Simulation and Gaming for Social and Environmental Transitions.

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Proceedings of the 54th Conference of the International Simulation and Gaming Association

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Modeling social parameters in renewable energy sharing: activity analysis in simulation game

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Abstract. The European energy landscape is currently undergoing a technological and societal transition that is questioning the energy market with Renewable Energy Communities (RECs). With the democratization of photovoltaic panels, the redistribution of roles between energy production and consumption is redefining the consumption model. This model must now achieve the goal of self-consumption, i.e. either consume the energy when it is captured or propose it, according to rules to be established, on the very local market of an energy community.

What behaviors will future consumers/producers adopt within these energy communities? How will the rules of remuneration between these actors influence the governance of these communities? To provide elements of answers to these questions, this article first presents the methodology used to build a board game simulating the management of a REC and write the game rules to synthesize real complexity. Using a platform for analyzing human activities, it then qualitatively analyzes a game and discusses quantitatively many key points identified among observed human behaviors. Finally, it proposes several perspectives useful for simulating environmental and social transitions.

Keywords: Gaming for policy making, Shared renewable energy, Social factors of transformative changes, Behavior modeling, Activity analysis

1 Context and problem statement

1.1 The Energy Transition

The Green Deal for Europe, presented in December 2019, calls for a reduction in our carbon footprint and aims for climate neutrality through the implementation of a circular energy economy [European Commission, 2019]. In this context, the European energy landscape is undergoing a technological and societal transition that challenges the energy market by diversifying its offerings : equipped with photovoltaic panels, millions of consumers are becoming micro-producers alongside traditional electricity suppliers, who are losing their exclusivity. The question now arises : how can we transition from a centralized and constant electricity production-distribution system to a distributed and intermittent energy production system ?

This energy transition is currently generating two emerging movements :

1. a digital transformation of interactions : data sharing, artificial intelligence, IoT and blockchain are tools that support the thinking and are seen as the keys to mastering the complexity of the new energy landscape ;
2. the emergence of Renewable Energy Communities (REC) as a new "consumer-producer" actor, bringing together a group of geographically close stakeholders with diverse needs and means (including households, communities, businesses, industries, and administrations).

The integration of RECs into the distributive energy equation is currently underway, but in a very techno-centric way, based on mainly economic strategies, where mechanisms of fairness and acceptability need to be specified at both individual and collective levels.

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1.2 The SERENITY Project (uSER ENergy communITY)

To promote this socio-technical transition of redistributing roles of production/consumption in the dynamics of energy "Uberization", our research project uSER ENergy communITY, for SERENITY, aims to address the following questions :

- what consumption models are emerging to achieve the goal of self-consumption among these emerging distributed production actors ? In other words, what behaviors will future consumer/producers adopt within these energy communities ?
- how will the rules of compensation between these actors influence the governance of these communities ?

Breaking away from current predictive approaches based on historical consumption profiles, the SERENITY project aims to identify the human parameters of this complex issue and to understand the mechanisms of self-consumption of electricity.

The governance of a Renewable Energy Community requires mastery of numerous multidisciplinary variables. We classify them into three categories : (1) technical concepts, related to the energy needs of buildings and their electrical equipment, (2) legislative and economic concepts, related to the frameworks and resources of actors to ensure their consumption, and (3) social criteria, related to human behavior during community negotiations and decision-making. These observable variables are themselves conditioned by uncontrollable variables, such as weather conditions, changes in the energy market, or the occurrence of impactful events (heat waves or international politics, etc.).

One of the peculiarities of our project lies in its bottom-up approach : the process is driven by the needs of end-users, members of a REC. Therefore, an ascendant approach is taken to conduct this research. In addition to traditional focus groups, which collect discourse (which may be biased to remain socially acceptable), the serious game approach allows actors to be placed in a situation and better identify spontaneous behaviors, reflecting their level of acceptability and engagement in the collective dynamic.

2 Research objective

To capture and articulate the interaction of these variables, we have developed a serious game that we have implemented as a tool for understanding and raising awareness of the shared energy issue.

Based on a brief preliminary literature review (section 3), this article first presents the methodology used to construct and analyze this board game, then synthesizes the real complexity (section 4). Using an activity analysis platform, it then studies a game session (section 5) and discusses several key points identified among the observed human behaviors (section 6), validates the approach and contributions, and finally proposes a perspective useful for simulating environmental and social transitions (section 7).

3 Literature review

Our literature review on serious games is based on the two fundamental concepts of the object of our research, which are energy transition and complex systems. We explored different categories of games to select the one that seems best suited to our research objective and carried out a review of serious game design methods to implement the construction of our game.

Serious games are already used in the field of energy transition to educate actors on the different issues and mechanisms of transition to more sustainable and renewable energies [Abdusselam, 2020 ; Ouariachi, 2020]. The historical energy supply system, managed so far by negotiated political arrangements, is now moving towards an "uberization", involving numerous new actors, making it more complex [Müller et al., 2017].

Serious games prove to be an effective tool for better understanding and modeling this socio-technical system [Bekebrede, 2010 ; Sajjadi, 2022 ; Varma & Liu, 2022]. Different types of serious games can be used in scientific research contexts to study their effectiveness and effects on users, whether in terms of learning, skills development, behavior change, or improvement of user well-being [Djaouti et al., 2011 ; Hammady & Arnab, 2022]. Simulation-type games [Mayor et al., 2014 ; Lanezki, 2020] provide participants with a simplified representation of complex reality and the opportunity to freely experiment with their strategies and experiences and question the consequences of their actions [Lukosch et al., 2018]. According to [Cohard, 2019], learners can observe the simulated impact of their own decisions, reflect on the concordance (or not) between anticipation and actual outcome. Here, serious game actors give us access to the complexity of the energy system [Müller et al., 2017] as they allow us to study their behaviors such as decision-making, social interactions, and problem-solving in situations that are difficult to observe in real life [Luo et al., 2017].

4 Methodology

4.1 Game Design

Based on Peters & Westelaken's method [2014], our game is based on three principles to synthesize reality and promote good gameplay dynamics : reduction, which consists of representing only the key elements of reality, abstraction of the complex system representing the game elements less detailed than in real life, and finally symbolization, which consists of giving a new appearance to real-life elements.

The design of our serious game is constructed in 4 steps : (1) definition of the system components, (2) establishment of the table of system components and game elements, (3) choice of the game format, and (4) game development.

Definition of system components

The scenario involves actors with varied resource profiles who will interact within a renewable energy community (REC) based on (1) their consumption needs, linked to the measurement of their activity, and (2) their production capacities, modulated by their photovoltaic panel surface areas.

The objective is to achieve self-consumption within the community, meaning to cover the needs through their own means of electricity production. Therefore, the actors are invited to distribute their energy units to satisfy a majority of them, as each unit of energy taken from the network market penalizes them all financially. Each person will make decisions personally, but they will involve the entire community : as the seasons change and faced with various individual situations, weather fluctuations, and energy market fluctuations, when to invest and in which equipment ? According to what rules should the productions be distributed and at what price ? How much trust should be given to other actors in negotiation ?

Time plays a preponderant role in the evolution of uncertainties and thus the intentions of each actor. It comes into play in the short term, considering a day during which a negotiation regarding energy distribution induces a sequence of decisions, and in the long term, over the seasons that modulate sunlight conditions and activity levels.

Ontological Model, System Components, and Game Elements

To synthesize the complexity of the future reality we are trying to model, we first compose an ontological model that identifies which elements will constitute the game, in relation to the components of the system (the approached reality), establishing the link between the serious game and the future reality of a REC. By respecting the three recommended principles of reality synthesis, namely reduction, abstraction, and symbolization [Peters & Westlaken, 2014], the concepts that synthesize the REC model are thus concretized in Table 1 below.

Choice of the game format

The second step consists of defining the format and type of the game ; which mode to adopt between a competitive game or a cooperative game ? In order to meet the main goal of the research, which is to observe social behaviors towards collective self-consumption, we choose to work on a cooperative board game : its type conveys the community aspect and its "board" format allows us to first observe in real-time the interactions between the players and then facilitate its deployment to multiply awareness-raising games among the general public.

Table 1. Ontological model synthesizing the energy sharing issue, linking the components of the system (approximated reality) and game elements.

Approximate reality	Ontological model : mobilized concepts	Game Elements
Social parameters	*Activity type and occupancy*	*Profile cards*
	Usages : consumption needs	*Profile cards; Action cards; Investment cards; Event cards*
	Individual and collective decision-making behavior	***Actions = observed variables***
Technical parameters	*Building characteristics and Production capacity*	*Profile cards*
	Equipment levels	*Profile/Action/Investment cards*
Economic parameters	*Market conditions*	*Event cards*
	Value production	*Points*
Legislative context	*Distribution rule*	*Game rules*
Physical context	*Meteorology*	*Event cards*
Temporality	*Quarter-hourly consumption*	*Time cards*
REC manager	***Governance = main research question***	*Game master*

Production of the game

In the final step, we proceed with the production of the game, which involves establishing the rules, constructing the scoring formula, and designing the cards and game board. We briefly describe them below in accordance with the game elements identified in the previous table 1.

Rules and Scoring

The goal of optimizing collective self-consumption is measured in "energy points", which count for each player the consumption units related to their usage and production, either from photovoltaic potential (positive) or from the electricity grid (negative). Each action chosen by a player earns or costs "virtuous points", depending on whether their behavior favors or penalizes the use of renewable resources.

Through repeated implementation, it has been specified that a turn must be played in four phases : (1) first, the declaration of each player's needs and production, according to their profile and the seasonal situation ; (2) followed by a three-minute debate phase during which players announce their possibilities and intentions, then negotiate with each other to find a compromise ; (3) the third phase is the action phase during which players play their cards. Their actions may or may not be consistent with what they announced during the debate phase. Each player thus has the freedom to play a card different from what they announced. (4) Finally, the last phase is the points tally, calculated at the end of the turn to assess the impact of the decisions of the different members.

Profile cards

The profile cards identify the individual status of the player : as a household, business, company, school, etc., they indicate their daily activity levels, the resulting consumption, and their potential seasonal photovoltaic production. The majority of players belong to the REC, but some players may not participate in it.

Action cards and investment cards

With a hand of three action cards per player, they actively participate in the management of their own energy and that of the REC by modulating their consumption or investing in equipment, which earns them points. Some actions carried by the investment cards have a permanent status : once played, these investment cards correspond to investments in equipments and therefore offer a permanent effect on all subsequent rounds (for example, investing in energy-efficient appliances reduces consumption permanently).

Event cards

The event cards generate random external factors that interfere with the intentions and goals of the players : for example, the occurrence of a power outage, extreme cold conditions, an energy market situation, etc.

Time cards

Time cards manage the pace of turns and establish a specific seasonal situation for each player, evolving throughout the seasons - predictably modulating production levels - and combining a random day of the week - modulating activities and therefore consumption needs.

Game board

The game board is designed to represent the collective energy potential of the REC, in which members can offer their produced energy for sharing.

Managing the game

The manager of the REC plays the role of game master : as in real life, they explain the principle and objective of the game and ensure that the rules are respected. They also act as a facilitator to promote collective dynamics.

4.2 The game protocol and experimental posture

Several rounds were initially organized, which made it possible to refine the components of the game and its rules in order to achieve a playable and relatively balanced level in terms of starting profiles, pace of drawing action cards, point reward, etc., including the management and deployment of the game over a reasonable period of time. The experiment consists of observing a game in real time. As researchers, we adopt the position of observer-participant : we play the game like ordinary players, i.e. not as game masters in order to not influence the game too directly. For our analyses, we use video files captured by a camera that is positioned from above, recording audio as well from the scene (figure 1).

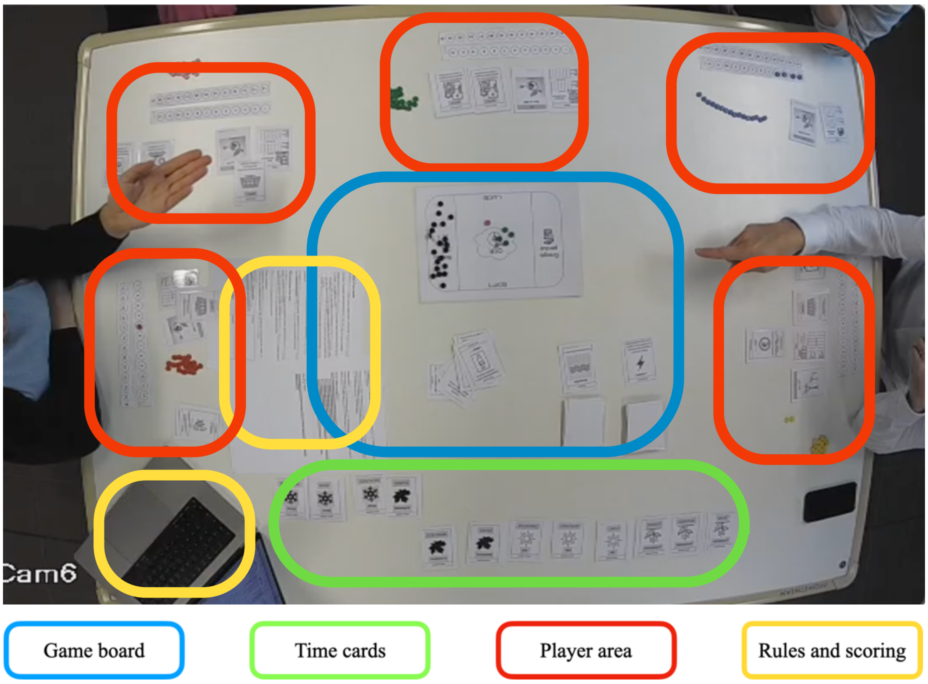

Fig.1. Video recording and zoning of the game space.

4.3 Analysis modalities

Behavioral analysis is performed using a coding method, using a platform for analyzing and visualizing human activity called COMMON Tools. Designed to study sequences of multi-actor interactions, this web application has been developed by our team since 2013 to manage large corpora of collaborative activity data [Ben Rajeb & Leclercq, 2015]. It allows the representation and analysis, through graphic comparisons, of the temporal or statistical evolution of multiple variables derived from verbatim or detailed descriptions of complex interactions.

4.4 Transcription method

The transcription method consists of sequentially transcribing the recorded verbatim, phrase by phrase, using one line per player and per focus addressed in each player's comment. Each line is completed with a timestamp and the player ID (table 2).

Table 2. Transcription grid with example.

Time stamp	Player	Verbatim
10 :23	*B*	*I play the "take 2 EU from the REC » card.* *I earn 2 points because I run the school dishwasher.*

The observation data is then specified on each line of these verbatim, using a pre-established coding grid that details the aforementioned variables (see section 4.1 Ontological model and table 3).

Table 3. Verbatim coding grid with their main categories.

Card played	Focus	Expressed motivation	Action performed	Temporality
• *Profile card* • *Action card* • *Investment card* • *Event card* • *No card*	· *Production* · *Consumption* · *Economic considerations* · *Points* · *None* · *Else*	· *Show solidarity* · *Judge as inequitable* · *Win for oneself* · *Invest in equipment* · *Change behavior* · *Judge as too expensive* · *No choice* · *Without motivation* · *Else*	· *Inform* · *Get informed* · *Influence another player* · *Announce his intention* · *Decide collaboratively* · *Decide neutrally* · *Decide in contradiction* · *Conduct the game* · *No action* · *Else*	· *Immediate* · *Future projection* · *Not applicable*

The grid is composed of five main categories, each with different subcategories (observable) to analyze users' social profiles. As an example, we take the "Focus" category, which allows us to identify players' interests in energy, production, consumption, or economic gain (e.g. points). Verbatims related to game behavior or rule reminders are qualified as "No Focus."

5 Game analysis

5.1 Corpus and Macro Analysis

A game is played with 4 to 10 players. It usually consists of 12 rounds, covering a year of four seasons, and lasts about 1.5 hours. The experiment we choose to describe here concerns a game played by five players who have already played several previous games (four on average) ; they are therefore familiar with the principles of the game and are aware of the cooperative goal of self-consumption. The observation covers three seasons (spring, summer, and autumn) because the last winter season is not very productive in solar energy, making it less useful to study : since the participants do not have energy to share, observing their actions is less useful.

Our corpus consists of 451 verbatim, stated over 78 minutes, transcribed and coded according to the procedures outlined in section 4.3. This initial measurement shows that the game was lively in terms of exchanges, with an average of 5.8 verbatim per minute for five players, or one verbatim per minute per person.

Our method starts from a qualitative observation that we translate into verbatims. The coding method then allows us to generate quantitative data.

145 verbatim are related to the conduct of the game. Issued by the game master as well as the four other players, they therefore account for one third of the exchanges. This number is an indicator of the complexity of the problem addressed : its high level reveals the need to recall or confirm the rules, which are nevertheless a simplifying synthesis of reality, to players who are already aware and trained in the notions of energy sharing.

The distribution of verbatim among the five players divides them into two categories in this game (figure 2) : three players state their actions equally (12 to 17% each) while two players (E and C) generate nearly 60% of the exchanges, already reflecting a "discussant" posture.

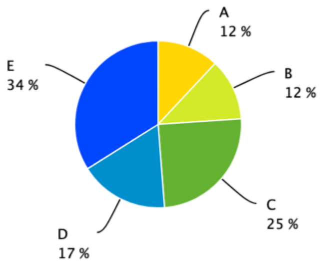

Fig. 2. Distribution of verbatim among the 5 players during the game.

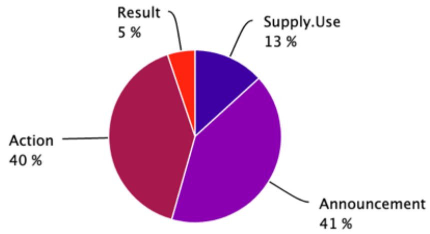

Fig. 3. Distribution of verbatim across the 4 phases of the game.

The distribution of verbatim across the four phases of each round (statement of energy supply and use / announcement of intentions / actions / round assessment) shows that discussions were equally lively during the announcement and action phases (figure 3). In the former case, discussions focus on conceptualizing possible scenarios, leading to negotiations between players; in the latter case, verbatim often reflect justifications for actions and reactions from other players who judge or adapt to them.

The majority of motivations expressed by the players during the observed game concern solidarity and behavior change (figure 4). They are complemented by references to investment and inequity. Self-centered positions only account for 3% of the exchanges.

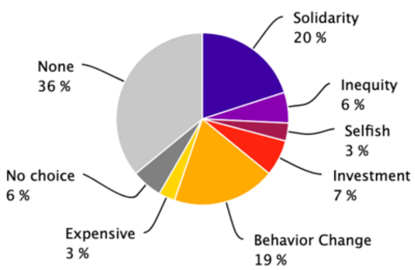

Fig. 4. Distribution of player motivations during the game.

5.2 Temporal progression of the game

The timeline, composed of the succession of verbatim (independently of their individual durations), traces, for each player, the evolution of a chosen variable. figure 5 provides a visualization of the evolution of motivations expressed in each verbatim : the abscissa of this graph represents the succession of the three observed seasons, with three rounds per season, while its ordinate superimposes the motivation lines of each player (A to E).

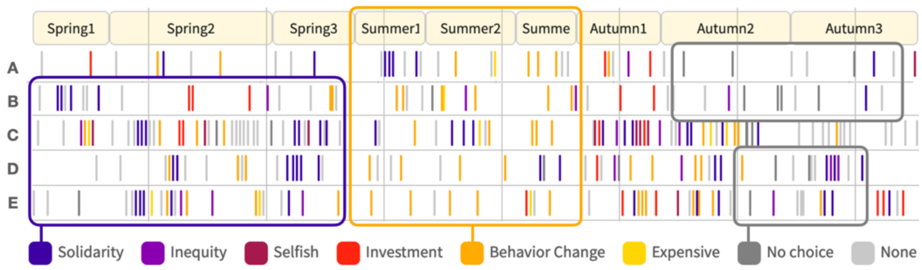

Fig. 5. Evolution of motivations expressed in each verbatim.

One interesting group phenomenon can be observed : during the summer season, when energy production levels are at their highest in the profile cards, players show a stronger tendency to change their behavior (i.e. to modify their habits to adopt more energy-saving postures in order to achieve a balance between production and consumption), both within the REC and for player B, who is outside the community and manages his balance at an individual level.

Before that, i.e. during the spring but also during the initial deployment of the game, the players express rather solidarity-oriented verbatim.

As autumn arrives, production resources decrease ; players who can invest in production equipment (photovoltaic panels) or household equipment that offers reduced electrical consumption. By analyzing the content of the verbatim, we can see that they adopt this investor posture in anticipation of the approaching cold season.

Finally, in the heart of autumn, we realize that a majority of players are playing cards that are imposed on them ("no choice") because their investments, shown in the form of investment cards, remain permanent and do not offer them the possibility of harvesting and playing various action cards. The end of autumn also shows a majority of verbatim without motivation, preceding the winter period that will freeze positions.

5.3 General distribution of verbatim

Let's see what the general distribution of verbatim reveals according to the main variables related to the energy transition issues in the REC for the entire group of actors : main concerns, short- and medium-term projections, and collaborative dynamics of energy sharing.

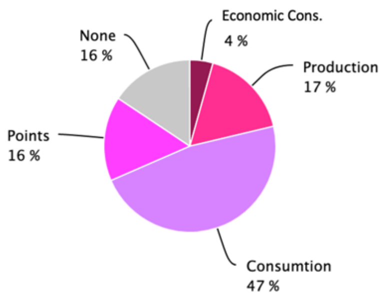

Fig. 6. Distribution of verbatim across the 4 phases during the game.

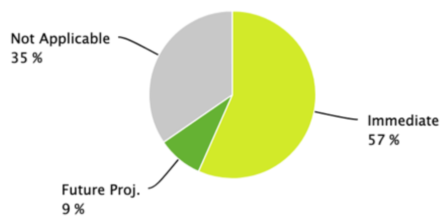

Fig. 7. Temporality expressed in the verbatim.

Main concerns

The observation of the themes addressed by each verbatim (focus) indicates a largely explicit formulation : 84% of the comments made are categorizable, since only 16% are "without subject" (figure 6). Almost half of these comments (47%) are related to consumption concerns, which corresponds to the most accessible action lever for actors, unlike energy production (17%) which requires technical capture devices or resources to invest in it. Remuneration, translated into points in the game, is only the subject of 16% of the conversations. With the mention of the budget at 4% of the exchanges, it shows that in the playful approach, the economic aspect does not seem to be the top priority, unlike the observations made by Bonnardot [2020].

Projection in the short and medium term

The analysis of temporal evocations in the verbatim reveals short-term strategies (figure 7) : more than half of the comments concern the current round being played. The future is mentioned only once in ten comments. Therefore, the short-term remains privileged over the long-term in the group's reflection as a whole. We will see later what characterizes individual action on this subject (see "Actor Profiling" below).

Collaborative dynamics of energy sharing

Referring to the overall distribution of motivations (see figure 4), we can characterize the collaborative dynamics of the group of players : 39% of the verbatim identifying a motivation (or 60% of the motivations expressed when not considering verbatim without motivation) involve cooperative attitudes for the benefit of the energy community, by taking supportive actions or adopting behavior that saves energy consumption. Less than 5% of the motivations expressed reflect selfish behavior.

5.4 Profiling of the players

Examining the same key variables related to the issues of the energy transition in REC, visualized by player, allows us to perceive certain characteristics of the players.

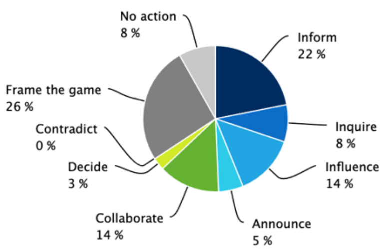

Fig. 8. Actions of player D during the game.

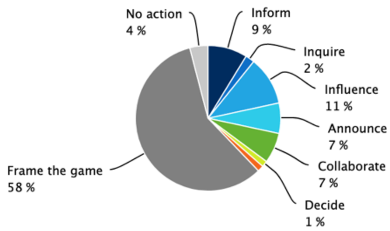

Fig. 9. Actions of player E during the game.

Actors D and E in particular account for 39% and 69% respectively of the labeled actions "frame the game" and "influences" (figures 8 and 9). This testifies to a certain control over the course of the game. It turns out that these players both have a greater mastery of its mechanisms since both of them are co-designers of the game and that E acts as the game master. As such, he is tasked with leading the other players and conducting the assessment at the end of each round. In this regard, he occupies the position of community manager, responsible for explaining the remuneration rules, advising actors to collectively achieve self-consumption equilibrium. The cards distribution allocated the players as follows: (A) is a business, (B) is a non-CER house, (C) is a corporation, (D) is a house, and (E) is a school.

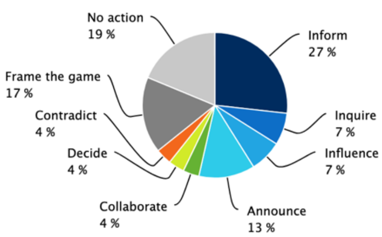

Fig. 10. Actions of player C during the game.

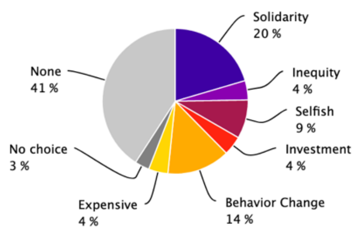

Fig. 11. Motivations of player C during the game.

Actor C has a "discussant" profile. This means that he participates a lot in the discussion even when it does not concern his own decisions or actions. He plays the role of social/emotional leader in the game. As identified above (figure 10) : a quarter of their interactions reflect game management (17% "leads" and 7% "influences"). They gather a lot of information (27%), but they also make decisions by both collaborating and contradicting their stated intentions. They could be considered a less reliable actor, which also corresponds to their highest rate of "selfish" motivations among all players (figure 11). More realistically, this actor acts according to their own interest in each situation that arises. While initially supportive, they do not hesitate to change their mind in response to the attempts of other actors to influence them.

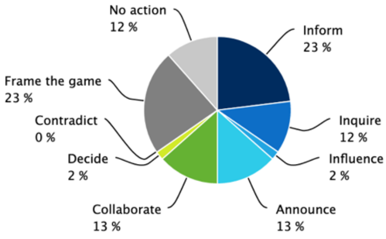

Fig. 12. Actions of player A during the game.

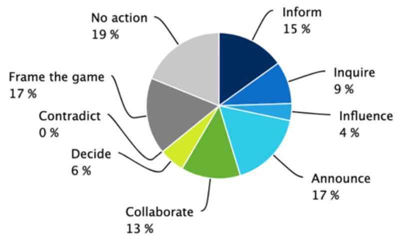

Fig. 13. Actions of player B during the game.

Actor A has the most balanced distribution of action verbatim among the actors in the REC (figure 12). He exerts very little influence, informs and seeks information, and makes decisions in a collaborative manner, consistent with his stated intentions. This is a cautious and thoughtful profile that analyzes the game as much as he plays it.

Finally, actor B, who does not belong to the REC, also presents a balanced distribution of actions (figure 13). He has the highest rate of neutral or collaborative decision-making (6+13%), which reflects his isolation : he remains consistent with himself, not accountable to other players.

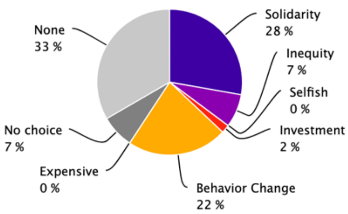

Fig. 14. Motivations of player D during the game.

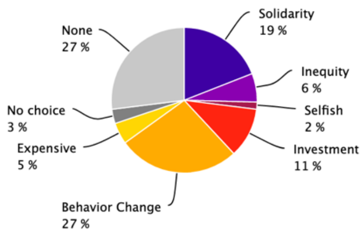

Fig. 15. Motivations of player E during the game.

We also observe that players D and E each have a more pronounced rate of verbatim evoking inequity (figures 14 and 15). They also have the two profiles that do not have a photovoltaic equipment at the start of the game. Actor E has the opportunity to install one in the middle of the game, while actor D is never equipped with a solar production means throughout the game. Their "inequity" verbatim are probably prompted by this unfavorable personal situation. In correlation, we also note the "temporality" graph of this disadvantaged actor D, who never has the opportunity to invest, and whose comments almost exclusively concern immediate action (figure 16). He is systematically in a problem-solving posture, having to find the energy needed to meet his short-term needs.

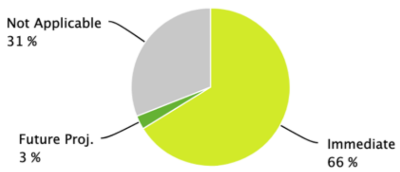

Fig. 16. Time expressed by player D during the game.

We remind here that this is one game analyzed to validate our method. We do not have the ambition to qualify the profiles obtained at this stage.

6 Discussion

6.1 Model validation

The ontological model on which the game was built, and which served as the basis for the construction of our analysis framework (section 4.1), seems to be stable and relatively complete. Indeed, all items in our grid are used, and none are missing. The "Else" item does not reveal any missing category or criteria.The games are played within the allotted time (less than two hours to cover the four seasons of a year). As for usability, the draw presents a balanced distribution of cards, as shown in figure 17 : (1) profile cards are used in 15% of verbatim, which corresponds well in volume to the 13% stated during the needs announcement phases ; (2) event cards and investment cards occur four times less frequently than action cards.

If the number of verbatim related to the game management (33% of actions, figure 18) recalls the complexity of the real world that the game tries to synthesize, the examination of the content of the verbatim themselves shows however that all players are sensitized to the issues of energy sharing and gradually master the impacting factors. They inform, learn and mutually influence in a third of their verbal exchanges.

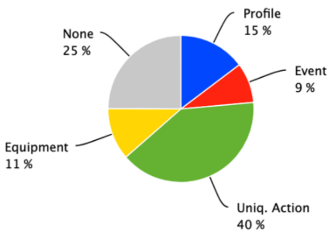

Fig. 17. Distribution of card types drawn during the game.

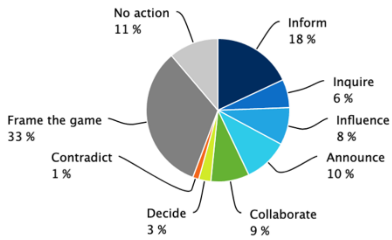

Fig. 18. Distribution of actions throughout the game.

The parameters of the proposed analysis grid thus allow for a good understanding of the role of human factors in relation to the multiple situations in which consumer/actors may find themselves. Their analysis makes it possible to characterize the trends adopted by all members of a REC (in the game analyzed here, a clear desire to aim for the common benefit) and also to identify specific characteristics adopted by each player (collaborative, cautious, investor, more egocentric, etc.).

6.2 Validation of the game through simulations

The rules of the game, which represent the legislative parameters framing the sharing of energy in a community, provide some keys to try to induce virtuous behaviors or to circumscribe possible drifts. In order to visualize the effect of the rules of the serious game, we have sought, on an exploratory basis, to calculate the balance sheet of a REC based on the simulation of three different community scenarios :

1. Scenario 1 : Players are not part of a REC and there is therefore no common objective of collective self-consumption ;
2. Scenario 2 : Players are members of a REC and follow a rule of full sharing ; they share all available photovoltaic energy equally among themselves ;
3. Scenario 3 : REC members only share their surplus energy produced between themselves equally, after satisfying their individual needs.

We simulated, based on PHP code, 57 rounds, specified with the following parameters :

- 5 profiles, labeled from P1 to P5, are selected to diversify consumption profiles and means of production ;
- 10 players, with a combination of 2 to 5 profiles, without any repeated profile, except for combinations of 6 to 9 profiles where the same profile may be repeated twice ;
- 3 seasons : winter, mid-season, and summer (as spring and fall have consumption and production data that are roughly similar) ;
- 6 combinations per seasonal situation for one round : for each season, one round is played with one weekday and one weekend day.

The results of this simulation are visualized by the number of energy units required, indicated in each box of a graph (figure 18) that shows, on the ordinate axis, the 57 different games with 2 to 10 player profiles, and on the abscissa axis, the six rounds/seasons for both situations (energy balance of the REC on the right and energy balance of the grid on the left).

Fig. 19. Serious game simulations based on three scenarios : no REC (on the left), complete sharing of production (in the middle), and sharing of surplus production (on the right).

Green boxes represent a positive balance for the scenario, while red boxes represent a rather negative balance, occurring when the surplus is not fully consumed or when a lot of energy is consumed from the grid.

These results first show that, for the 3 scenarios, the energy produced is not fully consumed during the summer and the consumption from the grid is higher during the winter. This logical observation is explained by the fact that photovoltaic panels are of course more productive in summer than in winter.

For scenarios 1 (non-REC) and 2 (full sharing), the negative balance is spread across all 57 rounds of the game as the energy produced is not allocated according to the specific and varied needs of each profile.

In the 3rd scenario (surplus sharing), the negative balance is rather marked during extreme seasons, but the unconsumed green energy remains always lower than in scenario 2.

As shown by the balance of scenario 1, the simulation of the Saturday/Winter combination is invalidated, revealing the inconsistency of a profile-card, which could then be eliminated thereafter. Indeed, prosumer profiles produce as much as they consume. Therefore, there will never be a surplus of production for this combination of day/season, no matter what the energy sharing rules are. This doesn't allow to observe changes in players' behaviors.

7 Conclusions

This study highlights the contribution of the serious game approach in understanding environmental issues, particularly in raising awareness and understanding of the complex challenges of energy transition.

The gaming instrument is first built based on an ontology that identifies the main parameters for synthesizing the future reality of energy sharing in a renewable energy community. It then allows players to be put in situations through games, one of which is studied in detail here. This analysis is carried out using a dedicated protocol and methods of analysis and validation.

The method provides good indicators on the evolution of individual behaviors, influenced by the situation of each actor. Without claiming to generalize the conclusions drawn from this single game presented here, it validates the serious game approach to build governance rules for renewable energy communities by integrating social parameters, and identifies the drivers of cooperative dynamics such as equity, and solidarity, through the identification of specific profiles of its actors and the detection of deviant behaviors.

7.1 Limitations

In order to ensure the good usability of the game, several concepts had to be neutralized or simplified in the ontological model : for example, the notion of profit comes in the form of points attached to actions, which constitute a dematerialization of the economic factor ; the notions of prior investment do not appear ; the point values are not correlated to actual monetary values, etc.

Similarly, the unit of time is one day (with two states : working day or day off) played three times per season, whereas the balance of electricity consumption/production is measured in 15-minute increments, or 48 times per day, requiring a much finer reactivity than what is simulated in a game.

On the contrary, a game played over one year does cover all four seasons, but it only allows to measure the initial effects of investments in photovoltaic panels, which actually bring a certain benefit to their owner over the course of about twenty years.

In our analysis method, many parameters could not be questioned in this article, such as the impact of a player's verbatim influence on the decisions of others, or the effect of anticipation on successive seasons, or even variations in decision-making depending on individual energy unit situations, etc.

Of course, this study comments on a unique and non-reproducible game, to identify human parameters, whereas it would be necessary to analyze thousands of games before claiming to understand in detail the motivations of decision-making behaviors.

7.2 Perspectives

To overcome this methodological pitfall and go beyond the combinatorial approach presented in our simulation (Section 6.2), the SERENITY project aims to model a variety of situational postures, animated by the specification of human parameters described in this experiment, which will be interacted through simulations of thousands of games rounds in fictitious communities. Based on an agent system parameterized on the observed behaviors here, this large-scale simulation will more broadly indicate which governance rules can govern, as fairly as possible, the ongoing energy transition.

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References

Abdüsselam, M. : The effect of serious games on the awareness of energy sources consumption. International technology and education journal 4. 7 (2020).

Bekebrede, G. : Experience complexity : A gaming approach for understanding infra- structure systems. Enschede, The Netherlands : Gildeprint Drukkerijen (2010).

Ben Rajeb, S., Leclercq, P. : Instrumented analysis method for collaboration activities. Proceedings of the Fifth International Conference on Advanced Collaborative Networks, Systems and Applications , COLLA 2015, San Julian, Malta (2015).

Bonnardot, Z., Haradju, Y., Salembier, P., Prieur, E., Vial, S. : Anticiper des interactions humaines par le design et l'ergonomie : le partage d'énergies renouvelables entre voisins. 55ème congrès de la SELF. Paris, France (2020).

Cohard, P. : Evaluation of Serious Game User Experience : the Role of Emotions. The Electronic Journal of Information Systems Evaluation, 22(2), pp. 128-141 (2019).

Djaouti, D., Alvarez, J., Jessel, J-P. : Classifying Serious Games : the G/P/S model. Handbook of Research on Improving Learning and Motivation through Patrick Felicia (ed), "Handbook of Research on Improving Learning and Motivation through Educational Games : Multidisciplinary Approaches » (2011).

Hammady R, Arnab S. : Serious Gaming for Behaviour Change : A Systematic Review. Information 13(3) :142 (2022).

European Commission : The European Green Deal, https ://eur-lex.europa.eu/legal-content/EN/TXT/HTML/ ?uri=CELEX :52019DC0640&from=FR, (2019), last accessed 2023/02/26

Lanezki, M., Siemer, C., & Wehkamp, S. : "Changing the Game—Neighbourhood" : An Energy Transition Board Game, Developed in a Co-Design Process : A Case Study. Sustainability 12(24) :10509 (2020).

Lukosch, H., Bekebrede, G., Kurapati, S., Lukosch, S. : A Scientific Foundation of Simulation Games for the Analysis and Design of Complex Systems. Simulation & Gaming. 49 (2018).

Luo, C.,Gil bert, L., Liu, A. : Designing Serious Games for Complex Systems : a Framework. (2017).

Mayer, I., Bekebrede, G., Harteveld, C., Warmelink, H., Zhou, Q., van Ruijven, T ., Lo, J. ; Kortmann, R., Wenzler, I. : The research and evaluation of serious games : Toward a comprehensive methodology. British Journal of Educational Technology. 45. 502-507. (2014).

Müller, J., Kreuz, S., Höhl, W., Lüdecke, V. : A Process Full of Challenges : A Serious Game About the German Energy Transition. Conference : ECGBL - 11th European Conference on Games Based Learning. Graz, Austria (2017).

Ouariachi, T., Elving, W. : Accelerating the Energy Transition Through Serious Gaming : Testing Effects on Awareness, Knowledge and Efficacy Beliefs. Electronic Journal of e-Learning (2020).

Peters, V., Westelaken, M. : Simulation games - a concise introduction to the design process. (2014).

Sajjadi, P., Bagher, M., Myrick, J., Guerriero, J., White, T., Klippel, A., Swim, J. : Promoting systems thinking and pro-environmental policy support through serious games. Frontiers in Environmental Science. (2022).

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