Innovation Studies Utrecht (ISU)

Working Paper Series

User-technology interactions in the construction of user-driven configurations – lessons from Dutch civic energy communities

Gerben W. de Vries

Wouter Boon

Alexander Peine

ISU Working Paper #15.02

User-technology interactions in the construction of user-driven configurations – lessons from Dutch civic energy communities

Gerben W. de Vries[1], Wouter Boon[1*], Alexander Peine[1]

[1] Innovation Studies, Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, the Netherlands

[*] Corresponding author:

Wouter P.C. Boon

Innovation Studies, Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, the Netherlands

w.p.c.boon@uu.nl, Phone number: +31(0)302532708

Abstract

In this research, we explore user innovations in five Dutch civic energy communities. We show how these user innovations where embedded in a wider community process around realizing desired socio-technical change, and how the rationale, conditions and competences needed to identify and implement user innovations are shaped by this wider process. This interplay of collective learning and implementing user innovations requires a variety of preparatory efforts by community members, that may be of a seminal importance to the eventual nature and success of new socio-technical arrangements. Moreover, it is suggested that the dynamics found here result from a specific user logic that may be characteristic more generally for user communities innovating in configurational settings, i.e. combining and tinkering with innovative as well as mundane technological devices into a local and tailored configurations.

Key words: user innovation; user-led technological change; user communities; civic energy communities; configurations.

User-technology interactions in the construction of user-driven configurations – lessons from Dutch civic energy communities

1. Introduction

In the context of a transition to a sustainable and environmentally-friendly society, bottom-up initiatives by end-users of energy have increasingly gained momentum (Hoffman & High-Pippert, 2005). A major example of this trend is the recent emergence of civic energy communities (CECs), where voluntary communities seek to collectively set up infrastructures in which decentralized, sustainable electricity can be produced and consumed. This has led to more than 700 registered CECs in Germany (Holstenkamp & Müller, 2012), to a wide range of small-scale community sustainability initiatives in the UK (Forrest & Wiek, 2014) and to nearly 500 initiatives in the Netherlands (HIERopgewekt, 2015). Specifically, these groups of end-users envision an energy system based on local self-supply, and attempt to realize this by implementing (collective) energy technologies that, in order to work, require connections to the grid, other technologies and a variety of non-technical actors active in the specific application environment. Frequently, these community efforts become a source of innovative energy solutions that typically consist of interconnected technical and non-technical components to make up new infrastructural arrangements (Walker & Cass, 2007). As bottom-up initiatives, CECs have also been widely recognized and studied as a significant societal movement with the potential to speed up the transition towards a sustainable system of energy provision (e.g. Seyfang, et al., 2014; Seyfang & Smith, 2007). This paper aims to make a contribution to a deeper understanding of these initiatives by addressing two gaps in the literature that may be bridged by taking a user innovation perspective to study the various endeavors of CECs.

First, we build on the expanding body of academic literature on local energy initiatives, identifying these as a distinct trend in social organization and civic culture (e.g. Bomberg & McEwen, 2012; Hoffman & High-Pippert, 2005; Middlemiss & Parrish, 2010; Walker, et al., 2010). The role of community-based initiatives in governing sustainable energy transitions is explored using the concept of 'grassroots innovation' (Seyfang & Haxeltine, 2012; Seyfang, et al., 2013; Seyfang & Smith, 2007). These studies have regarded local civic movements as social innovations, operating in a local niche from which 'ideas' and social practices may diffuse into society. They did not emphasize the role of technology and how users may reshape user-technology relations when collective desires for socio-technical change lead directly to creative implementation of novel technologies. A deeper knowledge of this is important as user innovation seems to be understudied in the transition literature.

Second, this focus on novelty creation invites us to relate to literature on 'user innovation' elaborated by Von Hippel and colleagues (von Hippel, 2005). After establishing the significant contribution of individual users to innovation, the last decade has witnessed the emergence of different kinds of innovative 'user communities' (Van Oost, et al., 2009), organized around common interests, normative objectives or specific technical challenges. Engaging actively not only in idea creation but also in the development and commercialization of these ideas, communities frequently give rise to innovative socio-technical solutions and are signaled as an emerging force in competitive industry trajectories (Baldwin & von Hippel, 2011) and societal change processes (Henkel & von Hippel, 2004). Prime examples are communities in open source software (Raasch, et al., 2008) and extreme sports (Franke & Shah, 2003). User communities have also begun taking position as a source of innovative sustainable projects in the energy industry (e.g. Hyysalo et al., 2013; Ornetzeder & Rohracher, 2006). In general, studies of user innovation in communities have focused on situations in which creative individuals are engaged in well-delineated technical projects developing distinct products. Less attention is paid to user innovations of configurational technologies, where users collectively arrange loosely related sets of components into local systems that work (Fleck, 1993, 1994; Peine, 2009).

Although studies on configurational technologies have largely focused on the ICT sector, implementation of configurational innovations in and by communities also becomes relevant in the arena of community energy. Different technological components for producing and conserving energy demand careful alignment in pre-existing local structures to become functional, with the resulting socio-technical arrangements taking shape around specific contextual requirements. Implied is a more socially-complex and user-driven innovation process of actively and collectively shaping a socio-technical environment (van Oost et al., 2009). Hence, in this paper we zoom in on the internal workings and social practices of innovative user communities and equip user innovation with the sociological concepts it needs in order to deal with configurational technologies and their dynamics.

The present study seeks to adopt a sociological micro-level perspective and broadly explores the characteristics and trajectories of a number of end-user communities who have successfully implemented collective energy facilities. This is done by drawing on a number of recent academic attempts to enrich user innovation accounts with methods and concepts from Science and Technology Studies (Faulkner & Runde, 2009; van Oost et al., 2009; Hyysalo & Usenyuk 2015) that emphasize (emergent) socio-technical practices and structures accompanying new user-technology relations. To sum up, this explorative study seeks to answer the question: *How do technical efforts and community building interact in civic energy communities implementing configurational technologies?*

This paper aims to increase our understanding of internal user-technology dynamics in civic energy communities and how they deal with energy production as a locally contextualized configuration. It provides insights about their potential to influence other stakeholders, remove structural barriers for local energy production, democratize the energy industry and inspire consumers to become more educated and aware of energy-related issues. This would facilitate management of and policymaking on these communities, as such contributing to a societal transition to sustainable energy.

The paper proceeds as follows. Section 2 starts with an overview of community energy in academic discourse, before briefly reflecting on the relevant theoretical constructs from user innovation and STS literature. Section 3 describes the methods, whereas Section 4 presents the main results from studying 5 CECs, by first discussing their main characteristics and then zooming in on commonalities in their trajectories towards successful implementation projects. Section 5 provides a deeper discussion of the theoretical significance of the dynamics identified, in terms of what they imply for analysis of collective user innovation in configurational settings. Finally, section 6 summarizes the main conclusions and proposes an outlook for more inclusive social research into the dynamics of user innovation.

2. Theory: civic energy communities and their configurational endeavors

In recent years a vast body of literature has grown to describe the general trend in which groups of consumers have emerged as an active type of stakeholders in the energy field. It is observed widely how users now assume active roles in production and conservation of energy, introducing both social and technical solutions in the local environment. Emphasizing this democratization of the energy industry, bottom-up energy initiatives have been studied as a new form of *social organization* (Walker & Cass, 2007). Themes that have been studied include the democratic governance in these communities (Hoffman & High-Pippert, 2005), communities as networks of individuals that differ in their degree of knowledgeability and motivation (Bomberg & McEwen, 2012; Hyysalo et al., 2013; Rogers, Simmons, Convery, & Weatherall, 2008), and trust as being essential for coherent and cooperative communities to form (Walker et al., 2010). This body of literature concludes that success of community organization structures depends on understanding their social context.

Alternatively, local energy initiatives have been related to the broader energy transition in the literature on *grassroots innovation*. This literature discusses how community-based initiatives can be niches where social innovations co-evolve with technologies to form new ways of service provision (Ornetzeder & Rohracher, 2013; Seyfang & Haxeltine, 2012; Seyfang et al., 2013). Ornetzeder & Rohracher (2006) have shown that users, teamed in "self-building groups", not only adopt new sustainable energy technology but also technically adjust them to their specific needs. These studies have demonstrated *that* local energy initiatives do engage in innovations (Ornetzeder & Rohracher, 2006, 2013). They used these insights to argue that and how the activities of users and user communities should be stimulated and enrolled in wider transition processes, and what hampering and enabling conditions influence the progress of such initiatives (e.g. Bomberg & McEwen, 2012; Middlemiss & Parrish, 2010; Seyfang & Smith, 2007; Walker & Cass, 2007). Still, *how* these communities operate as contexts in which technological user innovations are developed during implementation has remained at the background of this literature.

In our empirical analysis we contribute to closing this gap. More specifically, we zoom in on the innovation dynamics in CECs, and map their activities as processes of *user innovation*. The user innovation literature has long demonstrated and investigated that users not only contribute to technological innovations, but that they frequently also innovate themselves, and that such user innovations are commercially successful (von Hippel, 1988; 1976). While most of the user innovation studies during the 1980s and 1990s focused on innovations by professional users, the past decade has witnessed a prolific body of literature that highlights the importance of end-users and consumers as user innovators (von Hippel, 2005). In these studies, attention has been drawn to user communities as an important locale of innovation, focusing on fields such as open source software, sports equipment or 'mundane' technologies such as strollers or Russian all-terrain vehicles (Baldwin, et al., 2006; Dahlander &

Frederiksen, 2012; Franke & Shah, 2003; Hyysalo & Usenyuk, 2015; Lakhani & von Hippel, 2003; Shah & Tripsas, 2007; Tietz, et al., 2005; von Krogh, et al., 2003). This body of literature has emphasized that users often do not have a primarily commercial interest in their innovations, at least not initially. They are, therefore, more willing to freely reveal knowledge about innovations, thus allowing for more effective learning processes as compared with manufacturer-driven innovation processes (Hienerth, et al., 2014; von Hippel, 2007; von Hippel, et al., 2012). Large communities can thus identify and solve a wide range of problems at low individual costs. This pooling of resources is supported by a specific set of user motivations ranging from fulfillment of use needs to recognition and enjoyment of the innovation process (Franke & Shah, 2003; Jeppesen & Frederiksen, 2006).

Systems of sustainable energy provision have a notable and interesting technological form: tasked with the supply of energy at different times and places to multiple users, they must first be firmly embedded in a local environment comprising various social and technical elements, hence ensuring production *and* distribution of energy. In effect, innovation in the context of local energy communities is not a matter of implementing standalone technical devices but of arranging loosely related sets of components, local circumstances and skills into systems that work. In Science and Technology Studies, such open technical systems with no generic identity but multiple local manifestations have been termed *configurational technologies* (Fleck, 1993, 1994). The distinctive feature of such systems is that they cannot be purchased and used off the shelf. Rather, their definite set-up or configuration depends on the inputs of end-users that implement specific systems serving local contexts. As a consequence, innovation in configurational technologies exists not so much as a clear-cut evolution of a generic technological identity, but rather as a process of field learning in which technologies, skills and organizations evolve through subsequent instances of implementing local systems that work (Peine, 2009). These dynamics of open technical systems have been studied for ICT infrastructures in professional organizations, as for instance in the cases of automated production systems (Fleck, 1994), administration and learning software at universities (Pollock, et al., 2007), e-infrastructures for research (Voss, et al., 2010) and enterprise resource planning systems (Pollock & Williams, 2010).

In our empirical analysis, we investigate processes of user innovations for configurational technologies in the field of local sustainable energy provision. We build, in particular, on recent work that has demonstrated that configurational dynamics become increasingly relevant for consumer technologies as well, where they require consumers and end-users to perform the configurational work and diffuse knowledge and new solutions over time (Peine, 2008, 2009). To this end, we focus on a range of user innovations encountered in our case studies, and explore them as instances of configurational innovations – thus zooming in on the systemic and only loosely defined nature of sustainable energy provision. Following the emerging theory of configurational innovation, our analysis zooms in on three distinct processes:

1) Community identity: how, in each of the communities, a generic identity was obtained about what sustainable energy provision means and how it should be accomplished.
2) Configurational work: concrete instances of user innovations to explore the breadth and depth of configurational work necessary to implement local sustainable energy systems that work.
3) Community learning: user innovations as important obdurate instances of creating broader momentum at the community level, thus articulating further a community's identity.

In doing so, we explore instances of local user innovations in the context of a wider community innovation dynamics (Van Oost et al., 2009), and specifically elaborate upon the configurational work of citizens as an important, yet under-studied type of user innovation – a type that becomes increasingly relevant across important other ICT-driven fields, such as Smart Homes, eHealth and TeleCare, as well.

3. Methodology

3.1 Research setup and case selection

As we aim to study configurational innovations in innovative user communities in an explorative way, we chose to pursue an in-depth study of five selected CECs. In the Netherlands there are nearly 500 local sustainable energy initiatives aiming to organize local self-supply of energy by implementing various local energy production facilities to be managed by the participants, and also collectively reducing energy consumption (P-Nuts, 2013; Rijkswaterstaat, 2013). A large variety exists in terms of size, internal organization and interconnections between various actors (HIERopgewekt, 2015; Schwencke, 2012) but the local communities are commonly characterized as an 'innovative' and 'creative' new type of actor in the energy field, installing energy technologies in various original applications (P-Nuts, 2013; Van den Brink, 2013). Since 2007 nearly 100 formalized ‘energy cooperatives’ have emerged, applying a broad and ambitious energy focus in their attempts to becoming energy-neutral on a municipality level (Elzenga & Schwenke, 2014). The formation of formal organization structures suggests a longer lasting commitment to a common cause of socio-technical changes and a stronger sense of community.

Drawing from initiative databases (P-Nuts, 2013; “www.HIERopgewekt.nl”) we selected 10 communities using the following selection criteria: being by and for end-consumers; horizontally and democratically organized collectives; local orientation; presence of implementation projects for collective energy facilities; relatively high rigor and progress; active participation in finding creative implementation solutions. Four collectives were willing to participate. A fifth case, Lochem Energie, was added later on in the data collection process, its inclusion being recommended by a respondent as one of the Dutch frontrunners among civic energy communities. The qualification of these five cases being ‘best practice cases’ was validated as they featured prominently in recent reports on local sustainable energy initiatives (Attema & Rijken, 2013; Elzenga & Schwenke, 2014; Hoppe, Graf, Warbroek, Lammers, & Lepping, 2015).

3.2 Data collection

To map the activities in the communities that gave rise to tangible innovative projects a qualitative, inductive approach was taken, using three ways of data collection.

First, *semi-structured interviews* with key figures in the communities provided information on the undertakings of the communities, and the actual content of their activities and projects. The interviews were semi-structured and questions were based on the theoretical concepts elaborated in section 2. In preparation of these conversations, background information about the according community was sought online in order to apply a focus on the more interesting projects and elements of the community in light of the theoretical framework. In total, 24 respondents were interviewed – ranging from 3 to 6 per case – with an average of roughly 80 minutes per interviewee. The interviews were recorded and transcribed to capture the full value of interviewee accounts and enable thorough analysis afterwards.

Second, *community meetings and events* were attended, depending on the accessibility of the event and on the approval of involved participants. In four cases a collective event could be attended, including a working group meeting, annual village market, board meeting, and public presentation. Observing these collective events especially helped to understand attitudes and opinions existing in the community regarding feasible trajectories and projects and their roles in the decision-making processes. Recordings of the meetings were made so that specific details could be checked.

Third, *documentary evidence* provided background information and served as a source of triangulation for what was told in the interviews about ‘factual’ community shapes, activities, intentions and trajectories. Official and/or external publications, such as Articles of Association, Annual Reports and Business Plans could often be retrieved from community web pages, although it became apparent that these informal communities have not made large efforts in documenting their work in publicly accessible ways. At times, minutes and reports of General Assemblies and other internal discussions could also be obtained from respondents.

3.3 Data analysis

The first interviews and documents studied gave an overview of the development of the community in terms of pursued and realized projects, organizational principles, and general objectives. Subsequent conducted interviews in each community were combined to draw case narratives providing overviews of the various community activities and their relations to the intended implementation projects. Besides complementing each other, the successive interviews in each community provided a means to triangulate data collected in earlier rounds. Triangulation was also sought by comparisons to documentary evidence and the community meetings. These case narratives were then coded, using the three concepts as introduced in the previous section. This led to the identification of a number of stages and mechanisms in community development accompanying technical implementation efforts. The individual cases were then interrelated and cross-analyzed to find similarities over the five communities.

4. Innovative implementation projects

Table A.1 (in Appendix A) provides an overview of the five communities, including their objectives, main organizational features and practical approaches. As the last column demonstrates, all communities have been engaged in specific innovation projects that are at the center of our attention because they represent the specific configurations of technical tinkering with financial, legal and organizational elements that we are interested in. In the subsequent section, we explore three examples illustrating the processes of configuring community innovations.

Experimental hydroelectric station

Energy cooperative Hilverstroom has taken the lead in realizing a hydroelectric station at a local sluice, meant to generate electricity for about 70 households in the community. This project is centered on a pump house next to the sluice, containing two non-active pump engines previously used to pump water upstream during dry periods to maintain water levels in the region. As the sluice is now constantly draining large amounts of water, a voluntary working group paired with a regional expert hydropower engineer pursuing to reverse the direction of the pump engines and re-engineer them into power generators. The paddlewheels inside these engines were originally meant to *scoop up* water; a sufficiently efficient reverse mechanism therefore required the design and production of new paddles. Via a trial-and-error process making use of computer simulations and real-life tests eventually a suitable combination of paddle size and material was found. In addition, an electronic synchronization unit was added to the facility, in order to convert the station's power to the voltage level of the main grid and disconnect it in case of insufficient power generation or maintenance work. For this collective production facility to deliver electricity to the cooperative's members, arrangements were made with a local commercial energy supplier to take care of distribution and official balance responsibilities on the grid. In turn, Hilverstroom will organize the front office to its own customers.

Church ventilation and heating

The volunteers of Duurzaam Hoonhorst have designed a new church ventilation and heating system, bringing down their church's energy bill by at least 50% and significantly increasing the comfort of its visitors. Previously, the hot air blown into the church instantly took off and accumulated in the ridge of the building, making the internal climate too cold for attendees and too warm for the choir situated on a higher platform. In a new technical circuit – designed by a technically-skilled board member in close collaboration with other volunteers, technical students and installers – warm air is infused more horizontally, at a higher speed and a lower difference in temperatures. This way, the warm air tends to remain in the colder layer beneath, and only starts fanning out at the other end of the church. Also, the air is aspirated such that heat now circulates around the audience without being drafty. These preferred customized ventilation settings were found via a number of smoke tests revealing air diffusion patterns inside the church, and subsequently translated into a number of technical adjustments in the ventilation system's technical setup. Moreover, new information technology (IT) components were combined with a more indirect heating system enabling efficient pre-heating of the church, with heating levels digitally controlled and programmed via the Internet. At a final stage, the new system was even integrated with a unique (voluntary) work of art.

Energy neutral rental housing

Cooperative 'Morgen Groene Energie' has contributed significantly to an innovative business model enabling housing corporations to make their rental houses energy neutral without having to carry all investments and financial risks themselves. The novelty of the resulting model is to use the sustainability funds of housing corporations for the installation of more cost-effective and innovative energy-producing roof systems, hence turning the neighborhood at once into a solar park. This park is then managed and maintained by its own separate cooperative, allowing tenants to participate at reduced prices and households in the surrounding area to consume the residual of the solar energy produced via the governmental tax reduction scheme called "postal code rose" – a kind of collective net metering.

While the nature and character of these projects varies widely, they illustrate the range of user innovations that we encountered in our research. These projects are examples of collective and innovative efforts of citizens to implement local energy systems that work towards the goals of what the communities strive to accomplish. Neither the selection nor implementation of these projects has been straightforward, though. To the contrary, user innovations in our case emerged from careful and contingent attempts to configure community level values and resources with specific activities. In what follows, we explore in detail the peculiar dynamics of such local configurational user innovations.

5. Configuring user innovations: How CECs select and implement local innovations

In this section, we map in more detail the activities of the five CECs that ultimately led to the implementation of the innovative projects. As these projects pertain to configurations, the technologies involved cannot be understood separately from the wider dynamic community context in which they are embedded. We studied these innovative projects following the three processes introduced in Section 2: how innovative projects are constituted at the cross-section of community goals and values (identity), collective tinkering to configure generic and local elements (work), and momentum building at the community level (community learning). Together, all the activities indicate how user innovations emerged from a complex socio-technical process in which a broad range of generic and specific elements were configured into local energy systems that worked.

5.1 Community identity: goals and values

The CECs we investigated typically originated among a small set of key actors, the initiators, who pursued the idea of setting up a local user community in order to realize energy self-sufficiency. The main *motivation* to pursue these initiatives stems from a concern about an energy transition that is rolled out very slowly. Related to this, the interviewees expressed a general mistrust of non-transparent commercial corporations as well as governments in their willingness to endorse sustainable energy production due to their vested interests in fossil fuels. The objectives in the CECs' official documents and the interview respondents also underlined other motivations: independence (from fossil fuels, geopolitics, large energy companies and governments), empowering of citizens (by facilitating self-supply and self-organization), the establishment of social and economic cohesion at the local level, the (economic) resilience of local amenities, and the enhancement of user comfort in public buildings. The investigated communities sought to realize a range of broader goals and values, which provided and important context for the selection and implementation of innovative projects. In this array of objectives and values, energy neutrality is seamlessly coupled to local independence and empowerment.

The case of Hilverstroom illustrates the importance of values in making choices regarding community activities. The principal philosophy was to regain control over energy production as a social facility, in order to secure the village's future livability, and to enable cash flows to benefit local social goals. This local orientation, as expressed as 'core values' in the initial business plan resulted directly in a focus on hydropower, representing opportunities for local and collective energy production in a municipality that has both a river and a canal flowing through its territory. Hilverstroom's deeply engrained *"it's never too small"* (Hil, #3) attitude eventually led to the sluice being identified as a promising and innovative project.

These broader values of independence and empowerment are also reflected in the way the CECs in our sample *formally organized* themselves. Once these initiators had broadly imagined the outlines of their community and its goals, an audience of local residents was invited to join meetings, to discuss the intended community activities and to take part in the further refinement of the organization and its action plans. Moreover, available commitment, skills and expertise were mapped. At the end of this process, an official document would typically stipulate the CEC's commitment and objectives. After this definition phase all cases in our sample, except for the foundation Duurzaam Hoonhorst, assumed the legal form of a cooperative, demonstrating their adherence to democratic values of horizontal and transparent decision-making. For cooperatives, Dutch law requires that all substantial decisions proposed by the board must be approved by a General Assembly of members.

The organization as a cooperative has several effects on the operations of the CECs. Most importantly, the communities operate on a voluntary basis, which implies that board members that perform managerial tasks receive no remuneration for their efforts. Besides the board members, other active members typically support the board in a number of often organic working groups focusing on certain energy themes or specific projects. Often, the board is also supported by committees fulfilling additional organizational tasks such as a back office, communication, and a financial control committee. Outside this central core of a couple dozen committed citizens, a more passive outer shell of members exists, and in some cases also customers.

While this setup enables some orchestration of collective efforts, its voluntary nature also creates unique dynamics: being voluntary and independent poses limitations to expertise and financial resources communities have at their disposal, making it difficult for them to engage in larger projects. Internal communication inside and across community structures is relatively informal; new projects often emerge spontaneously with limited top-down planning; and members have no strict obligations to participate in activities, making community progress as a whole haphazard and directly dependent on the enthusiasm, time and creativity invested by citizens. At the same time, the potential power of local communities is an emphasized value of collective self-organization and strengthening of community ties. One of its board members of CALorie asserted that in the desired end-state of the local transition things would be done collectively, *"because that is cheaper and more fun and it would make you independent from the large energy companies" (CAL, #1).* Thus, when CALorie's solar working groups discovered a feasible business model for installing solar parks, they recognized this as a great way to serve also people without a rooftop suitable for installing solar panels.

Interviewees emphasized the importance of continued open-ended collaboration during the community's lifetime. They pointed out that this flexibility had striking advantages, and that overly-concrete action plans were often deliberately avoided at the outset:

> *…that is again the academic approach of how it should be, and how it would be done in a professional environment. But in a community like ours, and in most others, that just doesn't happen. Rather, it's like: 'Let's get together and organize a solar park.' 'Good idea. Who's in?' […] And that's how you start building. Against all rules. But this is how voluntary work is done. (CAL, #1)*

Hence, when translating broad ambitions into concrete projects, a bottom-up approach was followed where the communities started looking for projects that are feasible in terms of available resources, expertise and enthusiasm:

> *At first, everyone is searching, everyone is excited, and it is really a matter of pioneering. And we organized it in such a way that all contributions are valued. Discussions really only arise later on when limited resources have to be allocated. For example: 'Do we want to commit these to hydropower or biomass?' (Hil, #5)*

For selecting innovative projects, this bottom-up approach was crucial, and describes a process whereby community goals and values needed to be reconciled with the way in which these communities are organized, and whereby an identity was obtained about what sustainable energy provision means and how it should be accomplished. The inventive church ventilation system in Hoonhorst illustrates this. The foundation Duurzaam Hoonhorst originally emerged from common local concerns regarding the maintenance and continuity of several village facilities. Hence, it was decided to mobilize the villagers and collectively work towards an increased independence of and control over the village through increased self-sufficiency and local organization. Keeping the village livable also implied increasing the comfort and economic resilience of public amenities, which could be achieved by reducing their energy bills. Hence looking into the energy efficiency of the church, the idea to adjust its heating system arose once the volunteers realized that isolating this extremely porous building would be very costly while requiring heating only for small periods of time.

These examples demonstrated how community goals and values have been inherently entangled with technological choices to be made in the innovative projects. We demonstrate in the next section how the community identity, as well as the organizational specifics of the communities, remained an essential element of both the processes and outcomes of the local innovative projects.

5.2 Configurational work: from community identity to local innovations

Implementing systems of local energy provisions turned out to be a complex task. In the words of a community initiator: *"…anyone can buy a washing machine and get it to work. For energy production [technology], this is not the case, so it needs to be delineated still further"* (MGE, #3). This statement nicely illustrates the peculiarities of the innovative projects discussed above: not only were they implemented in the context of a voluntary, community driven do-it-yourself (DIY) culture, but they also implemented complex technologies *that were not available off the shelf*. For the innovative projects to work, an entire network of diverse elements (technical, social, legal) needed to be assembled and aligned. This implies a process of *collective tinkering* that characterizes the implementation of the innovative projects – a process that would typically meander between the levels of community goals and values, on the one hand, and local contingencies, on the other.

Initial guidance was often provided by knowledge of other local energy projects and the technical expertise of early community members. Such knowledge is quickly mobilized, and many respondents revealed a thorough knowledge of potential business cases, other local energy initiatives and cooperative movements in the Netherlands, and referred to these as important inspiration:

> *It started with us saying: 'Let's discuss how we can make Hoonhorst as self-sufficient as possible.' And if you want to realize that, you need to know what is going on in your village, but that is also related to the municipality of Dalfsen. How does it work over there? Moving on, you end up [in national politics] and in other initiatives. So by now we*

have plenty of knowledge, but back then we did not. Just a wide interest, the drive and the concerns" (DHH, #2).

In addition, board members mentioned interactions with other cooperatives, knowledge platforms and consortia in order to build knowledge of the Dutch energy field and draw inspiration for their own projects.

However, this knowledge of other local energy projects and expertise of community members was never sufficient. Many interviewees emphasized that the most valuable and efficient learning has taken place in the communities' direct efforts to implement new specific projects. This involves a rather iterative, inductive process of trial-and-error:

I did not know anything about the energy market, no more than any other common consumer. Most relevant is a kind of pragmatic problem-solving intelligence. […] It's a matter of learning-by-doing. […] We try something, then it either succeeds or it doesn't. Well, then you let it go, and you move on with whatever does work (MGE, #2).

Hence, innovative local energy systems could not be realized based on generally available knowledge, or experience from elsewhere. Rather, they were unique and thus required additional knowledge that was gained by learning-by-trying and experimenting with the subject matter during implementation. Our interviews revealed ample examples and insights regarding such collective tinkering, and show how local energy systems are highlight contingent upon local circumstances. For example, while assessing the potential for realizing a hydroelectric station at a local sluice, Hilverstroom 'discovered' a pump house from technical drawings of the site. The pump engines inside were opened up and tested to see whether they would work at all in the reverse direction. Running real-life tests and computer simulations, the specific water flows at the sluice and required power levels were iteratively translated into the design of a new paddlewheel and other technical adjustments, resulting in an engine system suitable for this site of application. In Hoonhorst, in the course of configuring a central biomass heating system they had to learn about the possibilities for installing an underground pipeline network, intending to connect the nearby church. However, they found that a line of 'infiltration crates' – meant to facilitate the drainage of rainwater – would block the intended path. Proving incompatible with the highly impermeable bentonite clay isolating the hypothetical pipeline, the municipal government would not provide the permits needed for such construction work. The only other possible pathway implied drilling underneath the village graveyard – another unfeasible option. The idea to connect the church was then discarded, but other public facilities may still be connected in the future.

Collective tinkering can be regarded as configurational work in two ways. First, the innovative projects could not be built on (a set of) off-the-shelf technologies or modifying particular technical devices. Rather, community members were required to make use of various knowledge sources and a combination of devices to configure unique systems in the light of local contingencies. Second, the elements of the innovative configurations were not solely technological but also included social and economic. An example is the attempt LE made at the time of its establishment to set up a business case for realizing a collective solar park at a large roof covering a local landfill. Together with an engineering company, a number of volunteers took their time to figure out the technical and financial possibilities and capture the results of this study in a report concluding it could not be made economically viable. As one interviewee recalled: *"But, for me and many others it was a great way to delve deeper into the subject matter and identify all the bottlenecks."* (LE, #2) Eventually, LE has managed to realize a solar park at the city hall, and is engaged in a range of other creative collective projects, showing that business case innovation is part of the eventual configuration.

This configurational work can also be perceived as a learning activity. As the most active volunteers accumulated knowledge, skills and experience from different projects, the communities became better equipped to identify other feasible or more challenging projects. These examples indicate the range and intensity of learning activities community members needed to realize innovative projects that also created momentum for further voluntary projects and activities. The local implementation projects, right from the start, were embedded in a wider process of generating momentum for realizing community objectives and values, and need to be understood in that context. We explore this matter in the following section.

5.3 Community learning: generating momentum and durable networks

Network building activities were focused on internal dynamics within communities themselves, thus creating and propelling community momentum. One important challenge is to keep members and volunteers motivated in the light of an initial lack of resources. In sustainable energy projects large advance investments are regarded as a major challenge (LE, #4). At the same time, community members are often reluctant to pay membership fees when the initiative has not yet realized results. In the cases we observed a number of interesting strategies to address this quandary. Seeking to generate quick initial cash flows, the communities often offered their members sustainable energy or installed or solar panels from incumbent suppliers. The cooperatives thus became contractual resellers and either receive membership fees, recruitment fees from the supplier, or both. In the cases of Hoonhorst and LochemEnergie governmental agencies provided subsidies that the collectives used to initiate projects that led to new ideas and ambitions.

Instigating activities and creating a firm member base appeared to be a crucial precondition for community progress, since community commitment is indispensable for both identifying and completing collective implementation projects. For instance, LochemEnergie has been very successful in building a committed member base that has also provided willing customers, innovative new ideas, crowd funding and a high visibility to potential external allies. However, such provisional networks may easily dissolve, as the CECs operate in an environment where many (potential) members were already served by a reliable and mature energy infrastructure. Narratives that would link sustainability, the community and concrete projects became important, but ultimately the continued realization of projects turned out to be essential in keeping an active member base:

> *So, you start looking for other [projects], because you know that if you don't have anything to show or tell for a year or two – while you wait for that large [solar] park to become feasible – you will have lost all enthusiasm. (LE, #5)*

This struggle to preserve momentum at the interplay of instable community networks and tangible achievements was nicely summarized be one of the initiators of CALorie:

> *[Project development is needed] to build credibility towards other citizens. To show that it is a good and honest and voluntary initiative. […] But then, you have to be careful, as you can't dictate volunteers to keep up the required pace. And then your credibility is at stake again. (CAL, #4).*

However, building a membership base was not enough to create sufficient momentum for the communities. External actors with access to and control of important resources were also crucial:

By itself, the cooperative can mobilize citizens and make them say and do things, but eventually you will need to involve technology suppliers and the government bodies. You need to put together different actors to really get things done. (MGE, #3)

So, activities as part of innovative projects were not performed in isolation. The first collective solar park of the CALorie project is a good example for this. Based on meeting and interview data, we found that the realization of the park has taken the continuous, collective commitment of a motivated group of 8 volunteers. Their efforts included: gaining access from municipal government to municipal rooftops; assessing building structures and energy profiles to select feasible locations; selecting PV technology and local installers; hosting information meetings and other marketing efforts to attract local customers; signing contracts with the municipality, contractors and installers, and participating customers; establishing a new cooperative with newly-designed articles of association; making arrangements for administrative tasks and maintenance (CAL, #6). Most of these activities can be regarded as network building activities, which are prevalent in other collectives as well. For instance, for Hoonhorst’s central heating system a supply network was set up to assemble local wood cuttings and have this yield sorted, chopped and dried by a local recycling company. Also, Hilverstroom’s hydroelectric station could not be connected to the main grid without proper arrangements with the grid operator, who demanded elaborate off-grid test runs. In addition, for a supply license an electronic synchronization unit had to be installed, which in turn required construction permits from the water board and municipality. Hence, project activities were both dependent upon and conducive for a range of network building activities that proved important for generating momentum for (future) projects.

Building networks with external parties occurred through community members spending much time building and maintaining networks with a range of actors and components so that these could be mobilized whenever needed in concrete projects. Such “weak ties” (Granovetter, 1973) provided the grounds for the socio-techno-legal networks that became crucial for implementing projects. At the same time, the implementation of the central heating system in the Hoonhorst community made effective use of pre-existing local connections with a woodstove supplier and a local recycling company willing to cooperate and cut costs. This demonstrates how the implementation projects were typically dependent on already existing technical infrastructures. For example, the coordinator of CALorie has remained in contact with the municipal government, pushing for a new overall energy scan of municipal buildings. In case the funding scheme turns out to create viable business cases, access to large roofs and clarity about the internal consumption of these buildings are prerequisites for being able to configure potential new projects. MGE has been interested in a biogas installation at a local landfill that has lost its function of fermenting waste. The installation may still be exploited when local biomass is supplied to it. This may be a future project opportunity for MGE, but only after the pool of interested commercial actors has decided that the business case is too small for any substantial profit margins: *"If everyone thinks: 'I will make a profit', then the business case will not hold. […] And then there is space for the civil initiative, because we don't need to make a profit."* (MGE, #2).

Finally, leverage and momentum of the civic energy movement may also be stimulated on a larger, national scale. This can be done for instance by simply promoting the local initiative to the outside world, discussing its concerns and challenges in more general media. Additionally, the energy communities may engage more actively in disclosing their own knowledge and experiences. For instance, in the province where LE is active, a 'community of practice' was formed for energy cooperatives to *"put spreadsheets on the Internet and elaborate business cases together"* (LE, #1). MGE has taken the time to write a 'manual' describing how to set up a collective solar park using the 'postal code rose' scheme. In the last few years, DHH has welcomed many visits from politicians, researchers and civic initiatives to tell them about their successes and how they got there. Such exploitation activities are important as they help gain leverage and recognition in national politics and from other actors in the energy industry such as grid operators, hence making lobbying efforts more effective. Lastly, core figures of LochemEnergie were involved in *"contributing significantly to the development of the [national] Energy Agreement"* (LE, #4). This agreement, steering Dutch national energy policy since January 2014, contains a paragraph fully dedicated to the encouragement of local, decentralized energy production (SER, 2014).

So, internal and external network building of collectives is important for maintaining momentum. External network building can also lead to access to resources, relevant to a specific project or as part of the more generic community building efforts.

6. Discussion

In this article, we have taken a new approach to studying decentralized, civic energy initiatives inspired by Science and Technology Studies and the study of user innovations, in particular. To this end, our empirical analysis of 5 CECs has started from the concrete user innovations that these communities have created, and then delved into the wider community context. This approach has delivered contributions to both the user innovation literature as well as the literature on grassroots innovations and sustainability transitions.

Our analysis reveals that systems of local and sustainable energy provision have a peculiar form: they are *open technical systems* in which technical components, business cases, skills, and community goals and values are configured into multiple local systems that work. The three projects we discussed in Section 4 are examples for such systems, and demonstrate the diversity of local solutions that CECs produce. Analyzing such examples in isolation could easily overemphasize them as local and isolated tinkering, and not as representing a broader technological trajectory. Only the conceptual focus on configurations has revealed how each specific project is embedded in a field dynamics that links a CEC's identity (goals and values) with a range of alternative forms of local energy provision. Our analysis thus discerns innovation dynamics in which it is difficult to pinpoint the technology that evolves. We would like to call such dynamics *configurational innovation:* each implementation of a local system of energy provisions is (more or less) unique and represents an innovation process that occurs at the community level. As our analysis in Section 5 has demonstrated, this innovation process is characterized by the configurational work needed to arrange available, often off-the-shelve technologies with new ideas and business models for local energy provision, rather than endeavor clear-cut changes to existing devices. Such configurational work draws on and further propels a wide range of internal and external network building activities to maintain momentum for a CEC's identity and activities.

In terms of active involvement of users in innovation, therefore, we witnessed processes characterized by configurational work rather than tinkering with independent technological devices. While all the projects we described in Section 4 comprised a fair amount of development by users, this tinkering took a back seat to the wider configurational work and dynamics. Hence, user innovation predominantly lay in configuring generic technical and non-technical elements into local systems that were embedded in a broader community development. In most cases we noticed that users were not interested in pursuing innovation for innovation's sake, but were satisfied with using mundane, off-the-shelve solutions that they configured in innovative ways (Heiskanen, et al. (2015) make a similar point for non-technological-savvy people in local communities).

The specific community dynamics that have transpired from our case studies are markedly different than those originally described by Fleck (1993, 1994) who studied implementing configurational technologies in professional organizations. In all our cases, users were the actors driving configurational innovation, with no involvement of component or system manufacturers. For some, the local system's components are not just to fulfill the broad, general function of providing energy that 'works' as an affordable and reliable power supply to their appliances, but also more specific secondary functions that stem from community goals and values. As we demonstrated in 5.1, besides delivering sustainable energy these goals included making the municipality more independent; empowering civilians by self-supply and self-organization; facilitating social cohesion and economy; improving the (economic) resilience of local amenities; or simply enhancing user comfort in public buildings. The shift to a new community-based social organization of energy, which these new desires imply, may be regarded as the actual core of user innovation. This core gave rise to the range of alterations in technical forms (cf. Faulkner & Runde, 2009) that we found in our case studies, hence leading to technological change.

In the process of configurational innovation, we see a wide range of actors inside the CECs becoming active. These actors gradually grew more knowledgeable about the technologies involved as well as about how to act as a user innovator. The cases show collectives of relatively inexperienced, unequipped users that had to deal with the uncertainties of a dynamic socio-political and technical environment. Members of the communities we studied started from the ambition to initiate and realize a social movement. In a technology-heavy field as energy provision, they only gradually became acquainted with technologies almost as a by-product (as user-technology relations grow more intimate; see also Hyysalo et al., 2013) and developed into the innovation communities that could produce the many technology projects we encountered in our empirical analysis. As shown in Section 5.3, the users learnt how to build and exploit network relations hand in hand with configuring local systems of energy provision.

In a nutshell, we argue that the relevance and potential impact of user innovations in CECs can only be grasped if the traditional focus of user innovation studies is broadened beyond instances that revolve around modified technical designs of devices or systems (cf. Baldwin

& von Hippel, 2011). Our cases bring to the fore communities of mundane user innovators whose activities have significant social, legal or economic dimensions that need to be modified and arranged. For example, the composition, presentation and realization of viable business cases are integral parts of these activities. It becomes clear that user innovation is not always a simple matter of putting together resources in a linear process. Technologies are increasingly interconnected and thus configurational in nature, and they need to be carefully fitted into a network of other actors in order to work. Tinkering with technological devices, in our cases, emerged as an element of the wider configurational work it was entangled with, and tinkering was significantly pre-structured by this configurational work. We thus found a process of community driven user-innovations whose concrete results appear localized and specific at first site, but acuminate into a field level dynamic through subsequent and linked instances of configurational work.

This, finally, provides new conceptual insights into CECs as grassroots innovations with a potential to contribute to sustainable energy transitions. While strategic niche management (SNM) has traditionally emphasized local communities as test beds for eco-innovations conceived elsewhere (Heiskanen et al. 2015), studying grassroots innovations has emphasized how CECs often create experiments in response to local problems (Seyfang et al. 2007; 2014). Focusing on the user innovations and original technical forms we found in CECs brings out how such experiments, while not utilizing particularly innovative technology, still represent paths of technological change. In our study key actors in the CECs emerge as "accidental entrepreneurs" (Shah & Tripsas 2007) that not only tinker with technology but naturally embed them into their wider business and social context. The many activities to assemble and re-engineer legal, social and technical components in advance of actual implementation efforts can thus be grasped as *pre-alignment work*, enabling configurational innovation to take place. Rather than focusing on local problems only, key actors in our communities seemed well aware of the necessity for scale and momentum. The communities face a strong need to size up the range of projects available to them initially. Practically, pre-alignment work entails building financial strength, mobilizing actors, and configuring components that operate often at a more general level and may be in need of re-engineering to better suit community needs. This may lead to a larger freedom of movement and opening up design space.

Finally, our work provides new cues to studying changes at the regime level. Indeed, at first glance the configurational dynamics we found in the different CECs indicates a barrier for scaling: we found solutions that only exist as local and specific manifestations of diverse components. Focusing on any such solution as the basis for upscaling and regime level learning might then be quite misleading, and in fact represent a misconception of the nature of the innovation process CEC activities represent. That is, the configurational dynamics that we have highlighted also emphasized the communities as already involved with scaling and momentum, as key actors have striven to implement similar ideas across sites to realize field learning. This seems to indicate an early form of scaling-up activities in the communities, and a keen eye of some of the key actors for configuring regime level elements with local particularities. As such, CEC not only emerge as grassroots innovation but also as potential drivers of regime level change. Further studying grassroots innovations with the conceptual lenses of configurational user innovations might provide pivotal insights into how to stimulate such user-driven regime level change.

References

Attema, R., & Rijken, M. (2013). *Succesfactoren voor lokale duurzame energie-initiatieven - Learning Histories van vier cases*. Delft.

Baldwin, C., Hienerth, C., & von Hippel, E. (2006). How user innovations become commercial products: A theoretical investigation and case study. *Research Policy, 35*(9), 1291–1313. doi:10.1016/j.respol.2006.04.012

Baldwin, C., & von Hippel, E. (2011). Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation. *Organization Science*, *22*(6), 1399–1417. doi:10.1287/orsc.1100.0618

Bomberg, E., & McEwen, N. (2012). Mobilizing community energy. *Energy Policy, 51*, 435–444.

Dahlander, L., & Frederiksen, L. (2012). The Core and Cosmopolitans: A Relational View of Innovation in User Communities. *Organization Science*, *23*(4), 988–1007. doi:10.1287/orsc.1110.0673

Elzenga, H., & Schwenke, A. M. (2014). *Energiecoöperaties: ambities, handelingsperspectief en interactie met gemeenten*. Den Haag: PBL.

Faulkner, P., & Runde, J. (2009). On the identity of technological objects and user innovations in function. *Academy of Management Review*, *34*(3), 442–462.

Fleck, J. (1993). Configurations: crystallizing contingency. *International Journal of Human Factors in Manufacturing*, *3*(1), 15–36.

Fleck, J. (1994). Learning by trying: the implementation of configurational technology. *Research Policy*, *23*(6), 637–652.

Forrest, N., & Wiek, A. (2014). Learning from success—Toward evidence-informed sustainability transitions in communities. *Environmental Innovation and Societal Transitions*, *12*, 66–88. doi:10.1016/j.eist.2014.01.003

Franke, N., & Shah, S. (2003). How communities support innovative activities : an exploration of assistance and sharing among end-users. *Research Policy*, *32*(1), 157–178.

Granovetter, M. S. (1973). The Strength of Weak Ties. *American Journal of Sociology*, *78*(6), 1360–1380. Retrieved from http://www.jstor.org/stable/2776392?seq=1#page_scan_tab_contents

Heiskanen, E., Jalas, M., Rinkinen, J., & Tainio, P. (2015). The local community as a “low-carbon lab”: Promises and perils. *Environmental Innovation and Societal Transitions*, *14*, 149–164. doi:10.1016/j.eist.2014.08.001

Henkel, J., & von Hippel, E. (2004). Welfare Implications of User Innovation. *Journal of Technology Transfer*, *30*(1), 73–87.

Hienerth, C., von Hippel, E., & Berg Jensen, M. (2014). User community vs. producer innovation development efficiency: A first empirical study. *Research Policy*, *43*(1), 190–201.

HIERopgewekt. (2015). Initiatieven. Retrieved from http://www.hieropgewekt.nl/initiatieven

Hoffman, S. M., & High-Pippert, A. (2005). Community Energy: A Social Architecture for an Alternative Energy Future. *Bulletin of Science, Technology & Society*, *25*(5), 387–401. doi:10.1177/0270467605278880

Holstenkamp, L., & Müller, J. R. (2012). *Zum Stand von Energiegenossenschaften in Deutschland* (No. 14).

Hoppe, T., Graf, A., Warbroek, B., Lammers, I., & Lepping, I. (2015). Local Governments Supporting Local Energy Initiatives: Lessons from the Best Practices of Saerbeck (Germany) and Lochem (The Netherlands). *Sustainability*, *7*(2), 1900–1931. doi:10.3390/su7021900

Hyysalo, S., Juntunen, J. K., & Freeman, S. (2013). Internet Forums and the Rise of the Inventive Energy User. *Science & Technology Studies*, *26*(1).

Hyysalo, S., & Usenyuk, S. (2015). The user dominated technology era: Dynamics of dispersed peer-innovation. *Research Policy*, *44*(3), 560–576. doi:10.1016/j.respol.2015.01.002

Jeppesen, L. B., & Frederiksen, L. (2006). Why do users contribute to firm-hosted user communities? The case of computer-controlled music instruments. *Organization Science*, *17*(1), 45–63.

Lakhani, K. R., & von Hippel, E. (2003). How open source software works: “free” user-to-user assistance. *Research Policy*, *32*(6), 923–943. doi:10.1016/S0048-7333(02)00095-1

Middlemiss, L., & Parrish, B. D. (2010). Building capacity for low-carbon communities: The role of grassroots initiatives. *Energy Policy*, *38*(12), 7559–7566.

Ornetzeder, M., & Rohracher, H. (2006). User-led innovations and participation processes: lessons from sustainable energy technologies. *Energy Policy*, *34*(2), 138–150. doi:10.1016/j.enpol.2004.08.037

Ornetzeder, M., & Rohracher, H. (2013). Of solar collectors, wind power, and car sharing: Comparing and understanding successful cases of grassroots innovations. *Global Environmental Change*, *23*(5), 856–867. doi:10.1016/j.gloenvcha.2012.12.007

Peine, A. (2008). Technological paradigms and complex technical systems—The case of Smart Homes. *Research Policy*, *37*(3), 508–529. doi:10.1016/j.respol.2007.11.009

Peine, A. (2009). Understanding the dynamics of technological configurations: A conceptual framework and the case of Smart Homes. *Technological Forecasting and Social Change*, *76*(3), 396–409. doi:10.1016/j.techfore.2008.04.002

P-Nuts. (2013). *Lokale duurzame energie in Nederland. Het speelveld bestormd!* NEWNRG.

Pollock, N., & Williams, R. (2010). e-Infrastructures: How Do We Know and Understand Them? Strategic Ethnography and the Biography of Artefacts. *Computer Supported Cooperative Work (CSCW)*, *19*(6), 521–556. doi:10.1007/s10606-010-9129-4

Pollock, N., Williams, R., & D'Adderio, L. (2007). Global Software and its Provenance: Generification Work in the Production of Organizational Software Packages. *Social Studies of Science*, *37*(2), 254–280. doi:10.1177/0306312706066022

Raasch, C., Herstatt, C., & Lock, P. (2008). The dynamics of user innovation: Drivers and impediments of innovation activities. *International Journal of Innovation Management*, *12*(03), 377–398.

Rijkswaterstaat. (2013). *Handreiking: De rol van lokale overheden bij lokale duurzame energie-initiatieven*. Rijkswaterstaat.

Rogers, J. C., Simmons, E. A., Convery, I., & Weatherall, A. (2008). Public perceptions of opportunities for community-based renewable energy projects. *Energy Policy*, *36*(11), 4217–4226. doi:10.1016/j.enpol.2008.07.028

Schwencke, A. M. (2012). Energieke BottomUp in Lage Landen. *AS I-Search*.

Seyfang, G., & Haxeltine, A. (2012). Growing grassroots innovations: exploring the role of community-based initiatives in governing sustainable energy transitions. *Environment and Planning-Part C*, *30*(3), 381.

Seyfang, G., Hielscher, S., Hargreaves, T., Martiskainen, M., & Smith, A. (2014). A grassroots sustainable energy niche? Reflections on community energy in the UK.

Environmental Innovation and Societal Transitions, *13*, 21–44. doi:10.1016/j.eist.2014.04.004

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.

Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, *16*(4), 584–603.

Shah, S. K., & Tripsas, M. (2007). The accidental entrepreneur: the emergent and collective process of user entrepreneurship. *Strategic Entrepreneurship Journal*, *1*(1-2), 123–140. doi:10.1002/sej.15

Tietz, R., Morrison, P. D., Luthje, C., & Herstatt, C. (2005). The process of user-innovation: a case study in a consumer goods setting. *International Journal of Product Development*, *2*(4), 321–338.

Van den Brink, J. (2013). Ruimte voor lokale energievoorziening. *TNO TIME*, *2013*(2), 26–27.

Van Oost, E., Verhaegh, S., & Oudshoorn, N. (2009). From innovation community to community innovation user-initiated innovation in wireless leiden. *Science, Technology & Human Values*, *34*(2), 182–205.

Von Hippel, E. (1976). The dominant role of users in the scientific instrument innovation process. *Research Policy*, *5*(3), 212–239. doi:10.1016/0048-7333(76)90028-7

Von Hippel, E. (1988). *The Sources of Innovation*. New York, NY: Oxford University Press.

Von Hippel, E. (2005). *Democratizing innovation*. Cambridge, MA: MIT Press.

Von Hippel, E. (2007). Horizontal innovation networks--by and for users. *Industrial and Corporate Change*, *16*(2), 293–315. doi:10.1093/icc/dtm005

Von Hippel, E., de Jong, J. P. J., & Flowers, S. (2012). Comparing Business and Household Sector Innovation in Consumer Products: Findings from a Representative Study in the

United Kingdom. *Management Science*, *58*(9), 1669–1681. doi:10.1287/mnsc.1110.1508

Von Krogh, G., Spaeth, S., & Lakhani, K. R. (2003). Community, joining, and specialization in open source software innovation: a case study. *Research Policy*, *32*(7), 1217–1241. doi:10.1016/S0048-7333(03)00050-7

Voss, A., Asgari-Targhi, M., Procter, R., & Fergusson, D. (2010). Adoption of e-Infrastructure services: configurations of practice. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences*, *368*(1926), 4161–76. doi:10.1098/rsta.2010.0162

Walker, G., & Cass, N. (2007). Carbon reduction,“the public”and renewable energy: engaging with socio-technical configurations. *Area*, *39*(4), 458–469.

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.

Appendix A: Case descriptions

Table A.1: Case descriptions of five civic energy communities

Case name Abbreviation Setting Start date	Background	General objectives	Organization type	Main technical focus areas in energy	Most notable projects in collective energy facilities (r = realized/ p = pending)
CALorie (CAL) Municipality 6 September 2010	Main initiator was experienced in studying/supervising civic initiatives; got inspired observing set-up of other cooperatives, and voluntarily started energy cooperative in his own municipality.	Castricum energy neutral by 2030, through local production and conservation.	Cooperative About 70 members, 40 active volunteers	Solar power Isolation technology	• Collective solar park (r) • Collective household isolation projects (r) • Energy neutral households (p) • Other solar park model (p)
Morgen Groene Energie (MGE) Region 31 August 2011	Main initiator saw potential for civic initiative to boost energy transition. Assembled small resonance group and developed organization and marketing strategy for overarching cooperative with local departments.	Energy balance of members to become energy neutral, by producing sustainable energy in region.	Cooperative with local 'departments' Over 200 members, 40 active volunteers	Solar power Isolation techno-logy	• Collective solar park (r) • Energy neutral rental housing (p) • Collectively installing solar & isolation technology in households (p)
Hilverstroom (Hil) Municipality 16 July 2012	Started as a village cooperative looking for ways to realize its own energy supply locally. Examining a potential business case at an industrial site, it was concluded that management of self-supply should be shifted to the municipal level.	Energy neutral municipality Hilvarenbeek, through local production and conservation.	Cooperative Member base unclear, about 40 active volunteers	Hydropower Biomass Solar power	• Hydropower facility at old sluice (r) • Biomass heating for large buildings (p) • Collective solar parks (p)
Lochem Energie (LE) Municipality 26 August 2011	Municipal executive councilor of Lochem wanted energy provision to be organized/managed locally, hence arranged independent civic energy movement to assess local business cases.	Energy neutral municipality of Lochem by 2030, through local production and conservation.	Cooperative Over 500 members, up to 100 active volunteers	Smart grid technology Energy storage Hydropower solutions Solar power	• Government pilot: smart grid technology/electri c vehicles (r) • Collective solar park (r) • Solar panels rental housing (r) • Energy storage in canal (p) • Small-scale hydropower facilities (p)

Case name Abbreviation Setting Start date	**Background**	**General objectives**	**Organization type**	**Main technical focus areas in energy**	**Most notable projects in collective energy facilities (r = realized/ p = pending)**
Duurzaam Hoonhorst (DHH) Village 24 September 2010	In 2009 several community facilities needed maintenance. Initiators decided it was time to mobilize civilians to keep Hoonhorst livable. Wrote bid book and won large provincial 'Sustainable Village' grant.	Keeping Hoonhorst livable, by making community more ecologically, economically and socially sustainable.	Foundation. No members, substantial part of villagers (1300) actively involved	Energy efficiency & isolation Biomass	• Church ventilation system (r) • Central village heating system (r) • Intelligent climate control in public facilities (r) • Biogas from local manure (p)