## Chapter 1

# Assistive Awareness in SmartGrids

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*SmartGrids use Information and Communication technology to underpin the network's infrastructure and performance, placing at the same time a particular emphasis on the demand-side, which requires both to better understand the behaviour of energy consumers and get energy consumers to understand better the effects of their behaviour on the grid. We are investigating Serious Games as an innovative way to train consumers and increase their active participation in the new "smart" energy infrastructure, i.e. SmartGrids. We specifically focus on local micro-grids, in which energy consumers can also be producers, who self-organise their own provision and appropriation rules in the context of an institution. Enabling assistive awareness in such a local grid helps users to better understand the specific roles that are occupying inside SmartGrids and enhance the sense of collective responsibility and action among them. Computational awareness enables the visualisation of different forms of information, while assistance services help users in their decision process to achieve individual and com-*

*mon goals.*

## 1.1 Introduction

The increased demand for efficiency, reliability and sustainability has driven the electricity network towards SmartGrids, that use Information technology and Communications to underpin the network's infrastructure and performance. Specifically, SmartGrids are concerned with policy demands (to address global warming and carbon dioxide emissions) and consumer demands for low and competitive electricity prices. Other important issues in the SmartGrid are security, smoothing out peak demand, increased generation from renewable resources, and more importantly, from the point of view of our research, active user participation.

The optimisation of the energy system depends on the users' behaviour and their interactions with the new technologies. User behaviour impacts the SmartGrid at both individual (e.g. a household) and collective levels (e.g. a community). However, the role of the consumer tends to be ignored by SmartGrids, as they assume that users will somehow adapt to new technologies. In fact, the main problem that arises from the evolution of the electricity distribution network is the negligence of the user-infrastructure interface and the imposition of Smart Meters as controlling and distributed sensors, that report to a monolithic and central control system.

We propose the use of Serious Games to support the user-infrastructure interface and encourage active user participation. The user-infrastructure interface is a virtual environment [Almajano *et al.* (2012b)] which integrates information visualisation for comparative feedback [Moere *et al.* (2011)] and new affordances for the Smart Meters [Bourazeri *et al.* (2012)]. Moreover, in the context of self-determination, we seek to encapsulate aspects of self-organisation and support the principles of enduring institutions [Ostrom (1990)] through the same interface. Our aim is to promote long-term user engagement and enable consumers to gain a better understanding, not just of prices, but of resource allocation –electricity distribution among different members of a community–, investment decisions –invest money on buying new electrical appliances or solar panels–, and sustainability –endurance of resources (energy). Finally, we provide users with agent-based assistance to help them in their decisions about both individual and collective goals [Almajano *et al.* (2012a)].

The remaining of this chapter is structured as follows: firstly, we introduce the issue of the user - infrastructure interface in Section 1.2 and we propose to combine alternative technological and scientific approaches to address the problem with the user participation and engagement in the SmartGrids. Then, in Section 1.3 we review how we can achieve user engagement through assistive awareness, whereas in the Section 1.4 we outline the impact of our research and the goals we aim to achieve. In the Section 1.5 we propose the 3D Serious Games Institutions and the Section 1.6 presents a game scenario and its mechanics. The 1.7 Section gives an overview of various interfaces for SmartGrids proposed in related works and we conclude with some remarks in Section 1.8.

## 1.2 The User-Infrastructure Interface

The $21^{st}$ century's electricity distribution and supply network is efficient, functional and it can meet the normal energy demands with a few variations. The energy generators and distributors have to comply with the government policies and laws, while meeting targets for reduced $CO_2$ emissions, consumer demand for low and competitive electricity prices, electrification of transport and heating and so on. All these targets should be met within limits and regulations set by policy makers. Advanced communication and information technologies are used to improve the utilisation and efficiency of the energy network, giving at the same time more choices to the consumers and trying to engage them with the new infrastructure.

Although SmartGrids place a particular emphasis on the demand-side and are predicated on consumer participation, the user-infrastructure interface is still largely neglected and the Smart Meters, which are supposed to be the means for providing information, are conceived as a centralised and controlling technology, rather than as an innovative and enabling technology for making the everyday life easier. Energy consumers need to learn how to interact with the new technologies and the infrastructure interface, something which tends to be ignored by SmartGrids, as they assume that consumers will somehow automatically adapt to these modern technologies. This problem is of critical importance as the negligence of the infrastructure interface has led to the demise of many water projects related to "Common-Pool Resources" (CPR), like water management, forests or fisheries. For example, one study [Lam (1996)] focused on the infrastructure development and maintenance of an irrigation management system in Nepal, proved that even though a new technology can improve the performance of an irrigation system, this advance is not enough for an effective management and maintenance of an infrastructure. This example highlights that the introduction of Information and Communication Technologies to the SmartGrid may not be enough as institutions, users' social arrangements and infrastructure attributes need to be taken under consideration as well.

To address the problem of user participation and engagement, we propose Serious Games as an attractive and engaging interface to train and hold users' attention for long-term decisions and actions. Moreover, Smart Meters, represented in the user interface, provide the user a way for managing and monitoring the electrical appliances [Bourazeri *et al.* (2012)] whereas, comparative feedback could give an overview of the electricity consumption. Finally, agent-based assistance in cooperation with Smart Meters, which could give details and advices to consumers on how to achieve their individual (e.g., reduced electricity bills) and common (e.g., smooth out peak demand) goals.

## 1.3 User Engagement through Assistive Awareness

Computational awareness can help users to better understand the specific roles they are playing within a community by means of visualising different forms of information. Moreover, it can promote the sense of collective responsibility and action among community's users. This process could be even enhanced if all this information was processed and presented to the users in a more understandable way, i.e., by providing users agent-based assistance. Thus, we propose *Assistive Awareness*, the combination of computational awareness and agent-based assistance, to engage users with the new infrastructure interface, gaining at the same time the necessary experience and knowledge.

*Assistive Awareness* is very important in a local SmartGrid as users should impersonate different roles and fully understand the goals they want to achieve. For example, in the 'prosumer' (consumer + producer) role, users make choices about prices, which energy provider to get their electricity from, or selling surplus energy back to the grid. In the 'citizen' role, users may be concerned about the impact of their consumption profile on the environment or may have an interest in setting and meeting policies and regulations. All the participants in the local micro-grid should be ensured that they receive a 'fair' share of resources with long-term endurance for the collective. This has to be done with respect to a set of institutional rules which have to be followed by all users.

With information visualisation for comparative feedback, users can gain a significant understanding by simply looking at images and figures; since data in any form can be visualised and conceived [Spence (2007)]. Comparative feedback should be based on actual energy consumption and it should be provided on a frequent basis (ideally at the end of every month) in order to be effective. Consumers should then be able to have an overview of how much they are charged for using specific electrical appliances at a particular time period [Pratt *et al.* (2010)]. Receiving feedback in a comparative basis helps users to identify their consumption patterns and observe possible changes in their behaviour towards energy use. Other studies based on the effectiveness of comparative feedback proved that a maximum 12% decrease in energy consumption can be achieved [Darby (2006); Fischer (2008)]. Other findings were that it is more effective than direct feedback and an efficient way to change users' behaviours and habits towards energy consumption.

However, changing behaviour and actions towards energy use could be a very demanding and difficult task. The available information coming from the different electrical appliances can be massive, whereas the individual and collective goals can vary along time and users. The agent-based assistant can help users in analysing all this information coming from the Smart Meters by providing them a number of assistance services (e.g., advice on how to reduce the electricity bill).

## 1.4 Research Impact

Designing and implementing a user-infrastructure interface for SmartGrids aims to impact users' behaviour; how users consume electricity in the grid, how the rules and regulations affect the introduction of new technologies, how the different incentives and behaviours influence society's values and how the overall consumption patterns affect the energy savings. Taking decisions to pursue a greener and more sustainable environment, promote the grid efficiency with ultimate goal the electricity savings. Desired goals (energy or money savings) could also be achieved by giving consumers the chance to impersonate the role of a local micro-grid user in a Serious Game. Serious Games are a challenging and motivating way for increasing awareness towards social and public issues. Energy consumers will understand better how their behaviour and actions affect the grid; taking part in a common pool resource problem will enable the energy consumers to gain the necessary knowledge and experience of 'fair' share and long-term endurance of resources. Finally, users will have a better overview of electricity prices, investment options and decision-making.

## 1.5 Serious Games for SmartGrids

SmartGrids place a particular emphasis on the demand-side, which requires both a better understanding of energy consumers' behaviour and getting energy consumers to understand better the effects of their actions on the grid. User engagement with the grid is of critical importance and the interface of this infrastructure must be taken into account. We are investigating Serious Games as an innovative way to support the user-infrastructure interface, especially for local micro-grids in which the energy consumers are also producers, who self-organise their own provision and appropriation rules in the context of an institution.

Serious games are digital games, simulations and virtual environments which purpose is not only to entertain and have fun, but also to assist learning and help users develop skills such as decision-making, long-term engagement and collaboration. They are experiential environments, where features such as though-provoking, informative or stimulating are as important as fun and entertainment [Marsh (2011)]. Serious games can help users to improve their abilities, while at the same time designing and implementing an user-infrastructure interface based on them can engage and motivate users for long-term decisions and actions. Users are able to observe changes in their performance and behaviour throughout this interface, whereas their active involvement, participation and confidence can be enhanced. Another important feature is the collaboration that can be established among players who play for achieving a common goal.

Serious games can be used in two different ways for establishing and encouraging user participation inside SmartGrids. The first way is to set up a virtual environment where users can have a direct and active participation in the "real" grid. The other way is to have a game for training purposes which helps users to better understand problems concerning resource allocation, prices, investment decisions and grid's sustainability. We mainly emphasize in the second way.

The game scenario can be a virtual house, representing a standard house equipped with all the electrical appliances and Smart Meters, and the users can interact with the appliances, observe their realistic electricity consumption or they can be provided with agent-based assistance about how to reduce the carbon dioxide emissions or save money. Smart Meters are like the known meters that are installed on our houses for reading the energy consumption, but their advanced features (process and transmit consumer's information to energy providers, provide feedback to users) make them more functional and useful [McDaniel and McLaughlin (2009)]. By connecting a Smart Meter to every electrical appliance consumers can have a real-time overview of the energy usage; they know exactly how much electricity each appliance consumes at this specific time period. Another advanced feature is the pricing scheme with the different prices and the variation in tariffs. Smart Meters should not be just passive devices for displaying data, but they should remotely control the electrical appliances and schedule them depending on consumers needs and preferences.

| Serious Game | |
|---|---|
| *Ostrom's Principles* | *User Participation* |
| 1. Clearly defined boundaries | Game access |
| 2. Congruence between appropriation/provision rules and local environment | Dynamic rules' configuration |
| 3. Collective choice arrangements | Deliberative Assembly |
| 4. Monitoring | Smart Meters |
| 5. Graduated Incentives | Sanctions and rewards |
| 6. Conflict resolution | Conflict resolution mechanisms |

Table 1.1: Ostrom's Principles encapsulated by a Serious Game

We propose a new user-infrastructure interface for SmartGrids based on Serious Games, encapsulating in it Ostrom's principles for enduring institutions [Ostrom (1990)]. These principles are necessary and sufficient conditions for an institution to maintain a common pool resource. Table 1.1 presents the correlation between Ostrom's principles and the user participation in a Serious Game for SmartGrids. We encapsulate *Principle 1*, clearly defined boundaries, by having access to the Serious Game (or not). The online world represents the institution, and a membership is needed in order the user to have access to this online world and play a character to the game. Regarding *Principle 2*, the users should be able to communicate with each other and decide whether to change the rules' configuration of their institution or not (e.g. the allocation algorithm). A specialised decision-making forum for collective choice is needed for implementing the above configuration (*Principle 3*). Smart Meters can have the role of a monitoring agency enabling the data streaming (*Principle 4*). Moreover, the Smart Meters can now have new affordances concerning the locations and the capabilities allocated by the environment. *Principle 5*, graduated sanctions, has been extended to graduated incentives in order the game to reward the successful game play and sanction the inappropriate behaviour. Finally, we provide conflict resolution mechanisms in cases where disputes occur (*Principle 6*). For our first prototype, we are not considering Ostrom's two last principles (no interference from external authorities and systems of systems) and they have been omitted in table 1.1. Both can be encapsulated to ensure that the Serious Game cannot be controlled or monitored from the external environment and the communication between different institutions is feasible.

Thus, long-term user engagement can be enabled through a 3D Serious Game interface in which Smart Meters, information visualisation for comparative feedback and Ostrom's principles for enduring institutions are integrated and encapsulated. A 3D Serious Game can provide all the necessary means for user participation in the grid; enable the users to control and guide their avatars (embodied characters). Within the game the following features can be enabled: *i) SmartGrid Representation & Simulation* which is the virtual environment (virtual household with all the electrical appliances and the Smart Meters) where the user can control and monitor the energy use; *ii) Multi-Modal communication*, where the users can discuss and set common goals using voice/text chat, gestures and so on; *iii) Voting System*, which can be represented inside a room (similar to real spaces) to allow the players to vote for the rules and regulations of the SmartGrid and resolve the occurred conflicts; *iv) Smart Metering* is basically the management of the electrical appliances and the monitoring agency for the visualisation of the data about the energy consumption and prices, which includes the comparative feedback that the users may receive regularly (which can be provided either on an individual or common basis); and finally, *v) Rewards & Sanctions*, for rewarding the good players with prizes or benefits (e.g. high priority in resource allocation), and sanctioning the bad players (e.g. with inappropriate behaviour) by means of penalties (e.g. increased electricity prices).

## 1.6 Serious Game Technology

The proposed user-infrastructure interface aims to visualise and represent a community which includes different households, equipped with electrical appliances and Smart Meters connected to a SmartGrid. This novel user-infrastructure interface aims to extend the communication bridge between the user (e.g., consumer) and the system (e.g., SmartGrid). We rely on the use of a game, 3D Virtual World (VW) and Multi-Agent System (MAS) based technologies to build this bridge. We advocate that a Serious Game for SmartGrids can be modelled as a Virtual Institution (VI) [Bogdanovych *et al.* (2008)], the combination of 3D VWs and an Electronic Institution (EI), that is an organisation centred multi-agent system [Esteva *et al.* (2004)].

VIs have been successfully used in a variety of e-applications, such as e-learning [Bogdanovych *et al.* (2010)] and e-government [Almajano *et al.* (2012b)]. The latter work implements a water market as a VI where participants (human and software agents) negotiate water rights. Whilst the EI models the market (define roles and interaction protocols), the VW offers a 3D advanced interface which facilitates the active participation of humans within the market. We use VIXEE [Trescak *et al.* (2011)] as the VI infrastructure, a robust *Virtual Institution eXEcution Environment* that provides interesting features, such as multi-verse communication and dynamic manipulation of the VW content.

On one hand, the 3D VW interface facilitates the active human participation in the system (in our case, a SmartGrid). A human gets immersed in the environment by controlling her/his avatar (embodied character) in the VW. Such a VW enhances the visualisation of information about the system and its facilities, e.g., data coming from sensors in the real world (or simulated ones). Moreover, the participants interact in a seamless and intuitive way with the other participants (to perform collective arrangements) and with the environment (e.g., virtual Smart Meters) by using multi-modal communication channels (voice chat, text chat, information panels, touching objects and gestures). Figure 1.1 shows how humans and agents can interact inside a room of a VI by performing gestures, establishing chat dialogues and displaying information in public panels.

On the other hand, the rules of the game can be enforced by the EI, which structures the agent interactions by defining the following components: an *ontology*, which specifies domain concepts; a number of *roles* participants can adopt; several dialogic *activities*, which group the interactions of participants; well-defined *protocols* followed by such *activities*; and a *performative structure* that defines the legal movements of *roles* among (possibly parallel) *activities*.

Furthermore, Almajano et al. proposed an *Assistance Infrastructure* [Almajano *et al.* (2012a)], which consists on an Assistance Layer on top of a MAS. Such a layer is populated by a set of Personal Assistants (PA) which provide general Assistance Services to participants within the system. Thus, a Personal Assistant can provided help to a user to fulfil her/his goals through the assistance services. These services include: information about the system, which can be included in the Assembly, when the agent enters the system for the first time; or decision support, which can be useful in the Household activity in order to help users to make an efficient use of the resources.


Fig. 1.1: Virtual World populated by 3D virtual characters performing collective arrangements (human-human and human-agent interactions)

### 1.6.1 *Game Scenario*

At the beginning of the game, the player selects which role to impersonate, such as 'prosumer' and 'citizen' in the context of a community. This community is a local micro-grid, composed of different households (see Figure 1.2). The players have to accomplish different challenges which are related to real situations that an energy consumer can face at a daily scenario. Three different activities can be enabled in the game: *Presentation*, *Household* (see Figure 1.3) and the community *Assembly*.

In the *Presentation* activity, the user gets informed about the configuration of the game and the different challenges which should be accomplished. The *Household* activity represents each individual household, where the player interacts with the Smart Meters to schedule and monitor the use of each electrical appliance. In the *Assembly* activity, the members of the community vote for the collective rules which need to be followed in the game concerning the electricity use and the sanctions to be applied to players with inappropriate behaviour.

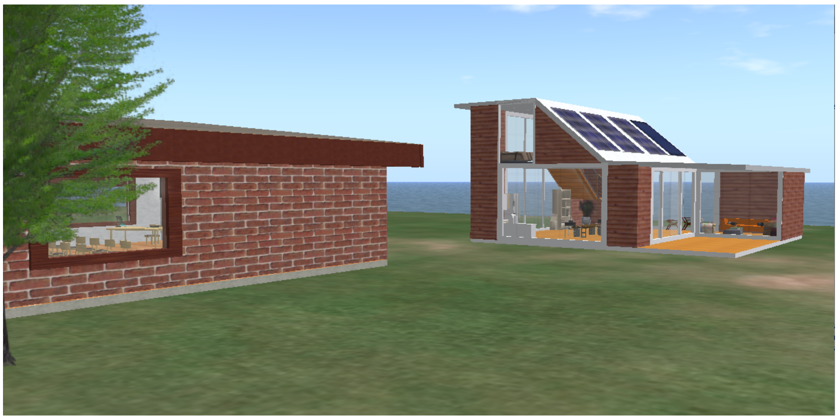

Fig. 1.2: The virtual community

### 1.6.2 *Game Mechanics*

This application is modelled as a Massively Multiplayer On-line Role-Playing Game (MMORPG), where multiple users play on-line and impersonate different roles based on a hypothetical scenario, in our case, a local SmartGrid. The different electrical appliances and the dynamic pricing schemes that are available to all players enable them to complete a number of challenges in the game. These challenges concern: i) money saving, ii) grid sustainability, iii) investment decisions with long-term benefits for both the individuals and the community and iv) 'green' behaviour.

Particularly, in the 'money saving' challenge the player needs to reduce her/his monthly electricity bill. For this challenge a dynamic pricing scheme is provided which enables the player to check the electricity prices among different time slots. The player gets also informed about the energy consumption of each electrical appliance that is available in the house. All these details (prices and electricity consumption) are pushed through the Smart Meters which are installed on the houses and provide real-time services and information.

Fig. 1.3: The virtual house

The player should take decisions according to the needs and challenges of the game in order to obtain as many rewards as possible (e.g., stars, badges, points) while at the same time s/he should avoid the penalties (e.g. points' removal). Most rewards and sanctions are given immediately to the players (e.g., when a challenge is accomplished or an improper behaviour is detected), whereas others can be given at the end of the game. Moreover, private and public chats enable the players to socialise and set collective strategies in order to win common goals.

Agent-based assistants can help the players to successfully accomplish their goals. These personal assistants, by processing the current and past data of both the Smart Meters and the institution, can provide services to users in order to complete the individual and common goals of the community (e.g., advice on when to schedule an appliance).

## 1.7 Related Work

Designing an interface engaging enough to enhance the user participation in SmartGrids is of crucial importance in order to co-create value. That means, value creation does not only rely on the electricity utility company that markets the electricity services but also on the users who actively and effectively use these services [Honebein (2009)]. [Honebein (2009)] introduced four key areas in which SmartGrid customers can co-create value and, in consequence, interaction designers should devote their efforts to develop useful and appropriate interfaces. They are operational efficiency (reduced cost of delivering energy), demand respond (reduced consumption at peak-times), energy efficiency (avoid energy waste) and load shifted (schedule energy usage). In the following we describe several research works that, in some way or another, address several aspects of these four key areas.

[Weiss *et al.* (2009)] developed an user interface to monitor the current electricity consumption of individual appliances in a mobile device. The monitoring can be switched on and off and the results can be compared to historical values. Their system consists of two more components. First, a Smart Meter measures the energy consumption of the devices. Second, a gateway connects the Smart Meter to the mobile device. It is composed of a parser to interpret the information coming from the Smart Meter, a database to store this information and a web server to provide access to the gateway' functionalities and the Smart Meter sensor values.

Other works offer more advanced features. For example, the Aware Living Interface System (ALIS) [Bartram *et al.* (2011)] can accommodate a diversity of energy sources, hardware devices, and home control contexts. With the aim of promoting user awareness, ALIS has been designed to take into account human factors, such as physical and visual constraints (place and aesthetic) and the idiosyncratic habits and expectations of users in home environments, as individuals and also as a community. ALIS connects to a web service layer which manages the data and commands of a control backbone which provides fine-grained measurement, device control and automation logic.

Alternatively, [Gamberini *et al.* (2012)] proposed a mobile web application (EnergyLife) which follows a game rationale to sustain users' motivation while increasing their awareness about energy consumption. EnergyLife provides feedback in a combination of real consumption data coming from individual electric devices and advices on energy conservation based on user's actual consumption behaviour. Moreover, users can share their new habits with the other members of the community. This application can access the data which is stored in a base-station in each house. This base-station caches the real-time consumption measurements from wireless sensors.

The previous three works enable the user to control directly the "real" SmartGrid devices, whereas the interface provides feedback to users concerning their actions. [Kim *et al.* (2012)] proposes a service interface for the customers which provides power prices and usage information, configuration over a set of preferences for electrical devices and at the same time it allows the system to automatically control and manage the home appliances according to the power price using a Universal Plug-and-Play (UPnP).

In the line of Gamberini (use of games to motivate) and Kim (control of appliances) approaches, we go beyond by advocating the use of 3D virtual environments as an interface and game which not only engage but also train and influence users behaviour inside SmartGrids. We propose to model a Serious Game for SmartGrids using Virtual Institutions technology, which enables the connection of a 3D Virtual World interface to a multi-agent system (MAS). In addition, facilitated by our MAS approach, we also provide the users agent-based assistance, to help them improve their understanding and their participation in the simulated SmartGrid and, in consequence, in the real one. Finally, we encapsulate principles for enduring institutions to ensure long-term and sustainable use of energy power.

There are other works as well which rely on games to give the players the role of citizen who take macro-level decisions about generation and use of different sources of energy. These games are currently used by public institutions to inform citizens about the importance sustainable energy use. *2020 Energy* [Tralalere (2012)] is a *Question and Answer* game where the player with the help of 3 advisers (economical, environmental and social) has to reduce the consumption of energy, increase the energy efficiency and choose the best renewable energy. The aim is to provide to user a general background about the energy usage. *Energetika* [Takomat (2010)] is a Serious Game where the player should sustain the energy supply of a hypothetical state (enact the role of a supplier) and keep track of social, economic and ecological impact, balancing all the different stakes for a sustainable resource management. These games aim to inform the users about the consequences of the current energy waste which results from the passive role they adopt. We focus on the active participation of a user who plays the role of the prosumer. We aim to engage users with the new technologies in order to support the sustainable use of electricity inside communities.

## 1.8 Summary and Conclusions

In this chapter we presented how Serious Games could be used as an innovative way for supporting the energy infrastructure interface, especially for local micro-grids in which energy consumers can also be producers, who self-organise their own provision and appropriation rules in the context of an institution. Comparative feedback and new affordances for Smart Meters could be also supported through the same interface, enhancing the user awareness towards collective responsibility and actions. Users will gain the necessary experience and knowledge that will enable them to interact and engage with the new infrastructure interface. They will also get a better understanding of electricity prices, resource allocation, investment decisions and sustainability. The system could be even enhanced by providing users agent-based assistance. In future work, we will implement our interface as a virtual household, fully equipped with all the electrical appliances and Smart Meters and we will evaluate it in order to collect the percentage of the active user participation and engagement.

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