

Empower Saving Energy into Smart Communities using Social Products with a Gamification Structure for Tailored Human-Machine Interfaces within Smart Homes

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Abstract

Residential buildings can contribute to save energy and to decrement electricity consumption in the world. On the other hand, the Internet of Things has allowed the implementation of smart homes that can profile the users. Nevertheless, end-users are not accepting the smart homes due to behavioral problems and usability problems with the Human-Machine Interface (HMI) or with the household appliances. As a solution, social products promote the interaction between the smart home and the consumer by including gamification features in the interface. Thus, smart homes can interact and compete with other houses to reduce energy consumption. Therefore, this paper proposes a three-step framework that takes advantage of social products to promote interaction between smart homes within a smart community to reduce electrical energy consumption. The first step collects from the literature review, the characteristics of the end-users, the behavioral and usability problems, and the most common gamification elements that teach, engage and motivate the user to reduce energy consumption. The second step proposes the gamification elements required for a tailored HMI in each social product and smart home through a fuzzy logic decision. The third step evaluates the interaction between social products in smart homes and the users to test which smart home is reducing more energy consumption. Finally, a three-level tailored gamified mock-up is depicted: level 1 for a single social product, level 2 for the smart home, and level three for the smart community. This mock-up can be implemented in small communities as residential complexes.

1. Introduction

Residential and commercial buildings represent 40% of the total U.S. energy consumption [1]. Users' habits impacts the amount of energy used in a building [2–4]. Thus, it is relevant to pay more attention to residential users and model their behaviors into a pro-environmental attitude. Unfortunately, trying to shape users' habits is challenging, as it is in human nature to return to old habits [3, 5–7]. Behavioral models and interactive environments can promote a more lasting change in individuals. Behavioral models like the Transtheoretical Model (TTM) [5], the Theory of Planned Behavior (TPB) [6], and the Self-Determination Theory (SDT) [7] are used to shape users' habits for targeting specific goals like the reduction in energy consumption.

Alternatively, the arising of the Internet of Things has allowed the increment of appliances in the home where the users can interact with the household products by monitoring the home throughout smartphones; those appliances may facilitate routine tasks, provide security and safety, or even adjust the visual and thermal comfort [8–10]. Nevertheless, the users are not adopting those products correctly due to usability and behavioral problems, and to the lack of personalization and interaction with the product and the Human-Machine Interface (HMI) [11–13].

Usability is a system design concept that tries to provide user-friendly products, services, or software to make them easy to use [14–17]. For instance, Nielsen evaluates software interface using approaches known as usability heuristics [18–20]. Moreover, heuristics evaluation demonstrates that identifies

usability problems in a fast, cheap, and effective way [15, 21]. Identifying behavioral problems when users had used household products help in avoiding future issues and preventing future problems. Thus, Ponce et al. [12, 22] identified six behavioral problems when household costumers used connected products. In that sense, Ponce et al. [23] proposed the concept of social product as a manner to communicate between the consumer and the product and between products to propose a tailored service, for instance, in a smart home [24].

A smart home is a connected dwelling equipped with software and hardware technology in the form of household appliances or social products that attends and satisfies the requests, comfort, safety, recreation, and well-being of the occupants. Hence, the household appliances in a smart home, considered as social products, can track and profile the user [2, 9, 24]. In [24], they proposed to use economic saving and eco-saving behavior intention, by using the TPB model, to promote electrical energy-saving behavior in smart homes. They also proposed to use personalized interfaces with gamification elements within it to teach, engage, and motivate users to reduce electrical energy consumption. In consequence, social interaction plays a primary role to understand and know better the user's patterns and profile them [25, 26]. A way to shape occupants' habits is by sending stimuli through gamification strategies [22–27]. Gamification, in this context, is defined as a *process of enhancing a service with affordances for gameful experiences in order to support the user's overall value creation* [28].

A set of smart homes, amenities, and green areas in which the residents have social interaction and relationships with their neighborhoods is a smart community. These homes are virtually connected in a same geographic region by a powerline communication technology, wireless communication technology as Bluetooth or Wi-Fi, phone line communication, and/or technology that requires dedicated wiring as Ethernet [29]. A smart community is the smallest component of a smart city, and it is in infancy stage [30]. For the purpose of this work, a smart community is a set of smart homes located and connected in the same region at a residential development. This smart community of housing owners is managed by a residential manager. Currently, the concept of a smart community is relatively new [29, 30, 36–40].

The smart community, smart home, and social products require of human conduct to make decisions and reasonings that impact, either positive or negative, on electrical energy consumption. In that sense, Zadeh [31–33] contextualized those decisions in an artificial system by proposing the use of fuzzy sets to model the uncertainty regarding human decision through a set of *If-Then* rules. In [34], they implemented a fuzzy logic model with gamification elements in a platform to profile five types of aspirants for personnel selection. Moreover, the authors of this manuscript proposed several papers regarding fuzzy logic in the context of social products and smart homes. In [35], they classified five types of energy end-users based on their personality traits using fuzzy logic for the use of connected thermostats and which gamification elements can personalize the interface [27]. In [25, 26], the authors proposed to use personalized HMIs with gamification elements to promote in-home physical activity and social interaction in elderly people by classifying them with personality traits or by tracking their mood through voice and face detection. Besides, by considering the users' personality traits, their economic activity, and the energy

target group they belong into a fuzzy decision system , it is possible to personalize their interfaces for the use of social products in a smart home [24].

This paper gets as a guideline the framework proposed in [22, 24] to propose a structure that considers the most common gamification elements for energy applications and a fuzzy decision system in a smart community to teach, engage, and motivate end-users to save energy. This work describes step by step how to propose and design a gamified community by taking into account the interaction between a single social product, between social products, and between the end-user and the products as [23, 24] suggest.

The remainder of this paper is organized as follows. Section 2 describes a brief background of gamified energy applications, the fuzzy logic system in gamification strategies, and the behavioral model and types of users for pro-environmental habits. Section 3 describes the proposed methodology. Section 4 shows the framework structure. In Section 5, the discussion section presents the scope of the structure, its advantages and disadvantages. Finally, in Section 6 is given the conclusion and future work.

2. Methodology

Behavioral and Usability Problems

Usability is the “capability of being used” and “refers to ease of use and the way users can perform their tasks” [14–17]. The end-users interact with the product, system or service to fulfill their expected goals through the effectiveness and satisfaction associated with the interaction. Nielsen [18–20] proposed ten usability heuristics for the evaluation in applications. Muller et al. [17] added three more usability heuristics to complement that evaluation. This evaluation has been used in the evaluation of electronic shopping [15], for interfaces for household products [12, 22], or for the evaluation of user experience [16].

On the other hand, in [12, 22], it was identified six behavioral problems when household costumers used connected thermostats; however, these problems can apply to any other household appliance. Table 1 depicts these behavioral and usability problems.

Types of users, gamification users, and ecological behavior

In [47, 48], the “Big Five” personality traits were described. These personality characteristics have demonstrated a strong association between the attitudes of individuals and their actions in different domains [49]. Personality-environmental behaviors have provided quite mixed results; nevertheless, it is feasible to forecast environmental concerns through personality traits [50–53]. Several studies revealed that each personality has a relation in the way it focuses, learns things, and adopt technology [49, 54–58].

Moreover, five energy end-users segments were proposed regarding energy use and based on traditional sector divisions [11], as well as three energy target groups based on their characteristics, household appliances, user availability, and energy awareness [61]. In [22], it was related the energy end-user segments with the energy target groups as following:

- Early adopter with Non-green selective and Disengaged segments.
- Cost-oriented with Traditionalist cost-focused and home focused segments.
- Energy-conscious with green advocate segment.

Table 2 describes each type of personality trait, energy end-user segment, and energy target group.

Table 3 describes the type of role player [62] and the type of Hexad gamification player [63]. Later, [64] associated the Hexad framework with the “Big five” personality traits [48]. Figure 1 shows the relationship between each gamification player with the Big five personality traits. Besides, each gamified player is related with some game design elements.

TABLE 1. Usability and behavioral problems in household appliances.

Usability Problem	<i>Characteristics</i>
<i>Visibility of the status [41]</i>	The interface neither informs the status nor gives appropriate feedback. A lack of information creates a lack of control. Appropriate feedback for the end-users keeps them informed, so they can direct the interaction correctly. For instance, by showing a progress indicator when a process needs time to finish.
<i>Match between system and the real world [42]</i>	The system uses system-oriented terms rather than following real-world convention language. The interface needs to show empathy, build trust, give sense of familiarity and importance to the end-users that eventually will lead to loyal users.
<i>User control and freedom [18]</i>	Users feel controlled by the interface and without freedom. They mischoose system functions, so the interface should show an “emergency exit” to avoid extended dialogue that make the end-user feel more confused. To avoid control a lack of freedom, the interface should allow undo and redo options.
<i>Consistency and standards [18, 43]</i>	The interface does not follow platform conventions. End-users should not need to know if different words, situations, or actions mean the same thing. 80% of success rate in the interface happens when users navigate in a structure scheme based on most users’ mental model, rather than the company’s internal thinking.
<i>Error prevention [18, 44]</i>	The interface is not carefully designed and develop error problems. There are two types of end-user errors: slips when users end up performing one similar action different from what in the beginning they were thinking. For instance, typing a “c” instead of a “v”. The other error is when the end-user does a very different task than what they really wanted to do, so the system displayed a mistake. For instance, the user wanted to move photos to other folder and instead of moving it, the user delete the photos. Therefore, to prevent that, the interface should display a message confirming that the user really wants to delete the pictures. In that case, user has incomplete or incorrect information about the task, and create a mental model different that does not match with the current task.
<i>Recognition rather than recall [45]</i>	The objects, actions, and options are not visible. Recognition involves more cues, so the users’ memory activates. Recall involves fewer cues than recognition, an example of recall is the interface login. By making the information and interface functions visible and accessible it is possible to promote recognition. For instance, by showing the content or elements that help the users reach their goals or by providing history and previously visited content.
<i>Flexibility and efficiency of use [18]</i>	Lack of custom actions. Access and operation are limited to average users. The interface should allow users to tailor frequent actions.
<i>Aesthetic and minimalist design [18]</i>	Dialogues contain irrelevant or rarely needed information. The interface should avoid dialogues that compete with relevant information.
<i>Help users recognize, diagnose, and recover from errors [18, 46]</i>	Messages are displayed in code; users cannot recognize, diagnose, and recover from them. Good error message should include explicit indication that something is wrong, it should have human-readable language, it should be polite phrasing that does not imply that the users are doing things wrong, it should be precise by giving the exact problem, and it should display constructive advice on how to fix the problem.
<i>Help and documentation [18]</i>	Information is complicated to search and is not focused on the user’s task and is extensive. The help and documentation information could be provided as a manual guide, video tutorials or by allowing the users to call the experts.
<i>Skills [17]</i>	The interface tries to replace the user’s capabilities, background knowledge, and expertise. The system should give support, extend, supplements, or enhance the user’s skills.
<i>Pleasurable and respectful interaction with the user [17]</i>	The design is unpleasing and nonfunctional. The interface should reflect user’s professional role, personal identity, or intention. The design should give balance of artistic and functional value.
<i>Privacy [17]</i>	The system does not protect personal or private information.
Behavioral Problem [12, 22]	<i>Characteristics</i>
<i>Use</i>	Users do not know how to use the connected product in the house. The interface does not display any tip or manual that help them understand better the product.
<i>Operation</i>	Users operate the connected product different than how the design engineers intended. The interface does not help them to understand the operation of the product.
<i>Functionality</i>	Users do not understand the functions. They feel using the connected product is complicated, they do not

	understand the interface.
<i>Benefits</i>	Users do not know and/or care about the advantages of the connected product. Saving money is not a priority.
<i>Environment</i>	Users are not aware of the environmental impacts.
<i>Energy awareness</i>	Energy saving is not a priority for the user.

TABLE 2. Personality traits, energy end-users segments, and energy target group.

Personality traits [47, 48]	<i>Characteristics</i>
<i>Openness [59]</i>	These individuals appreciate divergent thinking. They have new social, ethical, and political ideas, behaviors, and values. They have a curious, imaginative, and unconventional attitude. They have positive attitude to learn new things and use Internet for these purposes. They have positive attitude toward energy conservation.
<i>Conscientiousness [60]</i>	They are self-discipline, competitive, dutifulness, and responsible. They have a rational, purposeful, strong-willed attitude. They follow rules and have clear goals in life. They have positive attitude toward energy conservation.
<i>Extraversion [60]</i>	They are energized by social interactions and exciting and diverse activities. They are talkative and have an assertive and optimistic attitude. If they have high levels of extraversion, they are inclined to save energy.
<i>Agreeableness [56]</i>	These individuals are altruistic, modest, and have a cooperative nature. They have a sympathetic and tolerant attitude to others. They are inclined to save energy.
<i>Neuroticism [56]</i>	They tend to experience negative emotions like fear and sadness. They have an impulsive, stressful, and bad-tempered attitude. If they have high levels of neuroticism, they have positive attitude toward energy conservation.
Energy end-users segments [11]	<i>Characteristics</i>
<i>Green advocate</i>	They are interested in new technologies and they are energy aware.
<i>Traditionalist cost-focused</i>	Individuals have limited interest in new technologies. They have extensive overall energy-saving behavior and cost-saving is their motivation.
<i>Home-focused</i>	They are looking for household improvement and they care about saving energy and reducing cost.
<i>Non-green selective</i>	Individuals are selective energy savers. They focus on set-and-forget inventions, and they are not energy aware.
<i>Disengaged energy waster</i>	Cost savings, new technologies improvements and environmental concern are not their motivation.
Energy target group [61]	<i>Characteristics</i>
<i>Early adopter</i>	They want modern technology buffs, so they buy all the newest gadgets. They choose to buy households appliances on the cutting edge of technology. They are available anywhere at any time via smartphone. They become part of the social media communities. They are not energy aware.
<i>Cost-oriented</i>	These individuals take care of the household appliances and have a cost-oriented way of life. They are mostly connected through their mobiles and are social media users. Energy savings are important to them. They try to be sustainable within their abilities and capabilities.
<i>Energy-conscious</i>	They try to have a sustainable lifestyle. They buy household appliances with a long lifetime and low energy consumption. They use smartphones and are not usually active in social media. They are very energy aware.

TABLE 3. Serious games and gamification role players.

Serious game user [62]		Gamification user [63]	
Role player	Characteristics	Role player	Characteristics
<i>Achiever</i>	They are looking all the time in earning points and levels.	<i>Achiever</i>	Their main motivation is competence
<i>Explorer</i>	They find and collect all the information they can gather for the game and the players.	<i>Free spirit</i>	They prefer autonomy as a means of communicating independence. They act without external influence
<i>Socializer</i>	Their main goal is to interact with other players.	<i>Socializer</i>	They love the interaction with the others to create social connections.
<i>Killer</i>	Their main target is to impose themselves on others. They want to have control over others.	<i>Disruptor</i>	Creating positive or negative changes in the game is their main motivation.
		<i>Philanthropist</i>	Having a sense of purpose is their motivation
		<i>Player</i>	Similar to the achiever gamification player, competence is their motivation.

Ecological behavior

The theory of planned behavior (TPB) is usually carried out to understand energy-related behavior, pro-environmental behavior and sustainable choices. This model identifies the behavioral intention and attitude of an individual regarding particular behavior to understand three pairs of determinants [65]: behavioral belief – attitude, normative beliefs – subjective norm, and control belief – perceived behavioral control:

Attitudes towards the conduct created from behavioral beliefs, those beliefs outcomes of a conduct and the evaluations of those consequences.

Subjective norms shaped from the normative expectancies of others and motivation to conform with such expectation.

Perceived behavior control based on ideals concerning factors that may enable or hinder the habits.

The TPB model is widely used for pro-environmental habits [66]. Therefore, Figure 2 proposes to use gamification and serious game elements for economic saving and ecological saving to promote energy saving behavior in smart homes.

Moreover, in [35], they classified and assigned a level of Ecological Behavior. First, they trained an Artificial Neuronal Network model from 19719 answered surveys of the Big Five Personality Test from the International Personality Item Pool of a public database available in [67]. The backpropagation algorithm

uses Bayesian regularization with an adaptive weight minimization as the top condition. Then, based on the five energy end-user segment proposed in [11], they generated a radar map with the correlation of personality traits to create the rules for the fuzzy system. Finally, they classified and assigned the level of ecological behavior regarding the type of energy end-user segment and his/her associated levels of big five personality traits. Figure 3 shows the radar map of personality correlation with the type of user.

Gamification in energy applications

An energy gamified application is a *traditional application addressing an environmental goal extended with game-like features* [68]. In [69], she conducted an analysis of 25 gamified energy application to propose three best practices for sustainable applications:

- Make sustainability a fun and rewarding experience.
- Create positive peer pressure on sustainability issues.
- Use gamification to promote meaningful action.

The SDT used was used to classify nine-game design elements based on autonomy, competence and relatedness satisfaction for a gamified energy-saving campaign [70]. These nine-game design elements are personal profile, non-fixed structure, challenge, feedback, theme, short cycle time, competition, cooperation, and chat-based social network.

Johnson et al. [71] proposed twelve-game elements and five outcomes gamification energy applications feedback, challenges, social sharing, rewards, leaderboards, points, tips, levels, rankings, avatars, badges, and user-generated content.

In [72], they proposed a gamification-based framework to engage end-users in energy applications. They used the TTM model to shape end-user's energy behavior. To do that, they proposed the following game design elements:

Statistics, messages, tips, discounts in electricity bill, virtual currency, prizes, offers and coupons, competition, collaboration, energy community, dashboard, leaderboard, progress bar, message box, notifications, degree of control, points, badges, and levels.

The Octalysis framework proposed by Chou [73] analyzes and builds strategies to make engaging applications. This framework considers extrinsic, intrinsic, positive, negative motivations, and eight core drives.

Extrinsic motivation: People are motivated because they want something they cannot get, and acquiring it infers outer recognition or even monetary prizes.

Intrinsic motivation: The activity is rewarding on its own without a particular objective to accomplish.

Positive motivation: The activity is engaging because it lets the user feel effective, glad, amazing, and powerful.

Negative motivation: The activity is engaging because the user is continually in dread of losing something.

Core 1. Epic meaning and calling: Users believe that they are accomplishing tasks that could be more noteworthy than themselves and are picked to make a move.

Core 2. Development and accomplishment: Intern drive for succeeding progressing, developing abilities, achieving mastery, and so on.

Core 3. Empowerment of creativity and feedback: Users become occupied with an innovative process when they attempt various combinations to accomplish objectives. They additionally need to see the consequences of their imagination, get input, and change their inventiveness.

Core 4. Ownership and possession: the desired core, in which users believe, accept and feel that they own or are in charge of something.

Core 5. Social influence and relatedness: This core has social components that inspire individuals, including mentorship, social acknowledgment, social criticism, friendship, rivalry, and even envy.

Core 6. Scarcity and impatience: Users want something just because it is it is very uncommon, elite, or quickly out of reach.

Core 7. Unpredictability and curiosity: People constantly become engaged because they do not have any idea of what will happen later; this is the core behind betting addictions.

Core 8. Loss and avoidance: Users attempt to keep something negative from occurring. They feel the criticalness to act quickly, else they may lose the opportunity to act.

Figure 4 displays the Octalysis framework [73] considering the game design elements suggested in [72]. proposed a complete and the relationship with the types of user described in the previous section and used in [22].

The *Powersaver Game* uses gamification elements that impacts in the reduction of household energy consumption [74]. They proposed to measure the game by evaluating the following elements:

- Knowledge: In-game quizzes.
- Attitude towards saving energy: Questionnaires before and after the game.
- Actual energy usage: Through real-time monitoring of intelligent devices.
- Engagement: Regarding continue playing the game and by monitoring player's behavior during playing.

The *ecoGator* application [61] supports end-user awareness of energy-efficient buys and daily utilization of items through a gamification strategy based on rewarded activities. The users can scan the appliances energy labels, and they can compare between two scanned products to guide them in the decision-making process. This application had the perception of a good shopping assistant but did not raise awareness in the end-users. The application considers three types of end-users and the following gamification elements: reading tips, social media actions (sharing tips), earning points, quizzes, challenges, and money saving and efficient energy use tips.

De Luca and Castro [75] proposed the *Social Power Game* application for a community. The users can choose between two factions, yellow or blue, and they contribute by saving energy, playing collaboratively and cooperating with the community and friends by finishing missions. The meaning of community in this game considers besides the household electricity consumption, the consumption in transportation, infrastructures, groceries, among others. This game explores the potential of social interactions and game mechanics; however, this application can be upgraded by linking the activities with connected products in the house. This game uses the following gamification features: social comparison, social competition, points, rewards, achievements, feedback, monitoring, dashboard, energy community, progress bar, leaderboard, and levels.

The *Power House: The Energy Game* [76] is an online game that links smart meters to a virtual reality world social networks. Personal accounts with local energy providers monitor the player energy use. Then, the game collects the energy usage information to display the implications for the choices, rewards and credibility of players. This game also considers a virtual neighborhood as a representation of the users' friends. The users can compare with their friends by knowing their earned awards and achievements. The gamification elements in this game are leaderboard, dashboard, feedback, monitoring, progress bar, awards, achievements, social comparison, challenges, competition, energy community, and levels.

GAMEFULQUEST [77] is a guideline to evaluate customers' gameful experiences in systems within a gamification context. The measures use a seven-point Likert-type of scale, ranging from 'strongly disagree' to 'strongly agree'.

Consequently, in a context of teaching users to become energy aware, serious games complement any gamified energy applications. Serious games have the purpose of non-entertainment goal with an explicit educational objective. These games need to have a balance between entertainment and education, so the users do not feel the game disruptive or intrusive leading in the failure of intrinsically motivating. Such games are useful as the player is absorbed in the gaming environment, and the other participants provide feedback. Besides, they offer information to the user in a ludic way that the players feel involved [71, 78]. Existing energy serious games are: *Power agent* [79], *Power explorer* [80], *Less Energy Empowers You* [81], *Energy Battle* [82], *Residence Energy Saving Battle* [83], *Energy Chickens* [84], *EnergyCat* [85, 86], *Virtual city* [87], *Energy 2020* [88, 89].

Energy serious games should consider the following characteristics [90]: theme, player's role [62, 64], game objective, number of players, type of game, 2D or 3D graphics, and availability.

Moreover, in [22], they proposed and explained an updated achievement system structure extensively for a connected thermostat that is also applicable to other household appliances. This structure considers the type of customer, the required phases to solve the six behavioral problems, the achievement system reward and the gamification and serious games interface elements required in order to reduce electrical energy consumption.

Based on this gamification antecedents. It can be suggested that there are thirteen most common elements used in energy gamified applications: dashboard, monitoring, feedback, leaderboard, points, badges, prizes, coupons, bill discounts, challenges, social comparison and social competition.

Social Products

In accordance with [23], a social product is a product that *can observe, register, analyze, and change the consumer behavior or adapt its features online/offline by itself to improve its performance or acceptability in the market.*

The S³ product development framework can create social products by implementing sensing, smart and sustainable features within them [91]:

- Sensing is the ability of a system to detect events, get information, and measure changes utilizing sensors that permit observing of physical or environmental conditions.
- Smart is the consolidation of physical parts, smart components, and connectivity complements to make the product intelligent and accessible to interface with different gadgets.
- Sustainable incorporates social, environmental, and economic elements to produce balanced and optimized performance. The social aspect is related to the contribution of a product to people's satisfaction.

Besides, social products can be promoted by knowing the types of behavior and usability problems in the use of connected devices and by involving residential energy users in the process of planning, implementation, and monitoring of the energy usage.

Figure 5 displays the communication between social products proposed in [23] using as an example a connected thermostat. This communication is designed to improve energy efficiency in Smart Homes.

Social products in a Smart Home

In 1984 the American Association of House Builders introduced the concept of smart homes in terms of "wired homes"[9]. However, the term is often defined based on technological aspects and usage. For

instance, the construction sector defined a smart home as a residence *equipped with computing and information technology, which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond* [9]. This type of home collects and analyzes data, gives information to the habitants and manage different domestic appliances [92]. Besides, a gamified smart home has interactions that help the user feel comfortable. Figure 6 displays two examples of a gamified smart home structure. Figure 6 (a) presents the six types of interactions within the smart home [26]. Figure 6 (b), shows the structure of a gamified smart home that considers social products to promote energy-saving behavior in the end-user [24]. Social products could be accepted if [92]:

- The users know that they buy a connected product and they can exploit its advantages.
- They fit with the user's current and changing lifestyles
- The appliances and devices are quick and cheap to obtain.
- Those products demonstrate they reduce or eliminate physical demands for their operation; the users do not require high levels of user knowledge or regular intervention of experts for installation, troubleshooting and maintenance.
- The usability of the product considers end-user skills; the product does not fail or act unpredictability.
- The product interprets user requirements.
- They have privacy and security features, so the user's information is secure and private.

Set of smart homes that conforms a smart community

Researchers are still looking for the definition of smart community and what elements form part of it due to several interpretations of what a smart community should have. However, what researchers, housing managers, stakeholders, home builders agree are that a smart community improves the lifestyle of residents and involves the managers by providing to them modern high technologies that allow advanced information of the community [29, 30, 36–40].

In this current paper, the authors agreed that a set of smart homes located and connected in the same region at a residential development administrated by a residential manager form a smart community. For instance, a smart community can be held in a residential apartment, where each apartment is a smart home.

Figure 7 proposes a diagram of how it is conceptualized the structure of a gamified smart community. Each smart home composes the smart community. Within the smart home, the fuzzy logic system structure analyzes the interaction between the social product and the user to propose a tailored interface in order to achieve the energy-saving behavior target. The residential manager should consider the following tasks:

- Explain to the members the general function of a smart home.
- Orientate new members.
- Monitor housing energy consumptions.
- Feedback the users regarding their housing energy consumption.
- Propose and suggest collaborative activities that enhance energy awareness.

Fuzzy logic system in gamification strategies

Fuzzy logic proposes to model uncertainty based on linguistic variables related to human reasoning rather than using numerical values. In 1965, Zadeh [31] proposed this theory, in which a class of object belongs to a fuzzy set with membership grades from 0 to 1 and inference rules proposed by experts, polls, or consensus-building that do not require a mathematical model of the real system [93, 94].

The fuzzy logic has three steps:

- Fuzzification: Is a process where input variables have an uncertainty metalinguistic degree. These variables are classified into fuzzy sets. For instance, the engagement variable of an energy gamified system can be described as:
 - Engagement variable = {High, Low, Medium}
- Inference linguistic rules: The experts propose the rules to help the system behave in an accurate manner. The membership grade of each variable is evaluated in a set of inference rules. These rules have an antecedent *IF* part and a consequent *THEN*
- Defuzzification: This step determines the optimal output values. It consists in passing the degree of membership function derived from the consequent part of the inference linguist rules into crisp outputs.

Following, it is briefly described some applications that uses a fuzzy logic decision system :

QuizTime! [95] is a mobile game-based learning application that assesses the learners' knowledge level in the programming language C# in higher education. In the adaptive game, two students are playing simultaneously, but they are not in a competition. Both students have the goal of finishing the quiz successfully. If the answer is incorrect, a chat appears and help the student to decide the correct answer. This game classifies the student levels of previous knowledge, current knowledge level, and misconceptions to propose tailored suggestions while the users are taking the quizzes in order to make the students understand in which question they are failing. Later, in future quizzes, the game suggests to the student the collaboration with another student that may motivate him/her in acquiring the knowledge. They use these gamification elements: points, badges, feedback, social collaboration, and monitoring.

In [96], they proposed a knowledge-based fuzzy logic system for business games based on 362 players decision taken from a business management simulator. The fuzzy logic system profiled the user's decisions to predict the player's conduct patterns and performance.

In [97], they gave an approach of an educational game that uses serious games within a fuzzy logic decision system. This game profiles the knowledge level of the student; if the student is succeeding, then new concepts will learn. Although this proposal is at an early stage, it gives an example of how by combining serious games and a decision system, the student can learn new concepts engagingly. The gamification elements proposed in this project are points, badges, rewards, and progress bar. The serious game elements are single-player, leading role player, and storyline.

Moreover, there have been approaches regarding profiling and classifying users to offer tailored services. In [34], they implemented a fuzzy logic model with gamification features in a platform to profile five types of aspirants for personnel selection. This classification allows human resources to decide if the aspirant is adequate for the job opening.

Nevertheless, the authors of this presented work found a lack of proposals or projects that considers fuzzy logic to classify the type of user, either typical or non-typical user, based on their ecological behavior [35]. They also proposed gamified tailored HMI that teaches, engages and motivates the end-user to reduce electrical energy consumption by taking advantage of the end-user regarding energy usage, knowledge, energy-saving attitude, and engagement [22, 24–27]. Besides, in [22], the proposal uses a fuzzy logic decision system to promote energy-saving behavior in typical and non-typical users considering their personality traits, the kind of role player in gamification and serious games context, and the relation with the energy end-user segment and target group.

However, based on the review in the previous subsections, it was found that there is an opportunity field in proposing a gamified smart community based on a fuzzy logic decision system to help the users to achieve an energy-saving behavior.

3. Proposed Framework

This framework proposes the gamified HMI divided into three levels: a gamified interface of the single social product, a gamified interface of the smart home, and a gamified interface of the smart community (see Figure 8). Therefore, the methodology used is the framework proposed by the authors [22, 24, 27]:

Knowledge base step: this step collects from the literature review and databases, the characteristics of the household appliances, the occupant's energy profile consumption, the types of users, the behavioral and usability problems. It also collects the thirteen gamification elements most used in energy applications that teach, engage and motivate the user to reduce energy consumption as well as, the effects of the application in terms of knowledge, engagement, attitude, and energy usage.

Fuzzy logic step: This step has two parts. The first part considers the personality traits as the input values to display their levels of engagement, energy usage, attitude and knowledge, known as effects in this paper. The second part uses that effects to propose the gamification elements that best fit the user type.

Evaluation step: This step evaluates the interaction between the user and the social product in the smart home, the smart home and the smart community. Regarding the smart community, in this step, it is only displayed in a general form the social comparison, challenges, competition and leaderboard show to the users which smart home is reducing more energy consumption. This phase provides continuous feedback to the user and the knowledge base to determine whether the user is engaged or if adjustments are required.

Knowledge base step

The information used in this step has two parts. The first part considers the personality traits in terms of their relationship with the energy end-user segments and energy target group. It also considers their level of engagement when each personality uses the internet and their interests in energy usage. It examines their attitude about becoming energy-aware and their interest in learning new concepts. The second part relates the knowledge, engagement, attitude, and energy usage elements with the thirteen most common gamification elements used for energy applications.

Table 4 displays the ecological behavior relationship presented in [22] with normalized values for the fuzzy logic decision system. Table 5 exposes the associated personality trait with the gamification player suggested in [64]. Table 6 relates the users' interest regarding each personality trait. Furthermore, these outputs become the inputs for the second part of the knowledge base.

TABLE 4. Ecological behavior relationship presented in [22].

Ecological behavior relationship		Energy end-user segments				
		<i>Green advocate</i>	<i>Traditionalist cost-focused</i>	<i>Home focused</i>	<i>Non-green selective</i>	<i>Disengaged</i>
Personality traits correlation with the type of energy end-user segment						
Personality trait	<i>Openness</i>	1.00	0.42	0.23	0.23	0.17
	<i>Conscientiousness</i>	0.83	0.75	0.68	0.55	0.58
	<i>Extraversion</i>	0.60	0.57	0.83	0.58	0.37
	<i>Agreeableness</i>	0.72	0.63	0.50	0.43	0.25
	<i>Neuroticism</i>	0.05	0.17	0.33	0.55	0.75
Energy target group and energy user segments relationship						
Energy target groups	<i>Early adopter</i>				x	x
	<i>Cost-oriented</i>		x	x		
	<i>Energy-conscious</i>	x				

TABLE 5. Associated personality trait with six types of gamification player [64].

Associated personality trait with player's type	Gamified player					
	<i>Philanthropist</i>	<i>Socializer</i>	<i>Free Spirit</i>	<i>Achiever</i>	<i>Disruptor</i>	<i>Player</i>
<i>Openness</i>	x			x		
<i>Conscientiousness</i>	x				x	x
<i>Extraversion</i>	x	x		x		
<i>Agreeableness</i>	x	x				
<i>Neuroticism</i>				x		x

TABLE 6. Relationship between personality traits and the users' interests in becoming energy aware, learn new things and Internet usage. [49-58]

Big Five	Characteristics			
	<i>Engagement</i>	<i>Energy usage</i>	<i>Attitude</i>	<i>Knowledge</i>
<i>Openness</i>	High	High	High	High
<i>Conscientiousness</i>	Med	High	High	High
<i>Extraversion</i>	High	Med	Med	Med
<i>Agreeableness</i>	Low	Med	Med	Med
<i>Neuroticism</i>	Med	Low	High	Low

Fuzzy logic system

The fuzzy logic decision system examines the personality traits in the input system; the output system reflects the elements explained in the first part of the previous subsection. The linguistic rules for this part consider the relationship between the personality traits and the energy end-user segment presented in [35], and the type of effect and gamified player. Table 7 displays the input and output elements for the first part, and Table 8 shows the input and output elements in the second part of the fuzzy logic decision system [22].

Figure 9 displays the front panel and the block diagram for the first part, while Figure 10 shows the second part for the proposed fuzzy system.

TABLE 7. Input and output elements of the first part of the fuzzy logic decision system.

INPUT	OUTPUT		
Personality traits	<i>Effect</i>	<i>Energy end-user</i>	<i>Gamified player</i>
<i>Openness</i>	Engagement	Green advocate	Philanthropist
<i>Conscientiousness</i>	Energy usage	Traditionalist cost-focused	Socializer
<i>Extraversion</i>	Attitude	Home focused	Free Spirit
<i>Agreeableness</i>	Knowledge	Non-green selective	Achiever
<i>Neuroticism</i>		Disengaged	Disruptor

TABLE 8. Input and output elements of the second part of the fuzzy logic decision system [22].

Effects	Common gamification elements		
<i>Engagement</i>	Dashboard	Points	Challenges
<i>Energy usage</i>	Monitoring	Badges	Social Comparison
<i>Attitude</i>	Feedback	Prizes	Competition
<i>Knowledge</i>	Progress bar	Coupons	
	Leaderboard	Bill discounts	

For instance, some of the linguistic rules used for the personality traits classification are the following.

- IF Openness is high, and conscientiousness is high, and extraversion is high, and Agreeableness is low, and Neuroticism is low; THEN engagement is low, and energy usage is med, and attitude is med and knowledge is high, and home focused is active, and traditionalist cost-focused is active, and philanthropist is active, and socializer is high, and free spirit is high, and achiever is high, and player is high, and disruptor is low.
- IF Openness is high, and conscientiousness is low, and extraversion is high, and Agreeableness is low, and Neuroticism is low; THEN green advocate is active, and engagement is low, and energy usage is high, and attitude is high and knowledge is high, and philanthropist is high, and socializer is high, and free spirit is high, and achiever, and player is low, and disruptor is low.

Moreover, the evaluation step feeds the fuzzy logic decision system to continue updating the rules and membership functions to propose accurate output values used in the tailored interfaces.

The second part of the fuzzy system design was first proposed in [22] for a connected product and is used for this work, too. This system considers the level of engagement, energy usage, attitude, and

knowledge to display which gamification elements require the tailored interface. Figure 11, shows the relationship between the input values and the output values to promote energy-saving behavior.

- Knowledge: Challenges, dashboard, monitoring, feedback, prizes. In-game quizzes measure this element [74].
- Engagement: Challenges, competition, progress bar, leaderboard, points, badges, and prizes. In [74], they proposed to monitor users' habits while they use the application.
- Attitude: Social comparison, feedback, leaderboard, points, and badges. This input measures if the users change their attitude toward saving energy [74].
- Energy Usage: Challenges, competition, dashboard, monitoring, coupons, and Bill Discounts. In [74], they suggested measuring energy usage throughout monitoring devices.

Evaluation step

Table 9 shows the results of the first part of the fuzzy system. This user is highly open, moderately conscientious and extraverted, with lower agreeableness and neurotic. Table 10 displays the results of the second part of the fuzzy system. This part has these initial input values: low engagement (18%), medium energy usage (60.3%) and attitude (51.8%), and high knowledge (80.3%). Although in the three levels, the interface displays many of the same gamification elements, level three has the characteristic of providing more security among the other two levels. Thus, level three shows to the user the savings per house to compare themselves but not in which social products they have more saving, as a mean of privacy and security [17].

This user is mainly traditionalist cost and home focused with philanthropist, socializer, free spirit, achiever, and player gamified role player but has a low engagement value. Thus, the interface must focus on high and medium output values. For example, the application can give the user more rewards based on how much knowledge about the connected products and its economic benefits the user is learning. As this individual is a socializer, the application can promote social activities, challenges, comparison and competition.

TABLE 9. Fuzzy logic results for the first part of the fuzzy system.

Personality traits		<i>Input</i>	
<i>Openness</i>		0.61	
<i>Conscientiousness</i>		0.39	
<i>Extraversion</i>		0.46	
<i>Agreeableness</i>		0.07	
<i>Neuroticism</i>		0.13	
Gamification elements		<i>Output</i>	
<i>Effect</i>	<i>Engagement</i>	0.18	
	<i>Energy Usage</i>	0.6	
	<i>Attitude</i>	0.51	
	<i>Knowledge</i>	0.8	
<i>Energy end-user segment</i>	<i>Green advocate</i>		
	<i>Traditionalist cost-focused</i>	x	
	<i>Home focused</i>	x	
	<i>Non-green selective</i>		
	<i>Disengaged</i>		
	<i>Gamified player</i>	<i>Philanthropist</i>	x
		<i>Socializer</i>	x
		<i>Free Spirit</i>	x
		<i>Achiever</i>	x
		<i>Disruptor</i>	
<i>Player</i>		x	

Table 10. Fuzzy logic results for the second part of the fuzzy system.

Effects measured		Input		Levels		
Engagement		18.0 (low)	<i>Level 1: Connected Thermostat</i>	<i>Level 2: Smart Home (connected products)</i>	<i>Level 3: Smart community</i>	
Energy Usage		60.3 (med)				
Attitude		51.8 (med)				
Knowledge		80.3 (high)				
Gamification elements		Output		Gamification elements for the gamified HMI		
Trigger	<i>Challenges</i>	3.6 (med)	x	x		x
	<i>Social Comparison</i>	3.5 (med)	x	x		x
	<i>Competition</i>	3.6 (med)	x	x		x
Interface	<i>Dashboard</i>	3.6 (med)	x			
	<i>Monitoring</i>	3.6 (med)	x	x		x
	<i>Feedback</i>	3.5 (med)	x	x		x
	<i>Progress bar</i>	0.5 (low)				
	<i>Leaderboard</i>	3.5 (med)	x	x		x
Rewards	<i>Points</i>	3.5 (med)	x	x		x
	<i>Badges</i>	3.5 (med)	x	x		x
	<i>Prizes</i>	6.5 (high)	x	x		x
	<i>Coupons</i>	3.6 (med)	x	x		x
	<i>Bill discounts</i>	3.6 (med)	x	x		x

4. Results

Figure 12 presents the tailored gamified interface for the three levels the form part of the smart community:

Level 1 (Figure 12(a)) belongs to a single social product where a device, as a connected thermostat, interacts with the user and displays a series of recommendations, challenges and rewards that supports a reduction in electric consumption and promotes commitment.

Level 2 (Figure 12(b)) belongs to the smart home that gathers all the connected products and summarizes the total energy consumption and reduction, in this level, the challenges and rewards are proposed in collaboration with all the connected devices.

Level 3 (Figure 12(b)) belongs to the gamified Smart community. Here the type of challenges and competition are related in fostering interactions and competitions in collaboration with other homes. At this level, the residential manager monitors the community habits to give tips or recommendations that helps the reduction of energy consumption. The users compete and challenge each other without compromising the quality of life, comfort, and safety of information provided to the other residential users. Each gamified home has a tailored interface based on the household user profile. In each smart home, the user is profiled based on the level of engagement, energy usage, attitude toward saving electrical energy and how much he/she knows about the benefits of reducing energy consumption.

For instance, the challenges proposed at every level are:

Level 1: Reduce this week 2% of energy consumption by turning off the lights when you are not at home.

Level 2: If you turn on your HVAC system in the morning, check if the windows are closed, and the lights are off.

Level 3: The home 2 win you by only 5 points. Win them by completing successfully any social product challenge.

When the user begins to use the application, feedback and adjustment of the evaluation phase are executed to determine whether the proposed dashboard is correct for the target user or whether the gamification functions in the HMI should be updated.

5. Discussion

This paper proposes a novel approach for tailored gamified HMI in smart communities. In order to propose an accurate interface is essential to break down the smart community structure in three levels: the single social product or connected device, the social products that form the smart home, and the set of smart homes to get a smart community. Therefore, it is better, to begin with, the connected device because, at this level, the gamified elements will be more and will help the designer understand which elements and what type of information are proper to display for the following levels.

Due to its completeness, this manuscript took as a guideline the framework presented in [22]. This framework considers three steps: the knowledge base step, the fuzzy logic step, and the evaluation step. The first step gathers all the information from the literature review and databases. This phase analyzes the types of user, the ecological behavior, the usability and behavioral problems when products are deployed, the most common gamification elements used in gamified energy applications, and the effects of an energy application regarding knowledge, engagement, attitude, and energy usage elements. The fuzzy logic step analyzes the information collected in the previous step to propose the gamification elements in the interface. In this step, the system is divided into two parts. It was added a previous fuzzy logic decision system that considers the personality traits as the input values to display their effects regarding energy applications, their type of energy end-user segment, and the type of gamified player in

this paper. The second part uses the decision system previously proposed by the authors in [22] Finally, the evaluation step evaluates the interaction between the product and the interface to determine if the user is motivated, engaged and acquiring new knowledge.

Although this paper proposed a fuzzy logic decision system for the personality trait of the user, this framework can be improved by automating the usability and behavioral problems in the product to strengthen the framework. The gamified application does not consider linking it with the electrical grid system and consider the demand response; however, this will be feasible with further research that makes, even more, challenging the application. Moreover, this novel proposal allows the smart community designer to suggest new tailored gamified applications.

Besides, [22] presented a detailed guideline of proposing tailored gamified interfaces for a single social product by considering those problems with more in-depth detail. Regarding the interactive design, this proposal enhances tailored interfaces by bringing solutions that best suit the users' characteristics (personality traits, gamified player, and energy end-user segment) to promote energy reduction. A tailored gamified interface engages the consumer by providing them gamification elements in these six components:

- User control: By the dashboard, statistics, monitoring.
- Responsiveness: With the fuzzy logic decision system, the interface learn and provides customized interfaces based on the type of user and the interaction that the end-user is having between the interface and the electronic device.
- Real-time interaction: Through feedback, tips, messages, statistics, challenges, and competition.
- Connectedness: By the social comparison, community news, messages, and challenges.
- Personalization: With the badges earned, user profile customization, and by providing tailored interfaces through the step 2: Fuzzy logic system.
- Playfulness: Enhancing competition, challenges, social comparison, leaderboard, progress bar, points, coupons, prizes, and bill discounts.

This framework uses continuous feedback from the interaction between the end-user, the tailored HMI, and the electronic devices within the home and the community to improve the gamified elements displayed on the HMI. Therefore, this paper presents a guideline for the designer or engineer who wants to propose a tailored interface; it describes the fuzzy logic decision systems used and their rules and how to obtain an interactive and tailored gamified application. Hence, this typology allows its broadening into implementation in the smart cities by combining several gamified communities. Besides, the complexity increases as there are communities that consume more energy than others and the community's cultural characteristics. For instance, the Texas population does not behave the same as the California population.

6. Conclusion And Directions For Future Work

The main goal of this work is to describe a gamification structure based on a fuzzy logic decision system that allows the energy HMI designers to propose dynamic interfaces that engage end-users to adopt energy-saving habits. This structure considers three steps: knowledge base, fuzzy logic system, and evaluation. The knowledge base step allows us to realize that it does not yet exist an interface that uses gamification with fuzzy logic analysis to save energy in Smart communities. By combining these techniques, it is possible to engage end-user to become energy aware.

This paper proposes a gamified smart community by considering two additional interfaces, for the social products in the smart home and a single social product; this makes this framework ideal for the designer of gamified communities, gamified smart homes, or even a gamified social product to implement decision systems that tailor interfaces. A significant advantage of this proposal is that it considers the consumer's characteristics to propose adaptive interfaces that promote achieving specific community goals. An example of this is promoting energy reduction based on the type of gamified player, energy end-user segment, and personality trait through challenges performed based on the level 1, 2 or 3.

This proposal is designed to be implemented in smart communities by considering all types of end-users (non-typical and typical users). However, validating this proposal in a real smart community requires the development of more surveys to confirm the relationship between personality traits and gameful experiences; the evaluation and improvement of these interfaces based on the external assessment of users by considering the usability heuristics evaluation and several smart communities scenarios; the evaluation of the six types of interaction within smart homes in several countries to extensively validate this framework (user-house, house-product, product-product, product-user, product-interface, and user-interface); and updating these HMIs as required.

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Availability of data and material

Authors can confirm that all relevant data are included in the article .

Code availability

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Figures

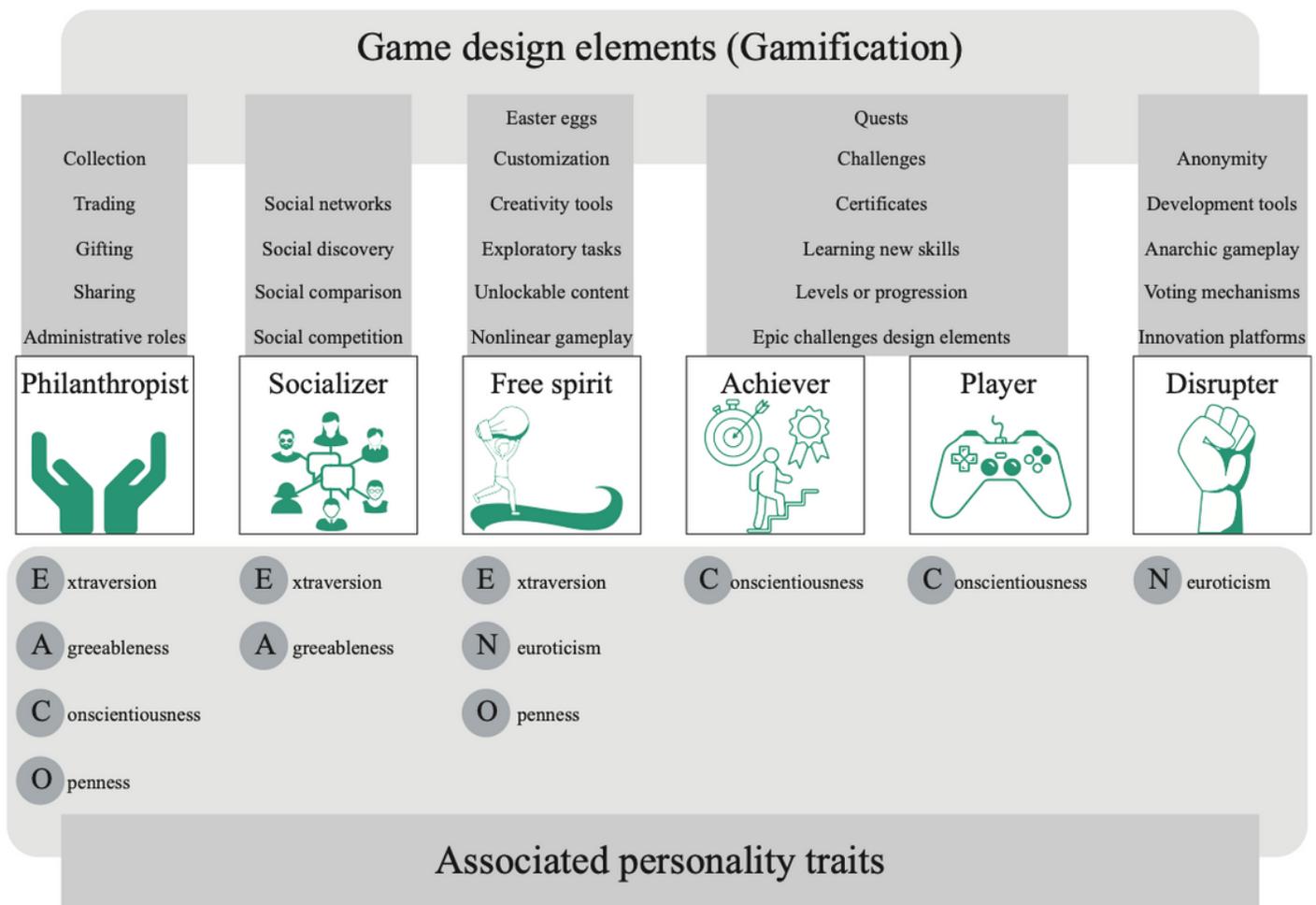


Figure 1

Six types of gamification players with their game design elements and their associated personality traits [63, 64].

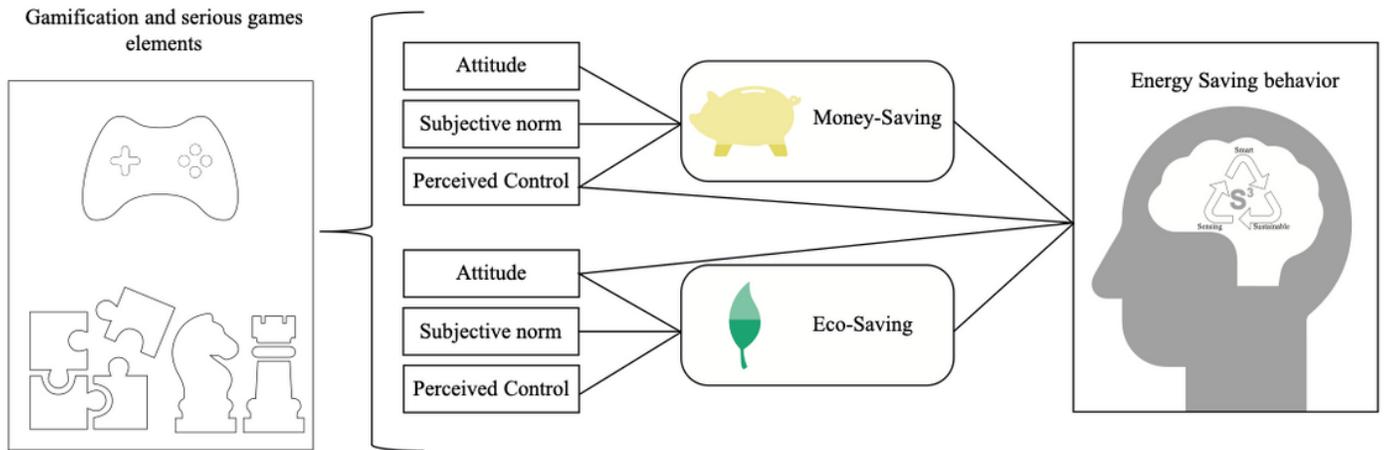


Figure 2

Proposed energy saving behavior model derived from TPB Model [66]

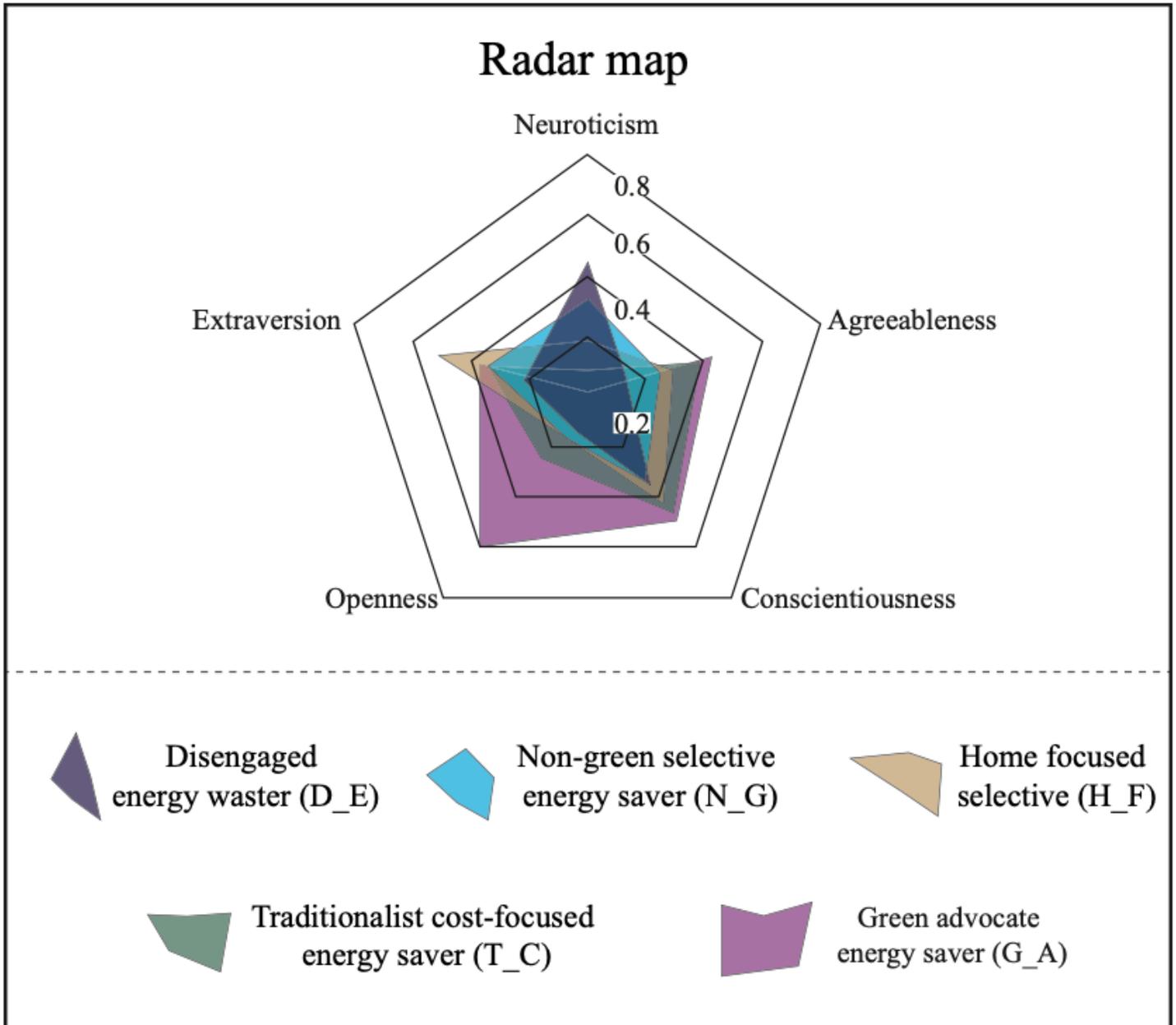
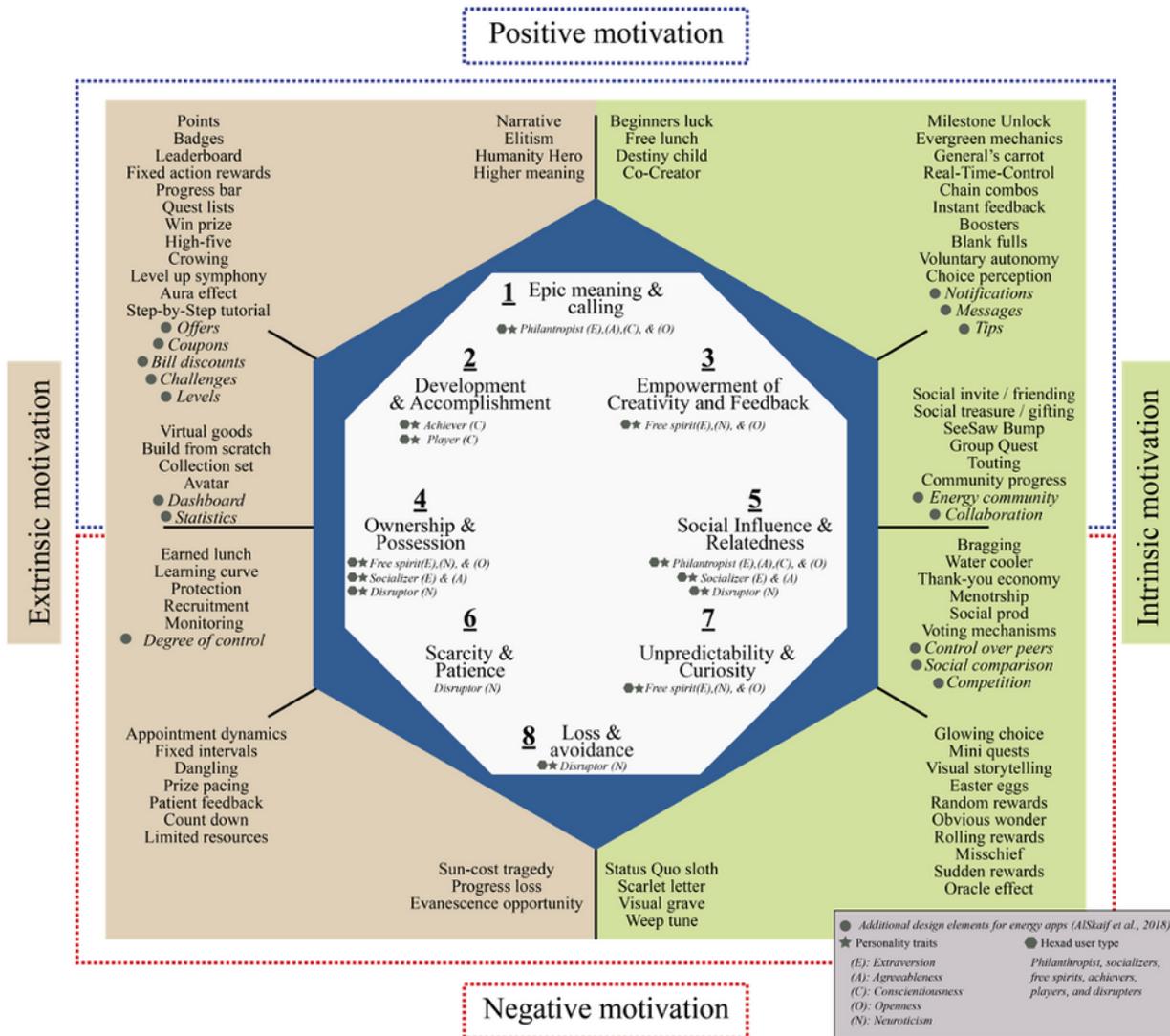


Figure 3

Radar map of personality correlation with the type of energy end-user segment presented in [35].



Octalysis core drive (Chou, 2015)	Motivation (Chou, 2015)	Hexad user type (Marczewski, 2015; Tondello et al., 2016)	Role player (Bartle, 1996)	Energy end user segment & target group (Ponce et al., 2017; Peham et al., 2014)
1. Epic meaning and calling	Extrinsic, intrinsic, positive	Philanthropist (E, A, C, & O)*	Socializer	Green advocate & energy-conscious Traditionalist cost-focused & cost-oriented Home focused & cost-oriented Non-green selective & early adopter Disengaged energy waster & early adopter
★ 2. Development and accomplishment	Extrinsic, positive	Achiever & Player (C)*	Achiever	
● 3. Empowerment of creativity and feedback	Intrinsic, positive	Free spirit (E, N, & O)*	Explorer	
▲ 4. Ownership and possession	Extrinsic, positive, negative	Socializer (E & A)* Free spirit (E, N, & O)*	Socializer & Explorer	
● 5. Social influence and relatedness	Intrinsic, positive, negative	Socializer (E & A)* Philanthropist (E, A, C, & O)*	Socializer	
■ 7. Unpredictability and curiosity	Intrinsic, negative	Free spirit (E, N, & O)*	Explorer	
4 6. Scarcity and impatience	Extrinsic, positive	Disruptor (N)*	Killer	
↓ 8. Loss and avoidance	Extrinsic, intrinsic, negative			

*Personality traits: (E): Extraversion; (A): Agreeableness; (C): Conscientiousness; (O): Openness; (N): Neuroticism

Figure 4

Updated Octalysis framework proposed in [22]. This framework considers the Hexad framework, role player, and energy end-user segment and target group proposed in [11, 61–64, 73].

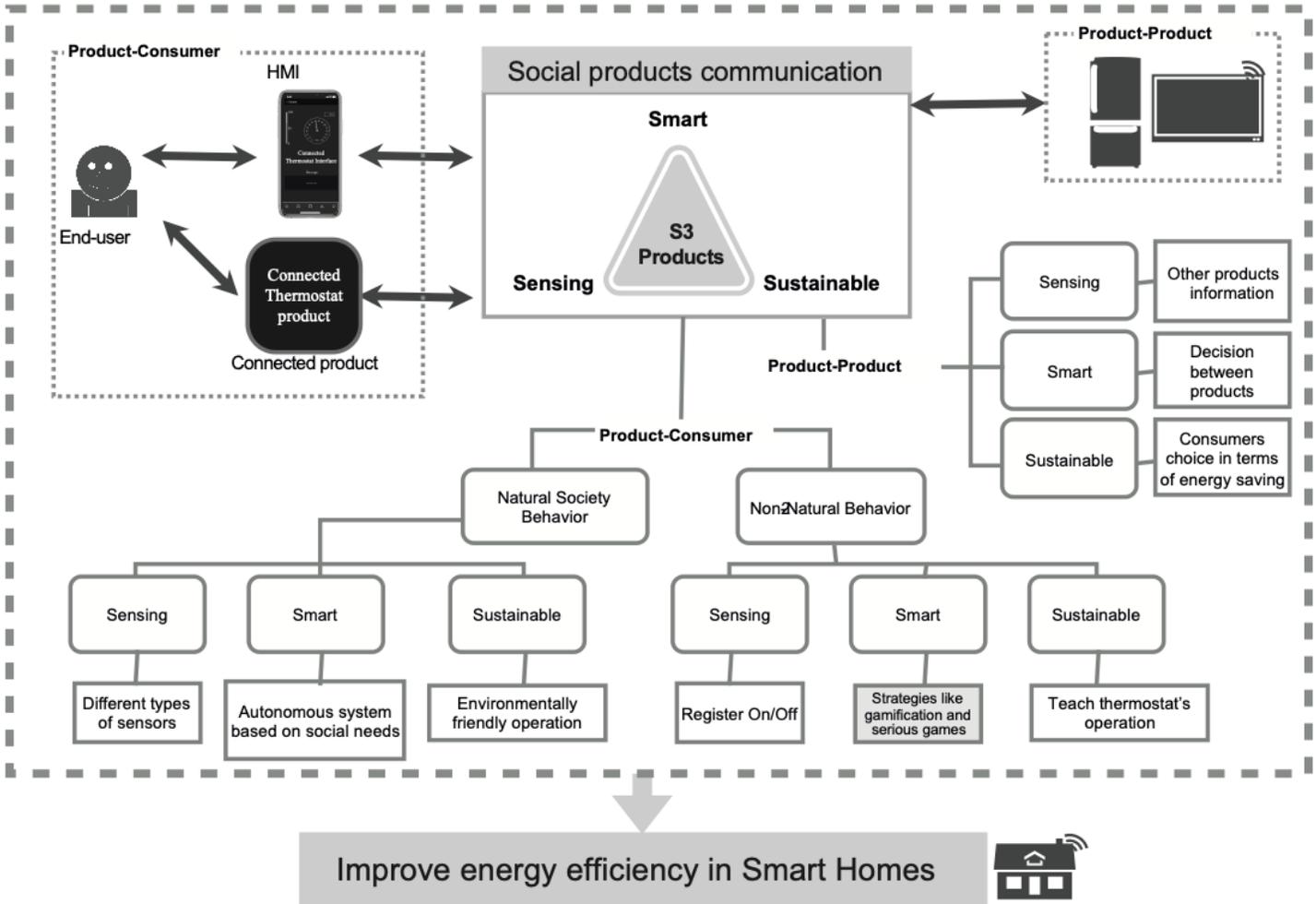
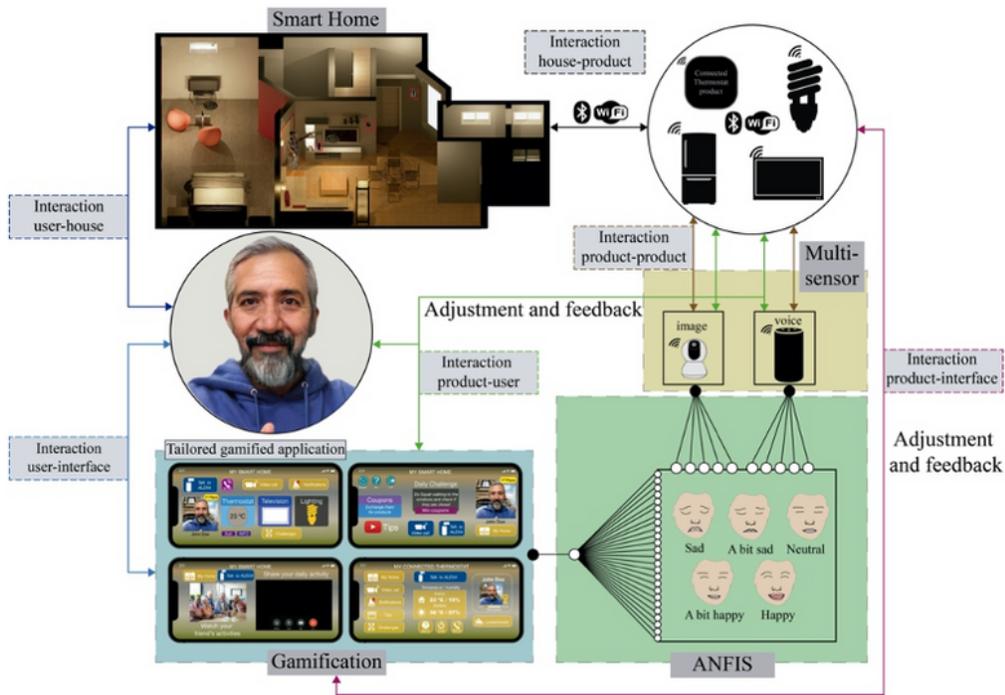
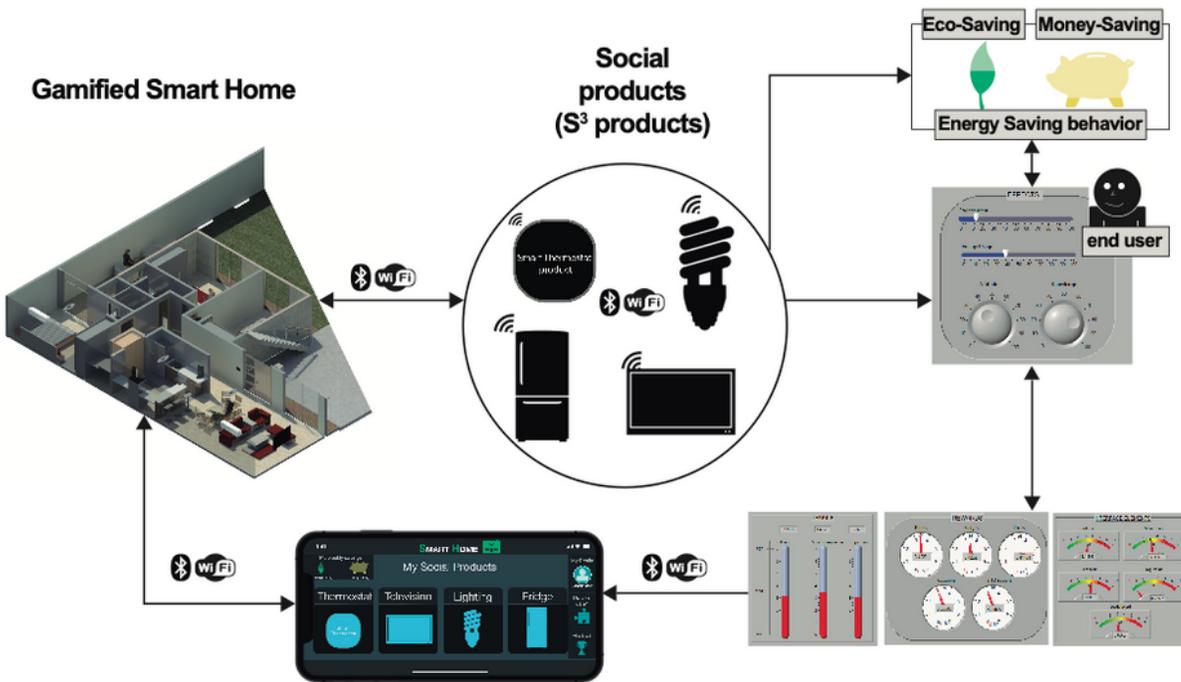


Figure 5

Social products communication



(a) Six types of interactions within the smart home proposed in [26]



(b) Gamified smart home structure by taking advantage of the social products [24].

Figure 6

Examples of gamified smart homes structures.

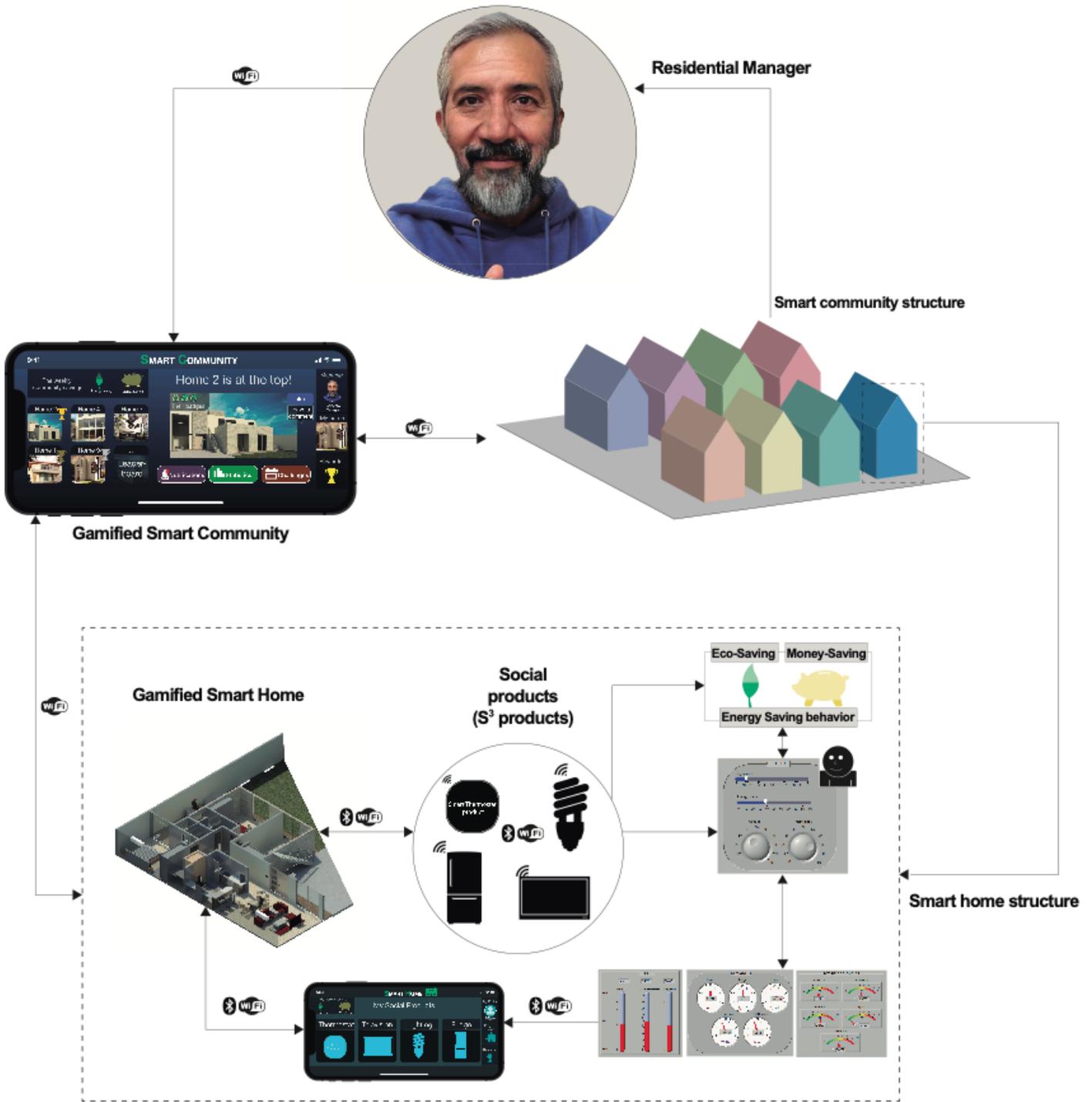


Figure 7

Gamified community structure.

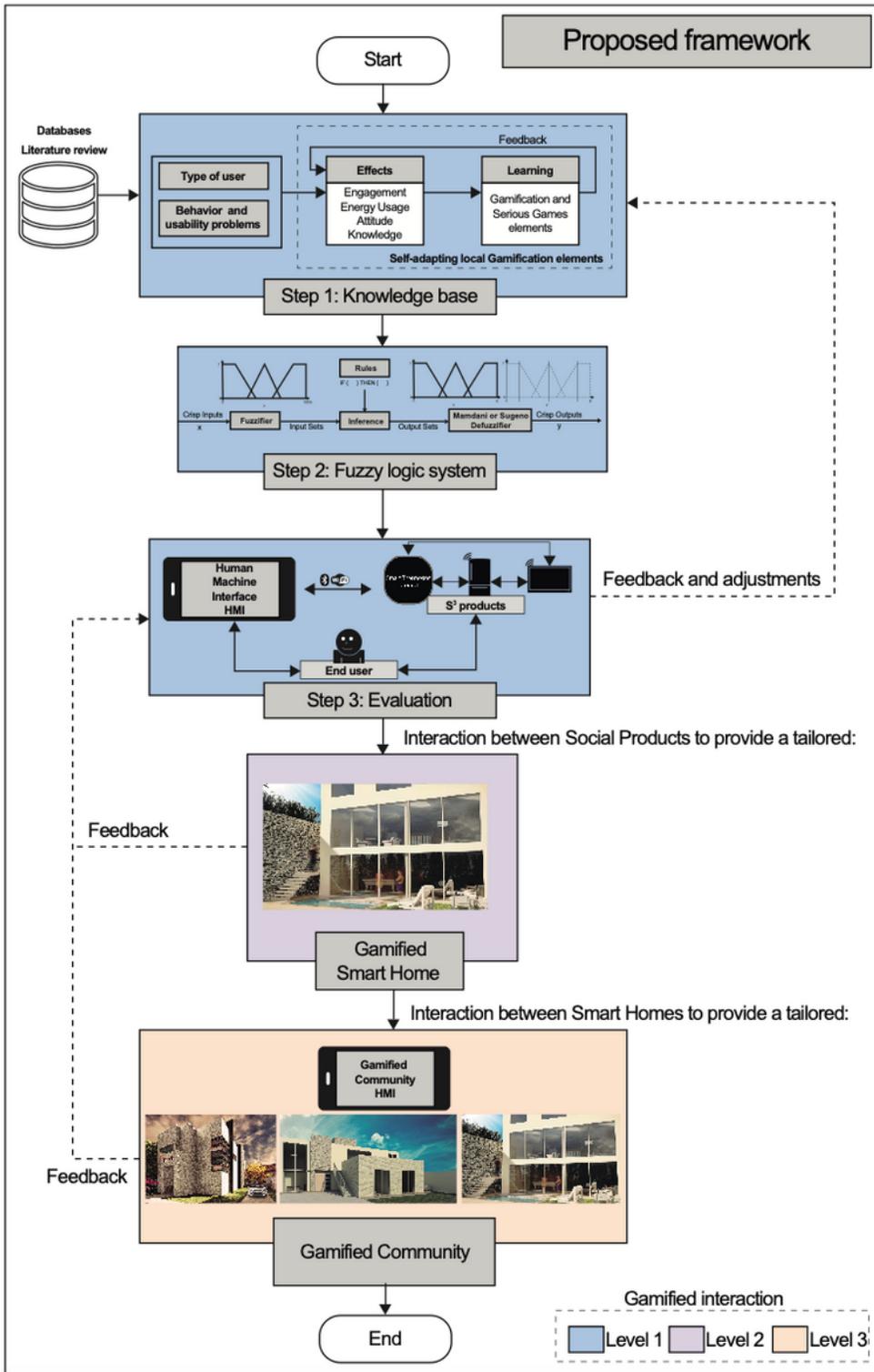


Figure 8

Proposed framework.

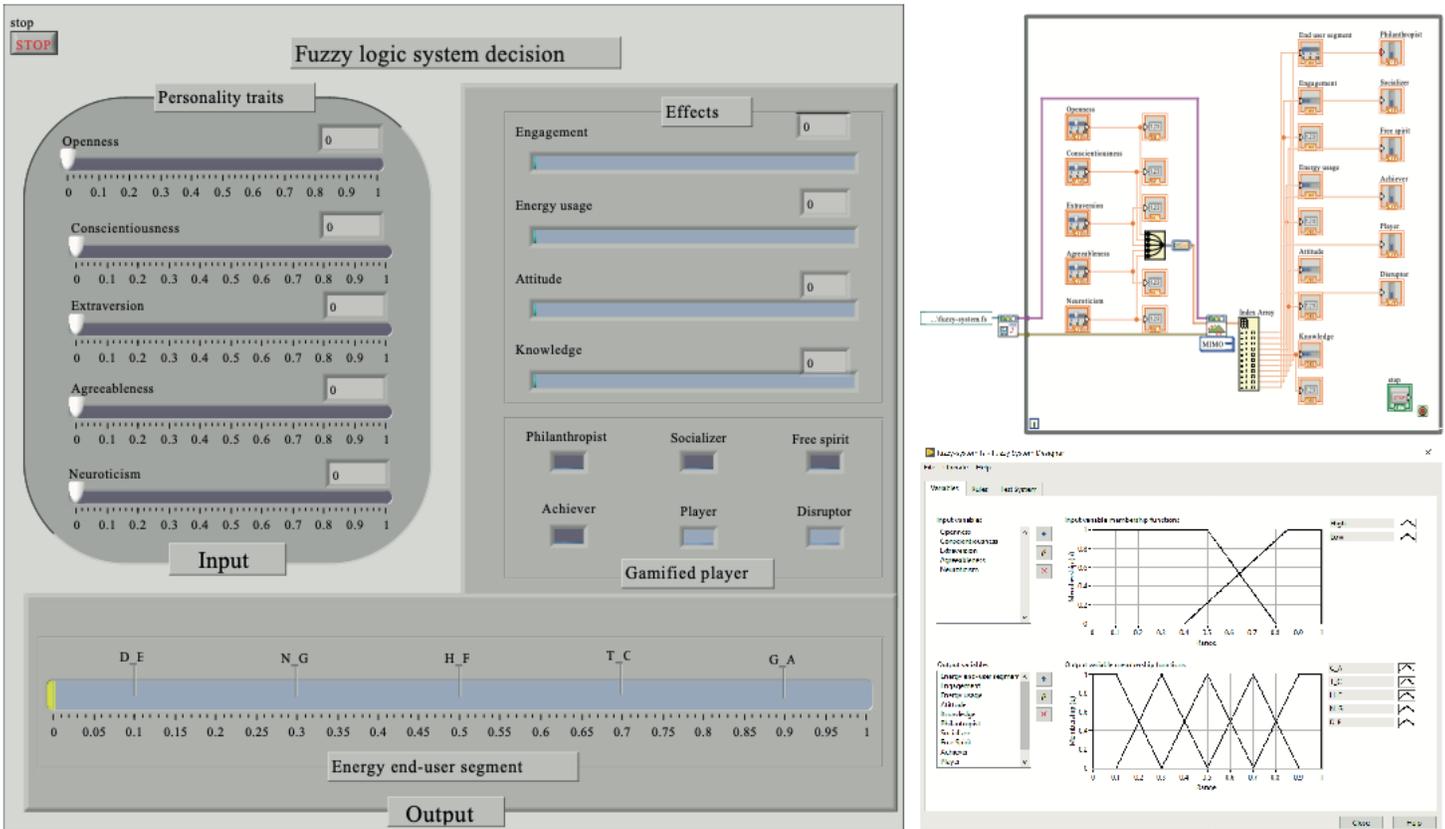


Figure 9

Proposed fuzzy system to test the first part of the fuzzy logic system.

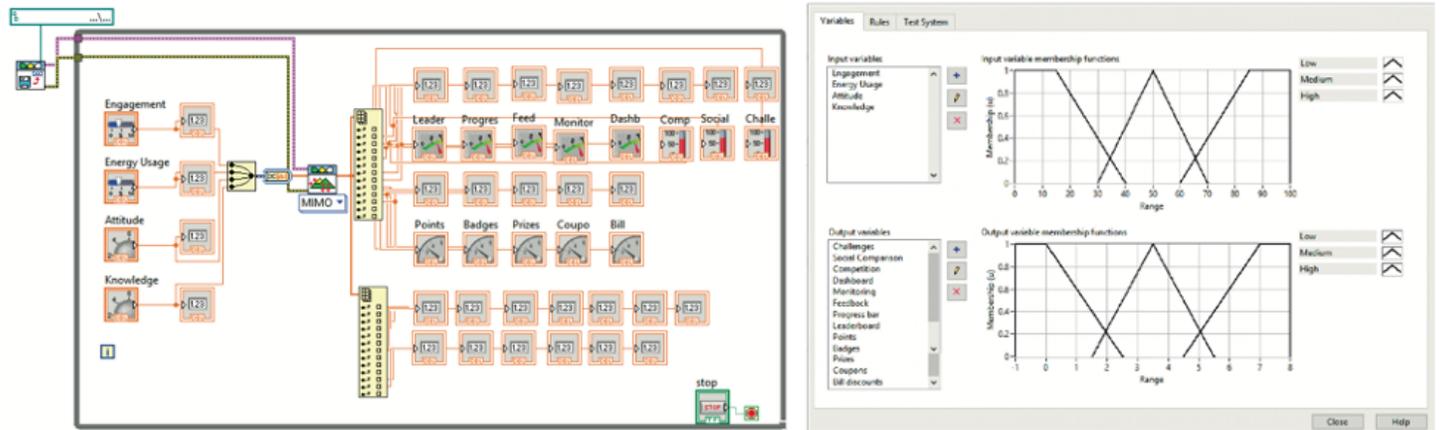
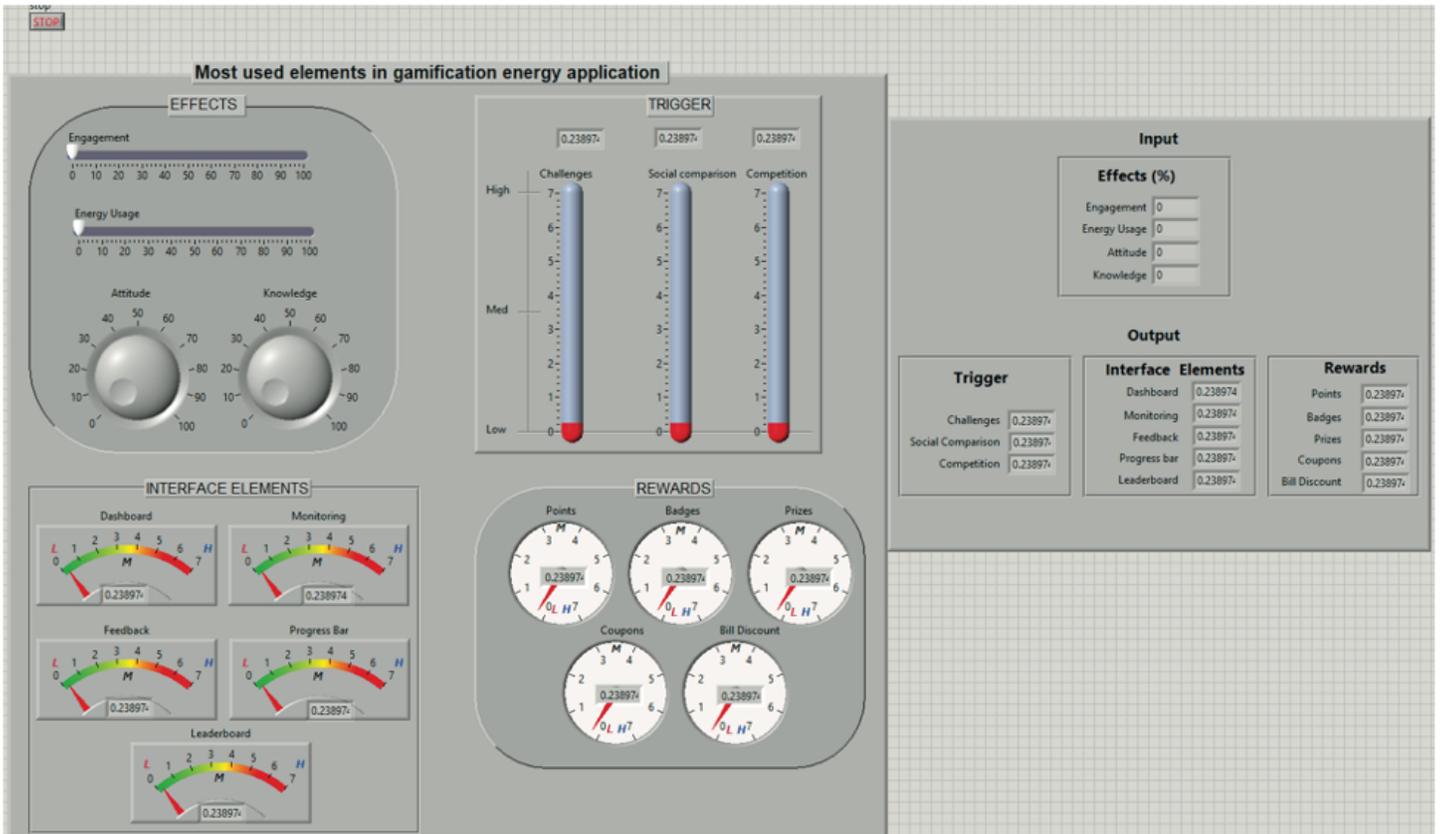


Figure 10

Proposed fuzzy system to test the second part of the fuzzy logic system.

Input/Output		Challenges	Soc. Comparison	Competition	Dashboard	Monitoring	Feedback	Progress bar	Leaderboard	Points	Badges	Prizes	Coupons	Bill discounts
Money-Saving 	Knowledge	●			●	●	●					●		
	Engagement	●		●				●	●	●	●	●		
Eco-Saving 	Attitude		●				●		●	●	●			
	Energy Usage	●		●	●	●							●	●

Figure 11

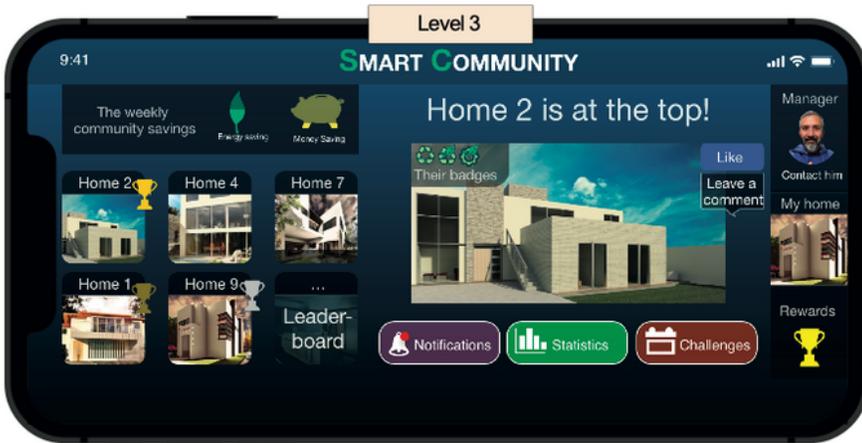
Relationship between input and output gamification elements.



(a) Level 1: Gamified connected thermostat HMI as a social product.



(b) Level 2: Gamified smart home formed by social products.



(c) Level 3: Gamified smart community interface.

Figure 12

Three-levels of the tailored gamified HMI.