

AGILE USER-CENTERED DESIGN OF AN IOT-ENABLED GAMIFIED INTERVENTION FOR ENERGY CONSERVATION AT THE WORKPLACE

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ABSTRACT

Energy conservation in workplace environments is recognized as both important and impactful towards reducing worldwide CO2 emissions and protecting the environment. However, the focus of existing research has not primarily been on the employees' energy consumption behavior, albeit its potential impact on workplace energy efficiency. Aiming to affect employee energy behavior change towards more conscious consumption patterns, we have adopted gamification, a contemporary instrument that, when carefully utilized can lead to employee behavior change. Furthermore, we have followed an Iterative & Incremental Agile User Centered Design (UCD) approach towards designing a gamified IoT-enabled mobile app that provides energy consumption-related feedback to employees at their workplace. We present the characteristics of the designed app, as well as explain the rationale behind their choice. Usability results derived from employees in 3 workplaces at 3 different EU countries indicate that through our approach we designed a prototype gamified solution very well perceived and engaging to our target audience, scoring high in both usability, as well as user experience aspects. We further enhanced the app with additional functionality, according to the test users' feedback, towards producing the first integrated version. Initial results from testing this revised first integrated version of the app, revealed even more enhanced usability and user experience results, compared to the previous version. Overall, our derived evidence suggests that, by following an Iterative & Incremental Agile UCD approach within our field of application, we have derived a gamified app for energy-saving at the workplace that is conceived of as highly usable and provides for a positive user experience.

KEYWORDS

Gamification, Energy Conservation, Employee Motivation, Workplace, UCD, Agile, Incentives

1. INTRODUCTION

Energy production has more than doubled worldwide since the early 1970s, along with CO₂ emissions (IEA, 2017). At the same time, buildings consume 20% of the total delivered energy worldwide (Lülfes & Hahn, 2013) and are responsible for 40% of the energy consumption, as well as 36% of CO₂ emissions in the EU, 1/3 of which attributable to non-residential buildings (European Commission, 2017). Consequently, the need to boost energy efficiency in buildings has been stressed through the Paris Agreement on climate change and the Montreal Protocol on ozone depletion, as a means to achieve broader environmental protection goals (UN News Centre, 2016; IEA EEFd, 2017). Electricity is the preferred energy source in the commercial sector, estimated to account for 62% of the global energy demand by 2040 (Conti et al., 2016). Moreover, energy efficiency in companies can also lead to improvements in worker comfort, product quality and productivity, as well as reductions in maintenance cost, risk, production time and waste (IEA EEFd, 2017). The largest potential savings are in heating, cooling and lighting, which together represented more than 60% of the energy demand in buildings in 2015 (IEA Digitalization & Energy Working Group, 2017; Conti et al., 2016).

With digital technologies rapidly changing, questions arise about how technology, behavior and policy will evolve over time and how they will impact energy systems in the future (IEA Digitalization & Energy Working Group, 2017). The growing application of ICT in energy systems enable real-time data provision that could lead to up to 10% energy savings in buildings by 2040 (IEA Digitalization & Energy Working Group, 2017). Furthermore, with technological innovation creating new opportunities for energy efficiency and digitalization increasingly becoming impactful on the energy sector (IEA EEFd, 2017), the total public energy R&D budget in IEA countries has more than quadrupled, from 4% to 21% since the 1970s (IEA Energy Data Centre, 2017).

Further to technological means, the behavior of buildings' occupants has been studied from a wide range of disciplinary perspectives since the oil shocks of the 1970s (Stephenson et al., 2010). It is an important factor in the consumption of energy that should be considered alongside the deployment of technological improvements to reduce energy consumption (Delmas *et al.*, 2013), as it can add – or save – a third to a building's designed energy performance (Nguyen & Aiello, 2013). Employee behavior in specific can significantly affect the successfulness of technology-based energy efficiency interventions (Lutzenhiser, 1993; Lo et al., 2012). Moreover, each employee consumed more than 5.600 kWh on average, in 2015, in the EU (ODYSSEE, 2015). However, limited literature exists on the role of occupant behavior, the behavioral aspects of energy conservation at work (Scherbaum *et al.*, 2008), employee energy use at an individual behavioral level of analysis (Bansal & Gao, 2006), as well as how organizational context affects employee energy-saving behavior (Lo et al., 2012).

Overall, a limited number of studies on energy conservation in workplaces are available, compared to households, with few examining energy consumption behavior at the individual employee level, none of which including inter-organisational comparisons (Lo *et al.*, 2012). Altruistic motives (supporting the organisation in energy & monetary savings, contributing to environmental protection, complying with peer expectations, etc.) have been found to be more salient towards engaging employees to conserve energy at the workplace, since no personal monetary gains are normally expected (Matthies et al., 2011). Therefore, promising means include educating employees in energy conservation, altering organisational procedures and norms, and utilising feedback to increase employees' awareness of their own behaviour and

its consequences (Lo *et al.*, 2012). Behavioural interventions employing feedback have led to 5-15% in energy savings via direct and 0-10% via indirect feedback (Darby, 2006) with tailored feedback more effective towards energy behaviour change (Matthies *et al.*, 2011). At the same time, according to a meta-analysis of energy conservation experiments conducted between 1975-2012, revealed that the use of feedback led to 7.4% reductions on average, while, in contrast, monetary incentives to an increase in energy usage (Delmas *et al.*, 2013).

Gamification is defined as “the use of game design elements in non-game contexts” (Deterding *et al.*, 2011). It is “a relatively new instrument in the orchestra of motivation” (Kotsopoulos *et al.*, 2016) that can lead to behavioural change, break existing habits and update them with new ones by utilising positive emotional feedback and continuously setting appropriate stimuli (Blohm & Leimeister, 2013). Moreover, it can be used to increase employee participation, improve performance and compliance in specific goals (Seaborn & Fels, 2015), enhance employee satisfaction (Robson *et al.*, 2015), as well as turn traditional organizational processes into fun, game-like, experiences (Robson *et al.*, 2014), leading to behavioural change, increased and sustained employee motivation, engagement and productivity within an enterprise (Webb, 2013; Pickard, 2015). Examples of organizations using gamification at the workplace include the U.K.’s Department for Work and Pensions (Burke, 2014), Deloitte (Huang & Soman, 2013) and IBM (Erenli, 2013). More importantly, gamification has been employed to increase occupants’ motivation for energy conservation and promote real-world energy saving behaviours (Reeves *et al.*, 2012; Knol & De Vries, 2011; Brewer *et al.*, 2013; Geelen *et al.*, 2012; Orland *et al.*, 2014; Bourazeri & Pitt, 2013), with energy savings in the range of 3-6% recorded and more than 10% achievable, as reported in a comprehensive review of relevant published studies (Grossberg *et al.*, 2015). Furthermore, examples of energy efficiency games deployed in workplace environments include “Cool Choices”, “WeSpire”, “Ecoconomy” and “Carbon4Square” (Grossberg *et al.*, 2015) – WeSpire has led to >5 million positive actions in 45 countries (WeSpire, 2017), while Cool Choices has helped over seven thousand employees, in organizations across multiple industries, to increase their energy savings through almost 260.000 energy saving actions (Cool Choices, 2017).

Inspired by the above mentioned facts, we decided to design an IoT-enabled gamified mobile application that will motivate employees towards energy conservation at the workplace. We adopted an agile user centered design (UCD) approach to ensure that the app will be appealing to its potential users and, thus, increase the possibilities of using it as part of their daily routine. We elicited users’ requirements from three different workplaces in different EU countries: a museum in Luxembourg, a public agency in Spain and a municipal service in Greece, utilizing physical observation of their work life and energy usage habits, as well as interviews to gather more detailed information on their energy and game requirements. We also performed a survey to select the game’s theme - “persona”. Finally, after designing the first game prototype, we performed a validation study with potential users. The collected feedback guided the choice of game alterations needed, in order to build an improved game that more closely fits the users’ needs and desires. In brief, this paper can support future designers of gamified apps for energy conservation in their efforts to explore their potential users’ requirements and translate them to proper game characteristics and functionalities.

Next, we present related literature, briefly discuss our findings from the user requirements analysis we conducted and present the design characteristics of our gamified approach towards conserving energy at the workplace through IoT-enabled gamification. Ultimately, we illustrate design guidelines for a personalised gamified application that dynamically provides feedback to employees towards saving energy at work, based on informed design choices.

2. BACKGROUND

The effectiveness of gamification relies on leveraging the psychology of motivation to encourage players to play (Ashridge, 2014). Furthermore, in a utilitarian setting, engagement by gamification can depend on the motivations of users and the nature of the gamified system (Hamari *et al.*, 2014). Therefore, understanding the individuals that are involved in a gamified experience is fundamental (Robson *et al.*, 2015) and gamification must be designed to match its target users' individual characteristics and preferences, towards increasing motivation for specific behaviours (Uskov & Sekar, 2015; Werbach & Hunter, 2012). Towards that end, a user-centered approach should be followed in the design of gamified systems, focusing on the end-users' needs and desires (Seaborn & Fels, 2015).

2.1 User Centered Design in Games

A number of design frameworks have been proposed to guide the introduction of gamification in various non-game contexts. 18 different design processes across different categories were described in a recent literature review on gamification design frameworks (Mora *et al.*, 2015). Existing frameworks include (a) high-level industry-proposed, that describe the process, such as "Six Steps to Gamification" (Werbach & Hunter, 2012), "Meaningful Gamification" (Nicholson, 2012), "GAME" (Marczewski, 2012), and "Octalysis" (Chou, 2012), as well as (b) academy-proposed for the design and research of gamified information systems (Liu *et al.*, 2017) and, more recently, (c) detailed methods for engineering gamified software (Morschheuser *et al.*, 2018). However, each framework bears both benefits and shortcomings, and no general consensus on their specific and contextually dependent suitability.

Creating a game that establishes immediate and continued motivation to continue playing over long periods of time is admittedly a very complex issue. The practice of creating engaging, efficient user experiences is called User-Centered Design (UCD) and it entails taking the user into account during product development (Garrett, 2011). Furthermore, it is a design approach, widely considered the key to product usefulness and usability, based on the active involvement of users towards improving the understanding of user and task requirements (Mao *et al.*, 2005). More importantly, UCD methods have been employed by commercial game companies, such as Ubisoft Entertainment, Electronic Arts and Microsoft, to make their products more pleasurable and enjoyable (Pagulayan *et al.*, 2002). Employing UCD in gamification has been noted as so important that, "meaningful gamification" is defined as "the integration of user-centered game design elements into non-game contexts" (Nicholson, 2012). In organizational settings it entails putting the needs and goals of the users over the needs of the organization, and is expected to result in longer-term and deeper engagement between participants, non-game activities, and supporting organizations (Nicholson, 2012).

User Centered Design as an iterative process on how to design gamified systems has been proposed as a way to obtain a thorough understanding of the potential users and their requirements in gamification. Player-centered design (Kumar & Herger, 2013) reflects UCD in the design of games. It has been introduced in the context analysis phase (Marache-Francisco & Brangier, 2013), as well as an approach to design gamified services (Kumar & Herger, 2013; Werbach & Hunter, 2012). Furthermore, elements of the UCD approach have been utilized towards eliciting users' needs, to design gamified systems in non-game contexts such as e-Government (Dargan & Evequoz, 2015) and e-banking

(Rodrigues et al., 2016). More importantly, in the process of constructing the Powersave Game that focuses on energy conservation, a series of sequential steps during the Design, Evaluation and Experimentation phases were conducted with the active involvement of potential end users following a user-centered design methodology (Fijnheer, Oostendorp, & Veltkamp, 2016).

2.2 Agile Development in Games

Although many view iterative and incremental development (IID) – the “modern” replacement of the waterfall model and a cornerstone of agile methods – as a modern practice, its application dates as far back as the mid-1950s, and indeed has been a recommended practice by prominent software-engineering thought leaders and standards boards for decades, as well as associated with many successful large projects, promoting greater project success and economic viability (Larman & Basili, 2003). Iterative evaluation processes can aid in the reduction of risk and cost in software development, as well as the management of change, improvement of productivity, and the delivery of more effective and timely solutions (Bittner & Spence, 2006). However, in order for the iterative process to be more effective, it also has to be incremental, to avoid the unnecessary repetition of activities (Bittner & Spence, 2006).

In essence, agile development is a process that combines iterative with incremental. It implies being effective and maneuverable by adopting processes that are both light and sufficient (Cockburn, 2002). Agile software development in specific represents a major departure from traditional, plan-based approaches to software engineering (Dybå & Dingsøy, 2008). It was introduced through the “Manifesto for Agile Software Development”, that recognizes the values of (a) individuals and interactions over processes and tools, (b) working software over comprehensive documentation, (c) customer collaboration over contract negotiation, and (d) responding to change over following a plan, as focal in software development (Beck et al., 2001; Cockburn, 2002). Furthermore, agile software development is people-centric, incremental, cooperative (with end-users), straightforward (easy to learn and modify, as well as documented), and adaptive (Abrahamsson, Salo, Ronkainen, & Warsta, 2002). Finally, the opportunities for feedback and responding to changes provided by agile methodologies, enhance the possibilities of achieving improved job satisfaction, productivity, and overall increased customer satisfaction (Dybå & Dingsøy, 2008).

Game development is considered especially challenging because games tend to feature complex interactions within the user interface, as well as a much larger emphasis on performance, and more subjective system requirements than traditional applications (Koepeke et al., 2013). Furthermore, the introduction of Iterative Game Design has been suggested in the literature because it is an adaptive process allowing the designers to: (i) improve upon the game idea, (ii) refine the game, and (iii) see the game idea perform in action (Macklin & Sharp, 2016). Moreover, feedback regarding the implemented features is received early, thus making improving the game – if necessary – easier, and communication, as well as cooperation among all those involved in the game creation, is facilitated (Godoy & Barbosa, 2010). Therefore, the use of agile methodologies for developing games has become very common, to allow designers to discover, focus on, develop and improve the game “fun factor” as soon as possible, towards increasing the likelihood of its success (Godoy & Barbosa, 2010).

The specific challenges in game development also lead to challenges in game testing (Koepeke et al., 2013). The overall purpose of validation is to acquire objective evidence that a

system fulfills its business or mission objectives, according to its stakeholders' requirements, and achieves its intended use in its intended operational environment (ISO, 2015). At the same time, the role of iterative usability evaluation during agile game development in specific has been identified and analyzed in the literature (Ma, Lu, & Saparova, 2014).

Based on the abovementioned facts, we follow an iterative design and evaluation process that allows us to design and improve our game through successive iterative loops and includes the following iterative steps (Macklin & Sharp, 2016): (i) Conceptualize – develop an idea for the game and its play experience, (ii) Prototype - produce a playable form of the game, (iii) Playtest - allow real participants to engage with the game and record their experience, (iv) Evaluate - Review the results of the playtest to better understand and strengthen the game's design. The main focus of the evaluation has been on functionality and usability during the pre-release phase, whilst in contrast the main focus in the post-release phase shall be on the participants' energy behavior change, as well as actual energy savings observed.

Our practical approach is presented in the following sections. Overall, to design an energy-behavior change solution that focuses on our end-users' needs at the workplace, we followed an incremental and an iterative and agile UCD design and evaluation approach to develop our solution. The first steps of the process were followed sequentially, to derive the initial insight we needed to formulate the basic design and use-case scenarios: (a) on-site visits to the pilot sites (where we assessed e.g. the energy consumption behavior, existing energy-saving opportunities), (b) on-site interviews (e.g. basic needs and preferences of employees), and (c) game concept selection survey (the game theme - "persona"). During the development phase, we follow an iterative agile approach, in order to develop sequential, continuously enhanced versions of the product, according to end-user feedback. Our approach is explained further and in more detail in the following sections and summarized in the discussion of the paper.

3. ENERGY AND GAME REQUIREMENTS ANALYSIS

3.1 Approach

We adopted a multi step process to elicit the requirements of employees, adhering to an Agile UCD approach to design our solution:

(i) As a first step, we visited our prospective users' work environments, to observe their everyday work routines and the extant opportunities for energy-saving therein. We examined the electrical infrastructure and devices, as well as their impact on energy consumption, and parameters that may affect future gameplay scenarios. Additionally, the daily work schedule and work characteristics (i.e. sedentary / on the move / in front of PC) of the employees were recorded. The working hours in each facility were noted, so as to derive when the gamified app should be providing content to the end users. Furthermore, we surveyed building characteristics that are relevant to our application, such as the orientation of each office space relative to the sun (to derive lighting conditions throughout the day and prepare appropriate lighting feedback). We also noted shared electrical equipment (printers, coffee makers, etc.) and shared spaces vs. individually used offices. As per the electrical infrastructure, a thorough survey was conducted, to record the characteristics of the facility, in order to prepare the deployment of IoT infrastructure to monitor energy consumption on a near-personal basis.

(ii) Having concluded our survey of the premises, we proceeded to interview a representative sample (>10% of the employees at each workspace), towards eliciting personal needs and preferences in a game that would be designed to motivate them to conserve energy at work. We kept notes during the interview process, covering aspects of the employees' preferences and preconditions for participating in our energy saving initiative. Furthermore, we explored their personal conception of their daily schedule, how they conducted their work, as well as energy-saving opportunities that existed within their work environment. We delineate our findings from steps (i) and (ii) briefly in section 3.2., while a more detailed account can be found in (Kotsopoulos *et al.*, 2017; Lounis *et al.*, 2017).

(iii) Finally, we conducted a survey to select the theme / "persona" of the designed app. The survey process and results are presented in more detail in section 3.3.

3.2 Energy-Saving Opportunities and Gameplay Insight

Consistent with existing literature (Nguyen & Aiello, 2013), the main opportunities for energy saving in our pilot sites, as identified both through interviews, as well as on-site visits, were turning a number of different personal and collectively used devices off when leaving or away from the office, using the stairs instead of the elevator, and operating A/Cs, as well as kitchen equipment optimally. A more detailed account of our findings can be found in Table 1(I). We translated these opportunities into corresponding in-game challenges and packaged them into fixed timeframe bundles, as described in the next sections, to further support long-term game use and engagement, as well as increase energy-saving motivation. As per the app design itself, we found that a team-based game scenario featuring both personal and collective actions, as well as a fair distribution of in-game incentives is desirable. A more detailed account of the collected insight on Gameplay can also be found in Table 1 (II).

Table 1. Energy-Saving Opportunities & Gameplay Insight – recorded via on-site visits and interviews

I. Energy-Saving Opportunities	
<i>Personal</i>	a. Turn PC off when leaving work, or away (e.g. lunch, meetings, on-site technical visits) b. Use the stairs instead of the elevator when ascending / descending floors at work
<i>Collective</i>	c. Operate thermostat efficiently, to keep indoor temperature within suggested optimal levels d. Make sure that windows are kept closed while rooms are heated or cooled/air-conditioned e. Turn lights off when leaving room or ambient light suffices (near windows on sunny day) f. Turn printer off while not in use g. Turning lights off in commonly used areas, when they are vacant or during afterhours h. Operating kitchen area equipment in an energy efficient way (e.g. kettle, coffee maker)
II. Gameplay Insight	
<i>General</i>	i. Few of the employees play games – a basic game play should be preferred
<i>Teamplay</i>	a. The majority (61.5%) opted for a team-based game scenario b. Both personal and collective actions, individual and team play should be available
<i>Incentives</i>	j. The majority (65%) believed that rewards are not necessary for being energy efficient c. Incentives should be allocated on – and be proportionate to – actions that can be validated d. In team game, incentives should be allocated according to individual players' contribution

3.3 Game Concept and Persona

In order to make the appearance and theme of the designed gamified app appealing to its target audience, we conducted a survey with selected participants from our pilot sites, as well as additional employees from other workplaces. The survey participants were presented with a welcome message that explained the aim of the questionnaire and the project as a whole. Afterwards, they were asked to provide an account of their feelings towards three different game concepts: (a) a Tree, (b) an Iceberg and (c) a Plain Informative Graph app. The three concepts were illustrated by different wireframes of the mobile app screen. Additionally, a scenario to have in mind while assessing the different concepts was described, followed by a short passage explaining that the personas grew and/or were enriched with appropriate vivid elements when the energy efficient action of “remembering to turn off the lights when leaving the office to go home for Thursday” was performed and the related challenge was won.

Attitude & Intention: After reviewing each of the three versions’ “personas” wireframes with this usage scenario in mind, the participants were asked to provide their feedback on 7-point Likert questions covering two axes: (i) *Attitude* was assessed by answering on three facets of the question “In the concept described how would you describe your feelings towards participating in the game?” {(Good → Bad), (Pleasant → Unpleasant), (Favorable → Unfavorable)}. These items were in line with the Theory of Planned Behavior (TPB), according to existing guidelines (Ajzen, 2010) and as implemented in literature covering attitude toward the ad (MacKenzie, Lutz, & Belch, 1986), consumer products (Spears & Singh, 2004), collaborative consumption (Roos & Hahn, 2017), and self-assessed experience (Diener et al., 2010). An average score for the three items was calculated. Scores between 1 to 3 were considered as a positive, 4 neutral and 5 to 7 as a negative indication of attitude towards the three different game designs. (ii) *Intention* was assessed by answering on two facets of the question “In the concept described, would you intend to participate in the game?” {(Likely → Unlikely), (Possible → Impossible)}. These items were also in line with the Theory of Planned Behavior (TPB), according to existing guidelines (Ajzen, 2010) and as implemented in literature covering intention to consume based on advertisement (MacKenzie et al., 1986), purchase intentions (Spears & Singh, 2004), and collaborative consumption intention (Roos & Hahn, 2017). An average score for the two items was calculated. Scores between 1 to 3 were considered as a positive, 4 neutral and 5 to 7 as a negative indication of intention to participate in a game that would feature the three different game designs.

Overall Favorite Concept – Persona: Having reviewed all three concepts, namely the Tree, Iceberg and Graph, the participants were also provided with a screen that offered a recap of the three personas and, consequently, were asked to state their overall favorite out of the three game concepts / personas. We collected a total of 141 completed questionnaires (38 from within our pilot sites and 103 from other workplaces). The results from the analysis of the survey for the two groups of participants can be found on Table 2.

Table 2. Preferences of survey participants regarding the Game Concept / Persona

		External Group %			Internal Group %			Both Groups %		
		Att.	Int.	Fav.	Att.	Int.	Fav.	Attitude	Intention	Favorite
Tree	Positive	75	70	51	77	74	50	76	70	50
	Neutral	14	14		7	10		12	12	
	Negative	11	16		14	14		12	15	
Iceberg	Positive	66	60	32	63	62	34	68	63	33
	Neutral	16	16		17	14		17	18	
	Negative	12	15		17	23		17	18	
Graph	Positive	56	58	17	58	60	16	59	60	17
	Neutral	20	20		14	15		19	16	
	Negative	18	21		25	23		21	22	

Based on the collective results from all the survey participants, we deduced that: (i) The overall favorite concept in both the two separate surveys conducted, as well as the combined results was the “Tree Concept”, with very similar results (>50 %) between the two surveyed samples. (ii) The second in preference was the “Iceberg” concept (33 %). (iii) The least preferred option was the “Graph” concept (17 %).

4. THE BASIC GAME DESIGN

Following the outlined UCD approach, we elicited the users’ requirements that guided the design of the first version of the game for energy conservation at the workplace. We also took into account existing insight from the literature indicating that: (i) The most successful mobile games fit efficiently and effectively into their users’ lifestyle; they don’t require prolonged concentration, allow busy players to pause the game as needed, are challenging, but don’t require special experience or knowledge to be successful at the start of the game (Pagulayan et al., 2002). (ii) Scoring systems should bear a connection with the underlying activity (energy-saving in our case) to be meaningful for the user (Nicholson, 2012). (iii) The most common way game designers employ to balance out the competition (allow less skilled players to compete effectively with more skilled) is to design team games (Pagulayan et al., 2002). (iv) By providing multiple ways to achieve within the gamification system, users can select those that are meaningful to them; by making each game element meaningful in a different way, we can increase the chances of tending to each user’s needs in the game (Nicholson, 2012).

We present the main characteristics of the game, starting with an overview of the game, in the following subsections.

4.1 Game Overview

Overall, a user that enrolls in the game can follow different journeys within the game play sphere. Two main paths exist simultaneously: The game can be played both individually and in teams. The basis for progression in the game is gathering points for successful adherence to suggested energy-saving actions/challenges, also packaged into specific timeframe challenges (daily/weekly/monthly). As a team member, the player can enjoy contributing to a team tree growing, flourishing, and gaining birds (ornamental badges) reflecting the successful

completion of challenges by the respective team members. Furthermore, as both a single player and a team member, the player can experience empowerment by gaining a good position in the respective personal and team leaderboards, as well as earning personal roles within the team and experiencing a feeling of relatedness when gaining team roles.

The gamified app is informed in real-time about the players’ energy consumption actions through an IoT-enabled platform, explained in more detail in (Papaioannou et al., 2018), that orchestrates a set of sensing devices (e.g. smart plugs, multi-channel power meters, Bluetooth Low Energy (BLE) beaconing devices, temperature and humidity sensors etc.), which monitor the energy consumption of personal (e.g., PC, office lamp, etc.) or shared devices (e.g., printer, air conditioner, coffee machine, etc.) in the workplaces/ offices. We employ energy-disaggregation techniques, based on the device power signatures and common non-intrusive load monitoring techniques, to derive the power load at the device level. Moreover, we utilize beacons and NFC stickers (attached on the devices) to be able to associate the energy consumed on each device with the individual employees. BLE beaconing devices detect the employees’ presence in a specific room or area, provided that they carry their smartphone with them. Finally, the users swipe their phone over NFC stickers placed on the devices, in order to signal the IoT platform that they have performed each energy-saving action on the “swiped” devices. Figure 1 summarizes the game logic structure diagram, delineating the available different player journeys within the game.

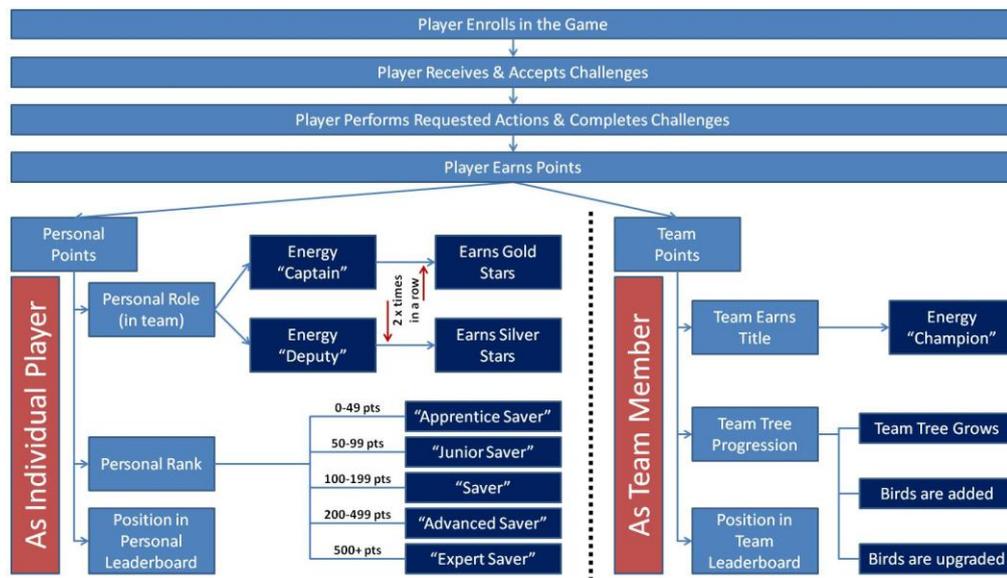


Figure 1. The Player Journey in the Game - Individual and Team Play Scenarios

According to the player journey depicted above, the players / employees receive and can accept energy-saving challenges, such as “Close your PC when you leave the office”, during the game. When they turn-off their PC, they must also swipe the NFC sticker placed on it, to self-report / claim the energy-saving action performed. The IoT platform then validates each action claimed, against energy consumption data recorded by smart metering infrastructure. Only when the player’s claim is confirmed in this way, the energy-saving action is rewarded and both the individual player and their team are awarded corresponding points in the game.

4.2 Tree Persona

Guided by and in line with the survey results about the game persona, the core concept of the gamified app we designed revolves around a virtual living and evolving main “persona” in the form of a tree that reflects the energy consumption behaviour of employees while using the energy consuming devices at their workplace. This visualization scheme aims to motivate the user to actively and continuously participate in the challenges provided by the app towards energy conservation. Furthermore, in accordance to the users’ preferences, the gamified app facilitates team play. A growing tree with vivid elements represents the user’s teams’ activity, as well as achievements within the gamified app, growing according to each team’s performance. Apart from growing, the features of the tree also become more detailed and enriched, and vivid elements in the form of birds occasionally reside on the tree according to a team’s performance. The use of animations makes the concept more vivid, attractive and motivating for the end users. The tree grows and is enriched with vivid elements as a result of challenges taken up and completed by users and their teams. The higher the score, the more the tree grows, while the more challenges completed, the more the vivid elements (birds) that reside on it. To preserve the scalability of the concept, more advanced vivid elements (birds) replace less advanced, thus preventing cluttering. Screenshots of the app, illustrating tree growth according to players’ performance in the game can be found in Figure 2.



Figure 2. Screenshots of the gamified app illustrating the tree “persona” growing in stages

The time horizon for the tree persona is four to six months, in order to enable users and their teams to reflect on their own behaviour, and form the basis for long-term energy behaviour change. By the end of this period, a fully grown blooming tree, enriched with birds (badges), can be achieved by systematically completing in-game challenges.

4.3 Gameplay Characteristics

In-Game Team Formation: Based on the insight we gathered, we derived that the gamified app should facilitate team play. Employees may concurrently belong to different categories of teams in the game (e.g. a geographical team, as well as a device-oriented team). However, all

points accrued will be reflected on both the main team scheme that has been selected in the specific game, as well as their individual scoreboard, available for viewing interchangeably in the app from the users. A comparison between teams is made based on their position in the team leaderboard (Figure 4), while more details on the team formation criteria within the game can be found in Table 3 (I).

Types of In-Game Challenges: Whenever an energy saving challenge is available, a visual notification informs the users of its availability. Each time the action is in turn performed by a player, points are credited both to their personal, as well as their teams' profile. Two main categories of in-game challenges can be accepted in the app. *Personal challenges*, like turning ones' PC off when leaving from work and *Team challenges*, like turning the workspace lights off when leaving for the afternoon. Team challenges, although taken-up by individual participants, are enacted on behalf of all the team and their outcome is mirrored both on the personal, as well as their team's progress in the game, with the points accrued by individual actions also perpetually added to the teams' scores. Furthermore, individual challenges are grouped into time-bundles that run each day over the course of the game – *the morning, daily and evening challenge*. The “*morning challenge*” includes sub-challenges through which the workplace's energy consumption is initialized each morning. The “*daily challenge*” prompts employees to perform energy saving actions, depending on environmental variables (e.g. temperature, luminosity), occupancy (e.g. leaving the office), IoT-sensed events (e.g. opening windows) and/or their work schedules and division routine. Finally, as part of the “*evening challenge*”, the employees are prompted to minimize the workplace's energy consumption for the night, when it is presumably vacant. The sub-challenges included within each challenge are explained in Table 3 (II). The forementioned challenges are also bundled into larger timeframe challenges – weekly and monthly challenge versions of the different challenges and sub-challenges – to increase user engagement. For example, the employees try to adhere to the same daily energy saving challenges on all days of a week, to attain the corresponding “weekly challenge” and, similarly throughout the month to attain “monthly challenges”. Finally, challenges can be accepted, abandoned, and/or completed. A screenshot of the app illustrating the list of challenges can be seen on Figure 3.

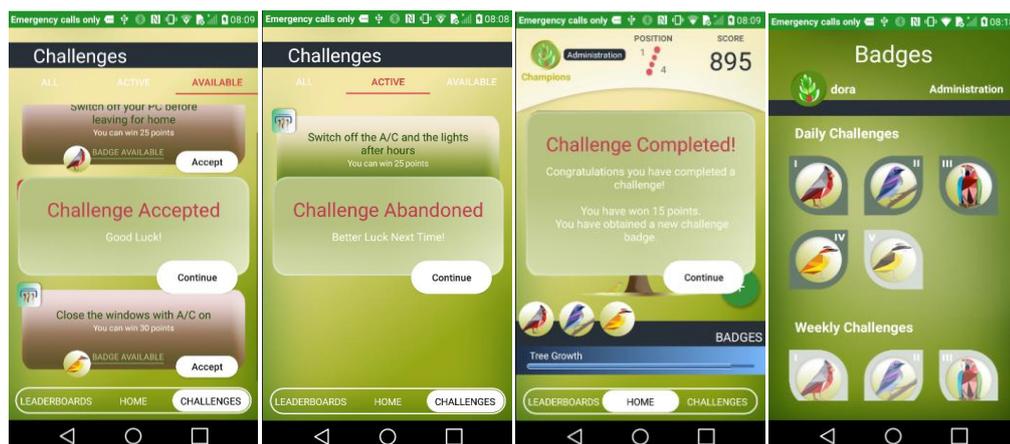


Figure 3. Screenshots featuring Challenges (accepted, abandoned and/or completed) and Badges

Individual and Team Roles & Badges: At the end of each fixed-time period (e.g. Week / Month), the team that performed best in the game shall be given the role / title “*Energy week/month Champion*”, the person that has performed best in the game within their team will receive the title “*Energy Week/Month Captain*”, and the second best within each team shall receive the title “*Energy Week/Month Deputy*”, based on performance within the week/month and not overall game progression. Details of the available roles within the game are provided in Table 2 (III). A star (badge) system has also been designed, to visually reflect repeated performance in the game. Every time the position of Energy Champion/Deputy is earned consecutively by a player, a *Golden/Silver star* is won by the player. Furthermore, additional badges in the form of birds can be earned by teams winning the team challenges. As an example, a team winning the “Daily Morning Challenge” will see a bird (badge) arriving on their team tree. By winning the “Weekly Morning Challenge”, the bird (badge) will be replaced by an upgraded version (larger / more vividly animated). To make the type of reward visually different, different types of birds will be won for performing different challenges. The in-game badges are outlined in Table 3 (IV). A screenshot of the app illustrating badges earned can also be seen in Figure 3.

Personal and Team Progression in the Game: To enable the experience of personal progression in the game, players receive an “*energy saving rank*”, based on their overall collection of points during the game. Five ranks of energy “saver” have been defined (*Apprentice / Junior / Saver / Advanced / Expert*), corresponding to different point thresholds, while a small figure of an avatar, indicative of each rank will be visible on the top part of the game interface. Both personal, as well as team progression in the game, on the other hand, is visible via the tree persona. The personal and team trees grow and are enriched with bird badges according to the energy efficient actions performed and challenges won by the users, or the team members. To enrich the experience, team members will also receive feedback regarding their team tree such as, for example, “Your tree has a new bird visitor, because you remembered to turn off the lights when leaving the office all the days last week”. Thus, the more active and successful the team members are in the game (according to challenges accepted and completed) the more their team tree is enriched by vivid elements, such as birds, and the more points are added to the team score, the more the tree grows.

The game interface also includes textual information about the team score/rank and personal position/rank in the game, which can be accessed at all times in the bottom part of the interface. Specifically, below the tree resides a scrollable area, visible when the user swipes up on the screen, containing the leaderboards, as well as recently accepted, won/lost challenges. An additional view exists containing a comprehensive achievements history per team and user, statistics regarding challenges, team positions and badges earned. In-game progression is further explained in Table 3 (V). Screenshots of the app illustrating the personal and team progression in the game can be found in Figure 4.

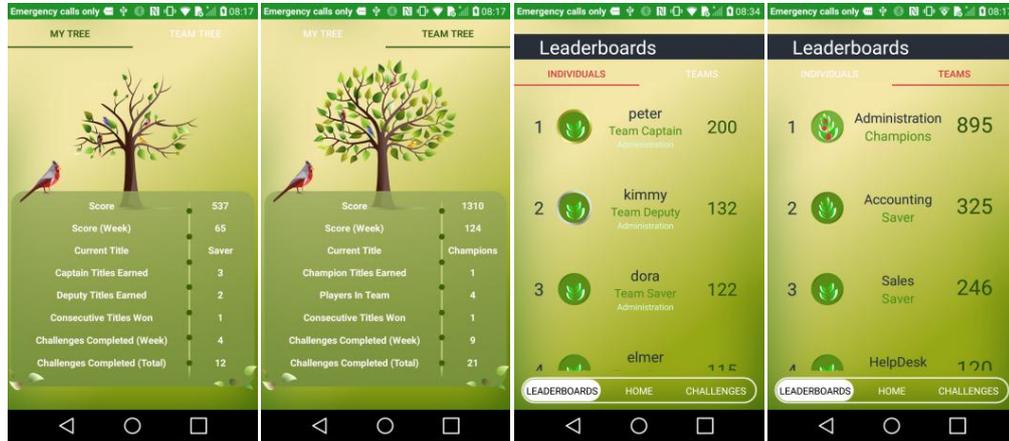


Figure 4. Screenshots of the app interface. The user can review their earned badges, personal and team status, position in the team and personal leaderboards, as well as status of the tree “personas”

Table 3. Overview of Gameplay Characteristics

III. Team Formation Criteria		
<i>Geographical</i>		e. Employees working in the same shared office space f. Employees in adjacent individual office spaces g. Employees in different rooms with similar functions h. Employees in a workplace competing vs other workplaces/buildings
<i>Role-oriented</i>		i. Employees working in the same department j. Employees with similar duties at work
<i>Device-oriented</i>		k. Employees who share devices (printers / air-conditioners, lights, windows, etc.)
IV. In-Game Challenges		
<i>Cat.</i>	<i>Name</i>	<i>Description of Challenge</i>
<i>Morning</i>	a. “Check-in”	Declare that you have arrived and want to start playing
	b. “Elevator up”	Use the stairs, instead of the elevator, to reach your office
	c. “Lights on”	Turn on the minimum necessary lights in your (teams’) office
	d. “Coffee on”	Prepare a unique (team) load of coffee to share in the morning
	e. “Kettle”	Use the kettle once to boil water for (teams’) tea in the morning
	f. “Equipment on”	Switch only the necessary office equipment needed for the day on
<i>Daily</i>	g. “Temperature”	Adjust thermostat when temp. is too high in winter, or low in summer
	h. “Illumination”	Turn the lights off whenever ambient light suffices
	i. “Windows”	Keep windows closed when air conditioners are on
	j. “Away”	Switch off any unnecessary devices whenever away from office
<i>Evening</i>	k. “Elevator down”	Use the stairs, instead of the elevator, to leave the office.
	l. “Lights off”	The last (team) member leaving the office, switch off all the lights
	m. “Coffee off”	Turn off (team) coffee maker before leaving the office in the evening
	n. “Equipment off”	Turn off any equipment that isn’t needed afterhours before leaving
V. Roles / Titles		
<i>Cat.</i>	<i>Title (Week/Month)</i>	<i>Description of Role / Title</i>
<i>Team</i>	a. Energy Champion	The team that performed best in the game within a fixed time period
<i>Personal</i>	b. Energy Captain	The team member that performed best within a fixed time period
	c. Energy Deputy	The team member that performed second best within fixed period

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VI. Badges		
<i>Cat.</i>	<i>Type</i>	<i>Mode of Attaining of Badge</i>
<i>Team</i>	a. Bird(s) on Tree	Winning team challenges – different birds for each type of challenge
<i>Personal</i>	b. Gold Star	Won for earning “Energy Captain” 2 weeks in a row
	c. Silver Star	Won for earning “Energy Deputy” 2 weeks in arrow
VII. Progression		
<i>Cat.</i>	<i>Type</i>	<i>Description of Progression Element</i>
<i>Team</i>	a. Team Tree Growth	Team tree grows and is enriched with bird badges according to the energy efficient actions performed and challenges won by the team
	b. Pers. Tree Growth	Personal tree grows according to personal energy efficient actions
	c. Energy Saver Rank	Rank appointed according to points accrued in the game
<i>Personal</i>	Apprentice	0-49 points accrued: Just enrolled in the game, has performed few to no actions
	Junior	50-99 points: Player earns the first basic bundle of points, becomes more experienced in game and upgrades to “junior” rank
	Saver	(100-199 points): After performing a normal level of actions, the rank of “saver” is attained
	Advanced	(200-499 points): Player has reached a threshold of points that corresponds to a relatively large number of actions
	Expert	(500+ points): Indicative of truly conscious energy savers. Only the very active players may reach this rank at the end of the game.

5. USER VALIDATION AND IMPROVED GAME DESIGN

5.1 Usability & User Experience Evaluation

To validate the usability and appeal of our designed app to the end-users, we conducted usability tests in our three pilot sites. After presenting the aims and scope of the developed solution to and a short video tutorial of the app, we asked the participants to playtest it for 10 minutes on Android mobile phones with the app pre-installed. Consequently, they answered questionnaires assessing usability and user experience. We employed the System Usability Scale (SUS), using an acceptable threshold of 68 (Bangor *et al.*, 2009), as well as the User Experience Questionnaire (UEQ) (Laugwitz *et al.*, 2008), that assesses: (i) Perspicuity (Clear, Easy to Learn, Easy, Understandable), (ii) Novelty (Leading edge, Creative, Innovative, Inventive), (iii) Dependability (Motivating, Exciting, Valuable, Interesting), (iv) Stimulation (Supportive, Meets Expectations, Predictable, Secure) and (v) Efficiency (Efficient, Fast, Organised, Practical). Finally the participants were asked to freely provide comments.

We recorded results from N=16 employees (10 male and 6 female) aged 41.75 years old on average. Across all sites, the average SUS score was 75.31, well above the acceptable threshold of 68. Furthermore, the vast majority (75%) of the participants rated usability above the threshold. Regarding the results from deploying the UEQ, the participants on average rated their experience (on a scale from 1- 7) very highly on Perspicuity (6.02), and sufficiently highly in Efficiency (4.81), Dependability (5.03), Stimulation (5.22) and Novelty (5.44). The complete results recorded on the SUS and UEQ, for all three sites (Greece, Spain and Luxembourg), along with calculated average scores, are included on Table 4.

Table 4. System Usability Scale (SUS) and User Experience Questionnaire (UEQ) scores (1st validation)

Site	Age	Gender		SUS	UEQ				
		M	F		Perspicuity	Efficiency	Dependability	Stimulation	Novelty
Greece	47	+		75.0	7.00	2.25	3.50	5.25	5.25
	34	+		85.0	7.00	6.50	6.50	5.50	6.50
	40		+	87.5	7.00	4.50	6.25	6.25	6.50
	43		+	95.0	7.00	6.75	6.50	6.50	6.75
	34		+	60.0	5.50	3.50	5.75	4.75	5.75
Avg.	39.6	2	3	80.5	6.70	4.70	5.70	5.65	6.15
Spain	44	+		77.5	6.00	5.25	4.75	4.75	5.25
	37		+	75.0	7.00	4.75	5.00	4.75	5.25
	55	+		57.5	5.25	4.50	4.50	4.50	4.25
	44	+		75.0	6.25	3.75	5.00	5.50	5.50
	29	+		80.0	6.00	6.00	5.00	5.75	5.50
Avg.	41.8	4	1	73.0	6.1	4.85	4.85	5.05	5.15
Luxem- bourg	53	+		87.5	5.75	5.25	5.00	5.75	5.25
	35		+	97.5	7.00	6.25	6.25	6.50	6.75
	55	+		35.0	4.50	5.25	4.00	3.25	3.00
	45	+		47.5	4.00	4.25	3.25	4.50	3.75
	31	+		72.5	5.50	4.25	3.25	4.50	5.00
42		+	97.5	5.50	4.00	6.00	5.50	6.75	
Avg.	43.5	4	2	72.9	5.38	4.88	4.63	5.00	5.08
Total Avg. (All Sites)	41.8	10	6	75.3	6.02	4.81	5.03	5.22	5.44

Based on our sample size (N=16), and the total population of office employees in our pilot sites (N=144), as well as the fact that 81.25% recorded acceptable SUS scores (>68), we deduce that the confidence interval of our results is 20.07% (Creative Research Systems, 2018). Hence, the avg. SUS score for (N=144), is expected to vary between 60.19 and 90.43 (+/- 15.12 from the recorded score of 75.31 for our sample), with a 95% confidence level.

5.2 End-User Feedback

After playtesting the app and answering the questionnaires on usability and user experience, we also asked the participants to provide their comments, based on preset themes. The collected insight is presented in Table 5.

Based on this insight, we deduce that, first of all, the vast majority of the participants (14/16) would be willing to use the designed application in an upcoming test phase, as they enjoyed using it (15/16) and found it potentially easy to include in their daily schedule (14/16) at work (see Figure 5). The participants' motives for using the app were various, such as for the mere fun in competing (4/16), out of curiosity (3/16), based on their environmental awareness (2/16), sense of duty (1/16), and/or towards socializing with their colleagues at work (1/16). All these motives need to be taken into account during the testing phase, in order to make the game scenarios appealing to the end-users. On the other hand, the minority that was unwilling to use the app, suggested reasons such as a lack of motivation/need (1/16) and time scarcity/busy schedule (1/16). Therefore, to convince them to use the app, we would need to further enhance its functionality in line with their needs, as well as further respect employees' time limitations, by making it as least intrusive and time-consuming as possible.

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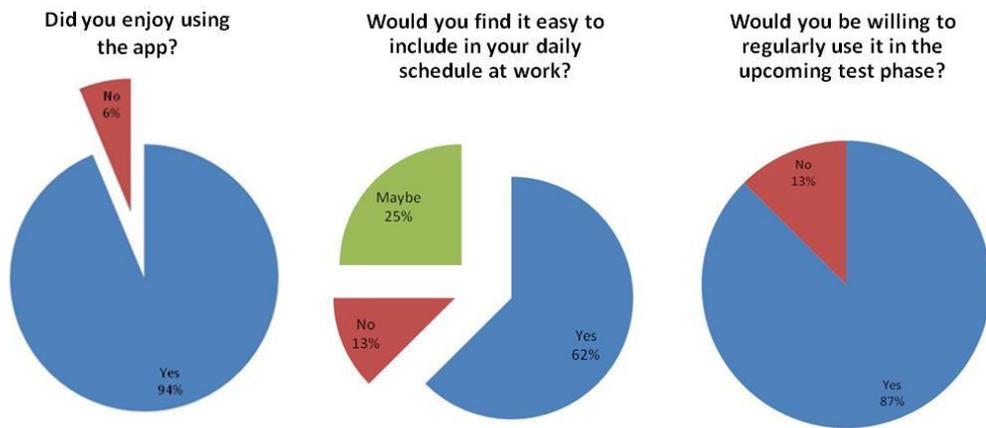


Figure 5. Willingness to use the app in an upcoming test phase

As per the app’s strong points, the best feature was found to be team play (6/16), followed by the tree persona concept (5/16), as well as its scope and potential (5/16), design (4/16) and gameplay (3/16). These are the points that can be leveraged during the pilot testing, in order to attract our audience. The most important perceived worst features of the app on the other hand were that there was no indication of the actual energy saved within the game (6/16), followed by the lack of in-game tips functionality (3/16). Furthermore, the participants directly suggested adding notifications / alarms functionality (4/16), projecting info on energy consumption (3/16), allowing continuous in-game progression (3/16), providing energy-saving tips (2/16), limiting the attention needed to participate in the game (2/16), and further enhancing the visualization (2/16) as ways in which the app and overall energy-saving solution we designed could be improved.

To further enhance our understanding of the participants’ experience with the app, upon answering the pre-set questions, we asked them to also note down their additional comments in a free-form manner. Furthermore, as soon as the questionnaire was completed by all the participants, we conducted a free-form discussion with them, to collect any feedback not already provided by them in writing. A basic comment noted by the participants was that they wanted to view information regarding the energy usage at their workplace, as well as the energy-savings achieved through their actions. More specifically, they noted that they wanted to know / view (6/15) the energy impact of each single action, the actual impact of the app on energy savings / consumption (the energy saved through the users’ actions in the game, as well as the progress made in energy savings), and a comparison of energy savings effected through the app between the participating buildings (in a building competition setting).

Additional insight was provided regarding the gameplay scenarios. More specifically, the participants suggested that they want to be engaged in daily actions in a hassle-free manner and that it may become boring to have to activate the same daily challenges in the game each day (e.g. a user who is always taking the stairs instead of the elevator, should not have to select the challenge every day, but once for many days in advance). Therefore, for actions that a user already performs as part of their daily routine, there should be the capability to accept / activate the relative challenges i.e. on a weekly basis with one click in the game. However, to ensure that players login to the app every day, daily logins should be encouraged, or rewarded

in the app. Furthermore, the points awarding mechanism should be designed bearing into account that not all users have access to the complete set of challenges and the game should be fair for all based on what actions they can perform. Additionally, the participants stressed that the game should provide feedback on their actions (e.g. an on-screen message verifying successful completion of an action) in the case that the conducted action is not enough to immediately lead to growth in the tree persona. Moreover, a user should be able to clearly see the open / participating challenges within the game interface.

Apart from the game design insight, a number of issues were also raised by the participants regarding the technical IoT infrastructure utilized in the game. This insight was not directly relevant to the game design itself but, however, the hardware settings suggested were taken into account in order to be able to optimally set-up the IoT infrastructure for the upcoming trials, and increase the users' engagement in the overall solution designed. More specifically, the users noted that doors may also be left open in rooms with the air conditioning on, leading to energy wastage. Therefore IoT sensors should also be placed on the doors, and the windows challenge may be extended to include doors. Furthermore, the NFC stickers that the users are expected to swipe should be put in a position to be visible and easily accessible by them, while respecting technical limitations for optimal use. Towards that end, the pilot site managers should be given a step-by-step manual of how to position NFC stickers in their premises and (re-) allocate users to equipment. Finally, as some users may feel that their privacy is invaded and they are being tracked by the infrastructure, all the steps taken to ensure their privacy when storing sensitive data should be clearly and thoroughly presented to them upfront.

Table 5. Comments and answers from the participants, based on the interview guide questions

Did you enjoy using the app?
<i>YES: 15/16 / NO: 1/16</i>
Would you find it easy to include in your daily schedule at work?
<i>YES: 10/16 / NO: 2/16 / Maybe: 4/16</i>
Would you be willing to regularly use the app in the upcoming test phase?
<i>YES: (14/16) - Why?</i>
<ol style="list-style-type: none"> 1. <i>Fun in Competing</i> (4/16): It's fun / it will be a pleasing experience / as I start winning points I will get even more challenged / I'm quite competitive 2. <i>Curiosity</i> (3/16): To see if we, as employees, can really have some significant influence in the buildings' energy consumption / I'm curious / I'm interested in trying - using the app 3. <i>Environmental awareness</i> (2/16): I am very interested in different ways to increase people's awareness about energy saving / to stimulate environmental conscience 4. <i>Sense of Duty</i> (1/16): I have been committed to it 5. <i>Socializing</i> (1/16): to create team building among the colleagues at work
<i>NO: (2/16) – Why?</i>
<ol style="list-style-type: none"> 1. <i>Lack of motivation</i> (1/16): I don't need it – I'm already very aware of how to save energy 2. <i>Time scarcity</i> (1/16): My schedule is very tight already
What did you find to be the BEST feature of the solution?
<ol style="list-style-type: none"> 1. <i>Team play</i> (6/16): team challenges / competition / comparison with other members and groups 2. <i>Evolving tree persona</i> (5/16): corresponds to the ecological conscience / team tree enhances group participation / sympathetic character of the app 3. <i>App scope and potential</i> (5/16): includes my daily energy consumption routine / we respect the environment / provides a positive message 4. <i>App design</i> (4/16): very interesting and innovative / easy to use / well-designed / specifies the concepts clearly 5. <i>Gameplay</i> (3/16): challenge-based / played on a voluntary basis / no negative scoring

What did you find to be the WORST feature of the solution?

1. *No indication of actual energy saving in game* (6/16): need to view the real impact of actions on energy consumption
2. *No help – tips available* (3/16): badges and corresponding challenges should be further clarified / not all have access to all the types of challenges / challenges surrounding PC usage need clarification
3. *No obvious real (tangible) personal gain* for the participants (1/16)
4. *Small screen size in mobile apps* (1/16)

Do you have any suggestions on how the app could be improved?

1. *Add notifications / alarms* (4/16): to remind pending actions / challenges to the users
2. *Project info on energy consumption* (3/16) : game should reflect real conditions as best as possible, users should understand what and how they are winning
3. *Continuous in-game progression* (3/16): a change depicted in the tree, or a new bird for each completed action (continuous tree growth) / new rewards each day / more challenges
4. *Limit attention needed* (2/16): not too many challenges per day / capability of playing without constantly using phone
5. *Enhance visualization* (2/16): more animations and videos / use of flowers as badges / intra-team progress visible in a “forest” of team trees

Do you have any suggestions on improving the solution in general?

1. *Provide energy-saving information and advice* (2/16): capability to view tips and actual energy saved in the game
2. *Support users to motivate peers* (1/16) - provide ways to engage users in the real world
3. *Add capability to hide progress in the game* (1/16) – play incognito

5.3 Additional Functionality & Improvements on the App

We utilized the collected findings and insight through the user evaluation process outlined above, to enhance the app that will be used during the pilot testing phase. Therefore, to fit the users’ needs and preferences recorded, we extended the game functionality to include: (i) *pop-up messages* that inform the user on the acceptance / abandonment / completion of a challenge (Fig. 3), (ii) *energy-saving tips* that educate users into how they can conserve energy at work while playing the game (Fig. 6), and (iii) *energy-savings reports* accessible within the app, through which the user can view the savings effected from their in-game actions, as well as a comparison of energy savings achieved between different participating workplaces (Figure 6).



Figure 6. Additional functionality in the game added after user evaluation (tips & energy savings)

To verify the utility, as well as acceptance of the new functionality introduced in this revised version of the app, we conducted a second validation with a smaller sample of employees. We followed the same process and utilized the same measures we used in the first validation phase delineated in section 5.2. The results can be seen in Table 6.

Table 6. System Usability Scale (SUS) & User Experience Questionnaire (UEQ) scores (2nd validation)

Site	Age	Gender		SUS	UEQ				
		M	F		Perspicuity	Efficiency	Dependability	Stimulation	Novelty
Greece	41	+		72.5	5.50	4.75	5.25	5.00	5.50
	45		+	85.0	5.25	3.75	3.75	5.50	5.75
	35		+	85.0	6.50	4.50	5.75	5.00	6.00
	35	+		77.5	6.50	6.75	6.50	5.25	7.00
	35		+	85.0	6.50	6.75	6.75	6.25	6.00
	35		+	100	7.00	7.00	7.00	6.75	7.00
	41	+		92.5	7.00	6.50	6.50	5.75	7.00
Avg. 2nd Val.	37.3	3	4	85.4	6.32	5.71	5.93	5.64	6.32
1st Val.	41.8	10	6	75.3	6.02	4.81	5.03	5.22	5.44
Change (Δ)	-4.5			+10.1	+0.30	+0.90	+0.90	+0.42	+0.88
“ %	-12.1			+13.4	+4.98	+18.71	+17.89	+8.05	+16.18

We recorded results from N=7 employees on one of the sites (3 male and 4 female) with an average age of 37.3 years old. The average SUS recorded by the 7 participants (3 male and 4 female) was 85.4, well above the acceptable threshold of 68.0 and 13.4% higher than the 75.3 average usability score recorded in the validation of the previous version of the app. All of the users also rated the usability of the app above the threshold of 68 (min 72.5, max 100.0). Furthermore, regarding the users' experience, the scores for the revised version of the app on the UEQ were very high on Novelty and Perspicuity, as well as high on Efficiency, Dependability and Stimulation, indicating that there may still be some room in improving the app by focusing on making it more Efficient, Dependable and Stimulating in the future.

6. DISCUSSION

To design an energy-behavior change solution that focuses on our end-users' needs at the workplace, we are following an iterative and incremental agile UCD approach during the design, release and testing phases (Figure 7). We analyzed the collected feedback on user interface and system design for a first version of the app and acted upon the resulting insight, to guide the incremental development of our solution by focusing on the specific requirements derived, while developing the second complete integrated version. Comparing the SUS and UEQ results attained for the two versions, we found that all the users rated usability above the threshold of 68 (min answer 72.5, max 100.0) in the revised version, as well as 13.4% higher on average. This shows an improvement to the first version, where 25% of the users had rated usability below the (60) threshold. Furthermore, regarding user experience, the revised version of the app was rated high on all UEQ pillars, also featuring an improvement compared to the results from the 1st version of the app. On average, the scores were very high on Novelty and Perspicuity, as well as high on Efficiency, Dependability and Stimulation, and the improvement was 4.98% for Perspicuity, 18.71% for Efficiency, 17.89% for Dependability,

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8.05% for Stimulation, and 16.8% for Novelty (see Table 6). To summarize, based on the above, by comparing the results from the user evaluation of these two successive versions of the designed solution, we found that we achieved improved results in the second version, both in application usability and user engagement, towards attaining the desired user behavioral change – energy conservation.



Figure 7. The Iterative & Incremental Agile UCD Game Development Process we followed

7. CONCLUSION

We designed a gamified app to be employed towards motivating employees to conserve energy at the workplace, following a UCD approach. After examining our prospective end-users' requirements, as well as observing the contextual characteristics of their workplace environments, and inherent opportunities for energy saving therein, we proceeded to select the energy-wasting behaviours that should be targeted, in order to effectively reduce energy consumption. Furthermore, following an agile process, we derived a game design to fit our samples' characteristics and context. A challenge-based, primarily team-game scenario, with fixed-timeframe bundled actions, was adopted according to the collected insight. Usability and user experience results were well within acceptable ranges for the first app prototype, indicating that the approach we followed led to a potentially successful app. Following our test-users' suggestions for improvements, we extended the app functionality and re-evaluated the revised version. Preliminary scores for both usability and user experience were significantly higher in the revised version of the app, indicating that by following the users' suggestions from the first validation phase, we derived an application with enhanced possibilities for engaging its target audience into conserving energy at the workplace.

However, since the sample size we consulted was significantly smaller compared to the previous test phase, we would need to involve additional participants towards gaining in generalization of the recorded results in the future. Moreover, our research would be better grounded through practical experimentation, to further verify and fortify the effectiveness of the process followed, as well as of the resulting app, in effecting employee energy behavior change. We aim to proceed towards this direction, by conducting experiments, featuring the designed gamified app, in workplaces situated in three different EU countries, in the future.

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