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Fossil-free village simulation game

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Abstract. How can the energy supply of a community be transformed to become fossil-free and thus become more sustainable while remaining affordable? "Sarnetz", an online computer game implemented by a multi-disciplinary research team from the Lucerne University of Applied Sciences and Arts, is providing possible answers for a specific case in the Swiss Alps. Unique measures for their implementation are discussed, in terms of relative impact on the CO_2-balance, sourcing of local energy and investments. Further consideration includes the attractiveness for inhabitants and tourists as well as the business case for a "small to medium size enterprise (SME)". The simulation is set-up as a game for teaching inhabitants and students. Participants compete as a team, taking on different roles, implementing measures to satisfy the objectives of a sustainable solution. The feedback and assessments from Swiss, Japanese, and Middle East students indicate that this approach could be successfully applied to other parts of the world. Suggestions are given, as to the transferability of the simulation, requiring different measures to achieve a fossil free community.

Keywords: Didactic online game / CO_2 neutrality / urban environment

1 Introduction

At the COP27 in Sharm El-Sheikh, Egypt, it was agreed that "rapid, deep and sustained reductions in global greenhouse gas emissions are required – lowering global net greenhouse gas emissions by 43% by 2030 relative to the 2019 level – to limit global warming to 1.5 °C target" [1].

The buildings and construction sector seem to have the biggest inertia, with regards to the "rapid, deep and sustained" target. In 2040, approximately 2/3 of the global building stock will be buildings that exist today. Without widespread existing building decarbonization across the globe, these buildings will still be emitting CO_2 emissions in 2040 and we will not achieve the Paris Agreement's 1.5 °C target. The magnitude of the challenge becomes evident, when recognizing the fact that on a global basis, CO_2 emissions from building operations are responsible for 27% of all emissions annually, while building and infrastructure materials and construction (typically referred to as embodied carbon) are responsible for an additional 13% annually [2]. Thus, the built environment generates approx. 40% of annual global CO_2 emissions [3]. In urban environments, the portion of CO_2 emissions from operating buildings increases even further. For instance, in New York City, the greenhouse gas emissions from the built environment even reaches 65% [4].

Achieving zero emissions from the existing building stock will require acceleration of the current rate of energy upgrades. For full building sector decarbonization, every existing building will need to undergo energy upgrades involving a two-step approach: (a) improvements in the energy efficiency of building operations and (b) a shift to electric heat pump or district heating systems powered by carbon-free renewable energy sources, and the generation and/or procurement of carbon-free renewable energy. A free on-line tool is available that succinctly puts the principles and actions behind carbon neutral and resilient built environments at the fingertips of designers, planners, builders, and policymakers worldwide. The swatches, or sustainable design strategies, in this online tool address energy consumption and greenhouse gas emission at all scales – from regional and city planning to building details [5].

Inhabitants of buildings represent the additional dimension for truly *sustainable* developments. Their preferences to technologies and design; resistance or acceptance of noise, lights, and smells; and/or their tolerance to heat and moisture will determine and influence the speed of implementation.

2 Methodology

Educational games have demonstrated great potential for informing students, policymakers, and the general public

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on environmental issues. Such a game has been created and is described in this paper, that allows participants to learn about the environmental consequences of re-development decisions and highlights the complexity of decision making with sustainability as a priority. To be effective, the game is based on an actual case and allows for project-based learning in a group.

2.1 The case

Recognizing the complex energy challenge of the building sector, a research project "Zernez ENERGIA 2020" was launched in 2011 by an interdisciplinary research team of the Swiss Federal Institute of Technology in Zurich (ETH Zurich) together with private partners and the local authority. As a result, a roadmap for the village of Zernez was established to become CO_2 neutral by 2050, with the aim of covering the entire building-related energy requirements by its own supply and reducing the resulting CO_2 emission to zero. The project was divided into three research sections and a pilot building, which together was to illustrate possible ways to achieve the ambitious goals, similar to the above introduction of this paper. In the first section, concepts for reducing building-related energy consumptions were developed. In the following section, the potential for renewable energy production in the municipal area was examined and a strategy for local energy supply was developed. The final section integrated the results of the first two sections into an overall strategy for sustainable local development [6,7].

The resulting roadmap integrated various "measures" to be realized. By making the choices of the "measures" variable, the ETH research team created a board game, initially targeted towards the inhabitants and the local authorities. In the following step, the Lucerne University of Applied Sciences and Arts has taken the board game to teach students on the interdisciplinary approach on "how to" transform a community and to make energy systems tangible. The target audience included not only students at the Lucerne University of Applied Sciences and Arts, but many High School Students at various institutions across Switzerland; notably in the German-speaking North, French speaking Geneva and Lausanne, and Italian speaking Lugano as part of the national "TecDays", i.e., in multiple languages (see responses at Fig. 1).

2.2 Didactic approach

The game-setting allows for hypothetical scenarios and in face of a real situation opens participants eyes to consequences and impacts. Furthermore, to play the game in groups encourages constructive interaction and increases the likelihood of superior results, if properly set-up. As such, by having a group of 5 players with equal authority but different priorities to reach a common objective in a competitive environment satisfies several best practices in "project-based learning". Players need to interact in the game cooperatively, taking on the role of leaders in making choices through open discussions on the various topics, having to agree on specific actions ("measures") while defending a certain position, implementing an amicable solution. Only unanimous votes are to be implemented, making the players aware that there are always compromises to be made when a plan meets the real world, which is one of the most powerful messages of the game. To operate in a competitive environment, further enhances the outcome. Thus, at least two groups of 5 players each compete to see who can create the better solution for a "carbon free" village of Zernez.

Selected responses of students to the question "What Did You Learn, while Playing the Game?":
- It's hard to get a consensus among those people from different fields of work.
- I realized the importance of thinking from many viewpoints and compromise with others.
- Cooperation and discussion is very important.
- How to more manage different scenarios and possibilities.
- Convincing people.

While the learning of international students was also well appreciated, working as a team was judged as less favorable – illustrating the difficulties of the negotiations (see Fig. 2).

2.3 Rules of the game

For maximum benefit, the game was embedded into a workshop with the following structure:
- Introduction of the topic – focusing on the type and effects of the possible "measures".
- How to play the game – accounting, timing, implementation of the selected "measures".
- Play in groups to achieve the goals to reduce energy demand and replace sources of energy.
- Presentation of results and reasoning by each group.
- Assessment and comparison of results by the moderator.
- Explanation of real-world solutions used in the actual case.

"Measures" are all related to either the energy demand or the energy supply of the buildings of the specific case and could / should be adjusted to other places in the world.

During the game, each of the 5 players takes on the role of a different stakeholder, who is involved in the issues: (1) the Representative of the Inhabitants, (2) the Energy Supplier, and the Municipal Council, consisting of (3) Energy Manager, (4) CO_2 Emission Manager, and (5) Financial Manager.
- *The Representative of the Inhabitants* has the objective to keep or increase the attractiveness of houses and community, being faced with the questions of: Are the landlords/tenants/homeowners unilaterally burdened by costs and what would be the alternatives? Can the desire of the inhabitants for less PV on the roof (especially in the village center) be implemented?
- *The Energy Supplier* has the challenge, that he/she is currently mostly selling fossil fuel for heating, being faced with the questions: What is or could be my motivation to support the "measures"? Are we planning a decentralized or central energy supply? What are the consequences and alternatives? Which business-case could results and be attractive?

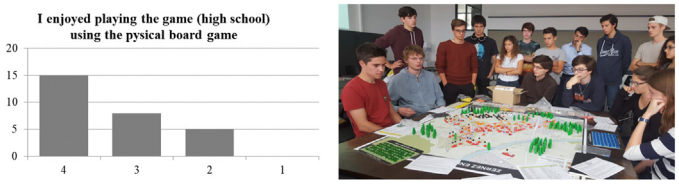

Fig. 1. Responses of 28 Swiss High School students (4 = strongly agree, 1 = strongly disagree).

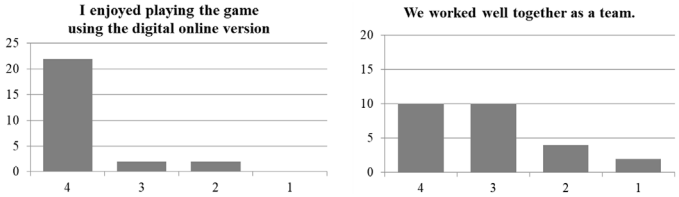

Fig. 2. Ratings from 26 Students from Japan and the Middle East (4 = strongly agree, 1 = strongly disagree).

- *The Energy Manager* (part of the Municipal Council) has the objective to obtain energy locally, which must be renewable, being faced with the Questions: Which measures increase the share of local energy? Which measures should be preferred? How could the wood required for some measures be made available locally and in which location would a reforestation make sense?
- *The CO_2 Emission Manager (part of the Municipal Council)* has the objective to avoid all building related CO_2 emissions, being faced with the questions: Which combination of measures lead to the objective? Are these measures supported by the other stakeholders?
- *The Financial Manager* (part of the Municipal Council) has the objective to minimize the investments for the proposed measures, being faced with the questions: Who pays for the various measures? Is the implementation of a cost burden particularly hard for one partner/stakeholder?

Proportional values are assigned to each of the "measures" in terms of investments, CO_2 reductions, and quantity of locally sourced renewable energy – all based on the actual case. The winning team has the least investments for meeting the objectives of satisfied inhabitants and avoidance of all CO_2 emissions by applying locally sourced renewable energy (possibly by integrating the energy supplier to keep his business going).

The accounting is done by using colored coins. Any team must reduce CO_2 emission to net zero, represented by 88 blue coins. Once all 88 coins are taken off the teams account, the team has reached the first objective. The team must at the same time increase locally produced renewable energy, represented by 75 green coins. Once 75 green coins are earned, the second objective is achieved. Investments are counted as yellow coins. No budget is given; but to win the game, the least investment is required when compared to the competing team(s).

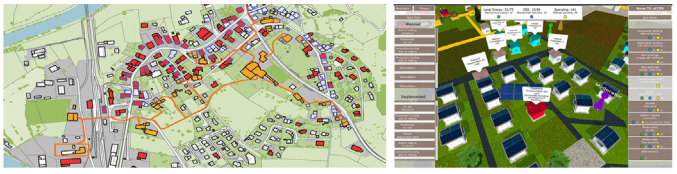

Fig. 3. Board layout of the village – physical vs digital.

3 The specific case of Zernez

The picturesque Engadine village of Zernez is located in the eastern part of Switzerland at 1474 meters above sea level. It was first mentioned in 1161 as Sarnetz. Today it is the home of 1500 inhabitants and the gateway to the Swiss National Park, Switzerland's biggest nature preserve.

3.1 Buildings and the community

In 1872 a major fire destroyed most houses leaving only 40 out of 157 houses undamaged. Part of the village was rebuilt in an urban style and with flat roofs. Today, there are:

- 304 buildings, all connected to an electrical power grid (100% hydropower), of which.
- 91 buildings are oil heated, mainly in the village center.
- 33 buildings are connected to a district heating grid, supplied by an outdated wood-chip heating plant.
- 180 buildings are equipped with wood and/or electric heating.

To strengthen the link to the actual village of Zernez, the game map is based on actual topology and property borders. The buildings are color coded: red = oil heated; yellow = district heated; white = electric heated. Historic buildings are specially marked, as their facades and roofs cannot be altered. According to the first section of the exercise, measures to reduce the energy demand are either marked as "renovations" or as new buildings to be constructed, either as self-sufficient or energy producing. The other "measures" relate to the second section, i.e., the energy supply.

In 2021, an initiative by the Embassy of Switzerland in Japan was successful to adapt the game into a digital version, to make it available as an educational tool for a broader audience and to provide a version that can be played in distributed groups despite physical distance and in any part of the world [8]. It is accessible from its own website "www.Sarnetz.ch" [9], whose name was derived from the original municipality name of Zernez and the English-language «Simulation-game EneRgia2020 for CO_2-NEuTral Zernez». On that website, the strategy game is presented with texts and various videos. In addition to the actual idea and the game instructions, the municipality of Zernez and its "Zernez Energia 2020" project is exhibited, as well as energy systems in general and results and news from the pioneering project (see Fig. 3 for comparison).

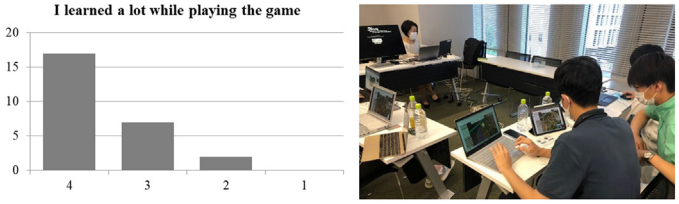

Fig. 4. Ratings from 26 Students from Japan and the Middle East (4 = strongly agree, 1 = strongly disagree).

3.2 Kind of "Measures"

The optional measures all relate to either the energy demand or to the energy supply of the buildings in the village of Zernez. The number of options represent generally accepted initiatives and are kept to a minimum to allow players to focus.

Step 1: Reduce energy demand to the minimum by spending as few (yellow) coins as possible. It is assumed that those buildings protected by preservation orders, can be renovated by placing thermal insulation internally and windows can be replaced by selecting alternatives with the same look as the replaced frames.

– *Renovation of Buildings with Oil Heating* (6 at a time): accounting 6 blue coins for reducing CO_2 emissions at a cost of 1 yellow coin. No green coins, as the measure does not provide any renewable energy.
– *Renovation of Buildings with District Heating* (6 at a time): at a cost of 1 yellow coin with a benefit of only 1 blue coin, as the CO_2 reductions in the wood fired central heating station is minimal.
– *Constructing new buildings (6 at a time) being either Self-Sufficient or Energy producing.* Teams are required to construct to total of 12 new buildings. Choosing self-sufficient buildings would cost 3 yellow coins with no impact on emissions nor on the energy balance. Deciding on energy producing buildings would require 5 yellow coins with the benefit of two green coins for producing excess renewable energy leading to a concurrent CO_2 reduction equivalent of 1 blue coin (based on the Swiss electricity mix).

Step 2: Meet energy demand with locally produced, renewable energy and spend as few yellow coins as possible.

– *Investing into a district energy supply*, using woodchip as a renewable energy source, allowing more houses to be connected to the grid compared to the current, outdated heating plant. The options given are:
– Central wood-fired heating station at an investment of 3 yellow coins, with no direct benefit to the CO_2 nor the renewable energy balance. The additional renewable energy can be attributed by the reforestation measure once houses are connected.
– Central cogeneration plant at an investment of 22 yellow coins, generating electricity while providing heat, leading to 5 blue coins for the CO_2 reductions and 35 green coins for the renewable energy, specifically based on the Swiss electricity mix.

2. *Connecting buildings to District Heating* (6 buildings at a time) costing 1 yellow coin plus another yellow coin for each 5 meters of Pipe. (It is therefore encouraged, to start with houses, which are next to the existing piping loop). CO_2 reduction account for 1 blue coin. Yet, connecting is possible only, once the heating plant has been upgraded and reforestation is allowed after each connected group of houses.

3. *Installing on-site Heat Pumps* (4 at a time) as opposed to electrical heating is reducing the electricity demand and thereby is reducing the CO_2 emissions by 1 blue coin for 4 houses, based on today's electricity mix in Switzerland.

4.*Installing Photovoltaic* on any roof of non-protected buildings or as free-standing within the territory of the village; costing 2 yellow coins for 36 buildings or 9 free-standing panels, resulting into 2 blue coins for CO_2 reductions and 4 green coins for locally produced renewable energy.

Examples of subject-specific feedbacks, are as follows:
– "I learned what people should think about to make eco-friendly city."
– "The learning includes the influence of renovation for environmental improvement on other components.
– "Interesting that we do not see a single one of these topics at the climate demos. I only saw posters against cars, aviation and co. And what everyone forgets: such projects do cost – to put it bluntly in young people's language – really big money. This is usually reflected in the rent or investment requirement. Even the whole embellishment of PV electricity is always only illuminated on one side and never shows the downsides. (see ratings at Fig. 4).

3.3 Beyond the game

To reduce energy requirements, renovations and energy producing new buildings are needed. The challenge is to assist / convince homeowners to invest. In the village of Zernez, the local utility is charging an extra 2 cents per kWh of electricity to feed an account, which serves as a fund to double-up the financial aids from the state government.

To increase the locally produced renewable energy, the outdated wood fired heating station was replaced by a modern, modular wood fired heating station as opposed to the co-generation plant, mainly because of the investment analysis, supported by the fact that electricity can be locally produced by a hydro-power plant. However, district energy solutions are gaining momentum across Switzerland, as it allows efficient and clean distribution of renewable energy. To make it affordable and manageable for the local authorities, it is important to integrate the implementation into the spatial planning of the village, like road renewal and townscape. Such interlinks are shown in Figure 5.

The installation of photovoltaics in Zernez is very slow, mainly due to aesthetic considerations, given the role of the village as the entry to the national park, emphasizing Swiss nature. These facts underline the important role of the inhabitants.

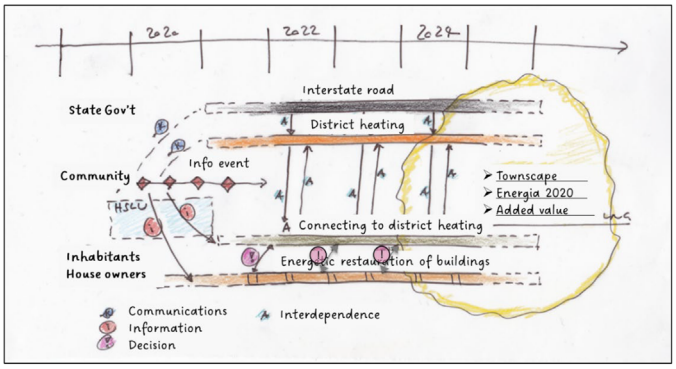

Fig. 5. Illustration of interlink between energy system and initiatives of various stakeholders.

Other recommendations for the private sector include instruments to unlock additional finance for zero-carbon-ready buildings and products, that will guide building owners and occupants towards clean investment. Under green mortgages, for example, a bank can offer preferential access to finance (such as discounted interest rates) for building construction or products targeted at meeting efficiency and sustainability criteria, with recent examples for instance in the United Kingdom and Australia.

New business models are critical to reach all market segments, in particular to reduce the upfront capital cost associated with the most energy-efficient and clean technologies. Solutions, such as heating as a service, cooling as a service, and on-bill and on-wage financing have been proved to be successful in several markets [5].

4 Conclusion and next steps

The didactic method has confirmed its suitability to teach students, while the topic of CO_2 neutrality of urban communities can be well addressed, for any part of the world. Adaptations of this type of game will require the tailoring of the "measures" to those that are typical in any particular region.

Given initial success with students from the Middle East playing this game, this approach will be tailored to the Arabian Gulf region's distinct needs and infrastructure, taking the UAE as an example. Here, water desalination, water-heating and space cooling are responsible for over a quarter of CO_2 emissions [10]. This is currently mainly powered by fossil fuel power stations, while the UAE has committed to using renewables to supply 50% of electrical power by 2050 [11]. In addition, water has been named most recently as a priority by stating "Parties to further integrate water into adaptation efforts to increase in protecting, conserving and restoring food security, agriculture, water and water-related ecosystems, including river basins, aquifers and lakes" [12].

This is a particularly pressing issue, as the Arabian Gulf region has very high fossil fuel consumption per capita [10,13], in large part driven by the need to use desalination as the primary source of drinking water and air conditioning to cool living spaces, where summer ambient temperatures can often be as high as 50 °C [14] and are expected to increase further over the rest of this century due to anthropogenic climate change [15]. As a result, member governments of Gulf Cooperation Council (GCC) aim to increase their renewable power generation capacity to 50% by 2050 [16,17]. As such, there are opportunities to reduce CO_2 emissions here by exploring increased water reuse, the various types of cooling options available and solar insulation and distributed solar power generation, to name a few possibilities. A game tailored to this region could help with environmental education regarding these options and their possibilities to impact environmental impacts and costs.

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