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*Article*

# Towards a Joint Local Energy Transition Process in Urban Districts: The GO2Zero Simulation Game

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**Abstract:** The depletion of fossil fuel sources for our energy system and the influence on overall $CO_2$ emissions drive the need to more sustainable energy systems. The transition towards a renewable energy system cannot be seen as a purely technical issue; it is strongly embedded within society. In this study, we analyze the stakeholder complexities of the transition in urban districts and research the use of a simulation game to increase the understanding of the complexity of the transition. Surveys and observations were used to collect data about the learning experiences of playing the game GO2Zero. The results show that participants liked to play the game and they considered the game a valid representation of the system. Further, the participants agree that they obtained a better understanding of the complexity of the residential energy system and experienced a variety of challenges in the transition. Simulation games, like GO2Zero, could become valuable instruments in local energy transition processes as they offer a safe environment for novices and experts to jointly experiment with the challenges in this process. These experiences could support the design of the transition process by helping actors to formulate goals and collaborative strategies for achieving those goals. Future research will focus on the use of this game for experimenting with different strategies and instruments and to analyze their effects.

**Keywords:** low carbon cities; energy transition; energy renovation; stakeholder management; simulation games

## 1. Introduction

The negative effects of using fossil fuel sources for our energy systems drives the need for new ways in managing these systems and new sources to fulfil our energy demand. In the European Union (EU-28), households are responsible for 25.4% of the final end use of energy use in 2015. The contribution is even expected to rise due to global warming and continued urbanization, leading to increased (peak) energy demand for cooling and, in turn, contributing to increased pollution and global warming [1]. Whereas many efforts have gone into the successful development of energy-neutral and zero emission concepts for new housing, the existing building stock turns out to be resistant to many of the policies and innovations supporting the reduction of carbon-based energy and increasing the use of renewable energy [2]. In the period 2007–2015, the EU-28 final energy consumption for the residential sector fell by −3.9% compared to −15.5% by industry [3]. Other sources than fossil fuel ones (e.g., wind, sun, biomass) and related technologies (e.g., wind turbines, solar cells, biomass combustion) are available and can be implemented, even though it is still a great challenge to fully fulfill our current energy demand with renewables [4]. However, at this moment, this is done insufficiently if we are to reach climate and emissions targets to which we have committed ourselves in international agreements, such as COP21 Paris, the UN Sustainable Development Goals, and European

and national legislation [4,5]. A faster and more impactful transition towards sustainable energy systems is necessary [6]. This requires not only the use of renewable sources. The transformation of cities from carbon-dependent systems to zero carbon ones will require a systemic change of the urban energy system [7]. Such systemic changes are also referred to as 'transitions'. Transitions have been described as transformation processes in which socio-technical systems change structurally over an extended period of time [8]. Transitions usually take place over a longer period of time. They are very recognizable in hindsight, but during the period of change it is difficult to recognize how individual actions and decisions contribute to overall system change. Due to the system complexities, such as the presence of multiple stakeholders, multiple levels of governance, multiple values at stake, and uncertainty of institutional and technological development in the longer term, it is difficult for actors to identify and assess the consequences of actions [9].

The transition towards a renewable energy system cannot be seen as a purely technical issue; it is strongly embedded within society [10,11]. A main concern is the resistance to energy innovations, e.g., by incumbents in the industry, governmental bodies, traditional energy suppliers, or by local communities, who perceive these innovations as disruptive, or even threatening, and seek opportunities to slow down or co-opt their development (e.g., [12,13]). However, without resistance, there is much uncertainty on the availability and costs and benefits of alternative energy resources and technologies to fulfil energy demand. There are many innovative technologies to choose from, each with their own individual and collective costs and benefits, financially and environmentally [14] and could have redistributive effects [11]. Making a choice depends on many interdependent social and technical variables with high uncertainties. Energy systems are, thus, complex social-technical systems, leaving actors who want to change the system with many unanswered questions about how to start, manage, and speed up the transition process.

Cities play a leading role in the energy transition. In 2013, cities were responsible for about two-thirds of global primary energy use and for about 70% of global $CO_2$-emissions, and with the growth of cities and urban economies, these numbers have undoubtedly risen and will continue to rise [4]. Implementing energy transition in cities involves an additional challenge. Decision-making is scattered over a large number of actors, and includes stakeholder networks from the energy domain and the domain of development and maintenance of housing. Due to the growing availability and affordability of local energy technologies and the increased recognition of the sovereignty of tenants and home-owners, individual residents have come to play a greater role in the urban energy system [15,16]. In addition, the awareness and recognition is growing that energy transition is not merely a technological process of implementation, but a process of allocating and distributing value, which requires democratic processes of deliberation and decision-making [17]. The transition from centrally-generated and distributed energy grids to more decentralized grids calls for interaction and coordination between actors from previously disconnected networks, operating according to different rule regimes, and adhering to different value systems and priorities [18]. To date, a coordinating actor or a set of coordinating institutions are absent, leaving stakeholders on their own when it comes to actions and strategies [7]. The absence of coordination is especially of influence in the energy transition of existing districts and buildings [19]. Throughout Europe, the implementation of energy improvement measures in existing residential buildings and homes is particularly difficult, encountering many obstacles, whether it involves simple technological add-ons or more intrusive processes of refurbishment, retrofitting, and renovation [2].

The development of a shared understanding of the opportunities and the benefits of a coordinated choice of energy measures is generally considered conditional for a legitimate, effective, and efficient urban energy transition, but, in reality, there are not many opportunities for stakeholders to jointly explore and discuss opportunities [1]. An interactive serious game might offer such a setting [20–23].

In this article, we present how a simulation game can be used to make stakeholders involved in local energy transition processes aware of the socio-technical complexity of the challenge of improving existing districts. In particular, the game aims to let participants understand the roles and opportunities

for actions of the stakeholders involved and the consequences of independent actions of the players on the direction and speed of the transition. They can explore their own preferences and constraints with regards to the transition goals, including when and how to achieve them, and experiment with different priorities and approaches. Further, they will experience that actions could have unexpected effects when other stakeholders decide to act in another direction. For example, when individual households decide to locally provide in all energy demand, it will affect the business case of an energy company who wants to construct a heat network in the neighborhood.

The main questions to be answered in this article are: what did the participants learn about the complexity of the local energy transition and on the opportunities to act? Which challenges and dilemmas did the participants experience? In addition to these content-driven questions, there is also the methodological question of whether this game was a good way to learn about the local energy transition.

This article starts with a description of simulation gaming and the steps taken to develop the GO2Zero game in Section 2. In Section 3, the article continues with an analysis of the challenges of the urban energy transition on a city district or neighborhood level, followed by a description of how these challenges have been integrated in the game GO2Zero. In Section 4 the research approach is explained and the results of the post-game participant questionnaires are presented. The results are discussed in Section 5. In Section 6 we conclude that GO2Zero is a valuable instrument in providing better insight into the complexities of the transition process. Both student players, as directly involved stakeholders, agree that gaming is a valuable method.

## 2. A Gaming-Simulation Approach towards Local Energy Transition

Serious games are games which are developed for purposes other than pure entertainment [24]. Among these other purposes are awareness-building, learning, health promotion, advertising, military training, and policy support. Commonly, serious games are often linked to computer or video games [25], however, there are also many non-digital serious games [14]. For this article, we focus especially on simulation games. These are games which offer participants a representation of a real-world complex system in a simplified way [26]. Participants can experience situations that are difficult to experience otherwise, and can learn from these experiences. In the multi-player, roleplay settings, such as GO2Zero, games also offer participants the opportunity to freely experiment with different strategies and experience and reflect on the consequences of one's actions [21]. Due to the complex nature of climate change and urban development, serious gaming is a useful support tool in this area [27,28].

Simulation games have a long history in the field of urban planning and, more recently, games are also used in the energy sector. One of the first games about urban planning is Metropolis [29], and, nowadays, examples can be found, like NRG [30], a single player game to optimize your house taking into account energy use as well as comfort. Another example is Flexnet [31] a multiplayer board game about the extension of the gas network. These, and other games, focus on a specific scope (household, gas network) or approach the issue from a specific actor who can take all decisions (e.g., household, gas company).

The simulation game GO2Zero intends to achieve learning goals at two levels: within the game participants learn of the complexity of and opportunities for action to further the local energy transition. In addition to learning within the game by participants, researchers can also learn from the game regarding the real-life complexity of relationships, possible actions, and their consequences as reflected in a game. As a simulation game can be considered as a complex system in itself, it makes it possible to represent a real-world complex system [26,32]. The knowledge and insights from the gaming sessions could be used in the design of the transitions' processes. In the debriefing of the game, the first steps can be taken to transfer the lessons learned in the game towards concrete actions or agreements [26,33]

The game has been developed as part of the *City-zen New Urban Energy* project [34], a project subsidized by the European Commission's 7th Framework Programme, running from 2014 to 2019.

In addition to demonstrating the best practices in urban energy transition in the lead cities of Amsterdam and Grenoble, the project hosts a roadshow, travelling to a number of small- and medium-sized cities in European countries to disseminate the technological innovations and lessons learned on local implementation. The game is part of this roadshow and invites local stakeholders to participate and learn about innovations and to explore possible individual and joint actions of key stakeholders. In addition to the roadshow, the game has been played in educational settings for academics and professionals. The participants in the game can take the lessons learned to heart when developing strategies and actions in their real-life environment in which they are also concerned with, or confronted with, local energy transition.

To achieve the learning goals, the goals *of* the game, GO2Zero simulates a small part of a neighborhood where a transition to zero building-use-related $CO_2$ emissions, a 50% reduction of energy demand and a change towards local production of renewable energy is required. These goals *in* the game, correspond with the overall goals of the City-zen project. Due to time constraints, the game has only been developed for one particular neighborhood, present in many European cities: a low-density suburban district with terraced houses, semi-detached houses, and low-rise apartment buildings. More urban typologies could be added to the game in the future, which would require a fine tuning in the type of energy measures available to participants, as well as the feedback provided on the costs and performance of these measures.

For the development of the game, an established game design approach was followed [21,29]. This includes a thorough system analysis. For the development of GO2Zero two key analyses were central to the set-up of the game: a stakeholder analysis identifying the key players, their goals, interests and concerns, and a systems diagram identifying the key variables in the system and the causal relationships between them. These analysis formed the foundations of the conceptual design of the game. After testing the conceptual design, the game was further developed (materials were designed and printed). Finally, the game were tested and played in the roadshows.

In the game, multiple players, representing different stakeholders, have to contribute to the goals in the game by selecting measures which influence a building's energy performance and energy use. Many of these measures are of a technological nature, such as triple glazing, insulation, and solar panels, but others are more service-related, such as the contract with the energy supplier. As in the real world, there is no guidance for participants on how they can best achieve the transition goals. However, they are explicitly invited to think of a strategy, which they can reflect upon and revise after each round played. This strategy may also involve the possible coordination of actions and collaboration with other players. While playing participants will observe the consequences of their decisions as well as the effects in relation to the decisions of other participants.

## 3. Energy Transition on a Neighborhood Level: A Multi-Stakeholder Setting

A transition towards zero carbon cities or districts has several challenges that need to be considered by actors involved in the transition process. There are two prominent challenges that have been at the core of the design of the serious game GO2Zero.

The first challenge concerns the many technological uncertainties. There is no straightforward strategy towards replacing our energy system with alternative resources and technologies [19]. The switch from a centralized, uniform system towards a more decentralized and distributed system leaves many opportunities for action for the stakeholders involved [11,35]. Some of these opportunities fit well together, but others may be dysfunctional when applied in combination. The different opportunities may influence each other's performance, in terms of environmental gains and return on investment, and may have redistributive effects. For example, on a building level, low-temperature heating requires a well-insulated home, and investing in such a technology in a poorly insulated home is inefficient and leads to a longer payback time; on a district level, the excessive local generation of energy requires increased grid capacity, requiring public investments besides private ones.

The second challenge, which will be the core focus in this article, concerns the involvement of multiple stakeholders, from house owners to network operators and from producers to different levels of public authorities, with different values, means, and scopes of action. Coordination between these stakeholders is complicated, given the absence of hierarchical relationships and networked relationships amongst stakeholders involved in the transition process [7,35]. Usually, such formal and informal relationships incentivize stakeholders to coordinate and attune actions. They operate on different scales, pursuing different goals and interests, which could lead to conflicting actions and an inefficient transition process, while, preferably, actions are taken that strengthen each other and maximize the individual and collective benefits [11,36,37].

In the following description of the key roles in the game, the main drivers and barriers for the support of the energy transition by the particular stakeholder are included. The stakeholders have been identified through the literature reviewed in this paper and through knowledge of the field by the researchers involved. Additionally, the system analysis, the diagram with key values, variables of the local energy transition process, and the causal relationships between these has been established in this way, making sure that the attention for the relationships was focused enough to be of use in a game, but that the overall set of relationships was simple enough to be able to be understood by (lay) participants of the game, and general enough to serve in different institutional and cultural settings where the game would be played.

The identified stakeholders and systems analysis with key variables and relationships have been verified in a series of interviews with different stakeholders involved in the City-zen project in Amsterdam and Grenoble, after which some final improvements have been made. In an iterative process in the game design, a simplified and combined stakeholder-systems diagram has been developed, which is the foundation of the game; this is presented in Figure 1. The interactions between these stakeholders of course take place within a wider institutional, cultural and regulatory framework, which participants are asked to take into account when playing the game. From each city, a civil servant, housing corporation/landlord, energy grid consultant, energy supplier, and a tenant or tenant representative were interviewed at the start of the project, in spring and summer 2015. In Grenoble, we also attended a workshop in which representatives from the landlords, tenants, and local government discussed the advantages and disadvantages of different energy renovation measures.
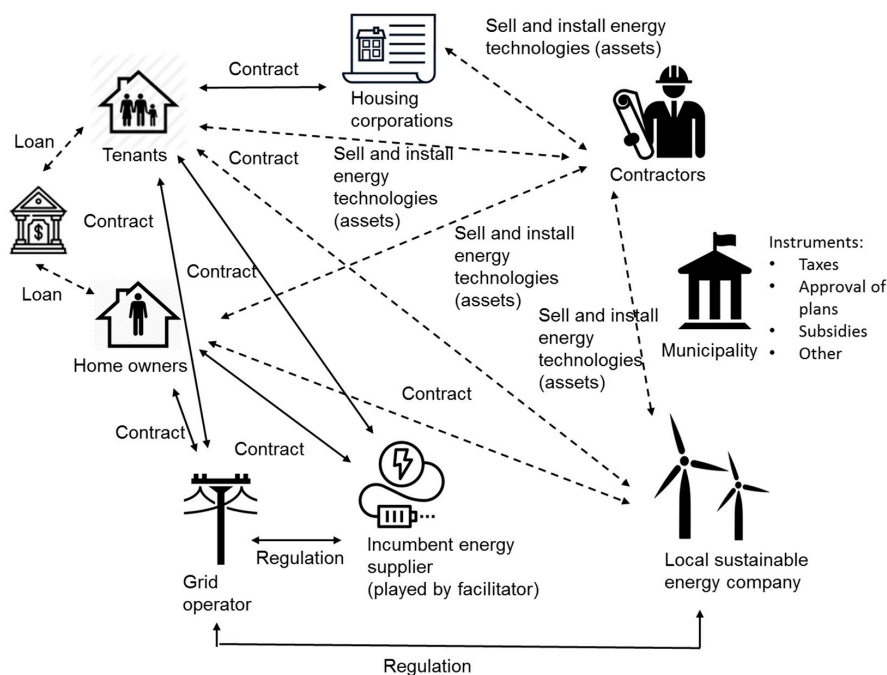


**Figure 1.** Overview of the actor network present in the game GO2Zero.

### 3.1. Stakeholder Network: Building Owners and Users

A first group of stakeholders involved in the urban energy transition are the building related stakeholders. This group is varied, including individual home owners, social, and commercial housing corporations. Each stakeholder operates according to its own values. The professional building owners and contractors are mainly driven by financial values, such as a high return on investment, market value of the buildings, and the lowest costs to reduce rental prices. In addition to direct financial considerations, more indirect financial and non-financial benefits of sustainable housing have become more important in recent years, due to regulatory pressures, such as the energy labels and the growing public demand for sustainable housing. Meeting such regulatory and market demand also asks for investments in properties. For home-owners, increased comfort resulting from energy renovation measures can be an incentive, in addition to a lower energy bill and value increase.

In addition to the owners, the users of the buildings, such as the families renting the dwellings, shop owners, small- and medium-sized enterprises working in the buildings, and community groups have a stake in the transition. The users of the buildings would like to have a maximum level of comfort, like a good in-house climate, low energy bills, and less maintenance. If you look on a more fine-grained level, these aspects may be valued differently per household. For one household, climate change issues may be more important than for another household. Another one may have more resources to spend on energy improvements than their neighbors. Additionally, other considerations might play a role. For example, shop owners could prefer to keep the doors open to attract more customers, while closed doors would reduce their heating or cooling expenses.

Looking at the variety of stakeholders and interests involved in the ownership, use, and also renovation and maintenance of buildings in a city, there are considerable differences between the goals and interests of these stakeholders. Some conflicting interests can be identified. As most of these actors are not replaceable, i.e., due to their presence in the area they are essential players in the local energy transition, and they are highly involved and impacted by the transition process, they are an indispensable part of the process of implementation of the energy transition.

### 3.2. Stakeholder Network: Energy Generation and Distribution-Related Actors

Stakeholders within current energy systems play a critical role in the local energy transition as well, such as grid operators, energy producers, energy suppliers, installation companies, and contractors involved in maintenance and refurbishment, and producers of renewable energy technologies. Most of these actors aim to run a profitable business. However, the energy supplier and the grid operator also have the task to deliver enough energy and ensure stability of the network. For a long time, energy systems in Europe had a rather simple structure of a couple of large producers, and a number of combined grid operators and energy suppliers. Since the liberalization of the energy markets in the EU in the late 1990s and early 2000s, the grid operators and energy suppliers have been forced to split into separate organizations, opening the market for new energy suppliers and increased competition. Furthermore, the introduction of local energy production, based on wind, solar, and biomass, resulted in an increasing number of stakeholders and a blurring of the distinction between producers and consumers when consumers, individually and collectively, started to feed the generated energy into the grid. Furthermore, alternative energy sources make the energy supply more insecure, with larger challenges for grid operators in stabilizing the grid, requiring additional investment in technology and infrastructure.

The transition towards carbon-free districts will most likely increase competition between different energy sources and local suppliers while risking grid imbalances with black-outs as the ultimate consequence. A number of configurations of local production and consumption reduction are possible, with consequences for the many variables and stakeholders involved. The main relationships and constraints for simulated action are: the choice for different local or residential production options (photovoltaic (PV) farms, wind farms, PV panels on roofs), the limited land available for PV farms, the need to increase the grid capacity to accommodate new decentralized production

capacity, the limited budget of building owners and residents to invest in energy savings or production. These choices have been included in the game as well, and players experience the consequences of these choices once selected. For example, the municipality may have decided to invest in PV farms, but only notices afterwards that the local energy producer needs to have the resources to build these and should have been included in the decision-making.

The companies developing, selling, and/or installing energy transition related technologies will play an important role as well. They will provide their preferred technologies and brands at a certain price, which could influence the choices stakeholders make for certain (configuration of) technologies and investments. Prices, however, are uncertain, due to rapidly developing markets and continued technological innovation. Additionally, the return on investment is uncertain, depending on many variables, such as the development of the energy prices and the actual savings achieved by innovations, since this strongly depends on characteristics of the energy behavior of users (residents) and the building (level of insulations, building size, materials used, etc.). Location specific characteristics of each apartment, dwelling and district result in different opportunities and constraints, making standardization of the configurations, sets of preferred energy transition measures, unlikely. Specialized and unbiased advice on suitability of measures is difficult to obtain from the stakeholders who have a stake in a particular grid, source, or technology.

### 3.3. Stakeholder Network: Governmental and Non-Governmental Organizations

Finally, stakeholders from both governmental and non-governmental organizations will try to steer or influence the transition process. Non-governmental organizations like environmental groups, local energy initiatives, citizen pressure groups, or housing associations often play an ambiguous role in the energy transition process. On the one hand, they are trying to support and stimulate the transition, by putting pressure on policy makers or providing information to citizens and other stakeholders. On the other hand, they sometimes try to delay particular processes of the transition if they believe energy transition has negative consequences for their constituency, members, or followers. Governmental organizations at the European, national, and municipal levels often have a more holistic view, attempting to balance climate objectives, financial aspects, and equality between citizens. Through their regulatory and financial instruments, they have the power to stimulate the transition process or incentivize the stakeholders who do not take part in the transition. Whether to use these instruments and to what extent depends on the political climate and availability of instruments, many of which are very local.

### 3.4. Highly Interconnected Stakeholders

All stakeholders in our analysis are interconnected to a certain degree, and the choices of one stakeholder could influence the choices of other stakeholders. In this way all stakeholders influence the path, speed, and efficiency of the transition process. An unstable or indecisive government will lead to an uncertain playing field, leading to risk-averse behavior of stakeholders. Dependencies between stakeholders are often based on rules and regulations. For instance, tenants who do not own the property they live in are not allowed to implement any changes without the consent of the landlord. In turn, landlords, private or public, cannot apply large changes without the permissions of the tenants. The extent to which tenants' consent is required differs from country to country, and within countries private landlords and public landlords may be regulated differently. Again, this increases the challenge of formulating uniform transition strategies.

Interdependency between energy producers, grid operators, energy suppliers and energy users, manifests itself through energy supply. During peak hours of use, suppliers need to increase the production and grid operators need to avoid blackouts. With an increase of local energy production, solar or wind, distribution grids need to be adapted to account for peaks in production, requiring increased grid capacity and additional electricity transformers in the area.

There is no single stakeholder who can manage the transition process on its own. It is also unclear which stakeholder is best positioned to start and coordinate the necessary changes. For example, experiences in the Netherlands, a country with a fine-grained grid to supply natural gas to homes, show how a lack of coordination can result in the expansion or renewal of the natural gas grid while, at the same time, a heat network is being developed and constructed. Coordination of investment decisions and strategies between the multiple stakeholders who play a role in the local energy transition is crucial for delivering a secure, zero carbon energy supply in cities and districts. This implies a need for communication and interaction between stakeholders who are not used to being dependent on each other, and in some cases have not met before in these roles or on this issue. This includes the communication and interaction between professional and non-professional actors, i.e., residents, who tend to be more focused on the direct impact of investments on their budget and homes than on the higher climate goals, but who also might sometimes be represented by, or organize themselves into, highly professional interest representation organizations.

When stakeholders have multiple roles, like being a home owner, energy consumer, and electricity producer, the complexity of coordination can increase even further. Another source of complexity is that new roles will emerge. For example, local energy producers and suppliers, neighborhood energy saving initiatives, or energy renovation advisors. In the near future, anyone involved in energy transition will have to deal with much more diverse and differentiated set of stakeholders and roles than today.

In summary, the transition process is embedded in a complex stakeholder network, consisting of highly interdependent actors, which is facing a period of dynamic change, with the emergence of new roles, stakeholders, and technologies, restructuring the technological system and the roles and power positions of incumbent stakeholders and the regulatory frameworks by which they are governed. If these actors have to work together to efficiently contribute to the energy transition, they have to get to know each other and start a dialogue about their roles, responsibilities, interests, and actions. As this takes place with multiple actors, Duke [12] used the term "multilogue". According to Duke, an excellent way of doing this is via gaming.

## 4. Simulation Game GO2Zero

In many cities, there is no clear agenda and commitment towards a transition to renewable energy systems and the adoption of technologies supporting this transition, even though there tends to be political support for the overall climate ambitions [1]. The locational peculiarities, in terms of properties of the stakeholders, buildings, and technological opportunities for energy reduction and the switch to renewables, will make it difficult to define one best approach of the energy transition. Addressing questions of authority, allocation of costs and benefits (including split incentives), scale (concerning the appropriate geographical and administrative levels for applying certain technologies), ownership, and renewable sources and technologies (both sources and technologies can differ with regards to availability, costs and benefits, lock-in etc.) will lead to different transition paths for different cities, or even different districts. Learning about different transition paths and configurations of local sustainable energy in relation to the energy performance of buildings requires experiential and exploratory approaches and tools. As concluded from the above analysis of the stakeholders, individual preferences and interaction between stakeholders are key in exploring possible strategies and actions. Simulation games offer a tool that takes these social aspects into account and, at the same time, provides the opportunity to experience and explore the playing field of the energy transition process, technologically and institutionally [38].

*GO2Zero: The Game*

The game GO2Zero simulates a transition process of a neighborhood towards sustainable energy situated in a generic residential neighborhood, with small terraced houses and semi-detached housing. In the design of the game, we have set some clear boundaries to make the game more playable and

more focused. As the focus is on the residential energy systems, the industry, transportation and the commercial businesses sector were left outside the scope. For reasons of playability, apartments or houses with specific characteristics are also not simulated in the game. Another abstraction of the reality is the representation of energy consumption, $CO_2$ emission, and energy production in fiches. The prices of assets (energy renovation measures and energy technology measures), energy, and income, as well as taxes, are not realistic numbers, as we chose to keep things easy and count numbers as 1, 2, 5, or a multiplier of this. We made sure that the prices are realistic in relation to each other.

Multiple players, divided over different roles, need to take actions to reduce energy consumption, to increase sustainable production, and to make their district $CO_2$-free. The district is represented on a traditional cardboard, with 12 houses with their families being connected to the gas and electricity grids (See Figure 2). All households have four piles of fiches representing per household: two piles represent the energy consumption (one for heat and one for electricity), a third are the renewable sources of the energy supplied, and the fourth illustrate the housing-related $CO_2$ emissions. The pile of renewable sources used should go up, whereas the other piles should go down during the game. The areas which can potentially be used for local renewable energy production areas have a place on the neighborhood map as well.

The participants play different families (tenants and home-owners), the municipality, the electricity grid operator, two technology contractors active in the field of heating, ventilation, and air conditioning (HVAC), a housing corporation, and a local energy company. Half of the families rent a house from the housing corporation and the other half are home-owners. At the beginning all households have a non-renewable (grey) energy contract with a national energy company (played by the facilitator). The grid operator is responsible for ensuring sufficient capacity on the grid. The capacity needed will change due to actions of the families and the housing corporation, but also by the newly-installed production capacity of the local energy company. The participants are placed at different tables in the room, with a placemat containing information about their role, objectives, available contracts, and assets (see Appendix A for the role description of the municipality). Players can move around and communicate with each other, but are not explicitly instructed to do so.

The challenge in the game is to reduce the $CO_2$ emissions in the district back to zero. Additionally, participants should reduce the neighborhood's energy consumption by 50%, and produce all energy locally. The transition process, the process by which they will make the necessary changes, has not been determined. Therefore, the participants need to think about strategies to cut carbon emissions, to reduce energy demand, and produce renewable energy locally. Cooperation and coordination is necessary, but they must consider their personal values, objectives, as well as their financial possibilities and consumption pattern.

A gaming session of GO2zero starts with a briefing about the background of the energy transition challenge and an introduction to the game (See Table 1 for the agenda of a session). The game starts with a strategy phase where participants have time to read the information on the overall goals and their role and develop a strategy. After the strategy, the game takes place in several rounds consisting of three steps: (1) payments; (2) negotiation; and (3) consumption. In the 'payments', households receive their salary and they have to pay their rent, energy bills, grid costs, and municipal taxes. During the 'negotiation', all stakeholders can buy technology assets, such as insulation, triple glazing, and solar panels, negotiate about costs, make appointments, change contracts with energy suppliers or landlords, and organize community meetings (see Figure 3). In the 'consumption' stage, the city map, including indicators for the $CO_2$-emission reduction, the share of renewables and the energy use reduction, is adapted to the new situation. A complete gaming session has four rounds, offering participants enough time to understand their role, the system, experience the consequences of their actions (did investments really lead to the intended results), and revise their actions and strategies. After the fourth round, the final achievements on the energy transition goals are registered and all participants have to count their money and receive an overview of their individual financial situation and energy performance.

Then a debriefing starts, during which participants share and discuss their results, followed by sharing of emotions surfaced during the game, and reflect on the overall outcomes of the game. Further, they discuss what has happened, which challenges they faced, and how this could have been done differently. Finally, together they look forward to what this could mean for the transition process in real-life, for their own particular city, and for their own role.
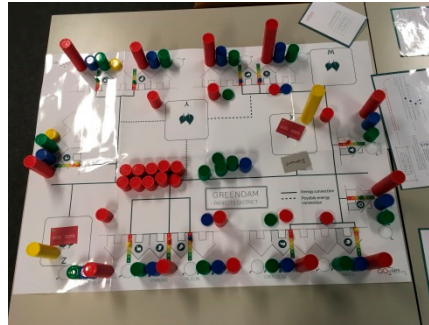


**Figure 2.** Representation of the district. The piles represent $CO_2$ emission, energy consumption per household (heat and electricity) and use of renewable energy sources.



**Figure 3.** Discussion with grid operators (picture used with permission).

**Table 1.** Agenda of a GO2Zero session.

| Time | Start and End of the Game | Game Play | |
| --- | --- | --- | --- |
| 30 min | Introduction | | |
| 45 min | | Strategy phase | |
| 45 min | | Round 1 | 1. Payments |
| | | | 2. Negotiations |
| | | | 3. Consumption |
| 45 min | | Round 2 | 1. Payments |
| | | | 2. Negotiations |
| | | | 3. Consumption |
| 45 min | | Round 3 | 1. Payments |
| | | | 2. Negotiations |
| | | | 3. Consumption |
| 30–60 min | Debriefing | | |

Each gaming session had at least two facilitators. In case of parallel sessions, each session requires an additional facilitator. The facilitators of the game have several roles. The game overall facilitator introduces the game and leads the discussion in the debriefing. During the game play, the facilitators keep track of the time and answer questions of the players. Further, they play the roles of the national energy company, where inhabitants can buy their energy, the bank, who pays salaries and who can give loans for investments, and a retailer, who sells assets. In the consumption step, the facilitators

update the map. Based on the investments in assets, the piles could change as well as the energy label of the houses and the capacity of the grid. After all changes are completed, the facilitator calculates the needed capacity of the network by summing the consumption of electricity and the local production of electricity (as a measure of the peak capacity) and compares this with the capacity of the grid. If the capacity is insufficient, the grid operator does not receive the income from the contract with the residents as a penalty.

## 5. Results

### 5.1. Research Approach: Questionnaires and Observations

The sessions were evaluated with a pre-game and post-game questionnaire or only with a post-game questionnaire if it was not possible to send a pre-game survey in advance. In case of only a post-game survey, personal and other background information was added to the survey. These questionnaires consist of Likert-scale statements, open questions, and multiple choice questions. The topics of the questions are personal information (such as age, role), expectations about the game, experiences with the game, and participants' opinions about the transition process. For the questions about expectations and experiences with the game a five-point Likert scale was mainly used as these are used in comparable game studies and the categories could be easily labelled (strongly disagree, disagree, neutral, agree and strongly agree). In the questions where people have to compare two extremes (such as simulation vs. game) a seven-point scale was used to obtain greater variance in the answers.

Preferably, printed surveys are distributed to the participants just before and just after playing the game, allowing participants to hand them in directly. This leads to the highest response rates (see Table 2). Missing surveys were mainly caused by participants who came late or had to leave early. If it was not possible to distribute printed surveys, an online version was sent to all participants. A first invitation was sent within one day after the session. After one week a reminder was sent. Participants were given approximately two weeks to fill in the online questionnaire. The response to the online survey was lower.

Observations were done by all facilitators. Facilitators wrote down the observations especially about the topics of meetings and remarkable actions of players. Additionally, notes were taken in the debriefing. After the session, the notes of individual facilitators were collected.

**Table 2.** Overview of the GO2Zero sessions, number of participants, and number of surveys.

| Sessions | Date | Number of Participants | Number Pre Survey | Number Post Survey |
|---|---|---|---|---|
| Amsterdam | 19 October 2016 | 16 | No survey | No survey |
| Dubrovnik | 2 November 2016 | 16 | 15 [1] (94%) | 4 [2] (25%) |
| Tilburg | 3 March 2017 | 49 | 32 [2] (65%) | 13 [2] (27%) |
| Menorca | 26 April 2017 | 14 | n.a. | 2 [2] (14%) |
| Delft | 5 July 2017 | 20 | 6 [2] (30%) | 19 [1] (95%) |
| Sevilla | 22 November 2017 | 11 | n.a. | 9 [2] (82%) |
| Birmingham | 7 December 2017 | 48 | 43 [1] (90%) | 41 [1] (83%) |
| Total | | 174 | 96 | 88 |

[1] Paper based survey; [2] Online survey.

### 5.2. Gaming Sessions

The first test gaming session was in October 2016, in Amsterdam, with professionals from various organizations involved in the local energy transition. Since then, the game has been played six times with a total of 174 participants. Three sessions were played with the real stakeholders involved in local energy transition processes in Dubrovnik, Sevilla, and Menorca. Two sessions were played in an educational context, at the universities of Tilburg and Delft, and one session, in Birmingham, was played with energy transition experts, but was not directly related to a specific transition process.

*5.3. Participants*

There were slightly more male participants (57.7%) than female participants (42.3%). The age of the participants was very diverse. The youngest participant was 18 years old and the oldest was 63 (Average = 32.5; sd. 12.5). This was expected as the game has been played with Bachelor students as well as professionals. In total 30.4% of the participants were students, mostly students participating in a policy-making course, several as part of a summer school on sustainable housing in Europe. Other participants were professionals, mainly with a role of innovator (15.2%) and researcher (22.3%).

*5.4. Quality of the Game*

Some of the questions relate to how participants experienced the game. Table 3 shows the results indicating the quality of the game and the session. Participants agree that the game was clear (M = 4.18) and relevant (M = 4.31). They liked to play the game (M = 4.31) and agreed that they have identified with their role (M = 4.15). Furthermore, they indicated they would like to play the game again (M = 3.89), however, the opinions about this statement varied a great deal.

**Table 3.** Statistics about the game play experiences.

| Statement | N | Mean | St. Deviation |
|---|---|---|---|
| The aim of GO2Zero was clear | 88 | 4.18 | 0.82 |
| The aim of GO2Zero was relevant | 88 | 4.31 | 0.68 |
| I really put myself into my role | 85 | 4.15 | 0.78 |
| Given the aim of the simulation, the performance indicators were sufficiently detailed | 87 | 3.68 | 0.95 |
| Given the aim of the simulation, the dynamics were sufficiently realistic | 86 | 3.86 | 0.90 |
| I enjoyed taking part in GO2Zero | 85 | 4.31 | 0.86 |
| I would like to play GO2Zero again | 85 | 3.89 | 1.08 |

Based on a 5-point Likert scale, where 1 means totally disagree and 5 totally agree with the statement.

Respondents slightly agreed that the game was sufficiently detailed and represented the dynamics of the real world, respectively M = 3.68 and M = 3.86. This can be explained by the high level of abstraction at which the game was designed, with only 12 houses and fiches representing the energy use and $CO_2$ emission.

*5.5. Games as Supporting Instruments*

One of the assumptions at the start of the development of this game, was that gaming is an innovative way to experiment with and explore social issues of energy transition, especially the dependencies between different stakeholders. In the survey, we asked the participants about the value of gaming in the transition process.

Table 4 shows the results. Participants agree that the GO2Zero game is worthwhile for regions and cities (M = 4.02) and can be used to promote communication (M = 4.01) and promote cooperation (M = 4.01) between different stakeholders. Thus, the game could be used to contribute and support the social aspects of the transition process.

**Table 4.** Statistics about the value of this game for the transition process.

| Statement | N | Mean | St. Deviation |
|---|---|---|---|
| The use of Go2Zero is worthwhile for regions and cities | 84 | 4.02 | 0.92 |
| I think that Go2Zero can promote cooperation between different stakeholders | 85 | 4.01 | 0.91 |
| I think that Go2Zero can promote better communication between different stakeholders | 85 | 4.01 | 0.87 |

Based on a five-point Likert scale, where 1 means totally disagree and 5 totally agree with the statement.

Furthermore, we asked participants how they describe the tool. Do they see GO2Zero as a simulation or as a game, as a learning instrument or as a policy support tool, and as a playful interaction or as a serious intervention? The participants could score on a seven-point scale, with 4 in the middle.

There was no consensus among the participants about how to define GO2Zero (see Figure 4). On the axes of the simulation vs. game, the median was 4, which means in the middle. Maybe this is coherent with our objective to build a simulation game. On the axes of learning instrument vs. policy support tool, the median was 3, which is slightly more to a learning tool, and for the axis playful interaction vs. serious intervention the median was 4. As the boxplot shows, the answers varied for all axes.
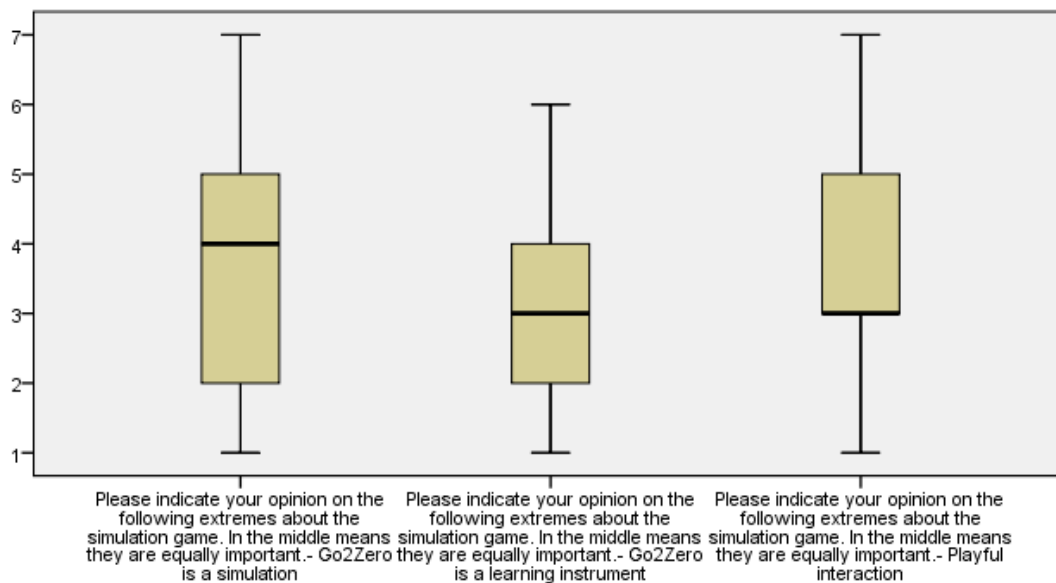


**Figure 4.** Boxplot regarding the opinion of the participant of the type of game.

*5.6. Learning about Transition Process*

One of the objectives of the game is for participants to get a better understanding of the socio-technical complexity of the transition process. The results can be found in Table 5.

**Table 5.** Learning experience after playing GO2Zero.

| By Playing This Simulation Game I... | N | Mean | Std. Deviation |
|---|---|---|---|
| 1. learned to work together with stakeholders | 84 | 3.80 | 1.027 |
| 2. gained knowledge about technologies in the transition process | 83 | 3.14 | 1.201 |
| 3. gained insights in different stakeholders in the transition process | 85 | 3.79 | 0.952 |
| 4. learned about different positions and actions of stakeholders in the transition process | 85 | 3.68 | 0.966 |
| 5. understand different transition paths to achieve the common goal of zero $CO_2$ | 85 | 3.39 | 1.176 |
| 6. experienced the dynamics of the transition process | 84 | 3.88 | 0.842 |
| 7. experienced the interaction between different actions of stakeholders and effects on a system scale | 85 | 3.89 | 0.802 |

Based on a 5-point Likert scale, where 1 means totally disagree and 5 totally agree with the statement.

As can be seen in Table 5 the participants mostly agree or slightly agree with the statements about learning effects. They especially learned to work together (M = 3.80), gained insights in the different stakeholders (M = 3.79), experienced the dynamics of the transition process (M = 3.88) and experienced the interaction between the stakeholders and effects on a system scale (M = 3.89).

If we look at the separate sessions we see varying results. The sessions in Dubrovnik, Sevilla and Menorca had much higher means (see Table 6). These results show that the game has an educational value to get a better understanding of the complexity of the transition process.

**Table 6.** Learning experience after playing GO2Zero in Menorca, Dubrovnik, Sevilla, and TU Delft.

| By Playing This Simulation Game I... | Menorca (n [1] = 2) | | Dubrovnik (n = 4) | | Sevilla (n = 9) | | TU Delft (n = 18) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| 1. learned to work together with stakeholders | 4.20 | 0.71 | 4.0 | 0.82 | 4.22 | 0.97 | 4.22 | 1.26 |
| 2. gained knowledge about technologies in the transition process | 3.50 | 2.12 | 3.25 | 1.26 | 3.87 | 0.99 | 3.89 | 0.96 |
| 3. gained insights in different stakeholders in the transition process | 4.00 | 1.41 | 4.00 | 1.16 | 4.11 | 0.93 | 4.11 | 0.83 |
| 4. learned about different positions and actions of stakeholders in the transition process | 3.50 | 2.12 | 4.25 | 0.96 | 4.00 | 1.00 | 3.89 | 0.90 |
| 5. understand different transition paths to achieve the common goal of zero $CO_2$ | 4.00 | 1.41 | 3.75 | 0.96 | 4.33 | 1.00 | 3.78 | 1.06 |
| 6. experienced the dynamics of the transition process | 4.50 | .71 | 4.25 | 0.96 | 4.22 | 0.97 | 4.06 | 0.93 |
| 7. experienced the interaction between different actions of stakeholders and effects on a system scale | 4.50 | 0.71 | 4.25 | 0.96 | 4.11 | 0.93 | 4.11 | 0.76 |

[1] *n* is the number of respondents of the post-survey per session.

## 6. Discussion

### 6.1. Quality of the Game

The numbers showed that the participants enjoyed playing the game and have succeeded in identifying with their role. This was in line with the observations of the facilitators, who saw hard working people trying to get the best out of it. All sessions showed some bottlenecks in the process (willing to invest but no resources to do this), and a lack of communication and coordination (such as increasing network capacity and, at the same time, taking energy reduction measures). The facilitators also observed that participants experience some realistic dilemmas during game play, such as who is taking the initiative (in most sessions participants were looking at the municipality, who lacked information to take a decision), operating alone or together. This became visible in one of the sessions

in Tilburg, where the residents discussed to collaborate to get a stronger position, and the facilitators saw some unexpected behavior: for example, the grid operator who was taking the lead in the process to make sure that it had a strong position in the network and that its role as network operator would be needed in the future [39]. The participants commented that they especially liked the need to communicate in the game, a need that participants in some game sessions discovered only in a very late stage, and experiencing the socio-technical complexity of the transition. Many participants remark that the game really shows the complexity of implementation of seemingly straightforward goals.

Some of the participants preferred to play longer as only after a few rounds they started to understand what the real challenge was. This is in line with the theoretical insights on learning via gaming, where you start with exploration of the system and the problems. After that there is the phase of experimentation and solving the issues, and the last one is a phase of excelling, where one masters the system and attempts to get the optimal score. Probably, the playing time of this game, 3 to 4 h, did not allow one to really master the system. Another point for improvement was the lack of background knowledge of the roles and the energy system in general of the participants in some of the sessions. Especially, the students at Tilburg University, not specialized in engineering or energy transition, commented that they did not know what the tasks and responsibilities of different stakeholders are in reality. Therefore, they had some start-up issues which could be covered by a more elaborate introduction on the urban energy transition challenge and the key stakeholders.

### 6.2. Games as Supporting Instrument

Participants disagree about how to describe the game as a tool. Most participants found the game something in the middle between a simulation and a game, in the middle between a learning instrument and policy support instrument, and in the middle between a playful interaction and a serious intervention. This is an interesting outcome as this is one of the strengths of simulation games that they can be used in multiple ways.

A discussion on whether GO2Zero is a learning instrument or a policy support instrument depends also on people's definitions of these terms, but perhaps also of the type of participants. When played with professionals, they emphasized that learning about the complexity of the transition process can support the policy-making process.

### 6.3. Learning about the Transition Process

The results showed a diversity of learning effects within and between different groups. According to the comments of participants, they especially learned to understand the complexity and the impact of (not) taking the lead. Even though European municipalities have limited formal or regulatory powers to initiate and enforce building-related energy improvements, participants generally considered the municipality the most authorized player to take up the coordinating role in the local energy transition process. The students in one of the sessions reflected on the experience of stakeholders being dependent on each other, the need to share information, and they remarked that even with the common, given objectives it was difficult all the same.

The second objective of learning about opportunities for further action mainly takes place in the debriefing. During the debriefing, especially in the Sevilla, Menorca, and Dubrovnik, a great deal of information was shared amongst participants on their regional specific traits and challenges and how different laws and regulations impact the energy system and the transition process. The discussion about the obligation to be connected to energy grids is an example. If a house owner has the freedom to disconnect from a grid, the house owner has a larger scope of instruments and more strategies to play and act than when a connection is mandatory. The results also showed a large difference between these sessions, with many expert practitioners involved, and the sessions with less directly involved participants. In sessions with directly involved people, the participants became quickly acquainted to the game scenario and started with making strategies earlier. Further, the experiences of the game could be related more easily to real practice and they brought specific local issues into the game.

Possible explanations could be the already-discussed active knowledge about the energy system and its stakeholders, their interest in this topic, and the direct connection to their daily practice.

An interesting follow-up question would be: what does learning in the game and from the game mean for the transition process itself? To answer this question, we need to further investigate the impact of GO2Zero game.

*6.4. Limitations of Gaming Simulations*

Simulation games as GO2Zero have an added value in simulating complex socio-technical systems and giving participants a safe environment to experiment freely. However, to make this possible gaming also has some limitations. Limitations are mentioned for the gaming approach, as well as the research approach.

Simulation games are, as well as simulations, abstractions of the real world system under study. In general for gaming this level of abstraction is higher as participants have limited processing capacities. In case of too many variables and choices players cannot decide anymore and game play will become impossible [33,38] (simulations can be used to add a certain level of detail to see the effects of choice, but they have the disadvantage that it becomes a black box and it is more difficult to understand the underlying relations. A consequence of the abstraction level is the challenge to make a direct relation to reality [33]. The role of the facilitator is crucial in the transfer of experiences in the game to actions in reality. Collaboration between a game facilitator and a local expert in the debriefing of the game showed a good combination to support the translation of experiences in the game to the local situation and discuss opportunities.

From a research perspective, games have the disadvantage of getting enough information to get statistical reliable data about the effects of chosen strategies in the game, as the large number of variables, are hardly to be controlled in a dynamic situation of game play, and the limited possibilities to play a game many times [40]. A comparison of specific outcomes are difficult as city-specific issues, cultural aspects, and regulations will be different. Therefore, we do not conclude that the outcome of the game itself is leading, but we focus on the process and the discussions which where underlying the choices. Another limitation is the choice for a subjective measurement of learning. However, self-reported learning is a good first indicator [26].

## 7. Conclusions

This article started with describing the need for the transition towards sustainable cities. To get better insights in the energy transition process on a neighborhood level the game GO2Zero was developed, played, and evaluated. The game was, after one test session, played six times with a total of 174 participants. Three sessions were played with the real stakeholders involved in actual transition processes. Two sessions were played in an educational context and one session was played with energy transition experts, but was not directly related to a specific transition process.

The main questions we wanted to answer were: What did the participants learn about the complexity of the local energy transition and on the opportunities to act? Which challenges and dilemmas did the participants experience?

Before we answer these we start with the methodology regarding the use of gaming as a learning tool. From the results of the surveys we can conclude that the participants liked to play the game and that they really played the given role seriously. The dynamics of the transition process in the game, the socio-technical complexity of the challenge, was considered realistic and gave room for discussion afterwards. Participants gave an average score for the level of detail of the game. Even though the simulated energy system was defined on a higher level of abstraction than the real world, participants emphasized that the game roles covered all key stakeholders and their roles in the energy transition. Main points for improvement are extending the time of play, to allow participants to reach the goals of zero $CO_2$ emissions, and the need to provide more detailed explanation about the roles and the energy systems for players not familiar with this topic.

Participants agreed that this game is a valuable tool because it can promote coordination and communication between different stakeholders, and that the use is worthwhile for both regions and cities. In combination with the realistic behavior of the stakeholders participants considered it especially valuable to experience the bottlenecks, lack of consensus about what to do, and the consequences of (a lack of) leadership in this process. They saw the GO2zero game as a learning and policy support instrument, as a playful and serious intervention, and as a simulation game.

The sessions with participants showed that participants learned and had relevant discussions about the different transition paths, the dynamics, the different perspectives of stakeholders, and the interaction between them. We can also conclude from the perceived learning as presented in Table 6 that the learning effects of these aspects are stronger amongst participants already involved in the energy transition process. In the game, participants observe different challenges as the question who needs to initiate the process and participants observed the consequences (unnecessary investments in the network) due to a lack of communication. These, and other, in game observations are input for the discussion in the debriefing to elaborate on and make a translation to the local situation.

These conclusions also give some interesting directions for further investigation. To mention some: What are the effects of having a better understanding of the energy transition and the need for cooperation on their behavior in real life; How can the game be used to experiment with new policy strategies and instruments? Or to experiment with new conditions, for example, in the form of changes in the pricing of different energy sources or technology? What are the mechanisms driving resistance of stakeholders to implementation? How could the technological complexity better be communicated to stakeholders? Addressing these questions will influence the potential use of the game, and the strategies developed by the players within the game.

To sum up, GO2Zero could become a valuable instrument in local energy transition processes as it offers a safe environment for novices and experts to jointly experiment with the challenges in this process. The sessions showed that the participants had to think of their goals and collaborative strategies for achieving those goals. In the debriefing, the participants started a discussion about the design of the transition process for their city. Further impact could be achieved when the game is more integrated in a real local energy transition process. The game could especially play a role at the start of a transition process, to make stakeholders acquainted with each other. In addition the gaming creates a joint experience, which can serve as a common frame of reference for the stakeholders during later stages of the transition process.

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## Appendix

The picture shows the role description of the municipality, which the players receive at the start of the game.

**Figure A1.** Example of the instruction materials handed out to the players at the start of the game: role description of the municipality.

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