A Gamified Approach on Inducing Energy Conservation Behavior

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Abstract. Motivating individuals to adopt energy-saving behaviors is critical for promoting environmental sustainability and addressing environmental issues. Gamification, which involves incorporating game features into non-game environments, has emerged as a potential strategy for promoting behavior change in various domains. This study aimed to examine the relationship between gamification elements, self-determination theory (SDT)-based motivational constructs, and motivation for energy-saving behaviors. Specifically, it investigated the impact of six game elements (personal profile, non-fixed structure, feedback, challenges, competition, and social network) on individuals' motivation towards energy-saving behaviors. An experiment with a simulated game and questionnaire was conducted at Tsinghua University with 40 participants. The measurement data were analyzed using factor analysis and multiple regression analysis. Using a novel combination of simulated games and questionnaires, the study assessed the impact of different game elements on energy consumption. The study revealed a substantial reduction of 49% in overall energy usage compared to the baseline, indicating the effectiveness of gamification in promoting energy-saving behaviors. Additionally, the findings also underscored the practical application of gamification elements for energy conservation, emphasizing the importance of incorporating challenges, feedback, and social network to satisfy psychological needs and enhance motivation in designing impactful interventions.

Keywords: Gamification · Self-Determination Theory (SDT) · Energy conservation · Game elements

1 Introduction

The use of game design and game components has a long history in human-computer interaction [1, 2]. Gamification is defined as the use of game design elements in non-game contexts [3]. An aspect of gamification is the use of motivating affordances to encourage specific behaviors [4]. Positive motivation is at the heart of gamification, with an emphasis on exploiting the game's inherent features to elicit an emotional reaction from the player. The success of applying gamification strategies has paved the way for empirical research into the effect of gamification on altering users' perceptions of gamified items and potential motivational elements for behavior changes in a variety of situations involving diverse applications and designs.

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Energy conservation is a major and urgent problem in today's society. In an age of unprecedented population increase and excessive consumption, the emission-intensive energy production that causes anthropogenic climate change is a serious global challenge [5]. Emerging countries' expanding energy-hungry middle classes and diminishing natural resources exacerbate the intensity of the dilemma. The increased cost of living is a direct result of scarcity and the pressing need to conserve and reduce energy use. Since 1990, both residential CO2 emissions and overall home energy use have been on the rise, making households a prime demographic to target [6]. Although human behavior and the factors that influence it have a significant impact on energy consumption, there has been mixed success in attempts to modify people's behaviors.

Motivating individuals to adopt energy-saving behaviors is a critical aspect of promoting sustainability and addressing environmental concerns [7]. Both intrinsic and extrinsic motivation variables might contribute to the lack of desire to participate in energy-saving actions [8]. While some individuals are intrinsically motivated by their values and beliefs, others may require external incentives, rewards, or social influences to stimulate their motivation. A combination of both intrinsic and extrinsic motivation strategies can be employed to effectively motivate individuals to adopt and sustain energy-saving behaviors.

The utilization of gamification presents a promising approach that harnesses the power of motivation and self-reflection [9]. This aligns with the principles of the Self-Determination Theory (SDT), a psychological framework that delves into human motivation and the factors that drive people to participate in specific actions. Incorporating the principles of Self-Determination Theory (SDT) in designing gamified interventions for energy conservation provides a strong rationale for enhancing motivation and promoting sustainable behavior change. This research has important theoretical implications as it provides empirical evidence for the application of Self-Determination Theory (SDT) in the domain of energy conservation behavior.

2 Literature Review

2.1 Gamification and Behavior Change

Gamification is a powerful approach that capitalizes on the principles of game design to enhance user engagement, motivation, and behavior change [3]. By incorporating game elements and mechanics into non-game contexts, it transforms mundane tasks into enjoyable experiences, driving individuals towards desired behaviors.

The appeal of gamification lies in its ability to leverage elements like challenges, rewards, competition, and storytelling, which are inherent to games and capture individuals' interest and attention. In the realm of behavior change interventions, gamification proves to be a valuable tool, utilizing game-like elements to influence and promote positive behaviors [10]. It draws upon psychological mechanisms such as positive reinforcement, goal-setting, feedback, and social influence to motivate individuals toward behavior change [11]. Through elements like points, badges, levels, leaderboards, and virtual rewards, gamification provides immediate feedback and tangible rewards, reinforcing desired behaviors and boosting individuals' motivation and engagement. The social aspect of gamification, which may involve collaborative gameplay or sharing achievements with others, taps into social influence and social norms, further amplifying the potential for behavior change [12].

2.2 Energy-Saving Behaviors and Motivation

Energy-saving behaviors refer to conscious actions taken by individuals to reduce their energy consumption and promote sustainable energy practices [13, 14]. These behaviors play a crucial role in addressing environmental challenges and achieving long-term sustainability. By conserving energy, individuals can contribute to the reduction of greenhouse gas emissions, mitigate climate change, and preserve valuable natural resources. Understanding the factors that motivate individuals to engage in energy-saving behaviors is therefore of paramount importance in promoting environmental sustainability.

Self-determination theory (SDT) is a psychological framework that emphasizes intrinsic motivation and the fulfillment of basic psychological needs as key drivers of behavior [15]. SDT posits that individuals are motivated when their three basic psychological needs are satisfied: autonomy (the desire for choice and control), competence (the need to feel capable and effective), and relatedness (the need for social connection and belongingness) [16]. In the context of energy-saving behaviors, SDT provides a valuable lens to understand the underlying motivations and psychological processes that influence individuals' engagement in sustainable energy practices. Several studies have examined the motivational aspects of energy-saving behaviors, with a particular focus on the three basic psychological needs outlined by SDT: autonomy, competence, and relatedness.

2.3 Gamification in the Domain of Energy

The conservation of energy is a critical global issue due to the continued reliance on fossil fuels and the resulting impact on climate change [17]. Households, as significant energy consumers, are a key target group for intervention [18]. While behavioral change is crucial for reducing energy usage, previous efforts have shown mixed results. Gamification has emerged as a promising tool to motivate and educate individuals about energy consumption and related concerns. Several studies have explored the application of gamification in the energy-saving domain, providing valuable insights into its effectiveness and potential. Geelen et al. [19] introduced a game-based intervention among student households, which featured direct feedback, an online platform, team rankings, and a game interface. The results showed significant enhancement in motivation to save energy, with average savings of 24%. Moreover, Orland et al. [20] conducted a study using a virtual pet game called "Energy Chickens" in a mid-size commercial office setting. The results showed a significant decrease in energy consumption, with an average reduction of 13%. Participants reported increased energy consciousness, highlighting the efficacy of gamified interventions for plug-load energy conservation in commercial offices.

Although the game-based intervention among student-households demonstrated increased awareness, positive attitudes, and motivation to save energy, it is essential to examine the long-term sustainability of behavior change and the extent to which these game behaviors translate into lasting habits. Additionally, while studies like Orland et al. [20] have shown significant reductions in energy consumption through gamified interventions, it is necessary to investigate the scalability and applicability of these findings across different settings and populations. Therefore, further research is needed to critically assess the effectiveness of specific game elements, scalability, and long-term impact of gamification in stimulating energy savings and fostering sustainable behavior change.

3 Research Framework and Hypotheses

3.1 Theoretical Framework

Aparicio et al. [21] presented a selection of game elements that match the objective and satisfy the needs of human motivation based on the SDT is an effective framework of gamification. In recent years Wee and Chong [22] adopted this framework and proposed a categorization of nine core game elements into the three categories of SDT to predict the usefulness of these elements in boosting the intrinsic motivation of users to engage in energy-saving behavior in an energy campaign. The chosen game design elements that enhance players' satisfaction with autonomy, competence, and relatedness needs were all validated by the study results. However, as of yet, this framework has not been tested for its relationship with decreasing users' energy consumption with measurements. To fill the gap, this research introduces a suitable framework that integrates established measurements and objective metrics in data collecting to increase the validity and dependability. The model for the proposed gamified energy system is depicted in Fig. 1.

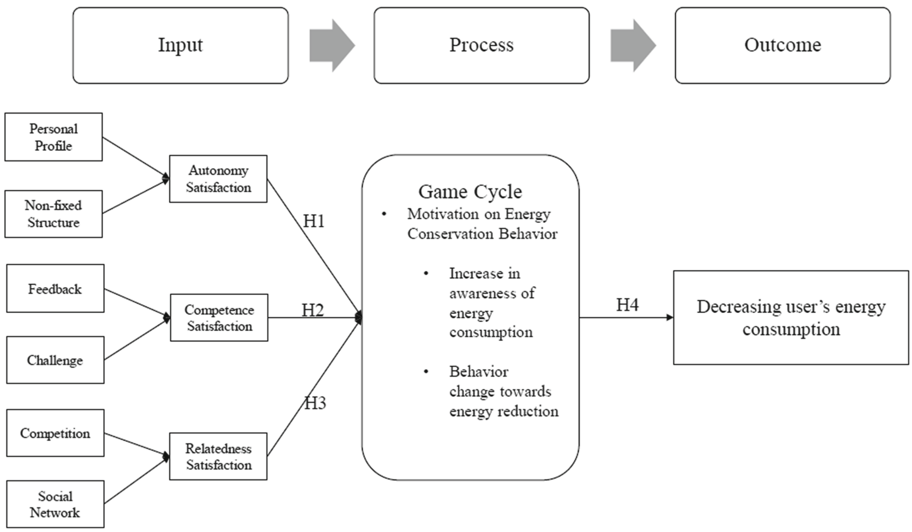

Fig. 1. Proposed model for gamified energy conserving system

The model is divided into three stages: input, process, and outcome. Personal profiles, non-fixed structures, feedback, challenges, competition, and social network, were selected to initiate a game cycle that includes judgments, knowledge of energy consumption, and actions toward energy reduction. Throughout the process, users are expected to be intrinsic and extrinsically motivated by the satisfaction of the three psychological needs, which leads them to translate motivation into energy-conserving actions. As a result, the consequence of using the system would encourage users to reduce their energy consumption.

This study's purpose is to evaluate the efficacy of gamification components in encouraging energy-saving behaviors in a simulated environment. The specific objective is to investigate the relationships between gamification elements based on self-determination theory (SDT) and users' motivation in energy-saving behaviors. The following research questions are presented to guide the study:

1. How can self-determination theory (SDT)-aligned gamification elements affect the motivation of individuals to engage in energy-saving behaviors?
2. What effect do gamification elements have on individuals' energy-saving behaviors and consumption?

3.2 Hypotheses

The following are proposed using SDT as the theoretical framework and taking into account the aforementioned literature:

- H1: Motivation for energy-saving activities is positively associated to satisfaction with autonomy needs.
- H2: Motivation for energy-saving activities is positively associated to satisfaction with competence needs.
- H3: Motivation for energy-saving activities is positively associated to satisfaction with relatedness needs.
- H4: The motivation on energy-reducing behaviors has a positive effect on decreasing energy consumption.

Motivation for energy conservation practices includes boosting energy consumption awareness and pushing behavior change toward energy reduction. Increasing environmental awareness entails several steps, including identifying specific energy-saving actions, acquiring knowledge, developing a deeper understanding of environmental and energy-related issues, learning about electrical appliances explicitly, and comprehending energy consumption patterns. Users may improve their energy awareness and knowledge by using a gamification-based energy conservation system. This may be accomplished by offering real-time insights into their energy use and allowing comparisons with typical energy demand for comparable equipment. Such interactive elements help users understand their energy consumption and promote a feeling of responsibility toward energy saving.

4 Methodology

4.1 Experiment Design

The Sims 4 was utilized as the experiment game, due to its inherent suitability for testing the desired game elements in this study. It is a well-known life simulation computer game that Maxis created and Electronic Arts distributed. Sims are virtual characters that may be created and controlled by users to be guided through many areas of their life, such as relationships, careers, and everyday activities. The Sims 4 offers a rich virtual environment that allows for the simulation of various aspects of daily life, including household management and resource consumption. By leveraging the existing features and mechanics of The Sims 4, the research objectives can still be effectively addressed. The game provides a platform that contains the six core game elements summarized in Table 1.

Table 1. Game Element details of The Sims 4

Game Element	Elaboration
Personal Profiles	Allow players to create and customize unique characters with distinct personalities, appearances, and aspirations
Non-fixed structure	Players are free to explore and shape their virtual home in the world according to their preferences
Challenge	Players have to manage their characters' needs, relationships, and aspirations etc
Feedback	Feedback mechanisms, such as meters and indicators, inform players about their characters' well-being, satisfaction, and progress
Social network	Interact and form relationships with other virtual characters in the game and engage in social interactions in a group chat for discussion with other players
Competition	Competition is introduced in the form of career progression, achieving goals, and building successful virtual lives. In addition, all participants are ranked by their energy usage for each round of the experiment for competition

The Sims 4 offers a utility bill for the controlled sim's household every game week. In The Sims 4, utility bills are simulated expenses that players' virtual households incur for the consumption of various resources, such as water, and electricity. These utility bills reflect the in-game usage of these resources by the Sims and their households.

Utility bills in The Sims 4 serve as a financial mechanism within the game, encouraging players to consider the resource consumption habits of their virtual households. This simulates the real-life costs associated with resource usage and provides a means for players to understand and manage their Sims' household expenses.

4.2 Experiment Tasks

The experiment design for this study involves two rounds of gameplay in The Sims 4, to examine the impact of energy-saving behaviors on utility bills in the game. The experiment is conducted with a group of participants who have signed a consent form and provided their personal information, including their name, and student ID.

In the first round, participants are introduced to the game and its basic controls. They are guided through the process of creating their Sims characters, with instructions to select young adults and personalize their characters based on their characteristics. Participants then enter the game and select a specific house to move in. During the first round of gameplay, participants are instructed to play for one game week, making decisions for their sims, taking care of their sims' needs, and managing their households. They are specifically asked to mirror their daily routine in real life and make every decision for their sim's actions. Participants' utility bills were recorded at the end of the first-round experiment as a baseline measurement of their energy consumption.

After the first round of the game, participants are put together into a group chat for further communication. The energy usage ranking from the first round is shared with the participants, and they are informed about the energy-saving goal for the next round of the experiment. Participants are then asked to share their thoughts on energy-saving strategies within the game in the group chat. Suggestions include turning off lights when not in use, removing non-essential appliances in build mode, or upgrading to higher-rated appliances.

For the second round of the experiment, participants resume the game from where they left off in the first round and continue playing for another game week. They are reminded of the energy-saving goal and provided instructions on how to check their energy usage throughout the week.

Before the end of the second round, the participants' utility bills were recorded once again. This enables a direct evaluation of any changes in energy usage induced during gameplay. The players are then requested to complete a post-experiment questionnaire.

4.3 Measurements

During each round of the experiment, the resulting utility bills of each player were recorded to measure the energy consumption of the simulated households. The utility bills served as an indicator of the energy usage within the game and provided valuable insights into the players' virtual energy consumption behavior. Changes in energy use were noted and the impact of energy-saving methods taken by the participants was determined by examining the utility bills throughout two rounds of the experiment. Since majority of the players were observed to perform energy-saving behavior, we denote positive changes as energy-saving. A higher value indicated greater amount of energy being conserved in the game.

The post-experiment questionnaire was divided into five sections. Section A consisted of demographic information and game experience. Section B measured satisfaction with autonomy (H1) included 3 items on personal profile and 4 items on non-fixed structure. Section C measured satisfaction with relatedness (H2) included 7 items on challenge and 3 items on feedback. Section D measured satisfaction on competence

(H3) included 5 items on competition and 3 items on social network. Section E consisted 7 items measuring motivation on energy saving behaviors. The assessment items used in this study were modified and adapted from a previous study by Wee & Choong [22].

5 Results

5.1 Participants' Profile

A total of 43 students from Tsinghua University were recruited to attend as the participants of the experiment. Recruitment was conducted through messages sent in WeChat groups consisting of Tsinghua University students. Of the 43 students recruited, 40 ultimately participated in both rounds of the experiment. The sample consisted of 22 male (55%) and 18 female (45%) participants. 52.5% were postgraduate students, while 47.5% were undergraduates. The sample was primarily composed of mostly local students (87.5%), with only 12.5% being foreign students. The mean age of the participants was 22.8 years, with a standard deviation of 3.006.

5.2 Model Evaluation

Confirmatory Factor Analysis. Since the questionnaire items were adopted from previous study, confirmatory factor analysis was performed to ensure that the items accurately reflected the measurements in this study. Based on the results, we deleted items with a factor loading of below 0.5, which included Ppro2, Ppro3, Ch2, Ch6, and Fb3. There were only three items in personal profile while two had to be deleted, we found it unfit to only use one item to measure this factor, therefore we decided to remove the entire factor, which left us with only non-fixed structure under the autonomy scale. It could be due to the irrelevance of personal profile in affecting energy conservation actions and the final utility bills.

Internal Consistency. After deleting the items, internal consistency was tested using the Cronbach's alpha coefficient. A value of above 0.7 showed good internal consistency for each factor and satisfaction scale. The reliability coefficients for all four sections of the questionnaire were found to be acceptable. Non-fixed structure ($\alpha = 0.805$), challenge ($\alpha = 0.840$), feedback ($\alpha = 0.817$), competition ($\alpha = 0.873$), and social network ($\alpha = 0.825$) were all well above 0.8. The coefficient for section B (Autonomy Satisfaction) was $\alpha = 0.805$, for section C (Competence Satisfaction) it was $\alpha = 0.845$, for section D (Relatedness Satisfaction) it was $\alpha = 0.882$, and for section E (Motivation) it was $\alpha = 0.896$.

Regression Model. The data passed the normality test ($p > 0.05$) and a multiple regression analysis was conducted on the five game elements and the motivation on energy conservation behaviors. The model is statistically significant ($F(5,34) = 7.717$, $p < 0.001$) with an adjusted R Square value of 0.463. Table 2 showed the detailed multiple regression analysis. Challenge ($t = 2.35$, $p = 0.025$), feedback ($t = 2.50$, $p = 0.017$), and social network ($t = 2.46$, $p = 0.019$) were all statistically significant, indicating a strong positive relationship between satisfaction of these three factors with motivation for energy conservation behaviors. This also indicated that competence needs have a strong positive relationship with motivation, as both challenge and feedback fall under this scale, supporting hypothesis 2. In contrast, non-fixed structure under autonomy satisfaction and competition under relatedness satisfaction, although not statistically significant, were found to be inversely related to motivation. As such, hypothesis 1 was not supported, while hypothesis 3 was partially supported

Table 2. Multiple regression analysis

Coefficients:	Beta	Std. Error	t	p
(Intercept)	0.983	0.569	1.73	0.093
Non-fixed structure	−0.205	0.140	−1.47	0.152
Challenge	0.421	0.180	2.35	**0.025***
Feedback	0.254	0.102	2.50	**0.017***
Competition	−0.162	0.127	−1.28	0.209
Social network	0.379	0.154	2.46	**0.019***

5.3 Energy-Reducing Behavioral Results

Hypothesis 4 examined the positive influence of motivation for energy-reducing behaviors on decreasing energy consumption in the game environment. Means and standard deviations of the utility bills before and after informing participants on the goal were recorded in Table 3. Utility bill before is indicative of the user's baseline energy consumption. Baseline data was found to be normal ($p > 0.05$) whereas utility bills after did not pass normality ($p < 0.05$), we assumed normality and used paired t test for comparing means between these two groups.

Table 3. Descriptive statistics of measured energy consumption

	Mean	SD
Utility bills before	148	35
Utility bills after	75	47

Based on the paired t test, the utility bills after significantly lowered ($t = 8.58$, $p < 0.001$) when participants were told to conserve energy. With the exception of three participants who had higher utility bills after, the remaining participants all demonstrated energy conservation behavior. On average, the amount saved is 73 with a standard deviation of 54. The findings revealed a significant reduction in overall energy consumption, with a 49% decrease from baseline, indicating the efficacy of the gamification intervention.

5.4 Correlation Test

Pearson's correlation test was conducted on the three psychological needs and motivation with actual behavioral changes observed in the game. From Table 4, autonomy ($t = 2.21$, $p = 0.03$, corr = 0.34) and competence ($t = 2.24$, $p = 0.03$, corr = 0.34) were shown to have a low positive correlation with the behavioral changes. As with regards to the self-reported motivation scale, competence ($t = 5.38$, $p < 0.001$, corr = 0.65) had a high positive correlation, while relatedness ($t = 2.37$, $p = 0.02$, corr = 0.36) had a low positive correlation.

Table 4. Pearson's correlation test

	t	p	Cor
Psychological needs with behavioral data			
Autonomy	2.21	**0.03***	0.34
Competence	2.24	**0.03***	0.34
Relatedness	0.52	0.60	0.08
Motivation	1.19	0.24	0.19
Psychological needs with motivation			
Autonomy	1.36	0.18	0.22
Competence	5.28	**< 0.001***	0.65
Relatedness	2.37	**0.02**	0.36

The difference in result of significant scales indicated that self-reported values may not be representative of how an individual would actually perform in real life. Non-fixed structure under autonomy gave players the freedom to navigate around in the game, which caused them to behave differently, although they may not feel that it is this flexibility that shaped their behavior. Competition and social network under relatedness were more actively experienced by the participants, which spurred their motivation to react differently in and out of the game.

6 Discussion and Conclusion

6.1 Discussion

The findings of this study are partially in line with the results of a previous study by Wee and Choong [22], which suggested that gamification is an effective way to increase university students' motivation for energy-saving behaviors. The results showed that satisfaction with competence needs had a significant positive effect on users' motivation for energy conservation behavior, which is consistent with this research. However, in contrast to previous studies, this study did not find a significant relationship between satisfaction with autonomy, and only partial relevance to relatedness needs, on users' motivation to conserve energy. While Wee and Choong [22] focused on the effect of game elements before implementing a gamified energy-saving campaign, this study contributes to the literature by incorporating a simulation game to measure the actual energy consumption of motivated users. These findings suggest that incorporating actual experiments to measure energy consumption data could result in different conclusions compared to relying solely on questionnaires.

A notable finding emerged regarding three participants who exhibited a significant decrease in utility during the second round of the experiment compared to the first round. Interestingly, these participants actively embraced energy-saving practices by opting for more energy-efficient appliances and implementing various conservation actions. Their conscientious efforts included actions such as consistently turning off lights, reducing cooking activities and minimizing computer usage. This substantial reduction in utility among these participants reflects the positive impact of their behavioral changes on energy consumption. Their proactive approach toward adopting energy-efficient appliances and engaging in energy-saving behaviors demonstrates a promising trend in achieving sustainable energy practices. Specifically, participants diligently replaced their outdated appliances with energy-efficient alternatives, contributing to a more environmentally conscious lifestyle. These findings provide valuable insights into the effectiveness of gamification strategies and the integration of Self-Determination Theory in motivating individuals to adopt energy-saving behaviors.

The theoretical implications of this research include providing empirical evidence for the application of Self-Determination Theory (SDT) in the context of energy conservation behavior. This highlights the relevance and utility of SDT in understanding the motivational factors that influence behavior in various domains. Additionally, this research presented a novel research design that combines a simulation game and questionnaire to measure the relationship between three psychological needs based on the SDT and energy conservation behavior. By incorporating actual consumption data this study avoided the desirability bias of using self-report data only.

The practical implications of this study are significant for researchers and developers in the field of energy conservation and sustainability. The findings suggest that when designing gamified energy saving systems, it is crucial to carefully consider design factors such as game elements, goals, and game mechanics to satisfy players' three basic needs based on the SDT. Implementing game design elements that promote users' sense of competence to motivate energy-saving behaviors could be effective in fostering energy conservation behavior among users. Therefore, greater emphasis of future developers should be placed on designing game elements specifically on challenge, feedback, and social network to push for greater motivation in energy conservation behaviors.

6.2 Limitations and Future Recommendations

Although the study showed promising results, there were limitations. The sample size of the experiment was small, with only 40 valid responses on the questionnaire and experimental measurements. The small sample size might have affected the experiment's statistical significance, which could explain why two of the hypotheses were not supported. In this study, only six game elements were selected based on the framework developed in Aparicio et al. [21] to meet the environment of the selected simulation game. Other game elements could potentially be a good fit for increasing the three psychological needs satisfaction. In the future, when designing an energy-conserving game system, it is recommended to explore the effect of more game elements on satisfying the three psychological needs. Another limitation was the experiment was conducted in the simulation game "The Sims 4", as a well-developed role-playing game, the game includes many other unnecessary features that could distract or affect the players. In the future, it is recommended to conduct actual measurements of users' energy consumption in real-life using a well-developed serious game and to observe the long-term effect of such a system on users' changes in lifestyle and habits.

6.3 Conclusion

Recognizing a gap in the existing research, this study adopted a unique research design that incorporated both a simulation game and a comprehensive questionnaire. By employing this innovative approach, this study examined the influence of six-game elements (personal profile, non-fixed structure, feedback, challenges, competition, and social network) in enhancing the motivation of individuals on energy-saving behaviors. Out of which, only five elements were used in the final data analysis, with challenge, feedback, and social network found to positively impact the fulfillment of the basic psychological needs specified by SDT. Additionally, the results demonstrated a substantial reduction of 49% in overall energy usage compared to the baseline, indicating the effectiveness of gamification in promoting energy-saving behaviors. This highlights the significance of addressing users' competence needs and an emphasis on social network when designing effective interventions to promote energy-saving behaviors. By understanding the effects of gamification elements on motivation, policymakers, designers, and researchers can develop effective interventions to promote sustainable energy consumption practices.

Disclosure of Interests. The authors do not have conflict of interest.

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