Consumer Engagement in Virtual Power Plants through Gamification

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***Abstract*—Virtual power plants (VPPs) are defined as an aggregator of different types of energy resources and flexibility, coordinated by VPP owner through a smart control system. A correct establishment of a VPP will result in reduced electricity costs for the consumers within the VPP. One of the key aspect of VPP's success is the consumer engagement in order to manage their flexibilities effectively. Gamification is an efficient way of learning and engagement, which can efficiently change the behavior of consumers towards participating in programs provided by VPPs for energy cost reduction. In this paper, a gamification-based approach for consumer engagement is proposed and a methodology based on Fogg's behavior model and Kim's model on player types is developed to examine the suitability of available gamification applications for energy saving/efficiency in the context of a VPP. Seven gamification applications are analyzed and evaluated based on the developed methodology and the results are provided.**

Keywords-virtual power plant; gamification; demand response; consumer engagement electricity market; incentive; social engagement

I. INTRODUCTION

Electricity prices have doubled in the past eight years [1] which has become a major financial burden for those on lower incomes who are already suffering from a housing affordability crisis. These factors have contributed to three million Australians considered to be living under the poverty line, including one million children.

Tenants of new properties could benefit from reduced electricity prices supplied by photovoltaic (PV) and energy storage within a microgrid, however residential developers are avoiding investment in renewable energy technologies due to uncertainties around financial feasibility, business model, and technology required to create a smart virtual power plant (VPP), especially where an effective interaction with other parties such as the Australian Energy Market Operator (AEMO) becomes critical. Without an affordable integration of renewables and storage, the expansion of new technologies on these sites will be questionable.

VPPs are usually defined as an integration of diverse kinds of energy and flexibility resources. These resources can consist of wind, solar, hydrogen and thermal units, electric vehicles, fuel cells, batteries and capacitors, different types of energy storages such as thermal or pumped storage PVs and storage units combined with demand flexibilities, combined heat and power (CHP), flexible loads known as demand response (DR), and sometimes traditional resources such as diesel generators [2].

Based on the capabilities of VPPs, it is forecasted that over one million residential batteries will be installed to form VPPs over the coming years. This level of VPP implementation requires effective incentive mechanisms from VPP owners or government to realise the capabilities of majority of batteries and VPPs. Also, it is essential to explore the demand side contributions, metering and control capabilities for the benefit of customers and the grid [3].

VPPs can potentially provide some important roles to community and consumers such as below [4]:

- CO_2 emissions reduction due to the integration of renewable energies into the grid;
- Improvement of renewable penetration by realising the benefits of them;
- offering cost-effective electricity production to consumers by incentives;
- lower cost of energy delivery to the market by providing an optimal bidding strategy;
- reliability improvement of supply of electricity by providing local electricity generation;
- deferral of network investment by the participation and control of VPPs;

When there are many consumers within a VPP, there are many challenges on how to manage the benefits and constraints of consumers, the VPP owner, and the electricity market.

Some of these challenges are how to provide the best bid for the energy produced by a VPP; how to optimize individual household energy consumption via incentives, how to manage PV generation; how to produce and store energy in electricity/thermal storage; and how to satisfy AEMO's and the utility's requirements. All of these questions require research and innovative solutions. Further, no complete solution exists in the wholesale market and peer-to-peer market [5] to provide the platform to integrate storage and smart appliances (i.e. heat pump hot water systems, air-conditioners, washing machines, etc.), PV inverters, smart meters and to optimize these based on real time wholesale market prices and the grid condition [6].

Consumers' flexible demands, PV and storage have the potential to provide energy where the electricity price is high and contribute to stable and efficient operation of the electricity grid. However, electricity generation is dictated by resource availability – that is, when the sun is shining, or the wind is blowing. Increased uptake of intermittent energy resources has caused a reduction in daytime energy generation supplied by the grid, while peak loads after sunset are

978-1-7281-9026-6/20/$31.00 ©2020 IEEE

increasing. This requires peaking power stations that must be maintained despite being sparsely active. This issue, commonly referred to as the ''duck curve'', is a major concern for grid operators. Increasing penetration of PVs also leads to some challenges in power systems such as frequency and voltage regulation. Effective integration of storages, PVs and demand response (DR) in order to address the grid side concerns is challenging, especially in the context of affordable building development to make a sustainable long-lasting solution to consumers.

In order to realize DR and customer engagement, an energy-related behavior change should happen, which can be identified through a human behavior change model. A combination of game design elements can fulfil the requirement of customer engagement. The customer participation is guaranteed by recognizing a value stream for the customers when using a gamification-based solution. Also, the value stream should bring some benefits to the VPP owner, the NEM, and the whole energy supply in order to achieve a sustained engagement of customers. Another application of game-based participation is energy efficiency improvement [7].

To address these issues, the available resources within a VPP should be managed optimally in order to participate effectively in national electricity market (NEM) and to manage efficiently the consumers' contributions as well [2, 8]. In order to engage consumers within a VPP, a smart and efficient way is required to be attractive and in a long-term guarantee the behavioral change of consumers. One of the most ancient ways of learning is through games that not only entertain people but also change their behavior. Gamification provides some motivation for consumers of VPPs to learn to save energy and to reduce the cost of energy through sustainability and an environmentally-friendly method. The purpose of gamification is mainly to engage consumers in energy efficiency, self-managing consumption and demand response programs.

There are some approaches for energy saving/efficiency through gamification such as Ecogator, Social Power Game, Makahiki, Power House, Less Energy Empowers You (LEY), Wattsup, enCOMPASS and Funergy [9]. This paper explores the gamification approaches to evaluate the strengths and weaknesses of those platforms in the context of VPPs.

II. Gamification Approaches

In this section, some applications of gamifications in energy-related studies are presented.

A. EcoGator

EcoGator is a smartphone application, which advises on efficiency and focuses on efficient energy consumption. This application has two modes of operation, which are presented as follows [10]:

- the shopping mode for identifying the most efficient appliances at sale points for customers with the following features:
  - scanning the appliances energy labels, which help calculate the yearly running cost of the appliance and the total life-time cost of the product based on the efficiency indicators of the appliance;
  - comparison between two scanned products as a decision-making tool for the customer.
- the day-to-day mode for increasing awareness of sustainable and efficient use of products, which provides advice on how to efficiently use the appliances and how to save money.

There are some gamification aspects to this application, including the awarding of points for the users when they are using the application, for example, scanning appliance labels, using the comparison tool or calculation functions, reading tips and sharing tips in social media. Also, earning points allows users to go forward to in different levels. Within each level, the knowledge of users is tested through quizzes and some challenges. After passing each level, the awarding system will allow the user to enter in a prize contest. The feedback shows that this application is very useful in shopping for appliances but not very encouraging in raising awareness [9].

B. Social Power Game

Social power game is another game-based mobile application for changing the users' behavior in a long-term move towards sustainable energy consumption. The application focuses on social learning through a collaborative and action-oriented model in the context of a challenging neighborhood-based energy-saving contest. Connecting to neighborhoods facilitates the collaboration and exchange of information amongst people. The application can provides visual electricity consumption trend over time and the effect of user actions, including visualization of team challenges to promote collaboration and competition [11].

The gamification aspects of this application are categorized in two dimensions: household dimension and social dimension. When users register to join the game, they are assigned to one team with a challenge or goal. There are some collaborative and cooperative tasks that should be completed through coordination with others. The participants receive some points by completing any of those tasks and get information about how to make efficient use of the shared resources to improve awareness of the energy use in their surroundings. There would be some competitions amongst teams through visual comparison of their points, average consumptions, and the individual player's contribution to the corresponding team. Badges are awarded to players for their individual achievements and also for continuous or outstanding contributions to their teams. The first results of a study of this application show that 75% of the households participating in the project reduced their consumption to some degree between 1% and 25% [9].

C. Makahiki

This gaming engine is an open source game which aims to enhance the awareness about energy conservation through education of a subject or training on a skill. This application facilitates the implementation of "serious games", which motivates players to learn about energy issues, to improve their understanding about energy consumption, and to teach

them how to use energy efficiently in their life. Watt Depot is integrated into this engine to collect and store the energy consumption of users and to provide near real-time consumption tracking. Google visualizations is also incorporated to dynamically visualize the consumption data in an understandable way [12].

To promote energy consumption awareness, Makahiki supports the creation of a sequence of actions, including commitments and daily energy goals. For example, replacing a light bulb in a home or attending meetings about energy efficiency are defined as actions. Also, it allows the comparison among floors or buildings and the players get points for any of these actions. The players can define daily, monthly or yearly goals as well with the corresponding tasks, which can be individual or collaborative goals. To earn points, players should perform certain actions and make public commitments to adopt more sustainable behaviors. In this platform, the player experience is improved by creating focus group and usability evaluations, which requires a good, planned and intensive communication strategy for its adoption. Moreover, incentivizing social influencers can create a positive impact in the adoption of this platform. Further, it is very difficult to find the best incentives where the player population is diverse, so prizes and incentives should to be carefully analyzed [9].

D. Power House

Power House is an online game that promotes improved real-world energy behaviors by connecting home smart meters and social networks.

After tracking users' energy consumption by its local energy provider, the data is sent back to the game environment for impacting player in-game behavior towards rewards and social reputation. Players' energy consumption during the last 24 hours is visualized in a dashboard for reviewing their scores and virtual credits and competition results with other players and teams. Virtual credits can be used on in-game items, or on real world products provided by the VPP or utility [13].

The gamification aspect of this tool is earning virtual credits and a leader board for showing the individual or team achievements and comparing them with the achievements of others. Furthermore, the players can compete against their neighbors in energy saving competitions by keeping track of the activities of every member of the family to reduce waste and improve efficiency. The points system is based on the ability to minimize the amount of electricity consumed by the family. The results of an experiment illustrates that this game-based tool positively improves the efficient use of energy by turning off the appliances after the gaming period [9].

E. Less Energy Empowers You (LEY)

To understand domestic energy usage, LEY proposes a persuasive pervasive-based serious game to help people change their energy-related habits. The three main components of the platform are: a sensor platform, a supporting web-based information system and a mobile game application. Real time data is provided by the sensor platform, then data along with the game rules are stored in the web application, which is equipped with visualization aspects as well. The two gaming modes of this tool are [14]:

- The single mode, in which players are challenged to enhance their energy consumption to an optimal level for getting the maximum points. In this mode, players are ranked based on the official European energy efficiency rating, which presents the energy efficiency of residences on a scale of A (most efficient) to G (least efficient).
- The completion mode, in which the players challenge other players in an energy-based quiz competition. The ranks and points are awarded at the end of competition.

The house avatar is another game feature of the LEY application, through which the household consumption can be monitored [9].

F. Wattsup

The aim of Wattsup, which is a Facebook-based application, is to encourage energy saving by using live and historical energy feedback in a social-normative context. Wattsup shows data for energy consumption and CO_2 emission to give the participants the ability to compare household data with their friends.

This platform uses Wattson Sensors to collect and store the consumption data of the households. The data is then transmitted to a server connected to a desktop application and a Facebook gamified application. This information is illustrated on Facebook in three different ways: a) individual consumption, b) Friends can compare the consumption against a selected friend, c) Rankings is based on their daily consumption in a leader board [15].

Results of two tests on this platform show that social interaction can effectively motivate consumers to optimize their household energy consumption as they are spending time on the rankings interface, viewing and commenting on the rankings table.

G. enCOMPASS and Funergy

The Encompass platform is another system for an holistic socio-technical gamification for energy saving with the following components, as shown in Figure 1 [16]:

- Sensors data acquisition: for conversion of acquired parameters (temperature, humidity, luminance, etc.) to data and communication with a centralized data centre to integrate those data into all components of the platform.
- User data acquisition: Using a gamified mobile app for household consumers and the associated appliances to engage users within the collaborative platform.
- Data analysis and user modelling: Algorithms are used for extracting data from applications for different purposes such as user behavior to measure energy consumption. Classification techniques and advanced analysis to extract from data divided into two main classes of visual and thermal comfort.
- Adaptive in-context action recommendation: Activity patterns in the building control system and the consumer app recommended to improve energy saving.

- Engagement engine with adaptive gamification: Making the gamification model adaptive and flexible impacts on energy consumption behavior of users, such as users' location and activity, indoor climate and interaction history [17].

This system will benefit consumers with a cloud-based applications programming interface (API) through enCOMPASS APIs. The components of the enCOMPASS platform are presented in Figure 1. The enCOMPASS provides a gamified web application via a PC or mobile phone, which offers an interactive visualization of energy consumption. Through this platform, consumers can explore their consumption profiles by time granularity (e.g., on a daily, weekly or monthly basis), by consumption source, by user context, and activity type. The system can compare the consumption against a reference values or neighbors to provide warnings to above-average consumers with personalized suggestions on how to reduce consumption. Players are encouraged by two gamified elements [9, 17]:

- Gamified rewards (points, badges, achievements, tangible prizes) which can be received through different types of mechanisms such as achieving goals, social comparison and social collaboration.
  - Funergy, which is a serious game through which points are awarded. This is a simple cooperative game where players try to reach the best final score by collaborating with each other. This game is a combination of a physical board-game with a digital app.

III. Methodology

As discussed in the last Section, some relevant tools have been developed to incorporate gamification into consumers' engagement with VPPs by targeting their interests, including motivations related to economic, environmental, and social issues. Based on the Fogg's model for the behavior change [18] shown in Figure 2, three elements should be available to facilitate the achievement of target behavior. These three elements for behavior (B) change are motivation (M), ability (A), and trigger (T), which is summarized in 'B = M A T'.

In this model, by an increasing motivation and ability, the likelihood of happening of behavioral change will increase. However, Fogg claims in addition to a strong motivation and high ability, an appropriate trigger align with the corresponding change of behavior is essential. Such triggers should generally satisfy three conditions, which are: a) users should be aware of triggers, b) addressing the target behavior, and c) timely introduced when both the motivation and the ability are at their maximum. Based on this theory, Fogg has provided some thresholds that ability and motivation should be above those values in order to make triggers effective. As seen in Figure 2, there are some sub-component for each element, for example, pleasure, hope, and acceptance are the components of motivation that are considered when designing a gamification approach.

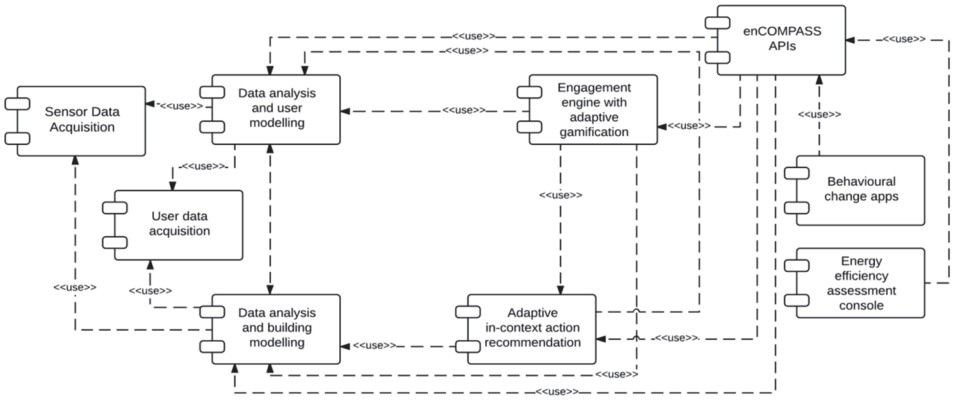

Figure 1. The components of the enCOMPASS platform [16, 17].

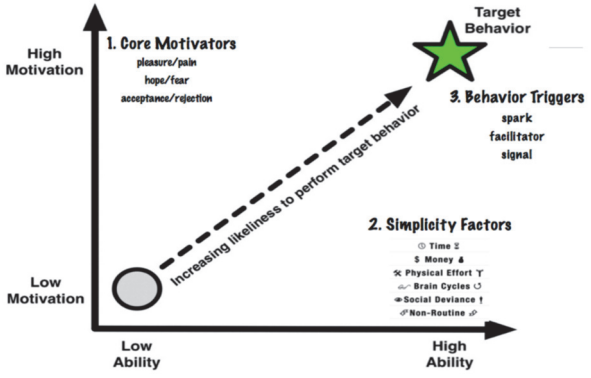

Figure 2. Elements of Fogg's model for behavioral change [18].

It is critical to know that the abilities and motivations of different people are different. Players can be categorized into four roles, which are Achievers, Explorers, Socializers and Express, as per Kim's model [19]. Players who like to compete are identified as achievers. Those players who prefer collaboration are known as socializers. On the other hand, explorers like to explore applications, tools' capabilities, contents, and people, who are motivated by information and access and knowledge. Finally, express players are those motivated by self-expression, as they want to express their abilities and showcase their creativity.

Amongst these players with different attitudes, collaboration is one of the most influential approach for engaging many users. On average, the players' population is

distributed as 80% socializers, 50% explorers, 40% achievers, and 20% express [19].

Therefore, the gamification approach for the engagement of the customers should provide motivation to consumers and enhance their ability towards achieving the targeted behavior. Also, the gaming strategy should consider the range of different types of players as discussed here. To achieve this aim, a gaming system should be established to increase the awareness and knowledge of consumers regarding their possible contribution to the economy and the environment in order to enhance the uses' abilities. This system needs to protect the privacy of users while providing a user-friendly interface. This system should be fun for users as this is a very important characteristic of gamification for triggering their involvement.

Based on consumers' energy consumption behavior, a rewarding system as a motivation offers a number of discounts, points and credits to participants to increase the satisfaction of residential customers. By using a private platform based on the web and a mobile device, customers can communicate in on-line gaming and share their problem solving. This collaborative system, that is attractive for more than 80% of players, scores consumers on the basis of energy reduction, for instance, while it encourages participants to compete to gain more credit or points [7].

The user interface will also provide the opportunity to customers to control and decide when and how to reduce their electricity consumption. Consequently, it has the most positive effect on customers. This is achieved through a stimulating and enjoyable engagement program such as dashboards, progress bar and message box. The performance status is another dimension of gamification that improves the motivation of consumers. Attribution and behavior scores of residential customers can be followed through the application process. For instance, when a customer acts in an energy application, the achievement of badges and points appears, and the way of behaving is changed as a consequence.

Figure 3 shows the whole methodology and the relationship amongst the Fogg's model and Kim's model in order to introduce the gamification capabilities. This paper considers the parameters shown in Figure 3 to explore the capabilities and effectiveness of available applications for gamification within a VPP context.

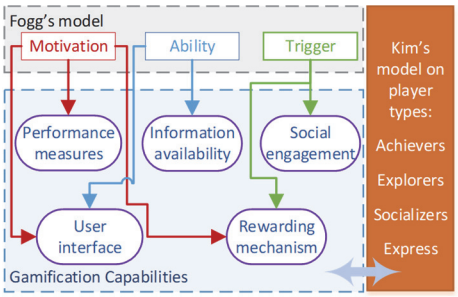

Figure 3. Parameters for the evaluation of gamification applications.

IV. Evaluation of Gamification Approaches

The characteristics of available gamification applications suitable for consumers' engagement in VPP in Western Australia is explored in this Section. There is an intention to develop VPPs in Western Australia, comprising many single storey residential dwellings with a rooftop PVs and controllable storages and loads.

This VPP will be managed as a VPP through a cloud-based data system, aggregating different energy resources to minimize the cost of electricity for residences through participating in the electricity market. Within a VPP, residents may need to respond to the signals from the VPP's owner for turning on/off their appliances or charging/discharging energy storages. In another words, demand response aspects of the energy consumption is the most important behavior, for which the gamification application should be designed.

The main residents of the VPPs are families with average/lower band of income, as the energy efficiency is more important to these category of consumers. Therefore, the gamification applications reviewed in [9] are filtered based on the fact that they are targeting families, as shown in Table 1.

Another important feature of the gamification application is the proper user interface. The interface has to enable user to work on a mobile platform, as an available platform for many family members including parents and teenagers. Consequently, only those application are appropriate to be able to provide this feature, as presented in Table 1. As discussed, social engagement is another important aspect of gamification that can be attractive for more than 80% consumers.

Therefore, Table 1 shows which applications can support multiplayer and social collaboration and competition.

Performance measures are the vital part of the gamification for providing the right feedback to consumers and motivating them to change their behavior.

All applications in Table 1 can provide some sort of performance measures such as consumption reduction, the number of times using the app, and number of games they played. However, the 'Social Power Games' and 'enCOMPASS' can provide more statistics and comparison against individual and teams to make the game more collaborative and competitive.

Information availability is suitable almost for all gamification algorithm. However, those application with a capability of social connection can provide knowledge sharing amongst neighbors and/or team members. Therefore, the ranking of those application would be higher as illustrated in Table 1.

The last capability of a gamification approach is establishing a rewarding mechanism. As seen in Table 1, some applications provide an approach for rewarding such as virtual credit, tangible rewards, or points/badges that are converted to some level of incentives. Among the applications in Table 1, 'Power House' and 'enCOMPASS' have a better built-in mechanism for rewarding and incentivizing consumers for their actions and behavior change, so the ranking of these two applications is higher than others in this matter.

By analyzing different aspects of capability of gamification application, the suitability of them for the use in a VPP platform is inferred. As seen in Table 1, the column of 'Overall evaluation: suitability' will provide a ranking for the application in this table in terms of suitability for VPP. As illustrated, the suitability of 'ecoGator' and 'Makahiki' is low

as they do not provide a social connection amongst consumers, cannot accommodate a rewarding system, or support mobile devices.

In addition, 'Power House' is not a family-oriented application that cannot support social connection and mobile devices, so its ranking for the use in VPP context is very low. The suitability of 'Wattsup' and 'LEY' are medium as there are some drawbacks in these applications such as not family-oriented or no strong social connection. However, there are some possibilities for upgrading these application in future in order to satisfy all criteria. 'Social Power Game' is a suitable gamification approach for VPPs as it can cover all required aspects for a VPP, so it ranked here as 'high' suitability.

Amongst all applications discussed in Table 1, 'enCOMPASS' has the 'very high' suitability for VPPs. As presented in previous Section, the enCOMPASS platform is a system of gamification for energy savings and behavioral change with the components of sensors data acquisition, user data acquisition, data analysis and user modelling, adaptive in-context action recommendation, engagement engine with adaptive gamification. The adaptive in-context action recommendation in this platform is an excellent way for monitoring the activity patterns of consumers in the building of an efficient control system. Also, data analysis and user modelling algorithms are used for extracting data from this application for different purposes, such as user behavior, to incentivize consumers accordingly. As the VPP is being established in Western Australia, the realistic data about the implementation of gamification method will be discussed in future publications.

TABLE I. THE COMPARISON OF GAMIFICATION APPLICATIONS IN TERMS OF DIFFERENT CAPABILITIES NECESSARY FOR VPPS

Gamification Application	Families as the targeted audiences	User interface platform: Mobile phone	Social engagement	Performance measures	Information availability	Rewarding mechanism	Overall evaluation: suitability
ecoGator	√	√	×	√	√	×	low
Social Power Game	√	√	√	√√	√√	√	high
Makahiki	×	×	√	√	√√	√	low
Power House	×	×	×	√	√	√√	very low
Less Energy Empowers You (LEY)	√	√	×	√	√	√	medium
Wattsup	×	√	√	√	√√	√	medium
enCOMPASS and Funergy	√	√	√	√√	√√	√√	**very high**

V. CONCLUSION

Virtual power plants (VPPs) are a promising framework for reducing the cost of electricity by the use of more renewable energies and the engagement of consumers to purchase energy from the wholesale market when it is very cheap. In order to coordinate the flexibilities of consumers through demand response programs, an appropriate customer engagement system is required. This paper develop a gamification-based approach for consumer engagement in VPPs and provides a methodology for evaluating different applications in this area. Seven gamification applications for energy saving/efficiency, which are available in the market, are examined using the proposed algorithm. The results showed that the 'enCOMPASS' application is the most suitable and available application in the context of VPP.

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