Gamification as a way to involve young adults in energy efficiency and sufficiency – a case study

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Abstract
Social, economic and environmental concerns regarding energy use have fostered energy efficiency programs as effective tools to improve the rational use of energy in all activity sectors, i.e. for residential, industry and services consumers. Behavioural change interventions play a key role to achieve energy efficiency. This paper discusses gamification as a tool to foster energy behaviour changes in young adults (higher education students) towards energy efficiency. The work was carried out as part of a research project (with the name *Learn2Behave*) aiming to characterize residential energy consumption behaviours, seeking to contribute to improve energy efficiency and reduce energy bills. The project uses a mobile application (*app*), called "Minha Energia" (My energy, in Portuguese), as an inquiry tool to characterize consumers' behaviours, giving suggestions and advices to participants as a reward. The development stage involves students and researchers from three higher education institutions in Portugal, a research institute and three energy agencies. The application was made available not only to the target participants, but also to the general population, aiming to help the development of energy efficiency programs devoted to promoting more energy efficient behaviours while considering energy sufficiency. The data gathering has just started and is foreseen to last long enough to contribute to a more detailed knowledge of energy use in the residential sector. The use of mobile *apps* as an inquiry and dissemination tool of best practices, through gamification, allied to the involvement of circa 200 students, has the potential to change younger generations' behaviours in the use of energy.

Introduction
The European Union (EU) defined ambitious energy policy goals until 2030 including: 40% cut in greenhouse gas emissions compared to 1990 levels, 27% share of renewable energy sources, and 27% energy savings compared with the business-as-usual scenario (EU, 2014). Empowering consumers, making citizens aware of the energy market, is also defined as an explicit strategic goal to reach these targets (Alskaif et al. 2018).

Concerns such as energy shortage, energy prices, and environmental impacts are now a globalized challenge that is greatly related to human behaviour and can be dealt with by promoting energy use awareness (Chui and Wai, 2017). The most common approaches to change users' behaviour regarding energy consumption involve the deployment of energy saving campaigns, usually based on disseminating information. Such efforts, based on information intensive approaches, rarely motivate participants' interest to engage in, even if they are aware of such campaigns (Chui and Wai, 2017). In fact, studies have shown that people tend to be somewhat uninformed and disinterested in the topic of energy, and interviews and questionnaires have severe limitations regarding both the information that can be gathered and the scalability of the approach (Tellols et al., 2016). Hence, to tackle these problems, we propose gamification as a strategy to involve young adults in energy efficiency (how to fulfil a certain energy service level with less energy inputs) and sufficiency (how much energy is needed). Specifically, we develop an approach that is able to engage young adults using a mobile application with a gamification strategy. A mobile *app* can be used to collect information that characterizes end-users' behaviour, motivating them to change or maintain habits that allow to achieve higher energy efficiency levels and even energy savings. Some incentives offered to the participants are a way of rewarding them for the data provided regarding their consumption habits. This approach allows users to interact, allowing greater feedback from their experience (Grünewald et al., 2017).

This paper discusses gamification as a tool to foster energy behaviour changes in young adults, as part of a research project, named *Learn2Behave*, aiming to characterize residential energy consumption behaviours and disseminate good practices. The project uses a mobile application (*app*), called "Minha Energia" (My energy, in Portuguese), as an inquiry tool to characterize end-users' behaviours, giving hints and advices to motivate and engage participants as a reward. The development involves students and researchers from three higher education institutions in Portugal, a research institute and three energy agencies.

This article is organized as follows: in Section II an overview is presented to emphasise the importance of residential consumptions and the end-uses most influential to global consumptions as well as to illustrate some energy efficiency promotion campaigns that have been adopted in Portugal. In addition to this perspective, this overview also illustrates the potential of gamification to gather useful information regarding energy use and behaviour characterization, including the presentation of examples of similar projects. Section III describes the mobile application development stage, specifying the *app* architecture, its main functionalities, and the gamification strategy designed to motivate the desired participation. Section IV is dedicated to data analysis, presenting the different methods to gather data (using the *app* and traditional surveys), illustrating how data is structured, reporting the main objectives of the analysis. Finally, Section V draws some conclusions and ideas for future work.

Overview

In this section, a general characterization of typical residential energy consumptions and behaviours is presented, highlighting the main difficulties to change energy consumption patterns. Gamification strategies applied to different contexts are also presented and projects like the one being implemented are briefly described.

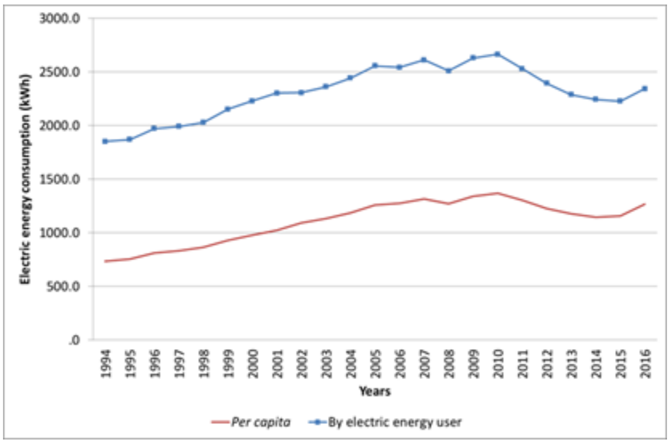

Figure 1. Electric energy consumption in the Portuguese residential sector, per capita and per electric energy user, between 1994 and 2016 (Pordata, 2019).

RESIDENTIAL CONSUMPTION AND BEHAVIOUR CHARACTERIZATION

Electricity consumption in the residential sector corresponds to about 26 % of total consumption in per capita values and 32 % regarding electric energy users, from 1994 to 2017 (Pordata, 2019). In Portugal, the residential sector is responsible for 17 % (INE and DGEG, 2010) of the final energy consumption (in EU-28 it corresponds to 26 %) (Eurostat, 2019) and, due to the high dependence on fossil fuels, this sector is one of the major end-use contributors to greenhouse gas emissions (corresponding to 12.4 % of the total emissions in Portugal and 20 % of the total emissions in EU-28, already including the transportation sector) (Eurostat, 2015). It is internationally recognized that in the last few years Portugal has done remarkable efforts in the deployment of generation from renewable sources to reduce the energy dependence and to effectively strangle GHG emissions.

In Portugal the annual electric energy consumption per capita as well as per electricity consumer in the residential sector has overall increased almost steadily between 1994 and 2010 (Figure 1). Due to the economic crisis, a gradual reduction in consumptions occurred from 2010 to 2015, but an increasing trend is again evident in the last few years.

The residential sector has been one of the principal targets of recent energy efficiency programs in Portugal. However, some barriers are commonly found that can be classified as (WBCSD, 2009):

- Financial barriers: consumers often report uncertainties related with cost/benefit analysis – more efficient equipment is also more expensive, and consumers are often unable to determine the payback associated with this investment.
- Technical barriers: lack of information associated with the choice of equipment. Energy efficiency labels and standards are already well disseminated and considered by the consumers, but a careful choice should also be based on proper capacities/sizes, technical data and the user profile. In this context, there is some room to highlight the importance of other technological characteristics beyond energy consumptions. Some examples are the luminotechnic characteristics in lighting systems or the effect of adopting different operation cycles in washing machines.
- Behavioural barriers: an increasing awareness and interest of residential consumers regarding energy efficiency is recognized. These efforts are being consolidated mainly due to recent energy efficiency initiatives promoted by the government, the national energy regulator and regional or local energy agencies, inducing the use of more efficient equipment. However, there is a margin to enhance energy behaviours of different consumers, such as demand shifting, peak demand control and more conscious choice of available commercial options. In general, Portuguese households are concerned and aware of their impact on energy efficiency but invoke unawareness of the best energy-saving practices and the perception of already saving as much energy as possible as the main reasons to justify the gap towards more efficient energy behaviours (Lopes et. al., 2017).

Table 1 shows the relative importance of different uses of final energy in Portuguese households. It also allows a comparison with similar information in the EU-28.

The significant differences in the Electricity consumption shares for cooking and water heating in Portuguese households may probably result from a lower total consumption of 254 kgoe per capita, when compared with 558 kgoe per capita for EU-28 (Eurostat, 2016b), which is probably a consequence of lower requirements for space heating.

Nevertheless, it becomes clear that there is room to find opportunities to reduce energy consumption associated with cooking and large appliances, water heating and lighting. Another characteristic that distinguishes Portuguese households is that electricity is the major contributor commodity, with 43 % of the overall consumption, followed by gas (natural gas, butane and propane) with a share of 27 % (INE and DGEG, 2011).

Several mechanisms to promote energy efficiency have been created, such as the Consumption Efficiency Promotion Plan (PPEC), which has been managed by the energy regulator since 2007, comprising tangible and intangible energy efficiency initiatives targeted at different sectors – industry and agriculture, commerce and services and residential, with relevant impact on energy savings and environmental impacts (Sousa et al., 2015; Sousa et al., 2013). For the household sector, several measures have been implemented, such as the replacement of incandescent bulbs by CFL bulbs (and, more recently, by LED bulbs), free distribution of smart strips (commonly known as stand-by killers) and a partial financing of more efficient equipment such as fridges and freezers, solar heating systems, heat pumps, electric water heaters and flow regulators. Intangible measures have also been implemented aiming to promote changes on consumers' behaviours, through training, education and focused information campaigns promoting energy efficiency improvement.

Although the energy efficiency of appliances and equipment is increasing, the number of services supplied by electric energy is also increasing. However, how consumers use energy is highly dependable and not easily characterised. Understanding consumer habits is a more complex task than it appears to be. Each user has her/his own energy needs and different ways of satisfying them, which often may or may not be conditioned by some reasons. According to Fabi et al. (2012), the conditioning factors of the end-user's behaviours may be based on environmental, contextual, psychological, physiological and social reasons. Physical environmental factors are related to the influence of natural phenomena on energy consumption (temperature, humidity, illumination, among others), while contextual factors have an indirect influence on the human being, and can involve the maintenance of the building itself, such as insulation of the building or the type of infrastructure and technology used (heating system type or the thermostat type). Psychological factors refer to the sense of thermal comfort, visual comfort, acoustical comfort, health, safety, awareness, habits and lifestyle. Physiological factors are related with age, gender and activity level, while social factors can be the number of occupants in a dwelling, the way they interact, or even the peer-to-peer influence.

The energy consumed in homes does not depend solely on the factors mentioned above. The consumer's motivation to adopt a "greener" energy behaviour continues to play a key role in this process. The scarcity of information for a better understanding of factors influencing consumption habits creates obstacles in promoting the reduction of energy consumption in the domestic sector (Hu et al., 2017).

In this setting, it is expected that the present work can also be adopted as a new strategy to persuade consumers to change their typical consumption patterns and to influence them to make more conscious energy decisions.

Table 1. Share of final energy consumption in the residential sector by type of end-use. Source: (Eurostat, 2016a).

Final Energy End-Use	Portugal	EU-28
Cooking	39.4 %	5.5 %
Water Heating	18.8 %	14.5 %
Space Heating	21.1 %	64.6 %
Lighting and Appliances	20 %	13.8 %
Space Cooling	0.7 %	0.3 %
Other End-uses	0 %	1.3 %

GAMIFICATION STRATEGIES AS TOOLS TO ENHANCE INFORMATION GATHERING

Gamification is the use of game elements and strategies in non-game contexts to motivate and influence user behaviour (Werbach and Hunter 2012). This concept has emerged with the goal of motivating and increasing peoples' engagement in a particular behaviour using a fun environment, with the assumption that games are fun and therefore any setup that benefits from the same approach could also prove to be valuable and engaging.

Gamification has been used in different contexts, such as business, marketing, health, politics, and education to engage users in fun and motivating experiences. The success of gamification greatly depends on the context where it is applied, the final users, and mainly its design (Tellols et al., 2016). Note that the rationale of gamification is that the final enterprise is in fact not a game, but it is enhanced with game elements. Elements such as game-thinking, mechanics, dynamics, and game-like principles can be considered as design elements during the application of the gamification concept.

In (Cechetti et al., 2017), a thorough description of game design elements in gamification applications is presented, including references of existing applications for further reading. Such elements include rewards, levels, points, goals, penalties, story, social interaction, feedback and characters, badges, difficulty levels, monetary elements, achievements, progress, leader board and challenges. In (Chui and Wai, 2017), a more specific approach for energy awareness applications is carried out. The most common game design elements identified are points, badges, levels, and leader boards. Prizes, trophies, avatars, virtual money, and virtual goods are also referred to, but with less impact on engagement. The more relevant game design elements are briefly characterised as:

- **Points:** points can be handed to users just by using the system or application, or performing a specific action, e.g. answering a question correctly or exhibiting a positive behaviour. Points can be used for leader boards or to collect trophies/badges or even to get real-life rewards.

- **Badges:** a badge is a form of virtual achievement that is usually obtained when a specific number of points has been reached. Badges constitute a mechanism to maintain involvement and motivation.
- **Levels:** a level constitutes a threshold to let a player know whenever she/he is gaining more power, becoming wiser in specific domains and is an easy way to enable monitoring progress. The threshold can be a number of points, but it can also be an improvement in behaviour, e.g., save 10 % in the energy bill. Sometimes the level also defines the degree of difficulty associated with the interaction. In game-based feedback, level up plays a key role to keep participants involved.
- **Leader boards:** competition is an almost ubiquitous presence in games. Leader boards are the most common way users can compare to each other, and often constitute a major source of motivation.

Taking a holistic view of gamification as a tool to enhance information gathering, these game design elements should be implemented so that they make it possible to obtain information as the user is engaged in the gamified interaction. To fulfil this goal a series of steps is usually carried out (Tellols et al., 2016):

1. Define objectives and target behaviours.
2. Describe the players.
3. Devise fun activity loops.
4. Deploy, play-test.
5. Evaluate the effectiveness of the gamification.

However, the context in which gamification is applied is of uttermost importance, namely in what concerns to the target audience. The "players" may adapt their behaviour to a game setting, giving a wrong image, namely if driven by competitiveness, and, a lower ability to handle this kind of tools may drive away a significant amount of people, e.g., more aged. In the author's opinion, gamification is recommended when the target is composed by young users. The stimulus to participate and to overcome the proposed challenges is encouraging and the potential of reaching new users is massive, with the aim of competition. On the contrary, gamification may not reach the expected effect when it is proposed to a senior audience, more adapted to traditional inquiries and that mostly prefer the opportunity to more reflective answers. Moreover, the way the communication is established along the participation is also determinant to the success of the strategy.

RELATED PROJECTS FOR ENERGY AWARENESS

Different gamification projects are being developed in the area of energy awareness, some of which are briefly illustrated:

The MOBISTYLE project aims to motivate behavioural change by raising consumer awareness through a provision of attractive personalized information on user's energy use, indoor environment and health, through information and communication technology (ICT) based services (http://www.mobistyle-project.eu).

More proactively, the main objective of the EnerGAware project is to decrease energy consumption and emissions in an affordable housing pilot and increase the tenants' understanding and engagement in energy efficiency by using a game for awareness of energy efficiency in social housing communities (http://www.energaware.eu).

From a more educational perspective, eTEACHER uses ICT solutions to encourage and enable behaviour change of building users towards energy efficiency, developing intervention strategies in three European countries according to climate, cultural and demographic indicators (http://www.eteacher-project.eu).

Focusing on student communities, the Students Achieving Valuable Energy Savings (SAVES 2) project supports students in minimizing their carbon footprint in their university and private accommodation, raising awareness about energy efficiency and smart metering, and installing good sustainability habits which may last beyond their time in education (http://saves.unioncloud.org).

The PEAKapp project aims to develop a serious game, which conjugated with smart meters triggers behavioural changes and continuous engagement (http://www.peakapp.eu).

Another vast area of research related to energy and gamification are smart cities, e.g., in (Kazhamiakin et al., 2016) a service-based gamification framework was used to develop long-running games on top of existing services and systems within the city of Rovereto to promote sustainable urban mobility.

Development of a mobile application to characterise energy consumption and behaviours

In this section, we detail the development of a mobile application for Android that aids to grasp the awareness and the behaviour of end-users with respect to energy consumption. The main goals of the application include the adoption of methods of gamification to engage the user during a long period, allowing for the capture of her/his behaviour regarding energy, and also the inclusion of advices to improve energy awareness.

ARCHITECTURE AND FUNCTIONALITIES

Figure 2 shows the general architecture of the system. It was divided into two main parts: the mobile application and the backend server.

The backend server (http://minhaenergia.inescc.pt) includes a database to store the questions and all the gamification strategy (points, badges, levels, and leader boards) as well as all the data on the users, including profile, their answers to questions and the registration of appliance usage. Additionally, it includes a back-office where the administrators can create questions and levels, and also retrieve statistics on the use of the application. Additionally, as shown in Figure 3, it is possible to define the electrical appliances which the users may report.

The mobile application, named "Minha Energia" is available at the Google Play Store (http://bit.ly/appMinhaEnergia). Figure 4 presents some screenshots of the application.

Once the user registers for a new account, it is possible to:

- Alter the profile

- Define the energy profile, answering questions organized in levels as in a game
- Register energy consumptions regarding specific electrical appliances
- Play using the Ecoquiz randomized questions on energy literacy
- Challenge Facebook friends to an energy match with versus mode
- Check individual, regional and friends leader boards

GAMIFICATION STRATEGY

The strategy of giving points for each question allows users to score based on the answers provided. Questions may have different values depending on their importance to define the user consumption behaviour and on how to define the feedback to be provided to the user. In this way, users are motivated to continue playing. Leader boards can be a fun way to drive competition among young players, who will be fighting for the top spot in a public leader board or comparing their progress with their friends. The users are encouraged to continue providing information by opening new levels in the application and obtaining related information about best practices. This additional information is revealed to the user in the form of advices and hints, which are derived from the user's responses. Each question to be answered has a value (in points), which are accumulated and stored in the database. These points can be checked within the application, showing in which position the user is in relation to the rest of users of the application. This encourages a user to answer the questions to compete with the other users. The emphasis lies on the fun factor to sustain and enhance the user's engagement and motivation.

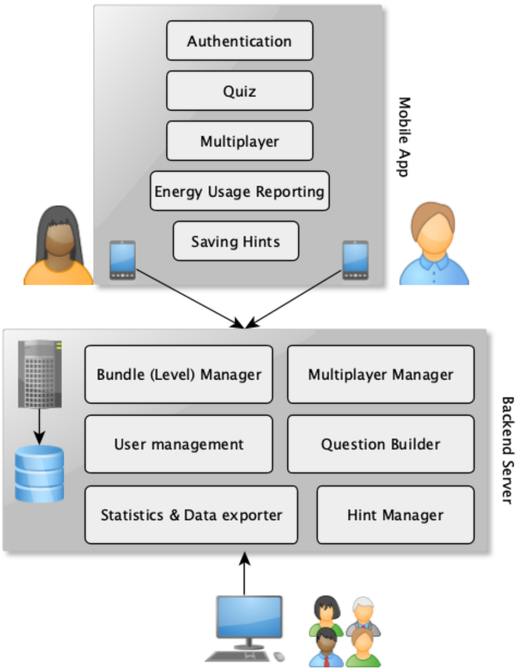

Figure 2. General architecture.

As can be gleaned from the first screenshot in Figure 4, there are three main challenges:

1. Energy profile ("Perfil energético")
2. Ecological Quiz ("EcoQuiz")
3. Versus mode for challenging other users ("Modo versus")

Both the ecological quiz and the energy profile are organized in levels. But, while the first is designed to act essentially as a game that aims to improve behaviour, the second constitutes

Eletrodomésticos

#	Imagem	Eletrodoméstico	Descrição	Tempo de utilização (minutos)	Potência (W)	Consumo Energético (kWh)	Classe Energética	Detalhes	Editar	Desativar
1		Televisão	Televisão da sala	240	30	0.03	A+++			
2		Forno	Forno da cozinha	120	2200	2.2	A+			
3		Frigorífico	Frigorífico da cozinha	1440	300	0.7	A+++			
4		Computador	Computador Portátil	240	35	0.04	A+++			
5		Aquecedor a Óleo	Aquecedor a Óleo	120	1400	1.4	D			
6		Aquecedor	Aquecedor dos quartos	120	1200	0	A+++			
7		Ventoinha	Ventoinha da sala	120	75	0.08	D			
8		Ar condicionado	Ar condicionado da sala	60	500	1	A+++			

Figure 3. Configuration of electrical appliances in the back-office.

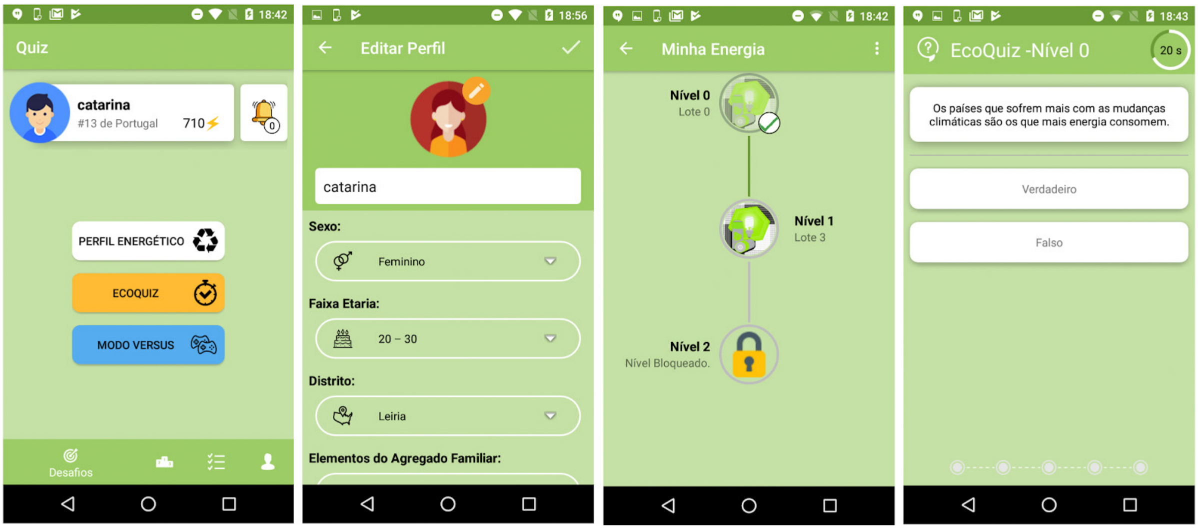

Figure 4. Mobile application screenshots.

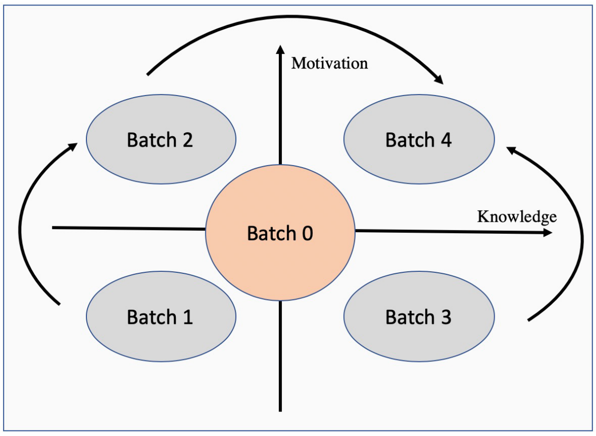

Figure 5. Survey structure based on different batches (or levels).

the main source of information with respect to the users' energy profile. In the latter case, the set of levels define different ways of presenting questions to the user. For example, if the user fails a large percentage of the questions in Level 0 (the first level that all users are faced with) the next level will still have simple questions to assure the user's motivation in carrying on filling the profile. This strategy is fully supported by the back-office that allows for the construction of levels with questions and the definition of transitions between levels (see Figure 5).

For this setup of the energy profile to work, it must be planned to better engage and motivate users. An extensive set of questions was structured into five levels (or batches) that are enabled, according to the user profile, promoting distinct navigation experiences when using the *app*. The levels or batches were formulated bearing in mind that users will have distinct motivation and knowledge (Figure 5):

- Batch 0: Level test
- Batch 1: Simple questions (similar to the Quiz approach with pedagogical purposes)/Comparisons with Model Families
- Batch 2: Feedback with specific hints/Brief energy consumption characterisation
- Batch 3: Feedback with more detailed hints/Comparisons with Model Families
- Batch 4: Includes several specific sub-batches to enable end-use consumption characterisation

When starting the Energy Profile option of "Minha Energia" *app*, all users have to answer Batch 0 questions. This generic batch is composed by simple characterisation questions, e.g. age, education, professional activity, and household size. Besides this generic information requested, Batch 0 also includes specific questions that can be determinant, as the answers control the user progress to one of the remaining batches. Batch 0 can therefore be regarded as a user's levelling test conditioning the users' path and participation in the *app*. The determinant questions considered are related with commercial options (perception of the contracted power adopted or the flat or time-of-use rate chosen), skills to identify the most energy efficient measures and how the user evaluates the importance of energy efficiency to promote economic and environmental benefits.

- A user that simultaneously reveals low literacy and weak motivation to energy efficiency is directed from Batch 0 to Batch 1. Low literacy is noticed by a low score obtained when answering to the questions related with the identification of energy efficient measures and their corresponding impact. In Batch 1, users must answer to some questions with different options in a playful way, the reasoning being corrected whenever wrong answers are given. Some examples of the questions adopted in Batch 1 are related with the identification of most significant energy end-uses in households, the perception of energy savings when stand-by consumptions are avoided or the meaning and potential benefits of time-of-use rates.
- When Batch 1 is completed, it is expected that the user has gained enough motivation to be addressed to Batch 2. However, a participant may demonstrate conditions to be directly sent from Batch 0 to Batch 2, whenever she/he shows low literacy but enough enthusiasm to participate. Examples of questions in this Batch 2 are the identification of a range

associated with the average monthly electricity bill and motivations to change electricity supplier and contract options.

- When Batch 2 is completed, it will give direct access to Batch 4, as the knowledge and critical sense will have increased.
- Batch 3 will be accessed by participants who demonstrates in Batch 0 to recognize best practices related with energy efficiency but, who are simultaneously sceptic about their benefits. This batch can be viewed as strategic to give detailed feedback to the participant (associating economic and environment benefits) to keep her/him motivated, knowing that the information provided must be carefully chosen and argued, because these participants already demonstrated some knowledge to interpret them. In order to better elucidate with examples, in Batch 3 users are asked to sort, in descending order according to the expected potential savings, some of the best practices to efficiently use a washing machine. In addition, the participants are asked to justify the contract options adopted.
- The conclusion of Batch 3 will provide access to Batch 4 that, being more extensive, will enable different end-uses characterisation. Nevertheless, Batch 4 can be directly accessed from Batch 0, in case the levelling test denotes the presence of a proficient and motivated user. An overview of the adopted batches' routing is also depicted in Figure 5. As examples, Batch 4 includes questions about the lighting technology adopted, the period of day when higher consumption equipment is often used or the adjusted temperature setpoints in Heating, Ventilation and Air Conditioning (HVAC) Systems. Some information about the type of renewable energy systems installed (or at least the willingness to install them), as well as information about mobility options, can also be voluntary answered by the participants in this Batch 4.

Additionally, after the questions are answered, the user periodically receives advices or warnings on how to improve energy consumption in her/his home through the mobile application.

Data Analysis

In this section we describe the data produced by the surveys, defining its structure and the objectives and methodologies that can be used to explore them. Although there is still no substantial data acquired, a first set of preliminary results of a paper-based survey is also presented.

DATA STRUCTURE

The Learn2behave project has so far been producing 3 different datasets which will be available for analysis. The main dataset regards the energy profile inside the mobile *app*, which aims to characterise energy use. As already introduced, the extensive set of questions was structured in 5 different batches, to match different navigation experiences inside the *app*, according to the motivation and knowledge of each participant.

A second dataset was built using a subset of the questions used to build the energy profile, but obtained in a more traditional way, using a paper-based survey. The aim of this second survey was to identify the bias introduced by the mobile-*app* driven questionnaire, both due to the typical self-selection bias of voluntary participants, as well as the one resulting from a more technological approach. Although less detailed, it still focused on energy behaviours and their influence on energy consumption.

The third dataset has information collected through the quiz. Although the aim was to create an additional source of motivation, the quiz may provide interesting cues about general knowledge on energy literacy and energy efficiency opportunities, and, has shown to be an excellent way to improve knowledge and raise awareness, namely among youngsters by profiting from their competitive nature. The quiz is organized in 5 different levels of knowledge and their degree of completion among respondents is in itself a useful information.

OBJECTIVES AND METHODOLOGIES

A first obvious choice to explore data is to perform a descriptive statistical analysis, assessing the most common responses to each question and deriving the most relevant characteristics of energy consumptions and behaviour. However, the data also allows other analysis to be performed, namely the associations between certain answers and specific characteristics of the respondents. As examples, we can try to understand if there are:

- Associations between basic knowledge or consumption characteristics and place of residence, age, qualification and even the size of the household (e.g., testing if bigger families have more care with energy consumption).
- Association between energy expenditures and residence characteristics.
- Associations between consumption practices and age, qualifications, house (size, ownership, and composition) and way of living.

Regarding the quiz, the associations between the results in each level of the game and the age or qualification are also interesting to address. To reveal these relations, statistical tests can be performed on data, namely assessing the association of variables using the Chi-square (χ^2) independence test. The Chi-square is a non-parametric hypothesis test that seeks to find a scatter value for two nominal variables, evaluating their association. The basic principle of this method is to compare proportions, i.e., the possible divergences between frequencies observed and expected for a certain event.

Developments of a scale validation for profiling behaviour regarding energy consumption and efficiency compliance are still being processed. Items on the questionnaire were part of an exploratory analysis. The confirmatory model is still to be closed. The factor analysis will indicate what items are more important to determine each output. This process is used to identify latent variables. The purpose of factor analysis is to reduce many individual items into a fewer number of dimensions. In addition, levels of compliance, i.e., percentage of energy efficiency awareness, may be calculated with receiver operating characteristic curves (ROC curves). This reveals how much the model is capable of distinguishing between groups, being one of the most important metrics to evaluate model performance.

RESULTS WITH PRELIMINARY DATA

At the time being, the mobile *app* deployment is still in an early phase, having still a reduced number of participants. The paper-based survey was already performed, producing 145 responses so far, from which we can draw the first preliminary conclusions.

As expected, age shows an association with: smartphone uses, awareness of energy label information, number of readings of energy consumption, number of changes of electricity rate and/or of energy supplier, all with p-values under 0.05. We may also conclude that younger respondents reveal less motivation to describe their use of individual appliances due a reduced number of answers on this matter.

Only 25.1 % of respondents already knew the Android application "Minha Energia", so this reduced overlap will not prevent a comparison between the results of both the paper-based survey and the *app* based survey in order to study the potential bias. The geographic distribution of respondents is quite spread, with a particular focus on the three regions where the members of the team are located – Coimbra (18 %) and Leiria (27 %), in the centre of the country, and Setúbal (29 %), in the south.

A few surprising results were nevertheless obtained just by looking at the responses to the paper-based survey:

- 34 % of the respondents do not know their own contracted power[1].
- 28 % are unaware of the different tariff options, namely, time-of-use options.
- 49 % never changed their tariff options and also never changed their supplier due to lack of information or inertia.
- 78 % already have LED lighting devices in their homes.
- 8.3 % still have CRT TVs.
- 66 % of the respondents use washing temperatures above 30 °C (49 % use 40 °C, 18 % use 60 °C).
- 23.6 % consider their home uncomfortable during winter.
- 25 % consider their home uncomfortable during summer.
- Regarding the latter two results, most cases of dissatisfaction are reported in Setúbal, mostly for summer, but also for winter.

Conclusions

This paper described gamification approaches to gather information and raise awareness and presents a mobile application developed with the aim to characterize energy use and behaviour, targeting residential energy consumers in order to improve their knowledge, awareness and mitigate scepticism about energy efficiency opportunities. The *app* deployment is expected to contribute to engage energy consumers, mainly young adults commonly regarded as gaming/tech enthusiasts. This effort is being developed by faculty, fellows and students from Portuguese Higher Education Institutions, with expertise in the mobile applications and energy management fields. Due to the project-based learning approach applied, students attending Energy Management courses participated and tested the app, and also helped to deploy the paper survey. Their participation allowed the update of the information in the back-office (e.g. updating questions in the Quiz, presenting/sharing different efficient practices and adding more specific hints) and provided a positive feedback regarding the effect of this experience in their training. Currently, the data gathering process is being pursued and more information will be extracted in the near future, but some preliminary results are already being derived which justify further efforts regarding the acquisition and treatment of information related to residential energy consumption. Some future developments in the *app* deployment are being considered, as it could be interesting to enable contextualized feedback using comparisons. On one hand, for each participant a comparison between actual consumptions and previous ones would be interesting to monitor trends and to identify the eventual effect of behavioural changes caused by the *app* experience. On the other hand, enabling comparisons between the *app* participants could also convince participants to keep engaged.

1. The apparent power limit that defines the cut-off current of the circuit breaker and which is specifically priced in the electricity contract in Portugal.

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