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Enabling collective awareness of energy use via a social serious game

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Abstract

Serious games are digital games, simulations and virtual environments designed for primary purposes (e.g. teaching, learning and training) other than pure entertainment. They are experiential environments where features such as thought-provoking, informative or stimulating are as important, if not more so, than fun or entertainment. A number of serious games have been developed for energy systems that act as educational tools and help energy consumers to better understand concepts such as resource allocation, electricity prices and grid sustainability. This paper discusses the development of a serious game, the *Social Mpower*, which visualises a community energy system in which players should avoid energy problems (i.e. blackouts) by individually reducing their energy consumption and sustain the Common-Pool Resource (CPR) of their community. Our experimental hypothesis is that if players are "collective aware" of their individual and community consumption, they consume energy in a more efficient and effective way and therefore, they can avoid potential energy problems (i.e. blackouts). Our experimental results show that *Social Mpower* can be productively used as an educational tool to bring a desired change in people's behaviour towards energy consumption.

Keywords: collective action, collective awareness, energy use, serious games

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1. Introduction

Serious games are digital games, simulations and virtual environments designed for primary purposes (e.g. teaching, learning and training) other than pure entertainment. The concept of serious games is common in applications which simulate real-world events and processes, with examples found in military, education, healthcare, management and engineering. A number of serious games has been developed for energy systems that act as an educational tool and help energy consumers to better understand concepts such as resource allocation, electricity prices and grid sustainability. In such gamified environments, players use technology to solve environmental problems such as 'green' environment, optimised energy and water infrastructure, sustainable resources and reduced energy use.

This paper discusses an autonomous energy community for local power generation and distribution visualised by the *Social Mpower* game. In this game, players share resources (i.e. energy) from a Common-Pool Resource (CPR) and they should coordinate and synchronise their individual actions to avoid the depletion of these common resources. In such a collective action situation, collective awareness will help players to resolve occurred collective action problems. Our experimental hypothesis is that if players are "collective aware" of their individual and community consumption, they consume energy in a more efficient and effective way and therefore, they avoid potential energy problems (i.e. blackouts). Our results show that *Social Mpower* can be productively used as an educational tool to bring a desired change in people's behaviour towards energy consumption.

This paper is structured as follows. In Section 2 we present the motivation behind our work and in Section 3 we review some related serious games. Section 4 presents the *Social Mpower* game which is a representation of a community energy system for local power generation and distribution, and Section 5 describes how this game can be used as an educational tool for encouraging players to reduce their energy consumption. Section 6 reports the results of the experiments

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that show that, 83.9% of the players stated that this game helped them to better understand energy consumption and how to use energy in a more efficient and effective way. Finally, in Section 7 we conclude our work with some comments regarding the effectiveness of serious games to be used as educational tools and remarks for future development.

2. Background & Motivation

Collective awareness is informally defined as an attribute of a community that helps it resolve a collective action problem and without it, community members may not be able to form a synchronised and accumulated body which works together for a desirable and collective goal. Serious games are extensively used to simulate real-world events and are designed to train or educate people on science, health care, management, engineering and so on. Energy systems are a particular area where serious games have been widely deployed to achieve a desired progress or change in players' behaviour.

2.1. Collective Awareness

Collective awareness is informally defined as "an attribute of communities that helps them solve collective action problems", i.e. analogous to the way that social capital is defined by Ostrom and Ahn [1] as "an attribute of individuals that helps them solve collective action problems". Collective awareness is a critical aspect within communities which promotes collective action; members of communities take the necessary actions as a synchronised and accumulated body to reach a desirable outcome for collective resources and services – water, electricity and data [2]. Collective awareness is the common knowledge that comes from social networking, self-organisation and coordination, and it is the essential link between self-organising communities and successful collective actions [3].

In communities in which collective awareness is absent, individuals are generally less willing to obey the norms or the rules, or able to understand that their actions have an effect on the community [4]. Individuals may understand the situation they are in from a micro-level perspective (e.g. reducing individual energy consumption) and might additionally recognise the macro-level requirement (e.g. meeting national carbon dioxide emission pledges); however, they might not be aware of interactions occurring at the meso-level which are critical for mapping one to the other [5]. There are communities where common resources are not sufficient for all their members, and the lack of collective awareness may prohibit individuals from changing their community behaviour or even taking actions that may lead to depletion of those resources [6]. Collective awareness can contribute to an efficient resource allocation within a community, ensuring at the same time the long-term sustainability of that community [7], [8].

The function of collective awareness of some proposition ϕ can be defined as a two part relation; firstly a belief that there is a group (Equation 1), and secondly an expectation that if someone is a member of that group, then s/he believes the proposition ϕ (Equation 2):

$$\mathcal{B}_a \exists G.group(G) \tag{1}$$

$$\mathcal{E}_a(group(G) \wedge member(b, G)) \rightarrow B_b\phi \tag{2}$$

If this holds for all (or most) members of the group, then we can say that the group G is collective aware that (or of) ϕ (Equation 3). With collective awareness, if someone else is a member of a group, then if s/he believes ϕ, s/he will intend action A, i.e. under these conditions someone expects that if you are a member of the community, then if a potential_blackout (ϕ) happens, then you will turn something off (action A):

$$\mathcal{E}_a(group(G) \wedge member(b, G)) \rightarrow B_b(\phi \rightarrow I_b A) \tag{3}$$

We consider collective awareness as being different from mutual knowledge and, achieving collective awareness in a community requires formation of an institution, regulation of behaviour within the context of the institution, and the direction (or selection) of actions intended to achieve a common purpose. Institutions can be defined as "the sets of working rules that are used to determine who is eligible to make decisions in some arena, what actions are allowed or constrained, what aggregation rules will be used, what procedures must be followed, what information must or must not be provided, and what payoffs will be assigned to individuals dependent on their actions" [9].

2.2. Serious Games & Gamification

Games are activities among two or more independent decision-makers who want to achieve their goals in a specific environment. In the context of a game there are rules, and players compete against their adversaries to meet their objectives. But not all games are competitions; there are games where players cooperate to achieve a common goal and there are not individual objectives. Games may be played just for fun but there are games, called serious games, that have a clear and intentional educational purpose and are not intended primarily for entertainment [10].

Serious games are extensively used to simulate real-world events, inform or make players aware,

and trigger their problem-solving skills. These games prepare people to work smarter by enabling them to visualise their actions and explore different events in an intuitive way. Serious games are games in which education in various forms is the primary goal rather than entertainment, and they help users to develop skills such as decision-making, critical thinking and analytical skills [11], [12], [13]. They are experiential environments that use characteristics of games to deliver a message, teach a lesson or provide an experience. The main goal of these games is to educate players while they entertain them. Serious games are very effective in teaching and training players despite their age and they can communicate their concepts in a very efficient way. Players, through their roles, need to solve problems, set strategies and make decisions without facing the cost of real-world consequences. Serious games allow players not only to learn but also to apply and show what they learned during the game [14].

Gamification is "the use of game elements in non-game contexts" [15]. Gamification is a natural extension of serious games from artificial settings with self-contained game-defined rewards and "win" conditions, to real-life situations where the rewards and "win" conditions may be rather different. In real-life scenarios, in particular, very often the "win" condition is sustainability, rather than termination of the game, i.e. the aim is to keep the game going. Game design elements, rewards and reputation systems (e.g. points, badges, levels and leader boards) improve the user experience, while the introduction of social contexts facilitate the user engagement and collaboration through gamified experiences [16].

3. Serious Games for Energy

Serious games and gamification are used to motivate or even change players' behaviour towards energy use. Serious games used in the energy sector simulate environmental-related issues and players, with the aid of technology, solve problems relating to 'green' environment, optimised energy, sustainable resources, reduced electricity use and so on. Many companies and institutions have developed games for teaching and awareness about power, efficient energy use and alternative forms of energy.

IBM develops serious games for many years that trigger players' problem-solving skills. In CityOne [17] game, players experience some of the most complicated energy problems currently faced by cities. This game belongs to company's smarter planet initiative based on the concept that the world becomes connected and intelligent, and therefore people use technology to solve environmental problems. Players should optimise banking, retail, energy and water in an online, sim-based environment, and should complete a series of tasks. Players should improve their city by making revenue and profits, make the environment greener and satisfy the citizens. Players learn how they should manage a city and use new technologies to propose innovative solutions in order to make the water cleaner and banks more prosperous and user-centric. This game introduces players to real-world planning and teaches them industry problems. CityOne visualises real-world problems faced by banks, water and energy utilities, creates awareness around these problems and teaches the general population that a smart IT infrastructure can revolutionise the energy utilities by accelerating, changing and integrating technologies.

Siemens Energy developed the PowerMatrix [18] game, an online game in which players should sustain a city's energy system. This game informs players about the mechanics and rules of the energy market and provides details about the interactions between the different types of power generation and smart grids. PowerMatrix is intended for the general population where players become energy managers in a rural area and whose aim is to develop a city by creating an intelligent power generation and distribution network. In this game, there are different energy sources such as fossil fuels (e.g. gas, oil and coal), biomass, nuclear and renewables (e.g. wind and solar energy). Players should create an energy mix combining the different energy sources and, the better the mix the faster the city grows. Players should be very careful with their budget to ensure that the resources are used in a sustainable and efficient way, and should raise money to grow their power grid. They should continually balance the energy output, operational cost, resource use and citizens' satisfaction, as by adding the energy assets, investing in energy research and trading the energy surplus will help them increase their earnings. PowerMatrix raises awareness and teaches players about the new forms of energy with the emphasis being on power generation and not on energy efficiency. PowerMatrix represents an idealised and simplified view of energy systems and presents today's trending technologies and solutions for the energy sector.

Power House [19] is an online, multi-player game which displays players' energy use based on actual meter readings (there are installed smart meters and sensors on players' houses). Players should complete different tasks relating to energy efficiency and management and are rewarded with points in the game. Real-time feedback challenges players' decision-making and educates them about energy consumption. Power House is connected to Facebook and promotes players' communication with their friends and other members of the online community to help each other save energy. There is a mini-game embedded in Power House

in which players should complete various tasks in a virtual house (turn on/off electrical appliances) using the minimum amount of energy. This game motivates players to reduce their energy use and lower their bills. Different graphs and plots display the energy consumption, while gamification techniques encourage players to change their energy behaviour.

Energy Chickens [20], a web-based serious game application accessed from desktop computers, use real-time energy consumption data from plug devices to manipulate animated chickens living in a personalised virtual farm that each player maintains. The energy consumption of each device is reflected in the health of the corresponding chicken; when energy consumption is low the chicken is healthy, grows bigger and lay eggs which are the players' rewards (players redeem eggs for virtual accessories to decorate their virtual farms), but when the energy consumption is increased the chicken is smaller, does not lay many eggs and eventually becomes ill. The effectiveness of Energy Chickens to reduce the plug-load was tested in a mid-size commercial office. 288 electrical appliances monitored for 24 weeks and 61 workers participated. The average energy consumption was reduced by 13%, and 69% of the participants said that this game helped them to become more energy aware.

2020 Energy [21] is a serious game developed within the ENERGY-BITS framework (a European cross-media awareness program) which targets teenagers (14-18 years old) and awares them about reduced energy consumption, increased energy efficiency and the best choice regarding the different renewable resources. The player receives environmental, social and economic advices and is responsible for making the right choices for improving our collective 'energy' future. This game introduces players to different energy-related issues for sustainable development through 9 interactive missions targeting the individual, local and global scale of these issues. The 9 missions are organised on energy saving, energy efficiency and renewable energies, and for example players should choose the best holiday destination based on CO2 emissions and modes of housing, or choose the best sustainable energy source considering the available solar panels, wind mills, tidal power and landscape protection. 2020 Energy game promotes the sense of responsibility among players and a citizen-centred approach, and encourages the exchange of ideas and experiences. From an educational perspective, missions replace the subjects and problems, scores replace the grades and players learn about responsibilities and impacts of their actions.

4. *Social Mpower*

Social Mpower visualises a community energy system which includes different residences, geographically co-located, and a Common-Pool Resource (CPR) for storing the locally generated energy (see Figure 1). Photovoltaic (PV) cells installed on the roofs of the residences generate the required power and are the only electricity providers for the community. The virtual residences are connected so that they consume the produced PV power and eventually, share any remaining energy with the rest of the residences. The produced energy is stored in each residence in appropriate energy storage systems (e.g. batteries). Each residence has a number of electrical devices the occupants may wish to use.

The electrical devices are divided into two main categories; the interruptible devices (i.e. television, computer, oven and fridge) that can be switched on and off according to player's preferences, and the non-interruptible devices (i.e. washing machine, dishwasher and coffee machine) that are switched on when the player wants to operate them, but are automatically switched off after a predefined time period (see Figure 2). For example, the computer is switched on when the player feels like entertaining himself and switched off any time without specific time limit, whereas the washing machine is automatically switched off after a specific simulation time reflecting the duration of its washing program. Players can operate these devices (touch the radio-buttons placed on them) and the colour of the radio-button reflects the state of the device (red colour indicates an inactive device, whereas green colour is for active devices). Whenever the player operates an electrical device, a pop-up message appears on the screen informing the player about the energy consumption and operating time of the specific device.

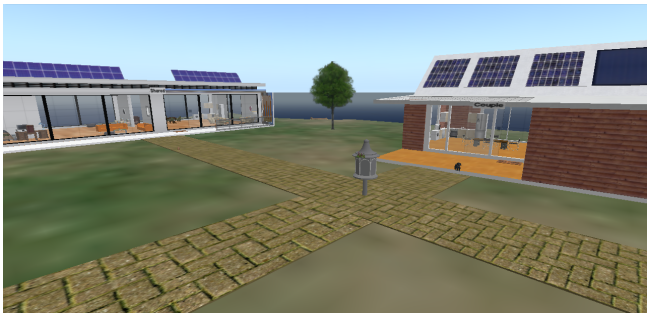

Figure 1. *Social Mpower* game

The residences include kitchen, dining room, living room and bedrooms. The kitchen is equipped with the electrical devices mentioned above, while sofas, beds, chairs, tables, desks, bookcases, plants and flowers are included in the rest of the residence to give players the feeling they are in their real homes. All

residences include a smart meter board, an electronic device that records the consumption in real-time, and communicates this information back to the players in a line graph form. The line graph depicts the functional relation between the consumption (Watts) and time. There are two different lines, one displaying the individual consumption and one which displays the community consumption. The smart meter board gets updated with the player's 'touch'. Animals such as dogs, cats, turtles and ducks can be found, making the game experience more enjoyable and entertaining, while avatars are customisable to meet players' preferences.

Figure 2. Electrical Devices in *Social Mpower* game

Players observe the immediate weather changes, learn about renewable resources and how to apply new technologies, and better understand how the energy system works, while at the same time they participate in decisions and actions that shape and affect their community. Players should discover the best way to address the community's environmental issues and complete their tasks within limited resources. In such a collective action situation, players need to collaborate and synchronise their individual actions to prioritise the energy distribution and avoid energy problems (excessive demand which causes temporary congestion or energy shortage that causes a blackout), achieve a fair resource allocation and sustain the community for the long-term.

5. *Social MPower*: An Educational Game

One of today's biggest challenges is to cover power demand. The energy system is evolving from a static, monolithic system to a flexible and user-centric distributed system which can host multiple users. *Social Mpower* supports this new topology and represents all consumer requirements for an efficient,sustainable and reliable energy system. This game provides intelligent, information and communication technologies to allow players balance energy demand and supply.

In *Social Mpower* players are consumers who face real-world energy problems. In the context of energy coming from renewable sources, PV cells produce the required energy for the virtual community. The game scenario offers players the opportunity to understand the implications of energy decision-making in an animated environment.

Social Mpower is an interactive game developed to inform, aware and motivate users towards energy efficiency and sustainability. Players should avoid blackouts by individually reducing their energy consumption and sustain the CPR. Players should work together to prioritise distribution in an economy of scarcity, achieve a fair allocation and sustain the community over the game play. The smart meter board should be considered as an 'intelligent agent' which operates on behalf of, and in cohort with the player, and the player should understand that energy is a limited and depletable resource. Players should understand that their individual behaviours and actions have an effect on the virtual community, and they should take the necessary steps as a synchronised and accumulated body to achieve successful collective action.

The use of a serious game helps in educating people fast and effectively. There are no consequences when players do something wrong during the gameplay, but instead they learn how to avoid problems and take better actions and decisions regarding real-life problems. During the gameplay, players develop social and cognitive skills and gain the required confidence to engage with serious games. Players explore new activities and experiences, communicate with other in-world players and practise new skills [22], [23]. At the end of the game, players receive feedback and advices regarding their energy use which challenge their critical thinking and understanding of electricity [24]. *Social Mpower* enables players to understand how the power generation and distribution network works, and through the different tasks they learn how energy communities can actually use the different technologies to become energy sustainable and efficient.

The educational aim of *Social Mpower* is not only to make the energy system that serves the virtual community more efficient, but also to enable players understand that they should unite into a group to effectively resolve a collective action problem. Players should recognise that they are impacted in a collective action situation, and that any small individual action will contribute to resolving any upcoming problems. Especially in the energy sector, if players are "collective aware" of an incipient energy problem they can proactively coordinate their behaviour to take a collective action to prevent it. *SocialMpower* encourages players to take actions regarding common resources that are suboptimal from a community-wide perspective without leading to the depletion of those resources.

6. Experimental Results

87 players took part in the experiments and the experimental hypothesis was that if players are "collective aware" of their individual and community consumption, they consume energy in a more efficient and effective way and therefore, they avoid potential energy problems (i.e. blackouts). In every experiment, players grouped randomly in teams of 3 and had to complete different tasks within a specific amount of available energy:

- Do laundry
- Wash the dishes
- Cook a meal
- Drink coffee
- Watch TV
- Use the computer

If players exceeded their available energy, an energy problem would occur from excessive demand. That caused temporary congestion or energy shortage that caused a blackout. The experiments took place both in UK and Greece (London, Glasgow, Brighton, Athens and Chalkida). The players are both general members of the population and college students (the youngest player is 12 years old and the oldest is 63 years old). 43.7% of the players responded that it was their first time they experimented with virtual worlds. Players were asked to complete a questionnaire and evaluate the *Social Mpower* game at the end of every experiment. 31 out of 87 players (35.6 %) experienced an energy problem (i.e. a blackout), but 83.9% of them stated that *Social Mpower* helped them to understand how to use energy in a more effective and efficient way and therefore, it would be more likely to avoid a future energy problem. 53.6% of the players agreed (agree and strongly agree) that sharing their individual energy consumption with the rest of the community helped them in avoiding energy problems (see Figure 3), and 72.4% of all the players strongly agreed that if they play again the *Social Mpower* game, then it would be more likely for them to avoid energy problems (see Figure 4).

Players answered open-ended questions about what they liked/disliked about the *Social Mpower* game. Some of the positive comments include: *"Very nice the idea of the game. It helped me to think more seriously about environmental issues and especially about energy problems"*, *"It is a great idea to encourage people to use smart meters and share energy responsibilities"* and *"The smart meter board showing our energy consumption was insightful about the energy consumption arising from daily household activities"*. Players also provided us with feedback, concerns and recommendations for future work: *"I used the local chat instead of the group chat, so partners did not hear me"*, *"Smart meter should give an alarm to inform the customer about the energy problem"*, *"Have a buzzer to remind the energy problem is approaching"* and *"If we could visualise the amount of energy required for each appliance beforehand, we could better coordinate"* [25].

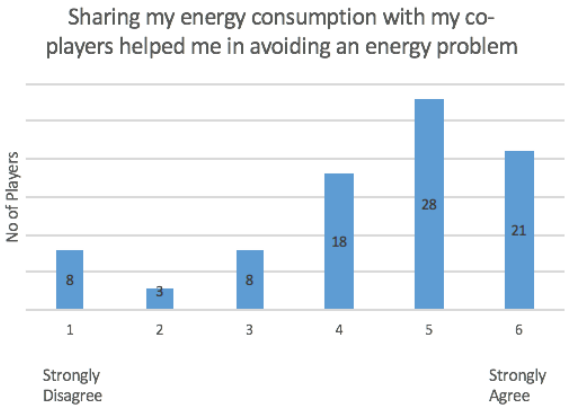

Figure 3. Players' evaluation regarding the sharing of individual energy for solving energy problems

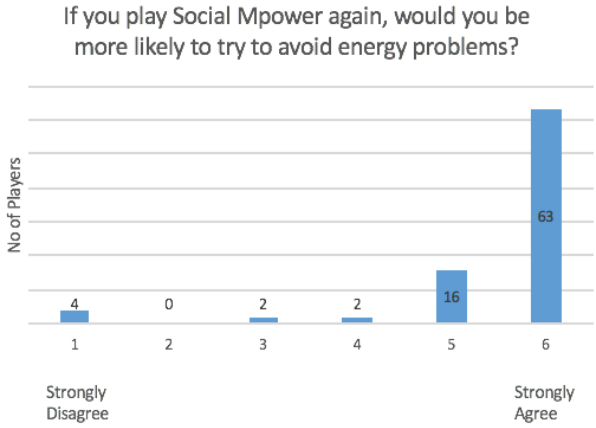

Figure 4. Players' evaluation regarding the effectiveness of *Social Mpower*

7. Conclusions

Serious games are widely used in the energy sector and simulate the electricity network. Players are encouraged to experiment in an animated environment and learn about power and the different forms of energy. A number of serious games has been developed for energy systems that act as an educational tool and help energy consumers to better understand concepts such as resource allocation, electricity prices and grid sustainability. In this paper, we examined the problem

of successful collective action in community energy systems in which their members should allocate the available resources with long-term endurance for the collective. This was done in reference to a proposed serious game, the *Social Mpower*, in which players have to avoid a collective blackout by individually reducing their energy consumption through synchronisation and coordination of their actions.

35.6% of the *Social Mpower* players did not manage to avoid an energy problem, but 83.9% of them stated that this game helped them to better understand energy consumption and how to use energy in a more efficient and effective way. 72.4% of all the players (87 in total) strongly agreed that *Social Mpower* is very effective as an educational tool and therefore, they will avoid potential energy problems in the future. Our results show that serious games can be productively used as educational tools to bring a desired change in people's behaviour towards energy consumption.

In future work, *Social Mpower* will become a massively multi-player game to enable us test the effectiveness of collective awareness since there will be many players playing at the same time who should synchronise and communicate effectively to notice and prevent potential energy problems. Other research directions include the gamification of the 'smart' houses, so that appliances in the game could be directly related to appliances in the 'smart' house, and actions in the real world could affect the state of the *Social Mpower* game.

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