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Co-producing energy futures: impacts of participatory modelling

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This transdisciplinary research case study sought to disrupt the usual ways public participation shapes future energy systems. An interdisciplinary group of academics and a self-assembling public of a North English town co-produced 'bottom-up' visions for a future local energy system by emphasizing local values, aspirations and desires around energy futures. The effects of participatory modelling are considered as part of a community visioning process on participants' social learning and social capital. This paper examines both the within-process dynamics related to models and the impact of the outside process, political use of the models by the participants. Both a numerical model (to explore local electricity generation and demand) and a physical scale model of the town were developed to explore various aspects of participants' visions. The case study shows that collaborative visioning of local energy systems can enhance social learning and social capital of communities. However, the effect of participatory modelling on these benefits is less clear. Tensions arise between 'inspiring' and 'empowering' role of visions. It is argued that the situatedness of the visioning processes needs to be recognized and integrated within broader aspects of governance and power relations.

Keywords: agency, built environment, cooperation, co-production, energy model, renewable energy, resilience, social capital

Introduction: bottom-up engagement with future energy systems

The UK energy system is changing, with a transition from a high dependence on fossil fuels to a more complex, varied and intermittent energy supply landscape. The consequences of this for the socio-material environment of neighbourhoods is significant; however, democratic involvement in the shaping of energy futures remains low (Seyfang, Park, & Smith, 2013; Walker & Devine-Wright, 2008). While there is a long legacy of involving local publics in re-imagining of the built fabric of their neighbourhoods (Aylett, 2013), this participatory approach has not been brought to bear on the interaction between landscapes, built environment and future energy systems. Adopting what Chilvers and Kearnes (2015) term 'residual realist' understandings of the public and of participation, dominant approaches to societal engagement in energy-related issues adopt pregiven models of who is a relevant public; how they are expected to participate; what is the issue in question; and how the participation is to unfold. As a result,

> the burden is placed on publics to engage with, change, get in line, or respond to trajectories and definitions of 'the energy transition' defined

> by others (most often institutional authorities, whether that be science, the state or industry). (Chilvers, Pallett, & Hargreaves, 2015, p. 14; see also Laird, 2013)

This approach is noticeable in the context of research on energy transitions and climate change adaptation, in which certain future realities (low-carbon systems and lifestyles, a different climate) are assumed from the outside, and citizens (not necessarily residents of a place under discussion) are *engaged* with (energy) transitions by being invited to give their opinions and contribute local knowledge (for recent examples, see, for example, Burch, Sheppard, Shaw, & Flanders, 2010; Eames, Dixon, May, & Hunt, 2013; Fortes, Alvarenga, Seixas, & Rodrigues, 2015; Gansmo, 2012; Ivner et al., 2010; Iwaniec & Wiek, 2014; and Sheppard et al., 2011). Consequently, there are few opportunities for residents of neighbourhoods to engage with the future of the energy system on their own terms to influence it according to locally held values and visions of the good life.

This paper presents a case study of a transdisciplinary research project called Solar Energy in Future Societies (SEFS) that sought to disrupt the usual ways public participation in the shaping of future energy systems is performed. The project brought together an interdisciplinary group of academics and a self-assembling public at the town of Stocksbridge, in the Sheffield area of England, to co-produce visions for a future local energy system by putting local values, aspirations and desires around energy futures at the core of the enquiry. This paper reflects on one aspect of the methodology adopted in the project: the effects of participatory modelling of local energy systems on participants' social learning and social capital. Models and visualizations which bring together expert (universal) and local knowledge are often used to facilitate debate and communication in visioning processes; however, their usefulness as tools for social leaning in participatory visioning remains under-researched (Senbel & Church, 2011). Importantly, research on the use of visualizations and models in a visioning context has focused mainly on the within-process use of models (Wiek & Iwaniec, 2014). This paper examines both the within-process dynamics related to models/visualizations and the impact of the outside-process use of these on their social learning and social capital impact.

Models in visioning: impacts on social learning and social capital

Visioning is a methodology typically used in planning (including sustainability planning), where residents are brought in to participate in the creation of urban or landscape visions (Iwaniec & Wiek, 2014; Peel & Lloyd, 2005; Sheppard et al., 2011). Importantly for the purposes of this project, visioning puts local norms, desires and values at the heart of the process. The aim of visioning is to engage the public in normative debates about what should or ought to be in the community, and to expand people's imagination as to what a desirable future might look like (Couclelis, 2005, p. 1363). Creating models of desired futures, using images, maps and physical representations, is often part of the visioning process (Wiek & Iwaniec, 2014), and these representations can play a number of roles: providing a focus for discussions of ideas; guiding participants through the design process; raising awareness of issues; and facilitating better communication (Al-Kodmany, 2001). Models can aid in the processes of developing future visions by indicating pathways for backcasting from desirable futures to current conditions, and by bringing together scientific knowledge and local perspectives (*e.g.*, Pahl-Wostl et al., 2007; Sheppard et al., 2011). While there is ample literature on participatory modelling in areas such as resource management (*e.g.*, Ginger, 2014), where models are used to facilitate stakeholder consensus around complex current issues, the use of models in the context of more aspirational participatory visioning has not been investigated to date (although see Senbel & Church, 2011, on visualizations).

In theory, models and visualizations are well positioned to act as facilitators of high levels of social learning and social capital by enabling debate, and consequently facilitating the creation of joint ownership of issues and emergence of new networks. In Rodela's classification, this project represents an individual-centric conception of social learning processes, as it assumes that social learning can be triggered in the context of externally organized participatory events, and that it can be evaluated by noting a change in the cognitive, moral, relational, and trust dimensions of those in attendance (Rodela, 2011). Based on Reed et al. (2010), it is asserted that social learning takes place if one can note

> a change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks.

The current authors are further interested in the network-building effects of social learning. Bull et al. note that social learning can be seen to have two key components:

- instrumental learning and cognitive enhancement through generation of new knowledge and skills, and a reflexivity around these

- communicative learning, which includes a change in how individuals approach situations or points of view, and how they work with others to achieve objectives (Bull, Petts, & Evans, 2008, p. 703)

At a high level, therefore, social learning can result in the creation of new interpersonal networks, and thus new social capital in communities. The concept of social capital builds on the work of Bourdieu (1987), and while different aspects of social capital have been discussed in literature (Bodin & Crona, 2008), this paper adopts a broad definition of social capital to indicate aspects of social organization such as networks, norms, and trust that facilitate coordination and cooperation for mutual benefit (Putnam, 1995). Social capital has been seen as key to mobilizing and cooperating in communities around shared goals such as energy initiatives, and is thus a key element of community resilience. Trust (Walker, Devine-Wright, Hunter, High, & Evans, 2010), shared vision (Parkhill et al., 2015) and a sense of place and belonging (Dale, Ling, & Newman, 2008) have all been noted as important to the coming together and functioning of energy/sustainability groups.

Project context

The SEFS research project brought together academic and non-academic actors to co-produce bottom-up visions of future energy systems, and to consider the role certain future energy generation technologies may play in those systems. The academic team consisted of colleagues from physics and material sciences (who specialized in photovoltaics (PV) research: principal investigator, post doctoral research associate, and doctoral researcher), geography (co-investigator, co-investigator, post doctoral research associate), and architecture (co-investigator and contracted researchers). The non-academic participants were a self-assembled group of residents from a town of Stocksbridge. The participants of the SEFS project were initially recruited during an exhibition that explored potential futures of the energy system in Stocksbridge, and was organized by the SEFS team in September 2012. Subsequently, 12 project workshops were organized every four to six weeks. In the second workshop five collaborative research pathways were chosen by residents, which placed locally relevant issues in conversation with energy generation, distribution and consumption futures. The five pathways explored visions for: developing electric vehicle public transport; local food production; increasing sustainability of local community buildings; meeting local energy demand through renewable energy generation; and sustainability education. These five projects are described in more detail in 'The Five Pathways' in the supplemental data online. Over the following workshops researchers and participants gathered information and carried out research into the questions the themes were presenting in order to create inspiring and relevant visions. Progress on each theme was reported to the whole group in project workbooks, created by us (the organizers) and circulated to all before each workshop. The structure of the workshops evolved through the project from more academic-led to participant-led activities as the projects matured.

The workshops were always open to new participants, and participation at the workshops varied from a maximum of 30 to a minimum of 10 participants. A core group of 15 participants had a continuous involvement with the project, and it is in relation to this group that participatory modelling processes and social learning outcomes are discussed. The core group was composed of individuals who were either already active in the Stocksbridge area, and involved in a variety of community projects (such as the community forum, a local church and local interest groups), or conversely who saw the project as a way to become involved in community life in a way which was not predetermined by existing channelling community-oriented action. Some of the more transient participants held positions of local political power, or represented local business interests. None of the participants had official political power over planning processes in the town. Instead, the participant demographic was more characteristic of community action groups, with a dominance of retired and well-educated middle-class individuals who were time rich but resource poor.

The project sough to enable a bottom-up engagement with the future of energy systems, both in the light of the normative rationale of participation (influencing socio-technical futures as a democratic right) and of the substantive rationale (public participation as beneficial to socio-technical processes such as energy technology development; Fiorino, 1990). The project's aim was to vision the future of the energy system by following the criteria of relevance set by the participating residents. This meant being responsive to participants' criteria of salience and non-salience both in reference to the project process and the object of enquiry (Wynne, 2007). As a result the processes and desired outcomes of the project changed dynamically over time. Initially the project aimed (1) to develop situated visions of a 'good' energy system and (2) to use those visions to query certain dominant techno-scientific imaginaries. A co-production framing was adopted (Callon, 1999) that assumed that the processes and products of future energy systems visioning will be of benefit to both the academic organizers and non-academic participants. However, the authors found this framing did not correspond to the participants' notion of valuable participation in the shaping of energy systems (Krzywoszynska et al., 2016). As a result the project's methods evolved from a focus on purely academic research to include building capacity for local action on energy as a desired objective. The focus of the project on creating social learning and social capital was thus a modification of the original project aims in response to the desires of the assembled public (cf. Reeves, Lemon, & Cook, 2014).

The idea of using models to enhance social learning in the group further also emerged from the participation process. This paper focuses on two models developed with the participants:

- a numerical model that explored the impact various renewable energy generation and storage technologies could have on Stocksbridge achieving energy independence
- a physical scale model of the town that illustrated participants' visions of Stocksbridge energy future

These present two very different kinds of modelling. The numerical model was created to answer a specific question: to what extent can Stocksbridge be energy independent? The scale model was developed to illustrate the visioning work done with the participants. It is useful to reflect on both of these, however, as they share important common features: both were developed on the basis of participants' visions, and incorporated participants' expertise (boundary conditions of the models, *e.g.*, what technologies where) and values (the 'why' behind the models); both brought together the work done by the participants into coherent narratives; both were developed to be used as political tools by the participants; and both were hypothesized to help generate further social learning and social capital in the group. The motivations for developing the models, the processes of their development and the effects the models had are discussed below.

Motivations for the use of models

The numerical model arose out of the activities of the group that explored how local energy demand could be met through renewable energy generation in a way which benefits the wider community (as opposed to for private interest, such as had been the case with wind turbines erected previously in the town). Initially academic and resident members of the group explored the use of local natural (wind, rivers, sun) and technological (waste heat from a local steel works, heat from flooded mine shafts, local reservoir) resources for energy generation and conservation. The motivations of this group reflected a desire to use local energy production as a means to revitalize Stocksbridge, which has seen economic decline as the employment as the local steelworks waned. It also reflected concerns about the disempowerment of Stocksbridge on the local political scene, and a dissatisfaction with the administration by Sheffield City Council. As participants put it:

> [. . .] I always feel like we are the poor relation of Sheffield and just tagged on at the end. (participant D)
> a lot of Stocksbridgers, because of what Sheffield City Council have done to this leisure centre, the threat of closure to the library, and the advice centre, that kind of thing, I think there's a sense in Stocksbridge that we need to pull together, you know, we need to do things for ourselves and not rely on those in Sheffield. (participant B)

Between workshops, the residents and academics involved in this group undertook research into land availability and feasibility and desirability of a range of energy generation and conservation technologies. The participants also calculated the potential for renewable energy generation in the town using market-ready technologies. By the fifth workshop, the participants started to stress the need to both push their research further: to increase its credibility to a wider audience, and to increase the potential for acquiring future funding. As one participant put it:

> it's all about having the vision and having the ideas and then you have got to think how realistic is this [. . .] you can then actually start and look at the serious feasibility study and from there you've got the evidence if you like to start acquiring funding. At which point it becomes a reality. (participant P)

Until then the academics had held back from taking the lead on researching renewable energy capacity in order to maximize space for the exploration of the desires and values of the residents. However, investigating the claims to Stocksbridge energy independence was seen to require a stronger involvement of academic expertise. As one of the participants explained:

> the academic–community partnership [. . .] as far as the community is concerned, yes, there may be individuals within the community with particular expertise [. . .] but then it's down to individuals doing their own research for the site etc. without necessarily having the expertise and not necessarily having a full understanding and to pursue things from that perspective is slow, it is limited, there's a lot of waste in that. (participant F)

As a result the idea of modelling different scenarios illustrating how local energy demand and generation could be met was proposed, and taken on by one of the co-authors who was associated with the project as a PhD student. The desire to use the model to influence decision-makers was explicit from the outset:

> based on the work that we have done so far, I don't want to get too far off actually putting together say three different scenarios of energy balance, and producing like an overarching philosophy as it were, which could then be taken to the neighbourhood planning group, and say look can we get this incorporated? (participant P)

The idea of developing a way to effectively communicate the various aspects of future energy visions for Stocksbridge also emerged from the fifth workshop onwards across different project groups. The participants felt that communicating their ideas to external audiences was now crucial in order to gain broader credibility, and influence local planning (*e.g.*, incorporating their visions in the Stocksbridge 'neighbourhood plan'). The idea of a project exhibition emerged, which would both showcase the work of the group and provide legitimacy and wider buy-in for further activity. The scale model of Stocksbridge, originally used for participant recruitment, had in the meantime been used by the participants as an educational tool at a local school, and other successful scale models were developed by MA-level architecture students for one of the sub-projects. The participants therefore felt that models were good communication tools, and the idea of readapting the original scale model to bring together all the work done by the five thematic groups developed.

The use of models seemed attractive to both participants and academic project organizers. As organizers, we hypothesized that by bringing together the interests of the various sub-projects the models will encourage the participants to develop feelings of ownership towards the future energy vision as a whole. The aim of the modelling was thus not only to enable a further exchange of information between individuals, but also to enable stronger cohesion in the group. The developing of the models coincided with the emergence of a new group of interest, composed mainly of participants in the SEFS project, focusing on sustainable generation and use of energy in Stocksbridge (called Renewable Upper Don Energy – RUDE). The exhibition constructed around the scale model was a promising platform for this group to gain legitimacy in the community. For the participants, the political role the models could play was thus crucial.

Developing the models

Numerical model

This model was conceived to understand, in as simple a way as possible, and from a physical point of view, both the energy conservation and energy independence of a system of renewable electricity generators, energy storage and electricity demand located in Stocksbridge. The model was used to calculate energy return on investment and energy independence of such a local system comprised of different combinations of generation and storage technologies. Energy return on investment was calculated as the ratio of energy generation over the lifetime of the system to the energy used to manufacture, install and operate the generator and storage over the lifetime of the system. Energy independence of the system was found by calculating the proportion of either time or energy that the system was able to fulfil its required demand. These independence metrics are called 'loss of load hours' and 'loss of load proportion' respectively. These were later adapted to an independence proportion value that includes both under and over production. Technical details of the model can be found in the online supplemental data file.

The modelling work was undertaken by a mathematics graduate with a computing background. Like the modelling in the participatory work of Lane et al. (2011), the model was written from scratch, without any reliance on toolkits or libraries. Because the model was based on a physical metric (energy) instead of an economic one (cost) it was seen by the researchers to better assess the long term sustainability of different energy system scenarios. The economic drivers were seen as short-term and likely to change with the evolving policy and economic landscape. Focusing on energy, the model was able to measure the significance of technological evolution in terms of embodied energy of the different system components. This was seen to potentially better support future technological investment in accordance with the desires of the participants for combining sustainability and energy independence in the town.

The locally identified generation and storage options (technologies and locations) (Figure 1) were modelled in specific scenarios as discussed in the workshops. These included rooftop solar panel mounting (location A in Figure 1); solar panel fields on land participants had indicated (location C); creation of a hydroelectric storage system incorporating existing infrastructure, identified by the participants, and owned by the town's steel works (location D). In addition, participant led discussion in and around the tensions concerned with the of aesthetics, politics (who benefits and whose house value do they affect) and potential noise of wind turbines in the area led to the modelling of both small (5 kW) and large (500 kW) options. Turbines were modelled in location B in Figure 1. While the locations for the technological deployment were taken from the group discussions, the quantities of the deployment were calculated as part of the sustainability/independence optimization within the numerical model. The results were then incorporated within the posters that were used in the final public exhibitions of the project. Figure 2 shows an extract from

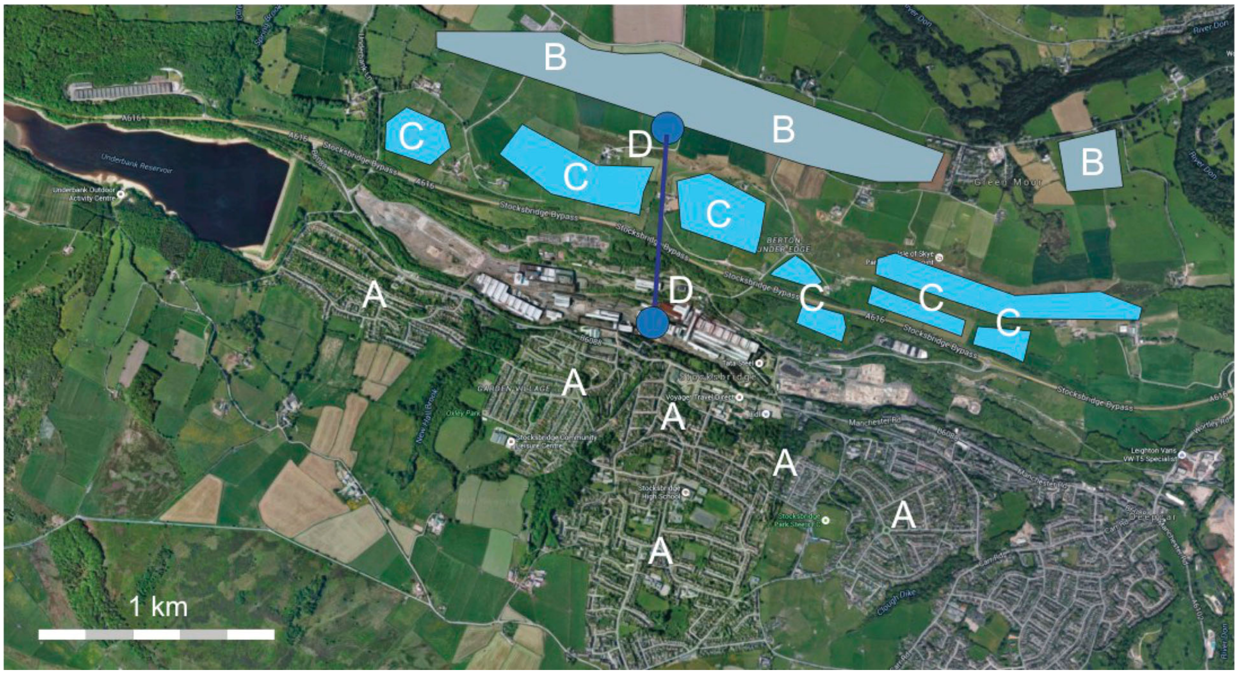

Figure 1. Aerial photograph of Stocksbridge town showing different deployment locations. *Note:* A = locations for photovoltaic (PV) roofs, B = locations for wind turbines, C = locations for PV fields, and D = location of pumped hydro storage. *Source:* Reproduced from Google Maps.

the 'energy balance' poster (see the supplemental data online) illustrating different scenarios that were modelled. Results from a full matrix of different technology options are given in Appendix B 'Modelling community energy: the energy independence model' in the supplemental data online. Of interest to the participants was the maximum grid independence that the numerical modelling suggested is possible for Stockbridge (while retaining high levels of energy return on investment). It was found to be around 80% for a combination of PV roofs, PV fields, large wind turbines (500 kWp each), pumped hydro storage and battery storage. The scenarios from the numerical model were also integrated into the physical scale model, where the different technology deployment options were superimposed for the final public exhibitions. Figure 3 shows the final physical scale model in location and ready for the final public exhibition in Stocksbridge.

Physical scale model

The design of the scale model was developed collaboratively with the participating residents over the course of four workshops. Two MA-level architecture students were employed to develop the original scale model in consultation with residents and with the assistance of the academic team. Redesigning the model provided opportunities for further debates around the visions for local energy futures. However, in that process the visionary elements which had been discussed in the previous workshops (the Stocksbridge of tomorrow) began to be toned down, and the participants stressed that for the model to do the political work needed it had to communicate practical messages about changes to the energy system that can be implemented *today*. For the model to be both *inspiring* and *convincing*, the participants suggested it had to combine visionary elements (this is desirable) with pragmatic elements (this is achievable). This tension between visioning and viability is illustrated by following discussion between the participants of the desirable content of the model excerpts in workshop 11:

> So you're really talking in terms of Stocksbridge futures and that might be something to actually hang it on. (participant P)
> But that is vague and nebulous, people will just turn away I think there needs to be some specifics and something practical there that can give people confidence that something's happened [. . .]. (participant J)
> We want people to go away thinking that actually it is possible for Stocksbridge to generate most of its own energy and that will benefit me because my energy bills will be less [. . .]. (participant P)
> I think until you start getting something tangible, you've partially got it already, people can see that we've got something quite good like and I'm probably using the words sell wrongly, but it's about selling them an image it's all about selling them that vision. (participant M)

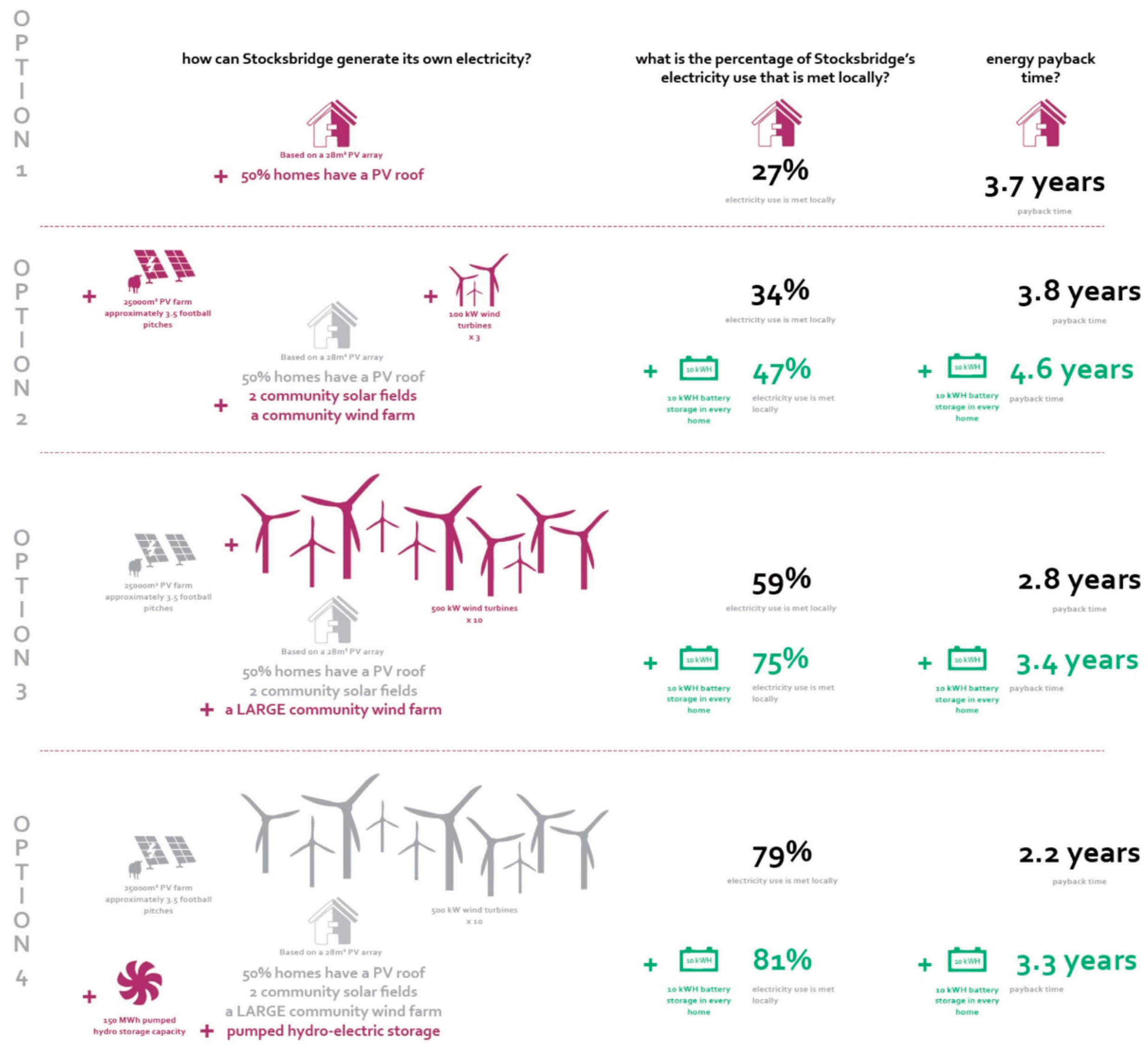

Figure 2. Extract from the 'energy balance' poster, as found in the supplemental data online. It illustrates the different power-generation scenarios explored by the numerical model. Different combinations (options 1–4) of solar photovoltaic (PV) and wind turbine deployment (left column) give rise to different energy payback time (right column) and different levels of grid independence (second column from the right).

Interestingly, then, using participants' visions in order to 'sell them' outside the group resulted in a certain shrinking of the original ambitions. Participants who had spent time re-imagining their neighbourhood in a 'what if' mode returned to preoccupations with achievability and viability in the now, as achieving 'tangible impact' in the community, and appearing as a trustworthy and productive group to the rest of the community, took on a greater urgency.

As a result, the final physical model sought to illustrate both visionary and innovative ways of matching local energy generation and demand developed by the participants, and more 'achievable' technology deployment. Figure 3 shows the physical model with accompanying posters giving further detail on socio-technological solutions illustrated by the model:

- geothermally heated blocks of flats (harvested from mine water); see the poster 'Ground Heating' in the supplementary data online
- a heat main reutilizing steelwork waste heat. See the poster 'Industry Heat' in the supplementary data online
- pumped hydroelectric storage. See the poster 'Energy Balance' in the supplementary online file

Figure 3. Solar Energy in Future Societies (SEFS) academics and participants interacting around the scale model and related posters in the lead up to the final exhibition. For the posters, see the supplemental data online.

- solar panel fields; see the supplementary data online
- rooftop solar panel deployment; see the poster 'Solar Electricity' in the supplementary data online
- growing willow for biomass; see the poster 'Biomass' in the supplementary data online

The posters explained the proposed innovations in more detail, and/or rooted technology deployment in the lived experience of particular participants. The model thus brought together and illustrated the joint research endeavour into Stocksbridge energy futures. It was used as the centrepiece of the final project exhibition, which was also a launch event for the RUDE group formed by the participants, and was attended by 73 visitors (excluding SEFS participants and academics).

Discussion

Impacts of the models

The numerical model had a limited and not uniformly positive effect on the dynamics in the group. Most of the participants were agnostic about the results, and did not mobilize the scenarios in further activities. The results did not provoke discussion, but were either incorporated into the political work the participants undertook, or rejected. One participant used the result of the model in his speech at the project exhibition event to bolster the vision of an energy self-sufficient Stocksbridge through renewable generation technology deployment:

> Can Stocksbridge be self-sufficient in renewable energy? And when you do the maths, the answer is yes. And that starts to get exciting. Yes there is a capital cost [...] but the government pays a feed-in tariff. It's carbon zero. [...] The government has targets [...] and because it's got these targets there is money out there to actually bring in [...] if we can put together a coherent plan, than this place which was once famous for the steel they made can be famous for the fact that it is energy self-sufficient. (participant P)

Paul was thus using the findings of the model to generate enthusiasm and 'sell and idea' of a self-sufficient Stocksbridge, down-playing the fact that even the most optimistic scenario showed the town would still need to depend on the national grid, and silencing the controversies around wind turbine deployment. This is significant, as a debate about the desirability of wind turbines was constant and never resolved within the group, and the eventual inclusion of wind power as part of the future visions led one of the participants, Helen, to leave. As Helen explained in her feedback interview:

> I don't like wind power, and I can remember right back at the first gatherings there were really strong opinions about not having that in

> the projects, and that's where we ran with the project work, and then suddenly wind turbines were back on the agenda. And that's fair enough [. . .] it's still putting a spotlight on this area, but this is when I suddenly thought there is nothing more in it for me I don't think. (participant H)

The numerical model results were incorporated into the scale model, and represented as a poster alongside other elements of future local energy systems (see the 'Energy Balance' poster in the supplementary data online). Importantly, the scale model did not present a comprehensive vision or a blueprint; rather, it expressed the heterogeneous, fragmented, and contested nature of the visions created. The model was retained by the RUDE group for further use as an educational tool, and the poster information linked to it has since been utilized by the group members.

Assessing social learning and social capital gains

The assessment of social learning and social capital gains in the group was qualitative, and consisted of assessing whether a change in understanding has taken place amongst the participants (*e.g.*, recall of new information, change in attitudes or beliefs); and whether these changes became situated within wider social units or communities of practice, and occurred through social interactions (as per Reed et al., 2010). The assessment was based on feedback interviews with the core group of participants, observation of their activities within workshops, as well as self-reported behaviour between workshops (as per Bull et al., 2008; Hojem, Sørensen, & Lagesen, 2014).

There was evidence of 'factual' social learning about (1) the potential for renewable energy generation and conservation in the valley and (2) more detailed learning in relation to particular technologies. The numerical model was seen as valuable in providing this information, however interaction with other residents was seen as just as important in that learning as interaction with the academics:

> The scientific side gave you an understanding of what could be what couldn't be, and the community side specialist knowledge in the sense of knowing who would know what and the time gone past. That was very exciting. (participant H)

In assessing the impact the models made on social learning and social capital gains, it is hard to disentangle the effects of the models from the broader effects of the structure of the research process. In all interviews, mainly the structure of the project was commented on by the participants, even though it was the construction of the (physical) model which provided a focus point for the interaction in the late stages of the project. In all interviews 'meeting like-minded people' was identified as the most important benefit. As one of the participants commented in a feedback interview:

> what you managed to do is bring a group of like-minded people together with like-minded thinking into a more structured format, lots of people have been talking about renewable energy in Stocksbridge for a long, long time but not together. (participant A)

The very fact of running an academic research project in the community, around the theme of energy, and for a sustained period of time, meant the project acted as a catalyst for new social relations. These new social networks exemplified the linking, bridging, and bonding forms of social capital described by Magis (2010). The linking capital focuses on relationships between more and less powerful actors in the community; the growth of that social capital was demonstrated by the creation of relationships between the representatives of the local steel mill and local community actors, who jointly developed a vision for the reuse of the mills' waste heat. The bridging capital represents loose ties between individuals and groups who would not normally have interacted, and it promotes knowledge exchange and reflexivity (Granovetter, 1973). The growth in this capital was visible in the creation of new relationships between academics and residents, who worked together in the visioning process. The bonding capital refers to close ties which build cohesion within groups. A key indicator that this capital had been strengthened was the creation of two new community initiatives as a result of the project: the RUDE group, and the Inman Pavillion initiative which grew out of the sustainable community buildings project (see the poster 'Inman Initiative' in the supplementary data online).

Conclusions and implications

This paper presented a case study of a bottom-up visioning of local energy futures co-created by a group of academic and resident participants. As part of the visioning process, the SEFS project developed a numerical model which explored a series of scenarios for the matching of local electricity generation and demand, and a scale model of the town which brought together various aspects of participants' visions. The case study shows that visioning energy systems can enhance social learning and social capital of communities. The participants valued the project as a forum for an exploration of different types of knowledge, and formation of new social relations (see also Reeves et al., 2014); the fact that two action-oriented groups did emerge out of the project was seen as one of the most valuable outputs by the participants.

The impact of models and participatory modelling on further enhancing social learning in a visioning context was less pronounced. Creating consensus and encouraging ownership are some of the key tenets of visioning (Wiek & Iwaniec, 2014). As project organizers, we hypothesized that participatory modelling would facilitate these effects in the group. These were however not observed: consensus emerged around the political use of the models rather than about their content. It is possible this was linked to the participatory modelling processes, as while the models were developed in a participatory way, they did involve a distribution of expertise which limited participant involvement at the construction stages. A more hands-on engagement may have enabled greater communicative social learning (*e.g.*, Standa-Gunda et al., 2003), although it may have impacted negatively the academic learning gains. An interesting paradox is also noted in relation to the effects of the models. As long as the visioning process remained mainly dialogical, potentially incompatible opinions and interests, and the lack of overlap between different ideas, as well as systemic barriers, could be left undisclosed. Modelling however made these tensions explicit, resulting in one participant leaving the group. The fragmented nature of the vision also became apparent, with the resulting poor ownership of the final models beyond their immediate political function linked with a particular exhibition event.

More broadly, this experience underlines the importance of the impact of broader power relations for the understanding and assessment of the impact of models in visioning processes. While it has been noted that models can be used as political tools in aiding groups to achieve broader support for their ideas (Couclelis, 2005), what effect this use may have on the process of participatory modelling has not been considered. In this case study the models and their effects embodied the tension between 'inspiring' and 'empowering', which tend to be collapsed in much visioning literature which suggests that visions automatically motivate actions (*e.g.*, Chitakira, Torquebiau, & Ferguson, 2012; Shipley & Michela, 2006; Wiek & Iwaniec, 2014). However, it is argued that in assessing the political or real-world effects of visioning processes it is necessary to be attentive to power relations inherent in these processes. Where visioning is undertaken with powerful stakeholders (*e.g.*, Wilkinson & Mayer, 2014) who have a capacity to address high-level or systemic conditions. These visions would be expected to have more pronounced effects than in the case of community-level visioning. As Senbel and Church note, visualizations and models of desirable future states are 'are insufficient if neighbourhood design decision making is embedded in larger power structures that preclude open communication and transparent process' (Senbel & Church, 2011, p. 434). In this case study, the participants involved in the visioning process were not politically or economically powerful stakeholders, which limited the potential for addressing the systemic context of the visions. As a result, the ownership of the models remained fragmented, and linked more to individual agendas of participants than to a vision of future energy Stocksbridge as a whole. While the models symbolically brought participants' visions together, it is difficult to assess how far they contributed to the creation of a consensus around an overall systemic change.

The lack of consensus-building and action-driving effects of participatory modelling in this case study highlights the tension between visions as spaces for 'imagination, innovation and blue-sky thinking' and visions as 'strategies for action' (Peel & Lloyd, 2005). According to some authors 'visions ought to be idealistic, free, open, innovative, and, in fact, not (too) realistic' (Wiek & Iwaniec, 2014, p. 498). For others, visions have to translate into pathways if they are too be more than 'utopias' (Chitakira et al., 2012; Peel & Lloyd, 2005). This begs the question of power in the generation of visions. Building shared visions does not automatically empower actors to take action towards their vision (Nieto-Romero, Milcu, Leventon, Mikulcak, & Fischer, 2016). However, 'scaling down' the visioning ambitions in order to create achievable goals may limit their innovative and social learning potential. Conversely, focusing on visioning with only powerful actors continues the exclusion of non-elite voices from visioning processes. The lack of consensus around and ownership of an overall vision for the future of local energy by the participants in this case study is not surprising in the light of very real financial and political challenges community groups face when seeking to change their energy systems (Seyfang et al., 2013). However, it does pose an important question in relation to bottom-up public re-imaging of energy systems in ways which are both innovative and relevant to local stakeholders. If publics are to engage with the future of energy to create better (local) energy systems, then what methods can be used to resolve the tension between eliciting creative and innovative local visions of desirable energy futures, and achieving impact desired by the participants while ensuring broad civil engagement?

The experience from this case study suggests that discounting the present in favour of the future, and not attending to power inequalities, both within energy visioning research projects, and within energy systems more broadly, weakens attempts at bottom-up visioning of and acting on energy transitions. In the context of academic research, visioning can produce inspiring, innovative and interesting engagements with energy futures, as was the case in this study. However, the authors concur with Whitman et al. that:

> simply working with innovative methods […] but within a conventional approach to research where the academic researcher has set the agenda and controls the process, inevitably leaves power structures unchanged and reflects business (or science, or policy-making) as usual. (Whitman, Pain, & Milledge, 2015, p. 624)

In the broader context of energy policy, the initiation of a transformation of the energy systems will require increased participation to be matched with a commitment to addressing the financial and political power inequalities inherent in the current paradigm. Government financial support for low-carbon technologies (through, for example, the feed-in tariff) has resulted in their widening uptake, but it has not enabled the development of locally adapted and innovative socio-technical energy solutions. Support for communities in developing such bottom-up innovation is unlikely to come from the 'community energy' policy framework, as that is geared more towards supporting the development of new energy technology markets than the enhancing communitarian principles (Walker, Hunter, Devine-Wright, Evans, & Fay, 2007). Alternative policy frameworks linking funding not to particular technologies but, for example, to tonnes of carbon saved may result in greater diversity and appropriateness of solutions, freeing local actors to link technological and social innovation in ways which are locally desirable.

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Supplemental data

Supplemental data for this article can be accessed at 10.1080/09613218.2016.1211838.

References

Al-Kodmany, K. (2001). Bridging the gap between technical and local knowledge: Tools for promoting community-based planning and design. *Journal of Architectural and Planning Research*, *18*(2), 110–130.

Aylett, A. (2013). Networked urban climate governance: Neighborhood-scale residential solar energy systems and the example of Solarize Portland. *Environment and Planning C: Government and Policy*, *31*(5), 858–875. doi:10.1068/c11304

Bodin, Ö., & Crona, B. I. (2008). Management of natural resources at the community level: Exploring the role of social capital and leadership in a rural fishing community. *World Development*, *36*(12), 2763–2779. doi:10.1016/j.worlddev.2007.12.002

Bourdieu, P. (1987). What makes a social class? On the theoretical and practical existence of groups. *Berkeley Journal of Sociology*, *32*, 1–17.

Bull, R., Petts, J., & Evans, J. (2008). Social learning from public engagement: Dreaming the impossible? *Journal of Environmental Planning and Management*, *51*(5), 701–716. doi:10.1080/09640560802208140

Burch, S., Sheppard, S. R., Shaw, A., & Flanders, D. (2010). Planning for climate change in a flood-prone community: Municipal barriers to policy action and the use of visualizations as decision-support tools. *Journal of Flood Risk Management*, *3*(2), 126–139. doi:10.1111/j.1753-318X.2010.01062.x

Callon, M. (1999). The role of lay people in the production and dissemination of scientific knowledge. *Science Technology & Society*, *4*(1), 81–94. doi:10.1177/097172189900400106

Chilvers, J., & Kearnes, M. (2015). *Remaking participation: Science. Environment and emergent publics*. Abingdon: Routledge.

Chilvers, J., Pallett, H. W., & Hargreaves, T. (2015). *Rethinking energy participation as relational and systemic*.

Chitakira, M., Torquebiau, E., & Ferguson, W. (2012). Community visioning in a transfrontier conservation area in Southern Africa paves the way towards landscapes combining agricultural production and biodiversity conservation. *Journal of Environmental Planning and Management*, *55*(9), 1228–1247. doi:10.1080/09640568.2011.640149

Couclelis, H. (2005). "Where has the future gone?" Rethinking the role of integrated land-use models in spatial planning. *Environment and Planning A*, *37*(8), 1353–1371. doi:10.1068/a3785

Dale, A., Ling, C., & Newman, L. (2008). Does place matter? Sustainable community development in three Canadian communities. *Ethics Place and Environment (Ethics, Place & Environment (Merged with Philosophy and Geography))*, *11*(3), 267–281.

Eames, M., Dixon, T., May, T., & Hunt, M. (2013). City futures: Exploring urban retrofit and sustainable transitions. *Building Research & Information*, *41*(5), 504–516. doi:10.1080/09613218.2013.805063

Fiorino, D. J. (1990). Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, Technology & Human Values*, *15*(2), 226–243. doi:10.1177/016224399001500204

Fortes, P., Alvarenga, A., Seixas, J., & Rodrigues, S. (2015). Long-term energy scenarios: Bridging the gap between socio-economic storylines and energy modeling. *Technological Forecasting and Social Change*, *91*, 161–178. doi:10.1016/j.techfore.2014.02.006

Gansmo, H. J. (2012). Municipal planning of a sustainable neighbourhood: Action research and stakeholder dialogue. *Building Research & Information*, *40*(4), 493–503. doi:10.1080/09613218.2012.676319

Ginger, C. (2014). Integrating knowledge, interests and values through modelling in participatory processes: Dimensions of legitimacy. *Journal of Environmental Planning and Management*, *57*(5), 643–659. doi:10.1080/09640568.2012.761132

Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology*, *78*(6), 1360–1380. doi:10.1086/225469

Hojem, T. S., Sørensen, K. H., & Lagesen, V. A. (2014). Designing a 'green' building: Expanding ambitions through social learning. *Building Research & Information*, *42*(5), 591–601. doi:10.1080/09613218.2014.905168

Ivner, J., Björklund, A. E., Dreborg, K.-H., Johansson, J., Viklund, P., & Wiklund, H. (2010). New tools in local energy planning: Experimenting with scenarios, public participation and environmental assessment. *Local Environment*, *15*(2), 105–120. doi:10.1080/13549830903527639

Iwaniec, D., & Wiek, A. (2014). Advancing sustainability visioning practice in planning—The general plan update in

Phoenix, Arizona. *Planning Practice & Research*, *29*(5), 543–568. doi:10.1080/02697459.2014.977004

Krzywoszynska, A., Buckley, A., Chiles, P., Gregson, N., Holmes, H., Mawyin, J., & Watson, M. (2016). Opening up the participation laboratory: Towards a generative mode of upstream public participation. *Manuscript Submitted for Publication*.

Laird, F. N. (2013). Against transitions? Uncovering conflicts in changing energy systems. *Science as Culture*, *22*(2), 149–156. doi:10.1080/09505431.2013.786992

Lane, S. N., Odoni, N., Landström, C., Whatmore, S. J., Ward, N., & Bradley, S. (2011). Doing flood risk science differently: An experiment in radical scientific method. *Transactions of the Institute of British Geographers*, *36*(1), 15–36. doi:10.1111/j.1475-5661.2010.00410.x

Magis, K. (2010). Community resilience: An indicator of social sustainability. *Society and Natural Resources*, *23*(5), 401–416. doi:10.1080/08941920903305674

Nieto-Romero, M., Milcu, A., Leventon, J., Mikulcak, F., & Fischer, J. (2016). The role of scenarios in fostering collective action for sustainable development: Lessons from central Romania. *Land Use Policy*, *50*, 156–168. doi:10.1016/j.landusepol.2015.09.013

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning and water resources management. *Ecology and Society*, *12*(2): 5.

Parkhill, K., Shirani, F., Butler, C., Henwood, K., Groves, C., & Pidgeon, N. (2015). 'We are a community [but] that takes a certain amount of energy': Exploring shared visions, social action, and resilience in place-based community-led energy initiatives. *Environmental Science & Policy*, *53*, Part A, 60–69.

Peel, D., & Lloyd, G. (2005). City-visions: Visioning and delivering Scotland's economic future. *Local Economy*, *20*(1), 40–52. doi:10.1080/0269094042000331296874

Putnam, R. D. (1995). Bowling alone: America's declining social capital. *Journal of democracy*, *6*(1), 65–78. doi:10.1353/jod.1995.0002

Reed, M., Evely, A. C., Cundill, G., Fazey, I. R. A., Glass, J., Laing, A., … Raymond, C. (2010). What is social learning? *Ecology and Society*, *15*(4): r1.

Reeves, A., Lemon, M., & Cook, D. (2014). Jump-starting transition? Catalysing grassroots action on climate change. *Energy Efficiency*, *7*(1), 115–132. doi:10.1007/s12053-013-9212-z

Rodela, R. (2011). Social learning and natural resource management: The emergence of three research perspectives. *Ecology and Society*, *16*(4): 30. doi:10.5751/ES-04554-160430

Senbel, M., & Church, S. P. (2011). Design empowerment: The limits of accessible visualization media in neighborhood densification. *Journal of Planning Education and Research*, 0739456X11417830.

Seyfang, G., Park, J. J., & Smith, A. (2013). A thousand flowers blooming? An examination of community energy in the UK. *Energy Policy*, *61*, 977–989. doi:10.1016/j.enpol.2013.06.030

Sheppard, S. R., Shaw, A., Flanders, D., Burch, S., Wiek, A., Carmichael, J., … Cohen, S. (2011). Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. *Futures*, *43*(4), 400–412. doi:10.1016/j.futures.2011.01.009

Shipley, R., & Michela, J. L. (2006). Can vision motivate planning action? *Planning Practice and Research*, *21*(2), 223–244. doi:10.1080/02697450600944715

Standa-Gunda, W., Mutimukuru, T., Nyirenda, R., Prabhu, R., Haggith, M., & Vanclay, J. K. (2003). Participatory modelling to enhance social learning, collective action and mobilization among users of the Mafungautsi Forest, Zimbabwe. *Small-scale Forest Economics, Management and Policy*, *2*(2), 313–326.

Walker, G., & Devine-Wright, P. (2008). Community renewable energy: What should it mean? *Energy Policy*, *36*(2), 497–500. doi:10.1016/j.enpol.2007.10.019

Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, *38*(6), 2655–2663. doi:10.1016/j.enpol.2009.05.055

Walker, G., Hunter, S., Devine-Wright, P., Evans, B., & Fay, H. (2007). Harnessing community energies: Explaining and evaluating community-based localism in renewable energy policy in the UK. *Global Environmental Politics*, *7*(2), 64–82. doi:10.1162/glep.2007.7.2.64

Whitman, G. P., Pain, R., & Milledge, D. G. (2015). Going with the flow? Using participatory action research in physical geography. *Progress in Physical Geography*, 0309133315589707.

Wiek, A., & Iwaniec, D. (2014). Quality criteria for visions and visioning in sustainability science. *Sustainability Science*, *9*(4), 497–512. doi:10.1007/s11625-013-0208-6

Wilkinson, A., & Mayer, M. (2014). Collaborative futures: Integrating foresight with design in large scale innovation processes-seeing and seeding the futures of Europe. *Journal of Futures Studies*, *18*(4), 1–26.

Wynne, B. (2007). Public participation in science and technology: Performing and obscuring a political–conceptual category mistake. *East Asian Science, Technology and Society*, *1*(1), 99–110.