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Multiplayer game for decision-making in energy communities

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ABSTRACT

Energy communities are widely studied from various perspectives, especially in the context of geopolitical events of recent years, when humanity is faced with the need for urgent solutions to mitigate climate change and alleviate the crisis of energy resources. Although citizens' interest in the use of renewable resources has gradually grown, energy policy support measures for more active participation of society in the implementation of energy efficiency measures are still being implemented with variable success, especially through mutual agreement. Serious games are a rapidly growing tool for awareness and collaboration on a single platform for gamers seeking solutions to energy resource optimization issues. The main focus of the article is on the opportunities offered by a newly developed simulation tool for promoting the development of energy communities and the experience gained by its users. The tool's description and simulation results provide new information and knowledge for those working in the serious gaming field. The proposed solution promotes the development of new methods (tools) for decision-making processes based on serious games. This study uses a multi-player simulation tool to enable the modelling of scenarios for energy efficiency measures for apartment building block residents and energy community target goals for decision-making decisions. User experience and game mechanics were tested on a pre-selected group. The results indicate positive feedback, including a practical application for both energy community and professionals, and provide valuable recommendations for further research and improvement of the tool.

Keywords

Energy community;
Social dilemma;
Serious game;
Decision making.

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1 Introduction

Energy resource systems around the world are undergoing radical changes because of technological, institutional and political changes, the depletion of fossil fuel resources and climate change as well as because of global energy crises [1]. Increasing distributed energy resources at the local level requires the reorganization of centralized energy systems [2]. Due to the anticipated fundamental changes in energy supply technologies over the next few years, it's crucial to coordinate investments in energy conservation initiatives with investments in the supply side. This will help prevent excessive investment in supply systems and ultimately reduce the overall costs of transitioning to Smart Energy Systems [3]. In Europe, 70% of the population lives in urban areas and consumes about 75% of the primary energy supply. To reduce the impact of energy consumption, energy communities can help address urban sustainability and energy security issues through local energy production and self-consumption. Energy communities are associations voluntary established by citizens with a common interest in implementing energy efficiency measures and introducing renewable energy sources to reduce their consumption, and energy costs, and increase self-sufficiency [4] Solar, biomass, and wind are the main sources of renewable energy commonly used in cities. [5]. Further exploration from a single building to

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the community level allows for further improvements through sharing of energy technology and community management [6]. Therefore, a single building is considered part of a sustainable and renewable community system [7]. Buildings account for a large part of the world's energy consumption and associated CO_2 emissions. For example, the construction sector accounts for 40% of energy consumption and 36% of CO_2 emissions in Europe [8,9]

In recent years, high-performance active and passive technologies have been developed to improve the energy efficiency and sustainability of the built environment [10]. For example, recent advances in sensor and tracking technologies have created opportunities to develop behaviour change systems because of human-computer interaction [11]. Also, the recent rapid development of smart meter technology opened unprecedented perspectives in the monitoring of people's behaviour in residential buildings and has diverse applications, for example, for modelling user behaviour, specifying design values or predicting possible loads [12]. Due to the physical properties of thermal energy, information about the building's thermal energy demand and its spatial pattern is useful for the development of climate protection measures - this is evidenced by the fact that many cities in Germany prepare "heat demand cadastres" - thematic maps that depict the heat demand of buildings [13].

High energy efficiency can only be achieved if the impact of both technical strategies and household behaviour is considered [14]. People are a key component of a community's energy system and therefore need to be widely involved to encourage their participation in energy efficiency and sustainability initiatives [15]. Only a few publications have discussed how actions should be implemented at the consumer level to facilitate the transition of building mass populations to heat saving and energy efficient technologies in buildings [16].The "double invisibility" of energy consumption (the fact that it cannot be seen as well as it is related to daily activities) affects the effectiveness of feedback on energy consumption [17]. While energy literacy is often assumed to be a requirement for (effective) energy saving behaviour, there is little evidence in the literature on the impact of energy literacy on energy behaviour[18]. Another of the prerequisites for achieving good results has been widely studied: the promotion of informing households about environmental issues, as this is an essential element in reducing emissions [19], in the adoption of technologies promoting energy efficiency [20] and in the development of sustainable transport systems [21,22].

Research shows that energy literacy may be the most promising way to promote household energy saving behaviour [18]. From an energy efficiency promotion policy perspective, information programs can be useful in addressing behavioural gaps. Providing more reliable information can reduce uncertainty in the decision-making process, leading consumers to make better decisions [23]. Given the sociological nature of the energy community, it also faces the social dilemma of a conflict between selfish interest and the common good, since anyone who pursues the former ends up with lower results than when cooperating with the community. In strategic interactions with complex choices, the prisoner's dilemma emerges, where individual and community gains must be decided. Also, in the case of common interests, participants may face not only collective action, but also the instability of joint choice, which is affected by the heterogeneous profile of decision makers. Therefore, bargaining as an element of interaction is characteristic of conflicting parties, and one of the ways to promote resource management in the energy community is through collective awareness-building platforms, through which innovative ways of citizen participation can be offered, while identifying their interests and giving them the opportunity to contribute to the solution of such sustainability issues. where a social dilemma occurs in an environment of many decision makers [24–27].

In many cases in resource management, where several interacting parties are involved, they create conditions when each user with his decision changes the environment of other users and affects his own expected results. A classic example of such potentially negative interdependence is the "tragedy of the commons" [28]. In recent decades, the world has become increasingly interconnected between nature, society, and technology, and the disciplines that manage them are also developing [29].

Serious games are gaining increasing interest as a means of social learning that leverages the appeal of games and the value proposition of technology. Recent technological advances have led to the introduction of realistic digital environments in which players can feel the spirit of adventure while gaining new knowledge, developing skills, and applying new competencies to achieve their goals [30]. Therefore it is a relevant tool today to explore the knowledge, attitudes and behaviors of individuals that influence energy consumption levels worldwide [31].

However, the main challenge of serious games is the potential transformation of passion and involvement into the acquisition and application of applicable knowledge - decision-making. Serious games must demonstrate transfer of learning while maintaining an engaging and entertaining format. A balance between fun and practical measures should be implemented throughout the game development stage [32-33].

This study focuses on testing an intervention strategy in multifamily housing blocks using a serious gaming approach, complemented by immediate player feedback in a final survey. The idea of using real-time data visualization and expressing the results in absolute numbers is a common approach. However, the integration of the social dilemma principle opened a new way of evaluating consumer behaviour, seeking a balance between selfish and communal interests.

Research has so far identified 34 games, of which four had aspects related to demand response and only five had aspects related to energy communities or shared energy resources. None of the games had both aspects, yet they had connections to real-life events, such as making the player's home energy consumption affect the outcome of the game. This highlights the fact that the concepts are new and there is a demand for a serious game that covers it [34].

The research question of this study is whether the developed simulation tool - a multiplayer game based on a physical system and an integrated model of role-playing elements - provides its users with a gaming experience (convenience and transparency) and helps to identify and analyze players' efforts in achieving a common goal.

It is a new approach that offers a new perspective on knowledge dissemination to users, social learning, and new experience of participation in shared decision making, based on a serious game simulation model and tool.

Serious games are process simulations or simulations of real events designed to solve challenges and can be used to track and evaluate complex energy consumption behaviours of users [35]. Research results already demonstrate that gamification significantly improves users' knowledge, attitudes, behavioural intentions, and actual behaviour, as well as economic bill savings compared to control groups, while reward-based game design elements improve sustainable behavioural outcomes [36].

However, new ways to balance the methodological trade-off between simplicity and comprehensiveness are still being sought. A serious gaming approach can serve as an effective platform where, using interactive digital simulations, complex modelling results can be turned into information understandable to the everyday user, which stakeholders can share, discuss [28] and use as a basis for decision-making.

To live up to the expectations placed on serious games, it is crucial that they reflect practice-based situations and their specific contexts. Collaborative and participatory approaches are potentially useful for developing serious games that can help to express and translate existing contexts, social conflicts, and institutional responses into a game context [37]. Although the benefits are recognized in the literature, researchers emphasize that collaborative and participatory design approaches to serious game development have still attracted only limited academic attention [38–40]. The essence of this study is to bridge the gap between academic and real-world approaches by rethinking game construction and suitability to the requirements of energy communities.

Serious games are widely studied in the literature and the energy sector is one of the areas where various serious games are implemented. While aspects of a power distribution system may seem self-explanatory to engineers, the concepts and system architecture can be difficult for non-specialists to grasp. Therefore, many serious games focus on universal and simple concepts, such as energy conservation and optimal use of electricity in people's homes. Only a few games go far beyond entertainment-based approaches and focus on joint decisions, such as the use of a shared energy resource, so that the actions of each participant do not jeopardize the quality of life and the availability of resources. Another major drawback of the developed games is their public availability after the conclusion of the research project - studies have concluded that serious games are a viable solution to increase awareness of energy consumption habits, but the value of the tool decreases rapidly if it is available to a certain group of participants for a limited time [34].

Empirical results from research to date show that people exhibit loss aversion when making decisions under uncertainty, assigning much greater importance to the loss than to an equivalent uncertain gain. In the context of energy efficiency, loss aversion can partly explain why consumers do not make profitable investments, as they weigh fixed upfront costs (losses) much more strongly than uncertain future benefits, even if they are of equal value in principle [23].

Energy communities are mainly established with the goal of producing renewable energy resources - this does not directly save energy but decarbonizes the necessary energy. Residents can share an infrastructure that includes both solar panels and technologies for the production of thermal energy or hybrid systems [41,36]

Research demonstrates that social aspects integrated in system dynamic models considered include behaviour and lifestyle changes, social acceptance, willingness to participate in socio-economic measures [42]. The goal of the study is to develop a dynamic model to simulate energy efficiency measures and on-site renewable energy sources in an energy community located in multifamily buildings and develop a multi-player serious game prototype to serve as a basis for multiplayer game.

2. Methodology

Within the framework of the study, an experimental game was developed - a simulation tool based on a system dynamics model created in the Stella Architect program for playing the role of decision-makers involved in social dynamics [43]. It includes an internet-based interactive interface with the necessary functions, as well as functions for tracking and processing data. A system dynamics modelling approach is used to create a model structure of physical energy demand and supply systems that is individual to each energy community. The tool is developed based on the test results of a single-player simulation tool previously developed in this study, adding more output variables and input data needed to build an energy community.

The player must make decisions in three areas of energy efficiency measures: energy saving, energy production, and transport usage patterns.

Energy-saving measures include insulation the roof, walls, and basement of buildings (specifying the thickness of a predefined thermal insulation material), replacing existing electrical appliances with more energy-efficient ones, building a ventilation system, replacing windows, as well as installing smart devices. Users have the option to indicate that they are willing to change their behaviour by changing the room temperature as a minimum. Energy production measures include the installation of solar panels on building roofs, defining their proportion and intensity of deployment. Studies have found that the self-consumption ratio does not necessarily have to be close to 100% for the investment to remain economically viable [44], so the user has the option to change the area and proportion as he sees fit. As the final sector of decision making is the review and updating of transport usage habits, this level should also indicate the willingness to share your private vehicle with the community.

The primary goal of developing the tool is to bring together participants and experimental systems to test hypotheses and learn about subjects' mental (behavioural) models in decision-making tasks. The players must decide on measures from a list of proposed energy efficiency and renewable energy solutions based on their preferences. From the beginning, each player sees only the results of their choices. Later, he has the opportunity to see the other players' choices that affected the overall result. Thus, an understanding is formed that the selfish interests of each individual can either improve or (most likely) worsen the overall result.

The model integrated in the tool envisages a social dilemma – the balancing of selfish (economic) interests (e.g. savings, payback time, etc) with community interests (e.g. heat, electricity and transport emissions etc), influenced by heterogeneous consumer motivation, social interaction, and individual adoption decisions over time. Players must evaluate their decisions and their impact over several rounds and adjust until a decision satisfies the wishes of the entire community (players involved). The developed model provides tracking and reflection of user behaviour in real time.

As a potential tool, the target audience is residents of certain multi-apartment residential buildings who delegate house elders to represent their community within the game. When starting the game, the user creates his

Table 1: Energy efficiency measures

Energy efficiency	Energy production	Transportation
• Insulation of roof, walls, and basement • Window replacement • Ventilation replacement • Appliances replacement	Solar panels by indicating: • Roof area used for production • Proportion of solar panels from the area used for roof production	• Frequency of use • Travel distance • Vehicle sharing

Table 2: Decision making indicators, including both individual and community interests

Specific	Financial	Percentages	Absolute
Heat consumption,	Costs, EUR/ year	Change in heat consumption, %	Heat consumption, kWh
kWh/m2	Heat costs, EUR/ year	Change in electricity consumption, %	Transport energy consumption, kWh
Heating, kWh/m2	Transportation costs, EUR/ year	Change in electricity costs, %	Heat emissions, t
Electricity, kWh/m2	Transportation costs, EUR/ 100km	Self-sufficiency share, %	Electricity emissions, t
Energy, kWh/m2	Investment, EUR	Self-consumption share, %	Transport emissions, t
Investment, EUR/m2	Savings, EUR/ year	Change in car usage, %	Surplus heat produced, kWh
	Payback time, years		Surplus electricity produced, kWh

Figure 1: Registration of nickname and the session title

username and joins a group created by a single lead player who has no additional privileges other than creating a group and giving it a name.

Before starting the game, users are familiar with the game annotation, which says that in this simulation game, players can search for different solutions to build their own energy community. Each player can use different measures to reduce energy consumption, develop energy production, or switch from private to shared vehicles. The potential of energy communities increases in self-consumption of renewable energy, community sharing of private vehicles, and reduced investment

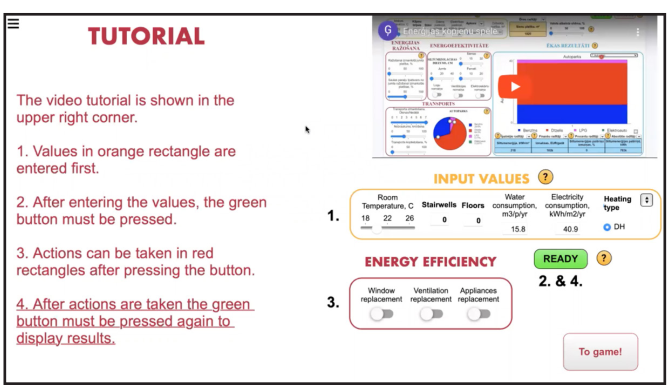

Figure 2: Tutorial of the game

payback time due to energy redistribution. The surplus energy produced is distributed among all the buildings in the community.

To improve traceability and reduce the possibility of interpretation as much as possible, a video instruction on the execution of the tool is placed in the tool. If necessary, the user can watch it again, because the video is in a publicly available format on the YouTube channel [45].

In the next step, the player enters data on the consumption of energy resources of his residential house - the existing room temperature (based on which the tool calculates the required amount of heat energy), as well as the annual consumption of electricity and hot water per 1 person. The user also specifies the type of existing heating and the number of floors and staircases of the building, so that the model calculates the number of inhabitants of the building and the related amount of electricity and hot water consumption for the house. These data are the basis for the calculation of the existing energy consumption and provide the user with the first immediate feedback on the energy demand of the building he represents. In addition, the user also indicates transport usage habits - the number of kilometres travelled per day and the frequency of car use per week.

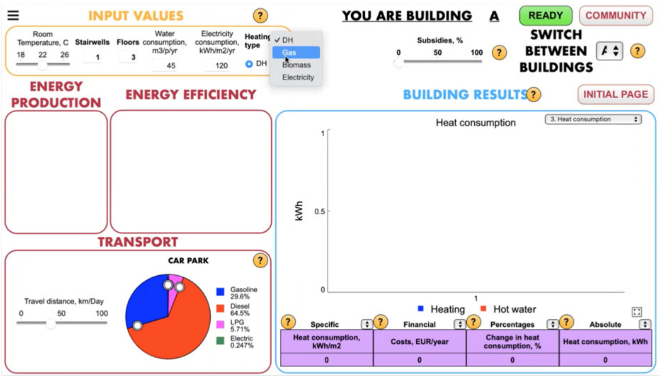

Figure 3: Input values section

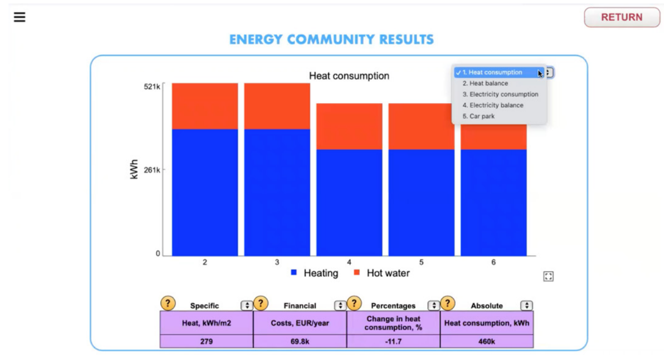

Figure 5: Summary of Community decisions

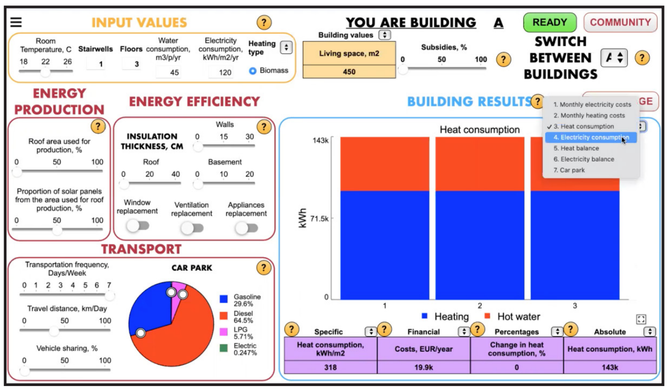

Figure 4: Full functionality of the game interface

After entering the initial data, by pressing the "READY" button, the user gets to the next level of the game, where he sees the first results about the energy efficiency of the building he represents, which is demonstrated by a series of calculated indicators - heat and electricity consumption and balance, the proportion of cars represented in the car park, the structure of expenses, investment, payback time, and volume of issues. The first and the last should be mostly attributed to the interests of the community, while the other indicators reflect more the selfish, economy-based interests of the players, which, according to previous studies, are superior to the common interests of the community. Under the data visualization window, various specific, financial, absolute and percentage indicators are visible, which the player can view and select the ones that are most relevant to him.

After familiarizing with the visualization of the results, the player must make choices in 3 areas of energy efficiency measures: energy saving, energy production and transport usage habits.

Once the above decisions are made, the player presses the "READY" button and thus, without changing the visual layout of the tool, sees updated data reflecting the results of his choices at the level of his building. The player can press the "COMMUNITY" button, where they can see the choices made by all housing representatives in the game and their impact on the common goals of the community towards the achievement of various economic and environmental indicators. The use of this visualization also allows us to contribute to research on how well people can extract information from a graphical representation, such as a line chart or a bar chart, as this has been little studied so far [46].

This makes this game different from a single-player game - the user sees not only his own, but also the decisions and consequences of other players and sees how it affects the overall scores. This forces him to evaluate his decisions and, knowing the goal, possibly sacrifice selfish interests. The structure of the tool allows you to track the participant's decisions in each of the sessions and observe which parameter changes make him give up his interests in the name of the community.

Within the framework of the game, the participants - delegated representatives of residents of various apartment buildings, using the possibilities offered by the tool (setting a common goal and a chat room as a real-time communication channel), cooperate by making choices about various energy efficiency practices. A communication panel can facilitate integrative decision-making, as this way players can not only easily communicate about common issues, but also share their ideas. This promotes player convergence and is a particularly appreciative format in real-world situations where physical contact is limited, such as during the COVID-19 pandemic [47] or people are physically far from each other.

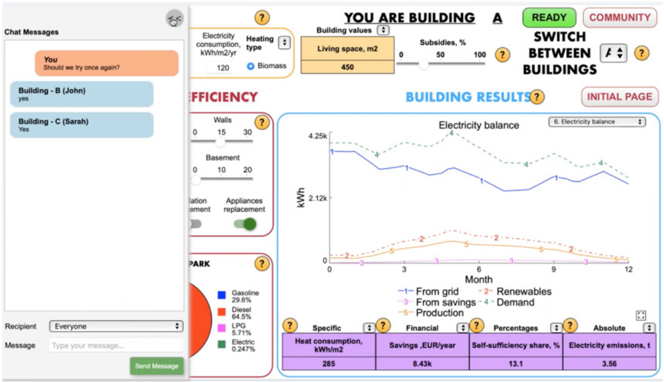

Figure 6: Chat window for communication among players

The game is divided into several rounds, which are separated from each other with the help of the “READY” function - after pressing it, the participants immediately see the results of their decisions and, using the “COMMUNITY” functional button, see the collective effect of the decisions made by all players on the achievement of the common goal. If this is not satisfactory, the players can agree to play another round with the help of the chat room. The number of rounds of the game is not limited - it can continue until everyone is satisfied with their and the collective choice. This approach is also based on research that cognitive information processing should be considered more in behavior change systems. Common sense is strongly influenced by preexisting knowledge structures (i.e., mental models and energy literacy) and depends on the analytical skills of users, which can vary greatly between individuals [48].

The system dynamics model integrated in the tool foresees a social dilemma – the balance of selfish (economic) interests with community interests, which is influenced by heterogeneous consumer motivation, social interaction, and individual acceptance decisions over time. Thus, a real-world scenario is included where, when one player makes selfish choices, the overall results move away from the goal set by the energy community. The goal of the players with their choices and communication is to achieve optimal decision-making based on the interests of the community.

3. Results

The results of the simulation show that the online tool prompts players to make decisions and encourages cooperation despite a complex set of parameters that require focus on the results of previous sessions. The tool allows players to experiment with their choices and see real-time results. The interactivity of the tool promotes social learning in an environment where players acquire new knowledge based on their actions.

Although the purpose of the study was to verify the functionality of the tool and within it representatives of the academic sector who are considered competent in the field of energy efficiency were selected as the testing group of the developed simulation tool, their feedback shows the potential of the tool’s application in real conditions. This can be explained by the fact that the selected target group identifies itself as apartment owners who must make decisions about the energy efficiency of their homes and the maintenance or increase of their value in the housing market. 29 participants took part in the testing, and at the end they also filled out evaluation forms, which allowed one to get players’ opinions about the functionality and usefulness of the tool.

3.1. Results of the test

The participants were divided into 6 teams of 4-5 players per team and joined the tool game by entering their (fictional, non-identifiable) username and their team name. The simulation took place after listening to the instruction, which explained the basic principles of the tool and the sequence of operations. 55% affirmed that the instruction is exhaustive for using the tool, 16% admitted that they were not familiar with the guidelines, while the rest indicated the need for several improvements, for example, it should be emphasized that the parts of the number are separated by a period instead of a comma, to give a separate mini-instruction at the beginning of each step (so that you don’t have to keep everything in mind) and the explanation should be given a little slower.

As part of the test, the teams played 4-9 sessions, the number of which depended on the team’s goal and internal agreement. Evaluating the obtained data, it can be concluded that, based on the initial setting, all teams aimed to reduce the CO_2 level, therefore it can be considered that the teams were able to cooperate with each other through the tool to achieve one of the goals of the energy community.

3.2. Tracking users’ decisions

The players agreed to reduce CO_2 emissions, which, by consistently making decisions, also succeeded - after the 4th session, a reduction of CO_2 emissions from an average of 618t to 331t was achieved. The largest decrease was by 80% (from 604t to 123t) in a total of 9 sessions,

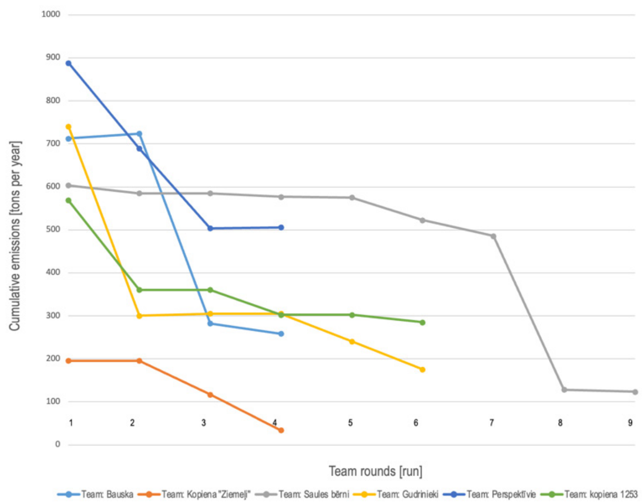

Figure 7: Cumulative emissions of CO^2 generated during the simulation

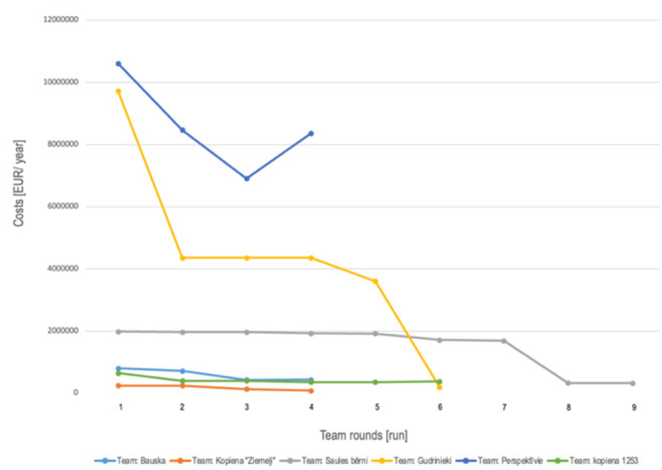

Figure 8: Dynamics of reduction of costs during the simulation

while the smallest was by 43% (from 889t to 506t) in a total of 4 sessions.

As another basic parameter, the players put forward cost reduction - it also decreased by 4 million after the fourth session. for 2.6 million EUR. The largest decrease was by 98% (from EUR 9.7 million to EUR 0.2 million) in a total of 6 sessions, while the smallest was by 41% (from EUR 0.65 million to EUR 0.38 million) in a total of 6 sessions. Data processing shows that both of the above indicators decreased with each session, except for one team, which saw an increase in pay-outs in the last session played.

On the other hand, the total amount of investments increased with each session, on average starting from

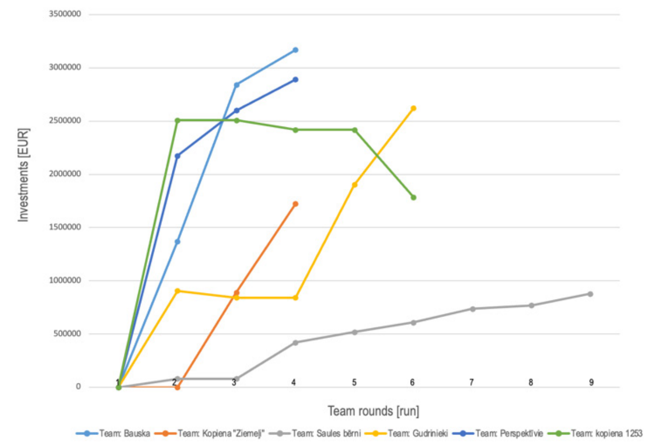

Figure 9: Investments to energy efficiency measures during the simulation

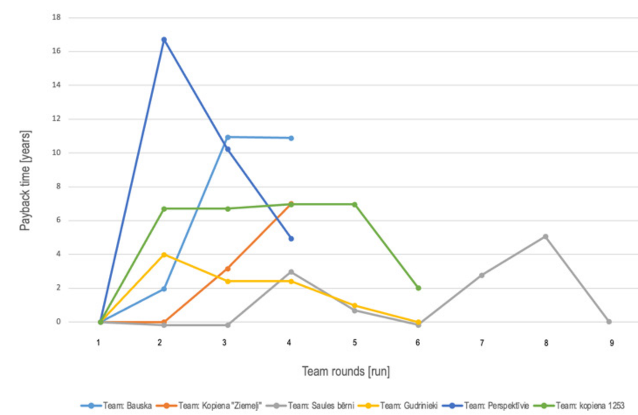

Figure 10: Payback time of investments during the simulation

1.2 million. in the 2nd session to 1.9 million in the 4th session. The largest increase was 91%, while the smallest was 25%. A team made choices that reduced the total amount of investment by 40% while still maintaining a positive trend in reducing CO_2 emissions and costs.

The average payback time was 5-6 years, where at the end of the game, the highest was 11 years and the lowest was 2 years. Three teams managed to finish the game with a payback period of 0 years, two in the ninth session, one in the sixth session.

The study observed that the number of opportunities included in the tool to change their habits, for example, to lower the room temperature, is relatively minimal. The specified room temperature varied between 18 and 24 degrees Celsius, indicating a low willingness of players to lower their daily comfort, instead choosing to take other measures to improve energy efficiency, while

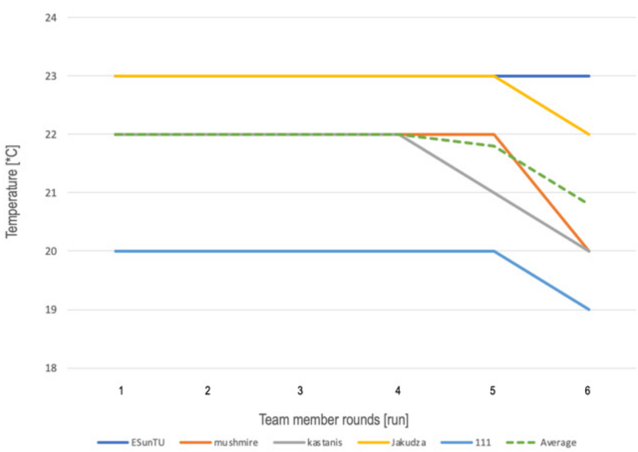

Figure 11: Case of the temperature decrease decision within a team

being aware that lowering the temperature can lead to a reduction in energy consumption.

One team agreed to reduce the temperature by 1-2 degrees in the last session. One participant did this in round 5, reducing by one degree, and in the final round, another 3 players did it, resulting in a decrease in average temperature compared to the initial choices. Players of all teams reduced the temperature by 27.5% with their choices.

The results of the simulation show that the players changed their decisions based on the agreement on the achievement of a common goal (for example, CO_2 reduction) and that in the following sessions they got confirmation that the players are ready to sacrifice their own interests.

3.3. Feedback of the online survey

In general, 81% positively evaluated the tool as a tool for obtaining information, while the rest of the respondents indicated that the positioned format (game, competition) did not allow it to be perceived as applicable in real conditions, and if they gave confidence about the reliability of the processed data, then it could be evaluated more positively.

In response to the question whether the displayed information was transparent, 70% answered in the affirmative, while the rest of the comments were basically related to the ease of use of the chat room and the desire to see several graphs at the same time.

When commenting on the comprehensibility of the calculations received, 48% answered in the affirmative, 18% in the negative, while some indicated that they had not delved into the explanation of the calculations. Similar answers were also given regarding the reliability of the calculations.

67% of participants assessed the information reflected in the tool as easy to understand, while 14% answered negatively, explaining it with the functionality of the chat room, not offering the opportunity to see the results of all community members at the same time, the need to visually see the common goal during the entire game, as well as the desire to see explanations of how individual parameters will change the community the results of decisions. As was additionally stated the desire to see current support mechanisms for energy communities to carry out joint activities.

In response to the question whether this tool would potentially allow the residents of residential buildings in the block to make an optimal decision, 41% answered in the affirmative, 19% rejected, and the rest of the considerations were related to the players' individual (selfish) interests (for example, the fiscal impact on the household budget) and the need to provide traceable data (results of the decisions made) during the entire play.

When evaluating their main motives for engaging in the game, respondents mentioned the desire to reduce consumption, take actions to live in environmentally friendly conditions, create a dialogue with the community, achieve joint action and transform cooperation into real results that affect the quality of life. Also, the spirit of competition could be observed in the answers, for example, by experimenting to conclude, how good results can be achieved or try as many different combinations as possible.

At the end of the survey, respondents indicated that the developed tool is suitable for players with prior knowledge of energy efficiency issues who are motivated to take action to improve the situation, but after the first play (decisions made), the community should initiate a discussion about the results and how to improve them together. Commenting on the impact of the tool on building an energy community, the respondents indicated that the tool helps to better understand the choices made and their impact on energy efficiency indicators, the diversity of player motivation and behaviour within the same community on the way to achieving a common goal, modelling different scenarios and seeing the overall results in real time, as well as enables communities to plan activities that improve the overall situation and promote energy independence. As an additional value, the respondents pointed out the reflection of the real situation - how the failure of one house can affect the community. Certain players indicated that they were motivated to act by seeing themselves as one of the biggest consumers of energy.

4. Discussion

The developed model allows players to engage in a real decision-making process on various energy efficiency practices and try different options to achieve a common goal. Compared to the first single-player game, which used fixed input data for a specific block in the historic centre of the city, the multi-player tool allowed for manual input of variable data, allowing the results to be closer to real conditions. However, several limitations arise during this study.

4.1. Suitability of the model for a specific block of apartment buildings

The findings of this study show that the "Energy Community Game" is applicable for building energy communities, but the involvement of stakeholders in the system dynamics model in decision-making requires adjusting the calculations to the appropriate type of houses, climate conditions, the climate policy of the specific country, energy costs, as well as the mentality and level of awareness of the players, to result in progress towards jointly defined goals. This question will be addressed in the next development phase, but other serious game developers should also pay attention to the fact that more universal data needs to be separated from specific data, thereby improving the accuracy of the simulation tool's performance.

4.2. Suitability of the model to a specific profile of the target audience

Another limitation is users' basic knowledge of energy efficiency and renewable energy technologies. On the other hand, the results of the simulation of the same tool among the population may differ due to the knowledge and mental behaviour model, because the daily priorities are not concerned with property value and making investments as efficiently as possible, even though because of the energy crisis, people's interest in energy production and saving measures has increased significantly. The developers of the tool suggest involving apartment owners (not tenants) in energy community related simulation games - the ones act as responsible and careful managers in their daily lives and take into account medium and long-term perspectives when making decisions.

4.3. Preparation of basic information before simulation game

The study shows that before participating in a tool with many players, it is recommended for homeowners to play a simplified, single-player game to understand the basic principles of the tool's construction, improve knowledge about various energy efficiency practices, which they will also encounter in the game with many players.

It is necessary that, at the time when the delegated representatives of the residents of multi-apartment residential buildings will participate in the simulation of the energy community tool, they will have gained the necessary understanding of energy efficiency measures, if necessary, they will have agreed with their community on the desired energy efficiency measures, as well as determine the possible limits in decision-making - thus, he would be able to fully participate in a collective game with representatives of other residential buildings in his block.

4.4. Factors influencing player behaviour

Within the framework of the research, one of the central issues of the discussion is the change of the players' behaviour pattern based on the information they get during the game, for example, information about the choices of other players or the data obtained because of the player's own choices. Also the test of this particular simulation game proves that the player's behaviour changes, depending on the information he gets during the game, because the principle of social dilemma works - a conflict between selfish (economic) and community interests. The results shows that the players would have a different behaviour pattern if they did not obtain information about the choices of other players and their impact on the achievement of the common goal after each of the sessions.

4.5. Aspects of socio-economic conditions

During the testing of the tool, there was an in-depth interest in various parameters and their impact on such indicators integrated in the tool as the total energy consumption, the amount of energy produced, energy independence, the number of necessary investments and the payback period. It is assumed that the readiness of the players to go deeper and play the game as close to reality as possible can be explained by the context of the specific circumstances - the crisis of energy resources and the rapid rise in prices related to it. When summarizing the results of serious games, context analysis must be performed as it explains the players' motivation and level of engagement, and therefore the achievable results.

5. Conclusions and perspectives

The research question was focused on analyzing the user experience of the developed simulation tool - how easy and transparent it was for users to use the tool and how successful serious game developers were in understanding player efforts to achieve common goals, as well as analyzing the data obtained.

The obtained results can be evaluated as practical and useful for the further improvement of the simulation tool, so that it can be passed on to a wider range of users who were interested in or familiar with energy efficiency issues daily. The insights gained within the scope of the study are a valuable source of information for serious game developers in the context of energy community development, as they provide insights into user experience and issues related to data acquisition, analysis, and further utilization. The tool developed as part of the research is useful for the residents of the block of apartment buildings to model their energy efficiency options, while for the administrators of the tool, to predict consumer behaviour patterns in making different decisions at different values of design parameters. The "black box" tool allows you to analyse useful information about the decision-making factors of each player.

Secondarily, the tool can be considered as a tool for promoting social learning, because during the game players review their decisions and improve them based on acquired knowledge and experience. In perspective, the tool can be positioned as an online platform for discussion and joint decision-making in situations faced by energy communities. This tool is being developed as a support tool for policymakers to make decisions about the diversity of business models in the context of energy community development, as it has the potential to test the socio-technical performance of systems over time, where system behaviour is subject to complex and dynamic individual human behaviour and social interactions.

Considering the further possible application in other disciplines, the potential of the tool is to use it for decision-making on wider areas, for example, solving social issues in the community, sustainable development of territories, balancing economic interests in local economies, where the interests of the community are regularly opposed to the interests of entrepreneurs (for example, active and leisure tourism development along with the quality of life of residents in their homes).

The results obtained can potentially contribute to the development of effective energy policies and business models, which are useful for decision makers and policy makers, laying the foundation for radical technological changes and faster development of energy communities.

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