An acceptable simulation of acceptability?

Participatory-model building of the acceptability of hydrogen infrastructure

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Abstract

Realising renewable energy innovation can adversely affect residents and lead to societal opposition. This causes delay of projects and missed opportunities. This paper proposes a participatory modelling process which leads to a more acceptable infrastructure, not in terms of interest but in terms of moral acceptability. The paper describes the process of modelling the acceptability of energy technology in households for the case of Stad aan ´t Haringvliet. Complexity, uncertainty and the need for very specific data ask for a modelling approach that goes beyond the traditional way of gaining input for and interpreting output of a model. Especially, when there is no clear problem owner, the problem specification asks for the engagement of relevant stakeholders. Participatory modelling is a method that is able to tackle this challenge as it captures the heterogeneity of the different stakeholders involved and gets grip on diverging views and complexity. This paper reflects on the agent-based modelling process that has been broadened with activities for stakeholder engagement. The case study of Stad aan ´t Haringvliet illustrates how to build and use an agent-based model to support a pilot project for introducing hydrogen to the local gas grid. The model assesses acceptability following the capability approach (CA). The CA is used as guiding frame to receive input from stakeholders and translate it into a model. The paper concludes that the modelling process complies with the goal participatory modelling and identifies the added value of engaging stakeholders in the case of Stad aan ´t Haringvliet.

Keywords Participatory modelling, agent-based model, moral acceptability, levels of engagement, capability approach

1. Introduction

Climate change asks for fast decisions and perseverance. Decreasing energy consumption and energy production from renewable resources are the most important measures that mitigate for climate change
and reduce CO₂ emissions. Decreasing consumption and switching to sustainable production causes a far-reaching change of the energy system. Consequences of this change for end users of the system are inevitable. The problem is that the changes are not always desirable as changes in production effects security of supply and changes in consumption effects costs. Realising renewable energy innovation can adversely affect residents and lead to societal opposition. This causes delay of projects and missed opportunities. Spatial siting of sustainable energy technology is still difficult (Devine-Wright et al., 2017; Jolivet & Heiskanen, 2010). Implications can be unequal distributed costs and benefits, misperceptions and unrest (van der Horst, 2007; Wolsink, 2000; Wüstenhagen, Wolsink, & Bürer, 2007). When developing project plans societal implications are often insufficiently thought through. This is why projects and pilots often cause diverging interests and a clash of values. More knowledge is needed to gain public support. Even though, many frameworks have been developed to assess acceptability (Cohen, Reichl, & Schmidthaler, 2014; Künneke, Mehos, Hillerbrand, & Hemmes, 2015; Wüstenhagen et al., 2007) of energy infrastructure, still no approach has been found to speed up projects and foster consensus between stakeholders and residents.

Modelling is a valuable tool to analyse these complex socio-technical energy systems and come up with policies for complex socio-technical problems. There is a variety of approaches and methods that capture the interaction of humans with their technical environment using a model or simulation. To make a model a powerful and valuable tool, the model should clearly not simulate the complexity of the real world as precisely as possible, but should address a specific problem (Nikolic & Kasmire, 2013). However, identifying such a problem is difficult. Socio technical-problems are often wicked and ill-defined(Weber & Khademian, 2018), it is hard to assure that the model answers the right questions. Especially when a project is in the early phase of its trajectory and most decisions have not been made yet it hard to get grip on what challenge to tackle. In this early project phase there might even not yet be a clear problem owner or project leader. The roles and responsibilities may still be undefined.

Modelling not only helps to assess quantifiable problems, but it is often applied in social sciences (Gilbert, 2007). Agent-based modelling in particular allows for identifying the mechanisms that explaining the connection between individual and broader social behaviour. This technique is capable of dismantling complexity to such an extent that uncovers elements playing a key role in the system performance. Modelling has the purpose of providing a shared understanding of environmental or social issues, analysing causes of issues, exploring strategies and structuring formulations of goals and objectives (Jones et al., 2009).

When simulating societal issues, it is an important first step to identify the problem to be solved. Modellers might have another problem in mind than stakeholders and the public. Participatory modelling is able to adapt to issues that arise from stakeholder engagement instead of building a model that matches the expertise and views of the researchers (Prell et al., 2007). Participatory modelling is an approach that considered for increasing the value of modelling approaches for decision making in practice. The approach allows for building multidisciplinary models due to stakeholder and even public engagement during the modelling process. Engagement asks for collaboration and collaboration on its terms causes mutual trust and learning. Another benefit is that collaboration and participation increase commitment towards actions that have been developed based on the modelling process (Videira, Antunes, Santos, & Gamito, 2003). A distinction must be made between public and stakeholder engagement. Public engagement addresses the involvement of a broad group of people that is not directly involved in the project, but somehow affected by the system.

During a participatory process it is important in how parties get a say. Parties that are more engaged than others might have a hidden agenda. The model must not only promote the ideas that serve their interest, but introduce a more abundant view. The modeller must find a balance in carefully weighing the information received keeping hidden interest in mind. Another important aspect that should be considered is how engaging stakeholders influences the system to be modelled. Intervening with the real-world system might change the outcomes and affect acceptability. Participatory modelling is extremely suited for coming to an agent-based model assessing the acceptability of new energy technology amongst households of a certain area. Furthermore, the modelling process increases the understanding of the system amongst stakeholders and support the value of the model itself as it might be easier to understand for stakeholders.
when it has been developed together with stakeholders. Other purposes are reducing conflict, improving legitimacy, informing stakeholders, increase learning, explicate tacit knowledge, gain common understanding and investigate individual behaviour (Jones et al., 2009).

The purpose of participatory modelling can be clearly defined. Participatory modelling is a common approach as there is literature about research on participatory model building and group model-building in environmental decisions making, for resource management and knowledge building (Bots & van Daalen, 2008; Prell et al., 2007; Röckmann et al., 2012; Videira et al., 2003). The building approaches describe agent-based modelling and system dynamics. However, no best practices have been described yet to evaluate acceptability of small scale pilots in energy transition. These pilots are bottom-up processes that often lack a concrete goal and structure and therefore need some guidance in coming to goals and agendas. This research presents an approach that aims at making energy infrastructure morally more acceptable, so not just in terms of stakeholder interests, but also in terms of moral acceptability, thus beforehand approvability.

Stad aan ’t Haringvliet is an example of a project where participatory modelling can play an important role for making the right choices and creating commitment to the realisation process of innovative technologies. Especially for pilots where there are many uncertainties and bottom-up realisation of decision-making is needed, participatory modelling helps to structure the problem and identify key issues. The case of Stad aan ’t Haro is used to propose a participatory process which leads to a more acceptable infrastructure and evaluate the process that is proposed.

### Stad aan ’t Haringvliet

For the pilot in Stad it has been decided to eliminate natural gas from the local grid before 2022. Choices how to supplement natural gas still have to be made. The municipality, technical experts and local stakeholders are recently researching the possibilities to feed hydrogen into the natural gas grid for replacing. In the future, the households of Stad are supposed to consume hydrogen as energy source instead of natural gas.

It remains unclear what the potential implications of hydrogen in households are. There is a lack of information about the required technical adjustments, costs and the attitude towards hydrogen. The advantages of hydrogen compared to alternatives as heat pumps or heat networks are twofold. On the one hand, boilers can be reused as only a small part of the installation has to be replaced. On the other hand, are there many old and poorly insulated houses that cannot be heated with low temperature heat as produced by heat pumps and heat networks (Schmidt & Donsbach, 2016).

The village has carefully been chosen as location for the pilot because of a close-knit community. The village council is eager to advance removing natural gas from the local energy system. Other practical benefits of the location are the size of the village and the large amount of buildings owned by a single housing corporation, which is keen to cooperate. Moreover, the grid operator is researching technical possibilities and economic feasibility of the pilot.

Despite of having chosen the location, the details remain unclear. The range of technical alternatives is still discussed, causing uncertainty for residents of the village. A better view on the different options and the consequences for users is needed. To address potential societal barriers as high energy costs, fear and distrust an agent-based model for assessing the acceptability of technical settings is developed together with Stakeholders.

### 2. Theory and methods

This case of Stad aan ’t Haringvliet asks for a participatory modelling approach that facilitates public and stakeholder involvement in making technical design choices. As other studies have proven that “participatory modelling has the potential to facilitate and structure discussions between scientists and stakeholders about uncertainties and the quality of the knowledge base” (Röckmann et al., 2012) this research addresses the question whether the participatory modelling approach suggested is really
participatory and what the added value of engaging activities for the case of Stad aan 't Haringvliet are. The approach facilitates stakeholders engagement as basis for future public engagement.

The modelling approach consist of five main steps. The steps are identified based on the modelling approach suggested by Nikolic & Kasmire (2013). The engaging activities are related to one or more modelling steps. Roughly the modelling approach of Nikolic & Kasmire (2013) has been followed to come to an agent based model for the use of hydrogen by households in Stad. Verification and Validation follows the approach of Augusiak, Van den Brink, & Grimm (2014). The steps suggested by Augusiak et al. (2014) and Nikolic & Kasmire (2013) are amplified with measures to engage stakeholders and end users of the planned system. Given the case of Stad aan 't Haringvliet, the theoretical concept of acceptability forms the basis of the model and structures content and form of the engaging activities.

2.1 Acceptability

The fundament of the model is the distinction between acceptability and acceptance. The distinction made between acceptability and acceptance is that acceptance is described “as behaviour towards energy technologies and acceptability as an attitude” (Huijts et al., 2012 p. 526). Acceptability is defined as the beforehand approvability of a process or technology in terms of function but also social effects values. These values are for example fairness, autonomy, legitimacy, trust or welfare (Demski, Butler, Parkhill, Spence, & Pidgeon, 2015; Ligtvoet et al., 2015). Acceptability can be seen as cause for acceptance.

The definition of acceptability and the urge to assess the acceptability of the hydrogen project in Stad leads to taking the elements described in the capability approach as starting for structuring the collection of input for the model. It also gives already a basic structure to the model. There are different interpretations of the capability approach. Here mainly the interpretation according to Amartya Sen is followed. The Capability Approach is a suitable way to approach acceptability of technology as it considers individual well-being and freedom of choice (Künneke et al., 2015).

The capability approach distinguishes between capabilities and functionings. The two concepts are used to evaluate human well-being: Functionings and capabilities. “Functionings are beings and doing” (Robeyns, 2016). Beings are states as being scared, being informed and educated or feeling heard. Doings are activities that a person can undertake as cooking, heating or travelling. Whether a functioning is valuable depends on the context. The functioning itself thus is morally neutral.

The ability to achieve well-being by choosing to undertake or not undertake certain actions and activities is called capability. The distinction between functionings and capabilities is between the realised and the effectively possible, between achievements and freedoms to choose from different opportunities. A capability can be seen as ability to choose from a set of functionings. The set of opportunities to realise functionings, being and doings, determines a person’s capabilities (Robeyns, 2003). The set of opportunities is determined by individual abilities and resources. These conversion factors allow for or restrict the realisation of a functioning. The higher the number of capabilities, thus the freedom of choice, the higher the acceptability.

2.2 Participatory Modelling

Participatory modelling is a modelling process that involves engaging stakeholders in one or more research steps (Hare, 2011). Usually the modelling steps are executed by modellers or researchers who are experts in developing a certain type of model. The choices made during the modelling process influence the perspective and outcomes of the model (Bots & van Daalen, 2008). Participatory modelling is able to let the model outcomes connect with the views and understanding of stakeholders.

A benefit of participatory modelling or group modelling is that the stakeholders already develop a shared understanding during the modelling process. Direct decision making during the modelling process has a positive effect on the final decision making process (Hare, 2011). Furthermore, legislation more often asks for stakeholder engagement when managing projects. The extent of participation can variate from
involving individual stakeholders separately, involving a homogeneous group of stakeholders to approaching a heterogenous group with different views and interest (Bots & van Daalen, 2008). More benefits are social learning and improvements of the model itself. Accuracy is increases, the model will be better accepted and be able to incorporate a variety of perspectives (Hare, 2011).

The problem of participatory modelling is that it is difficult to dive directions which approaches to use. For many fields and cultures no best practices have been defined yet (Hare, Letcher, & Jakeman, 2003).

3. Proposed Approach

The five steps of the modelling approach are broadened by three different approaches to include stakeholders in the process. The engaging activities are public information events, semi-structured interviews and a workshop.

The model conceptualisation is the identification of all elements that have to be represented by the agent-based model. The conceptualisation is shaped by semi structured interviews with technical experts and local stakeholders involved in the project process. The requirements and effects of the technical system are embedded in the structure of the capability approach. The conceptualisation is the basis of the model formalisation and the model specification. Here values, capabilities and individual conversion factors are identified.

The model formalisation takes place based on the insights from interviews with local stakeholders involved in the project. The model specification additionally considers an interview with a local expert who is not involved in the project. This broadens the perspective and specifies data because this expert has a different agenda than other interviewees. The expert is not so much interested in realising the project for reasons of sustainability. However, the pilot has effect on the local economy. After having determined the data for the model specification the software implementation follows.

Verification and Validation is done by analysing the modelling process but also by comparing the model output to expectations. Additionally, an external validation step is required for feedback about the model. Simulation leads to the identification of a worst and a best-case scenario. A third scenario is identified as base case as the results of the indicate that this specific scenario is most likely to occur.

The final step of the modelling approach is a scenario workshop that consist of three phases. At first model assumptions are tested to get feedback of local stakeholders and households. Secondly the participants are asked to evaluate the scenarios identified and determine the strength and weaknesses. Based on the strength and weaknesses stakeholders think about measures to improve the effect of the scenarios. The third phase is the evaluation of the scenario as form of engagement asking for feedback about content and process of the workshop session. This give insights in how useful the model is for assessing and improving the introduction of hydrogen in Stad aan ‘t Haringvliet.

4. Results

The result of the approach is an agent-based model that is capable of assessing the acceptability of households given different technical settings and uncertain parameters. To discuss the added value of participatory modelling in the case of Stad social goals for evaluation are evaluated (Beierle, 1998). These goals are educating the public, incorporating public values and knowledge into decision-making, building trust, reducing conflict, and assuring cost-effective decision-making. The results and benefits of the different modelling steps are presented using the assessment of social goals described by Beierle (1998).

During the public information events insights were gained which stakeholders to interview. The roles and interests of stakeholders could be assessed. The interviews with policy makers have given some limitations and broader structures that form a rough system boundary. It showed for example that it is unclear how
to finance pilots. Based on this statement the relevance of costs was simplified to be able to say something about the system without knowing the details.

One of the main reasons to simulate acceptability is to reduce conflict. Reducing conflict means decreasing scepticism so that no public opposition is formed. As there is few public communication about the progress in Stad it remains unclear what the public opinion is. Stakeholders sketch the public option but cannot clearly agree what it is at the moment. The modelling process resulted in a number of topics that might cause conflict and should be addressed in a broader workshop for more households as participants.

The benefit of semi-structured interviews is that they offer space to explore unknowns. The interviewees are able to sketch social dynamics as the share of information, trust, enthusiasm and fear. However, the stakeholders are not able to sketch the mechanisms in a detailed way. To sustain assumptions based on the interviews, theories on attitude and on exchange of information are considered additionally to the conceptual frame. The CA offers useful support to grasp the complexity of the system and introduce it into NetLogo. The interviews are analysed following the perspectives given by the different groups of stakeholders. Structuring the content by codes leads to insights about technical design choices, effects of the choices and conditions when choices are reasonable, thus translating information to the concept of acceptability.

The goal of incorporating public values is accomplished in two ways. On the one hand the research deals with social values and how these can be used to come to a better technical design. This means that values are even made explicit. The second way of incorporating the public is the boundary condition of how to time the next steps. The benefit of semi-structured interviews is that they offer space to explore unknowns. The interviewees are able to sketch social dynamics as the share of information, trust, enthusiasm and fear. However, the stakeholders are not able to sketch the mechanisms in a detailed way. To sustain assumptions based on the interviews, theories on attitude and on exchange of information are considered additionally to the conceptual frame. The CA offers useful support to grasp the complexity of the system and introduce it into NetLogo. The interviews are analysed following the perspectives given by the different groups of stakeholders. Structuring the content by codes leads to insights about technical design choices, effects of the choices and conditions when choices are reasonable, thus translating information to the concept of acceptability.

The workshop results in some concrete suggestions for the project leaders what issues to address and how to time the next steps. The evaluation of the workshop shows that workshop fitted well with the background of all participants. It was assessed positively that there was space for opinions and sharing those. The great benefit of agent-based modelling for the problem of Stad is that ABM structures and conceptualises the system and therefore succeeds in identifying issues that ask for attention in the next phase of the pilot. Letting stakeholders determine the important choices and relevant effects causes the model to be purposeful. A system that does not yet exist, now can be explored and possible interventions can be simulated. This enable project leaders to compare scenarios and think about how to present scenarios to other stakeholders that have less knowledge about the technology as for example households.

Building trust is one of the most difficult aspects and reached by creating transparency on the state of the project. A reason of mistrust is unclear motives processes and the lack of feedback of the effectiveness of participation causes distrust and scepticism. The modelling approach creates a platform were
stakeholders share their viewpoint with households. It becomes clear that most decisions are not made yet and that the stakeholders want input from the community to come to acceptable decisions. Interests and issues that must be further discussed are determined. Also new possibilities are found as the discussion is structured by the model and scenarios.

The model incorporates technical choices that have been illustrated by technical experts and the relevance has been evaluated by stakeholders of the project. Also, requirements for acceptability as for example autonomy and affordability have been identified. The strength of ABM is that it creates patterns of behaviour that does not need to be precisely the real behaviour but still can give important insights about causes and effects of uncertainties and choices.

The last goal to be reached is cost-effectiveness. The modelling approach is cheap as it needs few resources and stakeholders participate on voluntary basis. Activities to inform and engage a broader public based on the finding of the modelling process might be more expensive.

5. Discussion

Participatory processes can either have a normative, substantive or instrumental purposes. Normative means increasing legitimacy of a project. A substantive purpose would be increasing the problem-solving capacity of a process. An instrumental function increases the commitment to the outcome (Jones et al., 2009). The approach for Stad certainly meets normative and substantive purposes but at this stage is not capable of increasing the commitment to outcomes. However, it offers the opportunity to collaboratively define responsibilities.

To discuss the effectiveness of the participatory approach the level of engagement is evaluated. The five levels of engagement are summarized in Table 1. The case is used to evaluate the participatory modelling approach suggested. The levels are intertwined. The participatory process does not inform the stakeholders before consulting them. This uncovers that there is a lack of information amongst parties involved in the project. Technical facts, effects and conditions are unclear. Additionally, the stakeholders have different ideas of what desirable choices are.

Informing is the most basic form of engagement. The results of the workshop illustrate that informing is essential when making changes to energy systems that have a high impact on households. Information that is spread within the network is of importance. Even more important is the opinion and explanation of technology by experts. The participatory modelling approach itself can be used to inform but mainly uncovers the need and way of informing rather than being a tool for informing. When evaluating the scenario workshop, the participants indicate that new insights were gained with regard to the choices but especially on how other parties view the different options.

The interviews clearly serve for consulting the stakeholders. Especially because the interviews conducted are semi-structure, there is room to elicit views and interests. Applying a coding approach for the analysis allows for the integration of views and salient information in a structured way in the model. However, the modeller makes the decision how to structure. An additional step to involve stakeholders or experts would be possible. A broader view is included in the model as the public information events show how households react to the proposed project. The households expressed concerns about timing of the transitions, safety of hydrogen and the use of their end user equipment.

The workshop creates the opportunity for stakeholders to work together. Scenarios and model assumptions are used as boundary objects. It also clears the way to for future collaboration as stakeholders get to talk in an informal setting. Policy choices are discussed and improved. Experience and knowledge are exchanged as representatives of households present their view on what important and desirable choices are. The stakeholders in charge of leading the project to the next step, get an idea of priorities for the following steps.
The next level of engagement is collaboration which means not only increasing the solution space by gaining information through inaction of stakeholders, but actually incorporating this information. In the case of Stad the insights of the workshop are essential for the interpretation of the modelling results. The input shows that valuable conclusions can be drawn from the model. However, they must not be interpreted like as exact predictions. The conclusions address issues that ask for more information to be solved. The model succeeded in causing a discussion that is crucial for deciding which steps to take next.

The consulting of stakeholders illustrates that the project in Stad is in the hand of local parties and not determined by policy makers. This bottom-up approach can be fostered by gaining important insights that facilitate decision making. However, the modelling approach solely is not a tool to empower.

<table>
<thead>
<tr>
<th>Form of engagement</th>
<th>Goal</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informing</td>
<td>Stakeholders are merely informed engage those stakeholders with low urgency, influence, importance, or interest</td>
<td>websites, fact sheets, newsletters, observe policy discussions</td>
</tr>
<tr>
<td>Consulting</td>
<td>Elicit the views and interests, salient information that stakeholders have with regard to the policy concern</td>
<td>conducting interviews, administering surveys, opening up draft policy documents for public comments</td>
</tr>
<tr>
<td>Involving</td>
<td>Stakeholders working together during the policy development process enable diverse sets of stakeholders to have a shared experience and exchange knowledge</td>
<td>scenario building, engaging panels of experts, group models like simulating policy choices, games, or role playing; models, simulations, or scenarios as boundary objects</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Incorporate stakeholders’ advice and recommendations final decisions to a maximum extent</td>
<td>Citizen advisory committees, consensus building, participatory decision making</td>
</tr>
<tr>
<td>Empowerment</td>
<td>Final decision making is actually in the hands of the public</td>
<td>consensus building within legal parameters, citizen juries, stakeholder boards, living labs</td>
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The question when which methods are appropriate is hard to answer. There are different participation modes and modelling techniques. Also the right choice should be made when during the process to apply which modes (Bots & van Daalen, 2008). The model that results from the is supposed to answer the question of to improve the acceptability of the infrastructure. Single actor decision models and social system models are suitable for answering ‘how’ questions. As ABM incorporates single actors decision making that results in social behaviour it is more suitable than system dynamics for example. Most participatory modelling process as examples from natural resource management and water management address the clash of interests of stakeholders but do not incorporate moral questions nor individual values. Structuring the participatory process based on a moral frame allows for researching beyond interests. So far, mainly modelling approaches for natural resource management, water management and environmental decisions have been developed (Bots & van Daalen, 2008; Hare, 2011; Videira et al., 2003). In these models the decisions are leading while the approach suggested in this paper the effects of different decisions are evaluated. It is giving a new view on decision making rather than directly facilitating the process because there are so many technical and social uncertainties involved in realising pilots.
6. Conclusion

Some case specific conclusions can be drawn that lead to general insights about the practice of modelling acceptability applying a participatory modelling approach. The first case specific conclusion is that the process described is participatory in the beginning and the end. The intermediate elements form model formalisation until validation are rather isolated and offer more room for better participation. However, as the process is iterative, challenges during the model implementation can be addressed during the last interviews. A second conclusion is that the number of participants is too low to speak of public engagement. Nevertheless, the use and added values of participatory modelling is clearly determined and with further research a bigger number of participants can be included.

Jargon is a barrier for participation. The concepts used to conceptualise the model are abstract. In order to improve the results concepts and information needs to be simplified. Even though, the capability approach is proven to be a useful tool to come to an assessment of acceptability and an acceptable way, a good strategy is needed to communicate about the capability approach and its elements.

Good practices for evaluating acceptability of small scale pilots in energy transition are converging and diverging by first assessing the context and then specifying data by talking to local stakeholders involved in the concrete project. This provides for identifying the right stakeholders and considering a variety of views. As pilots are bottom-up processes that often lack a concrete goal the participatory modelling process can lead to collaboratively choosing directions to address in the next project steps. This can speed up processes by increase transparency and trust.

7. Future Research

This research gives insights into the effectiveness of the participatory modelling process when evaluating acceptability in terms of capabilities. This research can be deepened by further assessing interview protocols and workshop designs. It can be broadened by using the method for increasing the number and abundance of stakeholders involved or even involving a broader public or applying the modelling approach in other bottom-up contexts. Further, it would be interesting to research whether the approach leads to agent-based modelling as a tool in role-playing games as suggested by Matthews, Gilbert, Roach, Polhill, & Gotts, (2007).
Literature


