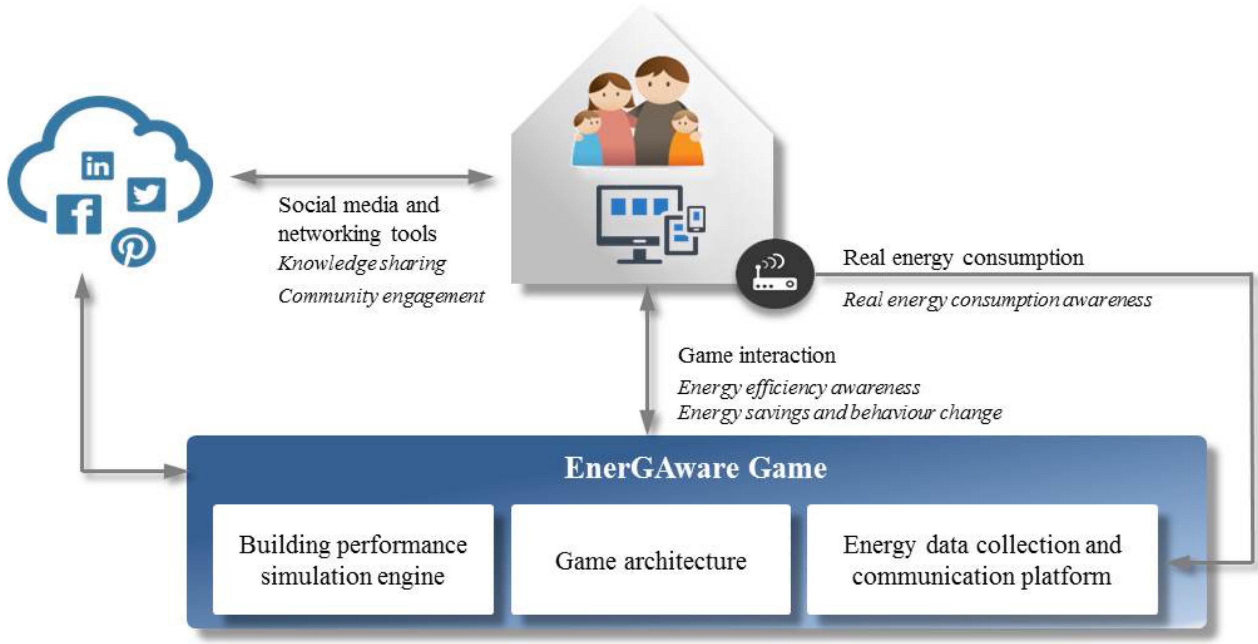

Figure 1. EnerGAware serious game schematic.

The successful balancing of energy consumption, comfort and financial cost will lead to the user generating extra in-game rewards which can then be reinvested in the home. The user will need to decide whether to invest in low cost options providing low energy savings (i.e. replacing plasma by LED TV, installing draft excluders, etc.), or high cost options providing high energy savings (i.e. solid wall insulation, solar photovoltaic panels, etc.) with the latter taking more time to save up for. In addition, the user will be able to play a series of missions related to energy use integrated into the main EnerGAware serious game. These will contribute to increase energy awareness and will provide the user with an opportunity to earn further in-game rewards. The EnerGAware serious game will also be connected to the actual energy consumption (smart meter data) of the house in which the user lives (Figure 1). This connection will have three purposes; firstly, real world energy savings will translate into in-game rewards; secondly, the user will be able to view their current and historic energy consumption of their homes' through the serious game interface; and thirdly, to validate the energy savings achieved in the real world from playing the serious game.

Finally and as shown in Figure 1, the EnerGAware serious game will be embedded in wider social media and networking tools (e.g. Facebook, Twitter, etc.). In the simplest form, these links with social media and networking tools will be used to disseminate the game and enable users to enter or re-enter the serious game from potentially anywhere in the world, thus reducing barriers to participation and encourage large scale uptake beyond the project's lifetime. The social media features will also provide users a platform to share data of their achievements, compete with each other, give energy advice, as well as, join together to form virtual energy communities.

2.3 *The EnerGAware game mechanics*

As shown in Figure 2, the cat is the main character of the game and the only one that can be controlled by the player. The human characters living in the virtual house are non-player characters controlled by the computer. They have non-energy efficient behaviours, which the cat will try to address. Neighbors may request the player's help in several kinds of situations (e.g. advices to choose an energy provider or actions such as turning off all the lights). Within the house customisation mode, the player is able to create his/her dream house. An editor function allows the player to buy appliances, furniture, decoration items and energy efficiency upgrades (e.g. wall insulation) in a realistic environment. A mission mode provides knowledge about energy efficiency and educates the player about right energy management behaviours. Missions take place in neighbours' houses with a fixed geometry that substantially ease energy consumption simulations. The mission mode also shows ideas about how the player's house could evolve.

The main gameplay loop starts with a daily pool of energy points. The player has an operational house with a global energy consumption and she/he will have to save energy points to complete energy efficiency objectives. It will allow him/her to unlock game content, mainly new items and upgrades for already owened items (e.g. appliances, insulation). New items might be more efficient, i.e. consume less energy points (e.g. a more energy efficient fridge), or just be a smarter version (e.g. a bigger TV).

Figure 2. Screenshot of the EnerGAware prototype.

If the player chooses the more energy efficient item, this will impact favourably the global energy consumption. Upgrades and new items will increase global happiness which will in turn increase daily money income. Money is then used to buy upgrades and new items.

The delicate balance between energy consumption and occupants' happiness is an important part of the gameplay. Reducing the happiness level too much to save energy points will decrease humans' productivity and as a consequence they will earn less money. The goal is to make the players understand the need to invest in better equipment, smart connected devices and insulation to reduce their need in energy points without decreasing the happiness level of their humans.

2.4 *Methodology to evaluate the impact of the EnerGAware serious game*

The game will be tested in a social housing pilot of 100 homes in Plymouth (United Kingdom) by studying the actual real-world energy savings achieved from playing the game, as well as households' reactions, feedback and improved energy literacy, while exploring the wider community benefits of implementing such a game.

In accordance to the International Performance Measurement and Verification Protocol (IPMVP) (EVO 2012), pre-post comparison will be applied in the EnerGAware project. As shown in Figure 3, the effect of the serious game will be estimated through comparison of the energy consumption, peak demand and other indicators before (baseline evaluation), after the intervention starts (mid-term evaluation) and at the end of the intervention (final evaluation).

In addition, a control group approach will be also implemented following the recommendation in the European ICT PSP Methodology for calculating energy savings in buildings (BECA 2012). An advantage of the control group approach is that the data are collected over the same time period for both the experimental and control group; therefore external influences (e.g. energy price changes, longer school holidays, sports events, etc.) which could have an effect on the measured dependent variables are also considered (Figure 3).

In the EnerGAware project, 50 households will be assigned to the experimental group and 50 households will be assigned to the control group. Social housing tenants in the experimental group will play the EnerGAware serious game and have their energy (gas and electricity) consumption monitored. The social housing tenants in the control group will have only their energy consumption monitored. Households in both groups will complete a series of additional surveys, at the end of the mid-term evaluation and final evaluation periods, regarding their self-reported energy consumption behaviours and awareness, energy knowledge, social media activity and IT-literacy as well as perceived physical comfort and socio-economic status and health.

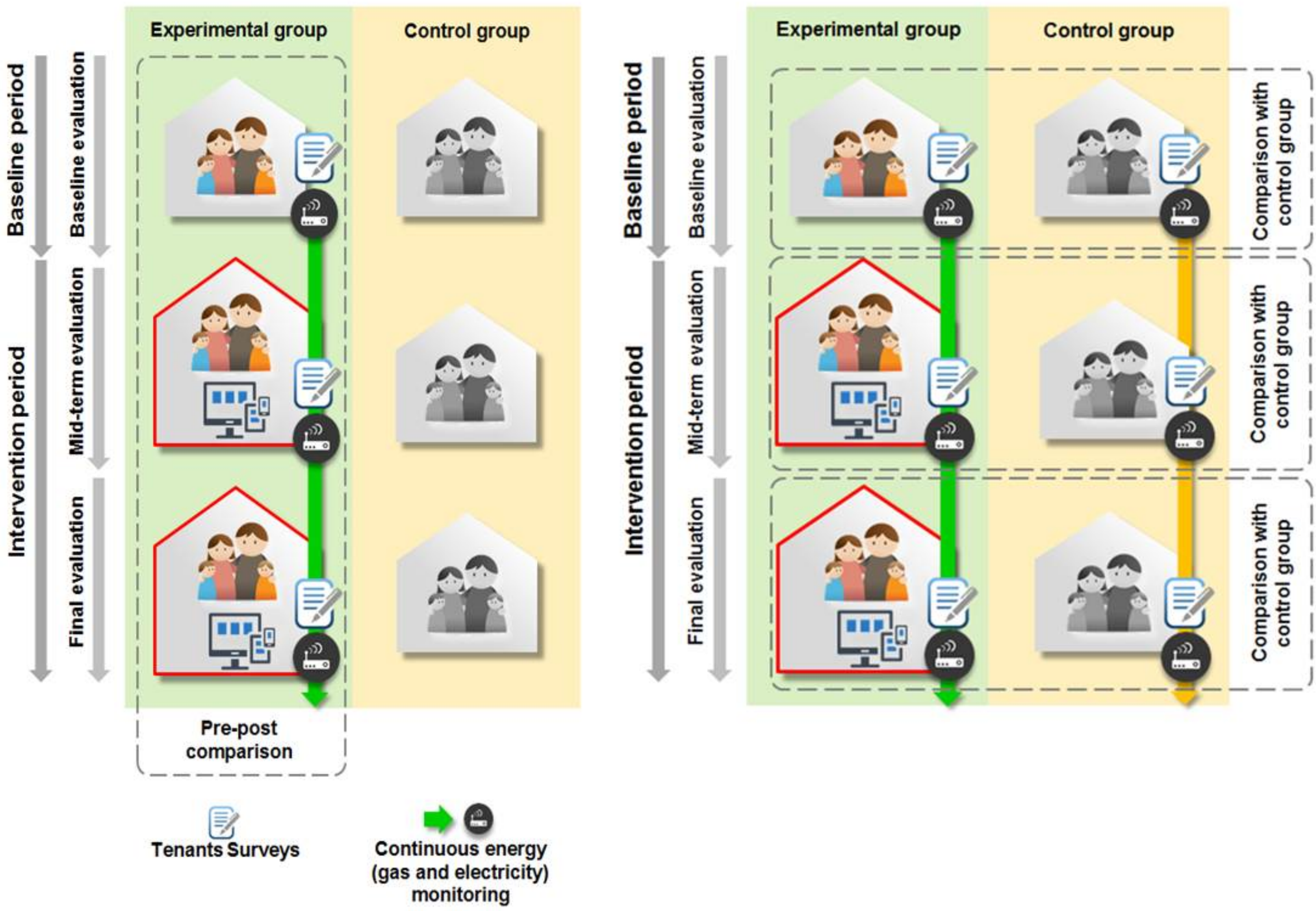

Figure 3. Pre-post comparisons (left) and comparison with control group (right)

Households in the experimental group will also complete a survey about the usability, usefulness, attractiveness and interaction level of the EnerGAware serious game.

3 CONCLUSIONS

This paper has presented the EnerGAware project aimed to reduce energy consumption and carbon emissions in a sample of European social housing by changing the energy efficiency behaviour of the social tenants through the implementation of a serious game linked to the real energy use of the participants' homes.

Regarding energy efficiency in social housing, past research initiatives have mainly focused on displaying real-time energy consumption data and optimising energy management (generation and usage) using ICT systems. The EnerGAware project will significantly advance the current state-of-the-art by developing and testing the effect of providing social tenants with a serious game, that is both linked to social media and networking tools (e.g. Facebook, Twitter, etc.) and to the actual energy consumption (smart meter data) of the house in which the game user lives.

In relation to serious gaming, the EnerGAware serious game will be the first of its kind: combining real-time energy consumption of the home in which the game player lives, with energy saving feedback and rewards (i.e. unlocking features and content in the serious game). The EnerGAware serious game will step beyond existing e-learning solutions and games as it is designed to appeal to the new generation of digital natives and to trigger them to stay engaged, play, absorb and learn. The serious game will also be linked to social media and networking tools, to address the communication and social routines of people in the new digital age.

Regarding internet of things (IoT), current games regarding energy consumption either use simulated data, or data collected once. To improve the realism of the game, and the educative impact on the final user, cyber-physical systems will collect data from the user's house. Another technical challenge that will be tackled by the project is the interaction with existing energy monitoring devices. Embracing the paradigm of a real IoT can lead to standardized and interoperable installations, which will result accessible to a broader public.

In relation to behaviour change psychology, the project will deliver principles and insights that transcend the transient nature of current ICT-based solutions for energy efficiency: understanding the cognitive and social processes that determine people's decision making and behaviours. This will provide a basis for further development of ICT-based solutions that can be used to make energy usage visible and enable people to achieve energy savings.

Regarding social media and networking, the project will explore whether social networking sites may be able to play a role in helping to support behavioural change, both structurally and by shaping beliefs and culture. Social media and networks will be exploited to engage a wider range of people, beyond the social housing pilots, with the EnerGAware serious game. We will evaluate which types of energy information and data people are willing to share (and which attract most attention and debate in their social network) and examine how people use these to discuss and reduce energy use.

4 ACKNOWLEDGEMENTS

This paper is based on the EnerGAware project (Energy Game for Awareness of energy efficiency in social housing communities), contract no. 649673. The research project is supported by the EU H2020 programme (H2020-EE-2014-2-RIA) and is being carried out jointly by the Universitat Politecnica de Catalunya (Spain), the University of Plymouth (United Kingdom), the Instituto Superior de Engenharia do Porto (Portugal), Fremen Corp (France), Advantic Sistemas y Servicios (Spain), DCH Devon and Cornwall Housing (United Kingdom) and EDF Energy R&D UK Centre Limited (United Kingdom).

REFERENCES

BECA Balanced European Conservation Approach 2012. *The ICT PSP Methodology for Energy Saving Measurement: A common deliverable from projects of ICT for sustainable growth in the residential sector, Version 3*.

CECODHAS Housing Europe Observatory 2011. *Housing Europe Review 2012: The nuts and bolts of European social housing systems.* Building and Social Housing Foundation (BSHF). Available at: <http://tinyurl.com/mtorf8l>. Accessed on 27 March 2016.

EVO Efficiency Valuation Organisation 2012. *International performance measurement and verification protocol. Concepts and options for determining energy and water savings, vol. 1, Technical Report.* Available at: <http://www.coned.com/energyefficiency/PDF/EVO%20-%20IPMVP%202012.pdf>. Accessed on 2 October 2015.

EnerGAware 2015. *Energy Game for Awareness of energy efficiency in social housing communities*. EU funded project. Contract number: 649673. Available at: <http://energaware.eu/>. Accessed on 26 March 2016.

European Commission 2013. *EU energy in figures: Statistical Pocketbook 2013*. Luxembourg: Publications Office of the European Union. Available at: < http://ec.europa.eu/energy/sites/ener/files/documents/2013_pocketbook.pdf>. Accessed on 15 January 2016.

Thomson, H. & Snell, C. 2013. *Energy Poverty in the EU: Policy Brief.* Available at: <https://www.openaire.eu/search/publication?articleId=datacite____::08e3ab33b677e1c3bc8df10c55245ead>. Accessed on 15 January 2016.