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Local niche experimentation in energy transitions: a theoretical and empirical exploration of proximity advantages and disadvantages

Lars Coenen (lars.coenen@circle.lu.se)
CIRCLE, Lund University

Rob Raven (r.p.j.m.raven@tue.nl)
Eindhoven University of Technology

Geert Verbong (g.p.j.verbong@tue.nl)
Eindhoven University of Technology

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Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)
Lund University
P.O. Box 117, Sölvegatan 16, S-221 00 Lund, SWEDEN
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Lars Coenen, Rob Raven, Geert Verbong

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Keywords: Strategic Niche Management, geography of innovation, sustainability, experiments, energy storage, The Netherlands

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Lars Coenen*
Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)
Lund University
Sölvegatan 10, Lund SE 223 62, Sweden
E-mail: lars.coenen@circle.lu.se

*Corresponding author

Rob Raven
Eindhoven University of Technology
Department of Industrial Engineering and Innovation Sciences
PO Box 513, 5600 MB Eindhoven, The Netherlands
Fax: 0031-40-244-4602
E-mail: r.p.j.m.raven@tue.nl

Geert Verbong
Eindhoven University of Technology
Department of Industrial Engineering and Innovation Sciences
PO Box 513, 5600 MB Eindhoven, The Netherlands
Fax: 0031-40-244-4602
E-mail: g.p.j.verbong@tue.nl

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1. Introduction

In the face of major sustainability challenges for the 21st century, such as climate change and rising oil prices, there is currently a lot of attention in Europe for securing a sustainable energy society. This ambition requires a transition from fossil fuels towards various sustainable energy technologies such as biofuels, fuel-cells, photovoltaics, wind-energy, etc. A transition refers to a fundamental change in the fulfilment of societal needs that unfolds in the course of 25 to 50 years. It entails dynamic interaction and co-evolution of new technologies, changes in markets, user practices, policy and cultural discourses, and governing institutions (Geels et al., 2008). At present there is a lot of uncertainty how the energy transition will unfold and, whether and how, this transition can be governed.

In the face of this uncertainty transition scholars advocate niche experimentation to play a crucial role. It refers to the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation in a societal context with the aim of learning about the desirability of the new technology and enhancing the further development and rate of application of the new technology (Raven, 2005). Translated to policy practice, the Strategic Niche Management (SNM) approach suggests a governance perspective to mainstream emerging sustainability innovations through niche experimentation and consecutive upscaling (Raven et al, forthcoming). While niche experimentation are often enacted in a local or urban setting (e.g. urban transport systems based on biogas), surprisingly little attention has been paid to the spatial dimensions of SNM nor at the agglomeration or clustering effects that may arise in these local contexts.

Introducing the hitherto unchartered fields of economic geography and regional studies, the objective of the paper is to gain a better understanding under which conditions actors that participate in SNM can leverage the ‘regional advantages’ (Saxenian, 1994; Rychen and Zimmermann, 2002; Filippi and Torre, 2003) which might take place in these localities for niche experimentation and upscaling. It offers a conceptual synthesis of key concepts in the geographical literature on innovation, i.e. clusters, agglomerations and regional innovation systems, on the one hand, and the literature on niche experimentation and SNM on the other. The usefulness of this synthesis will be illustrated with a case from the energy domain (energy storage in aquifers). The remainder of the paper will first introduce SNM and regional innovation respectively, followed by a synthesis of these disparate bodies of literature. This is followed by the case illustration, after which the conclusions of this paper are presented.

2. Strategic Niche Management: Key lessons and challenges

The origins of Strategic Niche Management can be traced back to the early 1990s. Driven by the observation that many sustainable technologies never leave the showrooms – or worse, remain on the shelves of laboratories as proto-types – Schot et al (1994) and Kemp et al (1998) performed research on early market experimentation with electric vehicles to understand why. Building upon evolutionary theories of technological change the argumentation goes that dominant technologies have become locked-in into stable ‘socio-technical regimes’: cognitive, normative and regulatory rules that guide technological change along incremental trajectories. Regimes are embedded in wider ‘landscape’ trends and events such as globalisation, urbanisation, wars, environmental disasters and international policy agreements. To explain radical innovation, scholars such as Schot (1992) and Rip (1992) developed a quasi-evolutionary perspective on technological change arguing that variation is not completely blind but that technology actors anticipate future selection environments and actively try to shape them in favour of new innovations. Early market experimentation such as demonstration projects were identified as critical loci where selection environment actors and variation environment actors meet, exchange views and ideas, learn and adjust their preferences, expectations, routines and habits. They also found that 'protection' of such 'societal experiments' – explicitly using experimentation as a concept to refer to the uncertainty and learning dimensions of such activities – was crucial, because prevailing regimes would otherwise reject those innovations and prevent them from becoming mature. Hence, experimentation in technological niches – intentionally, but partially protected spaces with subsidies and other public (or private) supportive measures – were identified as a crucial step in maturing innovations and regime shifts towards sustainability. Adding insights from social constructionist approaches and Technology Assessment, an iterative process of articulating expectations, setting up and breaking down protection, social network building, experimentation, learning and wider diffusion as a process of branching into new market niches and eventually mainstream markets was thought to be typical and desirable for governing sustainability transitions. In retrospect, several SNM scholars have criticised the initial, bottom-up, experimental focus of SNM. Hoogma et al (2002) conclude the following:

> "We were certainly over-optimistic about the potential of SNM as a tool for transition. […]. The positive circles of feedback by which a technology comes into its own and escapes a technological niche are far weaker than expected and appear to take longer than expected (5 years or more). […] The experiments did not make actors change their strategies and invest in the further major development of a technology."

Indeed, a critical challenge that SNM is facing concerns how the process from the initial 'niche' to a large-scale transformation can be accelerated (Geels et al., 2008).

Recent contributions on SNM have started to address this challenge by introducing a (non-spatial) local and global dimension of niches. In this perspective early SNM scholars expected too much of single experiments in terms of niche creation, long-term commitment of actors to sustainability and wider social embedding of sustainable technologies. Hence, building upon Law and Collon (1992), Hard (1991), Disco and van der Meulen (1998) and Deuten (2003) and a long-term case study on biogas development in the Netherlands, Geels and Raven (2006) developed a stylized model of the niche development process which consisted of both a local and a global dimension. The local dimension relates to experimentation with a variety of novel technologies generating hands-on and contextualised knowledge and locally applicable lessons. The global dimension (not to be mistaken by the geographical connation of the word global) refers to an emerging field or proto-regime supported by a network of actors that is concerned with defining de-contextualised, shared rules such as problem agendas, search heuristics and abstract theories and models independent of their local context. The relations between the local and global dimensions are not easily managed, but require dedicated work and aggregation activities. Similarly, while the emerging field at the global dimension is potentially a valuable resource for local networks and experimentation, global to local coordination is also not a linear and straightforward process (Raven et al, 2008).

[Figure 1 around here]

As illustrated in the above figure the local-global dimensions play an important role in conceptualizing upscaling of niche experiments. Upscaling is defined as increasing the scale, scope and intensity of niches experiments by building a constituency behind a new (sustainable) technology, setting in motion interactive learning processes and institutional coordination and adaptation, which helps to create the necessary conditions for the successful diffusion and development of those technologies (Kemp et al., 1998). However, we remain wary that the local-global dimensions might remain only metaphorical if no 'proper' spatial connotations are in place. The present lack of geography in SNM prevents it from capturing how combinations of institutional, entrepreneurial and innovative processes and heterogeneous networks co-evolve and coalesce into more stable configurations that can challenge existing regimes. Indeed, grounding SNM in a spatial context will force it to address the question how and why experiments are performing differently in different geographical settings and, consequently, what the governance challenges are for translating localities into generalities and backwards and ultimately upscaling into mainstream regime practice. Hence, connecting geography and SNM holds the potential to reveal why certain networks, technologies and institutions manage to transcend the local niche context and 'go global' while others don't.

3. Innovation and geography

Studies on the geography of innovation have made longstanding contributions, ever since the seminal work of Alfred Marshall (1920), to demonstrate (1) that innovation (incl. technological change) is unevenly distributed across the geographical landscape and (2) that geographical proximity and agglomeration economies are conducive to innovation processes (Asheim and Coenen, 2005; Cooke and Morgan, 1998; Florida, 1995; Maskell and Malmberg, 1999; Storper, 1995). The popularity of these arguments can be traced back to empirical studies of regional success stories such as the high level of innovation in industrial districts in e.g. Italy and the UK (Asheim, 2000), the exemplar industrial system of Silicon Valley (Saxenian, 1994) as well as other examples of successful regional clusters in most developed as well as developing economies (Porter, 1990). These studies all draw the conclusion that territorial agglomeration provides a superior context for innovation because of localised learning processes and 'sticky' knowledge grounded in social interaction (Gertler, 1994).

Because no firm is in complete control of all the resources it needs, it is dependent on its territorial environment. Economic globalization renders more and more traditional local resources such as natural resource endowments, investment capital, labour and infrastructure ubiquitous. This means they become available everywhere at more or less the same price. According to Malmberg and Maskell (2006) the knowledge base and institutional set-up are those resources that are least sensitive to this ubiquification process. Through cumulative causation these knowledge bases and institutional set-ups are reproduced generating stable patterns of industrial specialization and territorial differentiation. These clusters form the basis for a local milieu facilitative to knowledge spillovers and other forms of 'learning by being there' (Gertler, 2004). What exactly is meant with 'local' in the context of localized learning processes and clusters remains somewhat elusive in this literature (Coenen, 2007). It can however be asserted that localized learning to a large extent involves specific, and partly tacit, knowledge, as opposed to more global, generic knowledge (see also Moodysson, Coenen and Asheim, 2008 for a similar discussion).

To explain the suggested positive effect of local contexts on (interactive) innovation processes Boschma (2005) distinguishes between five notions of proximity: cognitive, organisational, social, institutional and geographical proximity. *Cognitive proximity* refers to the overlap in knowledge and competence base between organisations. A certain level of cognitive distance is necessary to exchange knowledge that gives rise to the emergence of novelty. However, too much cognitive distance precludes mutual understanding. *Organisational proximity* refers to the extent to which relationships are shared in a formal, organizational arrangement. More specifically, it involves the degree of control and rate of autonomy under which knowledge is exchanged and learning processes are carried out between and within organizations. Organizational proximity reduces uncertainty and the risk for opportunism. However too much control and too little autonomy may lead to a lack of flexibility and lock-in which in turn stifles creativity and innovation. This leads Boschma (2005), following Nooteboom (1999) to argue for loosely coupled systems as the governance structure that is most instrumental to change and renewal by combining sufficient control and flexibility. Further investigation is needed to further explore concrete governance configurations that are able to balance control and flexibility in favour of innovation (particularly of the radical type). *Social proximity* is based on friendship, kinship, or mutual experiences, and refers to mutual trust. When involved in collaboration-based innovation, trust between actors needs to be in place before they start committing their key resources and proprietary knowledge. However, an overload of trust (i.e. blind trust) is detrimental to innovation because close ties result in lock-in and myopia. While organizational and social proximity primarily referred to relationships on the micro (niche) level, *Institutional proximity* refers to similarities in the contextual norms and values on meso level (i.e. regime): i.e. the rules of the game by which actors play (Edquist and Johnson, 1997). It provides stable conditions for interactive learning and coordination to take place effectively. In contrast, too much institutional thickness precludes innovation, especially of the radical type, as it creates rigidity and inertia. Experimentation requires some leeway in rule-following behaviour to effectively take place. Finally, Boschma (2005) mentions *geographical proximity* straightforwardly defined as the physical distance between actors. Short distances literally bring people together and facilitate information and knowledge exchange. Here face-to-face interaction has proven to possess superior communication characteristics that are very difficult to emulate through electronically mediated communication across distance (Storper and Venables, 2004, Asheim et al., 2007). It offers an unrivalled capacity for interruption, repair, feedback and learning. The downside of this dimension of proximity is that it prevails actors from access to knowledge in the outside world, which results in insular attitudes to new knowledge. Below we draw on these types of proximity to arrive at a more spatially sensitive SNM framework.

4. Adding geography to niche experimentation and upscaling: towards a spatial theory of SNM

To explore spatial dimensions in niche development processes we start with discussing three 'internal niche processes' which are considered of particular importance in SNM studies (Hoogma et al, 2002; Raven, 2005, Schot and Geels, 2008):

- Shaping heterogeneous social networks including outsiders
- Articulating shared, tangible and specific expectations
- Broad and second-order learning

Social networks

SNM emphasises the importance of shaping new social networks for sustainability experimentation. Social networks are important because they provide necessary resources, sustain development, carry expectations, articulate new requirements and demands and enable learning and diffusion of lessons and experiences between actors and locations. For sustainability innovations networks dominated by regime actors are considered not beneficial, as they might suffer from a tendency to optimise prevailing trajectories rather than to explore new (and more sustainable) ones. Hence, regime-outsiders are considered crucial participants in social networks supporting sustainability experiments. Based on insights from Technology Assessment and empirical observations of an overly presence of technology actors in experimentation, SNM scholars also promote broad and heterogeneous networks existing not only of technology actors such as firms and technological research organisations, but also actors representing social concerns such as policy actors, users and non-governmental organisations including representatives of the environmental movement. Involving users in experimentation is also considered a key mechanism for stimulating deep learning.

For social network building, organizational and social proximity appear primarily relevant. The SNM literature has so far paid only little attention to issues related to trust-building and organizational control. These two factors are, in fact, often compensating each other as effective governance mechanisms in heterogeneous actor settings. Low trust requires higher degrees of control in order to coordinate the collaboration while high trust provides greater autonomy for the individual agents while at the same time acting as glue that binds the actors together. How this trade-off between trust and control is played out in niche-experimentation is highly relevant, but requires more empirical investigation. Indeed, emphasises on outsider participation in niche experimentation creates larger organizational and social distances, which is intentionally advocated by SNM scholars as it creates ample opportunities for second-order learning. However, from a proximity perspective scholars argue that it may be expected that high trust arrangement are more conducive to experimentation than low trust arrangements. Geographical proximity is most likely to stimulate social network building because short geographical distance favour social interaction and trust-building. At the same time, too strong local networking may lead to an introverted experiment that faces serious difficulties in upscaling.

Articulating expectations

Articulating expectations is an important resource in niche-experimentation (Van Lente, 1993; Brown and Michael, 2003; Borup et al, 2006). Articulating expectations helps to reduce uncertainty in innovation processes, they enable the mobilisation of resources by providing promises about future benefits and once accepted and transformed in (public or private) agenda's they act as scripts that position and influence others. SNM scholars have found that expectations are especially powerful when they are shared by an increasing number of actors (guiding them into similar directions), when they are tangible (i.e. they are not just promising ideas, but realistic and backed by results from research and experimentation) and when they are specific (not just sketching utopia, but enabling falsification and the definition of next steps). However, given the heterogeneous composition of actors involved in niche experiments it would be naive to assume that all participants in the experiment will have shared, similar expectations about the pros and cons of the technology.

Therefore, articulating expectations – and in particular shared expectations – in niche experimentation would require cognitive and social proximity. At the same time it holds the potential to contribute in shaping institutional proximity. Rather than seeking assimilation of expectations into one coherent set of norms and values, the actual contribution of the articulation process(es) lies in mutual adaption and adoption of individual expectations among actors. Diversity of expectations can also be conducive to the niche-experiment, especially in the early, fluid state of technology development as it prevents the experiment to lock-in to sub-optimal configurations. It is therefore crucial to acknowledge that expectations are not static, but change. In early SNM research experimentation was thought to be a way to help articulate and change expectations to the benefit of sustainability. Later research showed that articulating expectations is still important, but that the effect of experimentation on changing them is limited compared to the effects of dynamics in the wider environment of prevailing regimes and the socio-technical landscape (Raven, 2005; Geels and Raven, 2006). Thus, to avoid too narrow a focus on the local experiment per se, the wider institutional framework in which the experiment is embedded needs to be taken into account (Markard and Truffer, 2008). This needs to be addressed both theoretically and empirically.

In sum it can be argued that it is important for niche-experiments to be underpinned by a dynamic set of diverse but complementary expectations that are not fixed but are open to internal and external adjustments while at the same time providing a stable basis for collaboration and coordination within the niche. Geographical proximity may be helpful to facilitate this articulation process as it allows actors to be involved in interactive, continuous and, at the same time, deep expectation exchange. Moreover, SNM has primarily paid attention to expectations that are closely tied to the technological domain. Bringing the wider institutional framework into the scope of analysis (tied to the locality in which the experiment is carried out), can be helpful to understand and concretize the expectations that actors have. Moreover it provides an analytical vantage point to investigate how expectations are reproduced outside the domain of the niche experiment as an important attribute of upscaling.

Second-order learning

Learning plays a key role in innovation literature and is also considered a key process in SNM. In fact, being an intellectual offspring of (Constructive) Technology Assessment, SNM can be considered a strategy to optimise social learning processes rather than a simple tool for sustainable technology diffusion. SNM scholars have found that learning in niche market experimentation was too often characterised by a narrow focus on technical and economic dimensions. While certainly important, other dimensions were often neglected or not considered relevant. SNM proposes to broaden traditional techno-economic learning with learning about user preferences, cultural and symbolic meaning, industry and production networks, regulations and government policy and societal and environmental effects of the new technology. Alignment between the technical and the social is crucial and can go both ways: firms and other technology developers learn about users, policies and societal preferences and adjust the technology, while users, policy makers and other social actors learn about the technological characteristics and adjust preferences, laws, routines and norms.

Broad and, in particular, second-order learning in SNM challenges our understanding of the importance of cognitive, organisational, social and institutional proximity for innovation. Through the heterogeneous set-up of the experiment, the technology may profit from the diverse knowledge bases that are brought together. During the course of the experiment, one can argue, the cognitive proximity between the diverse actors increases. However, while alignment is needed, some level of disgruity needs to be maintained to avoid myopia about the technology's attributes and, more importantly, to maintain a sufficient level of reflexivity to stimulate second-order learning. Otherwise the potential for learning becomes hollowed out. Similar to expectations and network building, a key challenge to learning in niche-experimentation is not become myopic and locked-in. This requires a sound balance between internal and external (local and global) learning processes that transcend the direct context of the niche experiment.

5. Case study: Aquifer Thermal Energy Storage

This section discusses the Aquifer Thermal Energy Storage (ATES) niche in the geographical area of the Netherlands. It provides a historical perspective on niche development using the SNM classification of expectations dynamics, networks and learning as well as the classification of different forms of proximity. The main data source is data collected in the context of a book project on the history of renewable energy in the Netherlands in the period 1970-2000 (Verbong, 2001). Recent reports on the state of the art of ATES complement the case study.

The storage of thermal energy in aquifers is a successful niche in The Netherlands. The principle of ATES is rather simple. An aquifer is an underground water-bearing layer, from which groundwater can be extracted (Wikipedia). This layer can be used to store seasonal energy. During the summer cold water can be pumped up and used for cooling. During this process the water takes up heat and can be returned to another well. During the winter this process can be reversed. The warm water can be pumped up, used for heating and returned to the first well, the cold well. Often heat pumps are used to upgrade the temperature of the water (or air). This cycle can be repeated each year; hence ATES is referred to as seasonal energy storage. Thermal energy storage can serve several purposes, the main being energy conservation using renewable energy sources, optimization of energy systems and reduction of greenhouse gases (Nielsen).

The application of ATES was a spinoff of a national research program on geothermal energy, starting in 1979. This exploratory research fuelled technical expectations about the feasibility of geothermal, but not much happened due to low economic expectations. In particular financing the costs of drilling to depths of 1000 meters and below proved to be a major barrier for experiments. The government expected that other actors would contribute to the costs, but this did not happen and only one exploration occurred, with disappointing results. In a follow-up research program expectations shifted to thermal storage of energy and created some initial cognitive proximity in the form of a shared expectation about a promising application. However, due to the level of novelty of this innovation, no prevailing social network, nor any organizational or social proximity between relevant actors existed. Hence, this had to be build up from the start.

Two experiments took place during the second halve of the 1980s. The main actors involved were a small group specialised in energy projects within a construction firm and a large engineering and consultancy firm. The first project took place at the building of a large contractor; the small energy group was located in this building. This project used stored thermal energy from the sun and from computers as an additional source of energy for heating. The expectations on the amount of energy saved were not met at all. It was learned that the least developed technological component – the heat pump – was the weakest link, but the storage system worked reasonably well. The second experiment took place at a newspaper printing company in Amsterdam. In this experiment water was cooled during the winter and stored in an aquifer; during the summer the cold water was used for cooling the large printing machines during the summer. Despite several problems, due to technical problems and mild winters, delaying the loading of the systems, the general consensus was that the system worked well. Hence, the experiment drew a lot of interest from actors not involved in the initial niche network.

However, the low energy prices of these years reduced all expectations about future applications (Verbong, 2001). As a result new projects were delayed and the major actors in the social network, the construction and the consultancy firm, lost interest. But two employees from the last company had different expectations. They had learned from previous experiments that storing cold is much more attractive than storing heat. Indeed, most cooling machines run on electricity, while heating machines use natural gas. As at that time electricity was much more expensive than natural gas, the application of ATES for cooling was really competitive. More important, they had learned from previous experiments and research that the geographical situation in the Netherlands is very favourable for energy storage, so ATES can be applied almost everywhere. They expected a major market and decided to start their own company, IF technology, to develop and commercialize new technologies. An employee from the construction firm shared their expectations and started an installation and advisory company, DWA. Together with the small drilling company Hajtema b.v., this new, but informal network had a high level of social proximity (trust) due to participation in the previous experiments. This group became the nucleus of the new social network of the ATES niche.

During the 1990s several projects were successfully implemented in large industrial companies, horticulture, offices, hospitals and large malls. From experimentation and application in these divers settings the social network learned that scale is an important factor in assessing the feasibility of a project, because costs for drilling and for the construction of the underground system including the heat exchangers with the heating and cooling systems are quite high, making a small system, e.g. for a couple of houses, not attractive. They also learned that pay-back times of projects varied between 2 and 10 years; a large demand for cooling reduced the pay back considerably. Because of this, subsidies were not longer needed. There was one exception: exploratory drilling was a crucial element in the process determining the feasibility of a new project. The Dutch government agency for sustainable development and innovation subsidised these costly feasibility studies, removing a potential barrier for niche development. Also in other ways, government agencies and branch organisations proved to be instrumental in the successful development of the ATES niche. They organised meetings for the dissemination of knowledge, the exchange of experiences and the education of new experts. In this way gradually a national social network emerged and local knowledge was translated to the expanding global niche network (Verbong 2001). Hence, while the early actors still have a prominent position in the network, several new actors entered the niche, including large consultancy firms but also property developers and water companies. The number of ATES systems rose substantially. Since the 1990s the number of ATES systems installed increased: from 5 projects in 1990, 34 in 1995, 214 in 2000 to well over 600 in 2006. One favourable context development was that the use of groundwater for cooling and other purposes became institutionalised in regulations (institutional proximity between the niche and its context was created). It was no longer permitted to just dump the water used into the sewer system. ATES provided an viable alternative for this practice.

Although ATES systems can be applied almost everywhere in the Netherlands, geographical proximity between projects and agglomeration is emerging in four provinces: North and South Holland, North Brabant and Gelderland contain over 75% of all projects. The provinces are an important actor in the current network. They are responsible for the control and management of groundwater in their regions. According to the Law on Groundwater, in order to prevent degradation of the quality of drinking water from groundwater, groundwater can only be used for other purposes under strict conditions and its use has to be monitored. There are, however, large institutional differences in the permit procedures and conditions between the provinces, partly explaining the differences in the number of projects in each province. Another explanation is that successful projects locally serve as example, leading to a concentration of projects in some urban areas, e.g. in Amsterdam or Eindhoven. A third explanation can be found in the expectations of local governments, e.g. in relation to developing new urban areas or redeveloping old industrial areas (Bodem onder energie, 2007). Hence, geographical proximity has spurred further niche development. But there also disadvantages to this geographical proximity related to fear for interference between projects (Bodem onder energie, 2007). Heat exchange between nearby systems can have an unexpected and negative impact on energy efficiency and extraction of ground water by several projects simultaneously can result in changes in the groundwater level with potential disastrous effects.

Currently the expectation is that the number of systems constructed each year can grow from about 100 to 1000 (Ecofys, 2007). So in 2008 the Dutch government formed a new actor, an ATES taskforce. This task force was asked to make an inventory of the main barriers for implementing ATES systems. One problem is the increasing geographical proximity in the underground in the Netherlands of other infrastructural systems (cables, pipes, sewers systems, tunnels, storage systems etc.). Another problem is the lack of a clear regulatory framework for the use of the underground and the groundwater. Moreover, it is not clear how the government should deal with conflicting interests of different users of the underground and groundwater. Because of this, the ATES network expresses confusion and uncertainty about what is permitted and what not. Another barrier is the already mentioned potential interference of systems.

6. Conclusions

In this paper we have discussed how local niche experimentation relates to proximity advantages in innovation processes as identified in the geography of innovation literature. This literature claims that the locations where innovation emerge and thrive are not coincidental, but that they follow certain patterns and explanatory logics. Such specific attention for explaining locations is not explicitly present in SNM, although this literature makes claims about the importance of experimentation in local settings, and local and global dynamics. Hence a confrontation of both literatures was thought to be promising. We have presented a case study to explore relationships empirically. The following conclusions can now be drawn.

First, we have found evidence that the proximity in local contexts for niche developments of Aquifer Thermal Energy Storage in the Netherlands has played a role in a variety of ways. Cognitive proximity relates in particular to shared expectations. Social proximity turns out to be important in relation to trust between actors. Geographical proximity is crucial in this case, because there is a clear dependence on available resources (i.e. underground heat and cold resources) that turned out to be widely available in the Netherlands. Institutional proximity – i.e. proximity between the niche and external institutions such as regulations – was also found to be important. In this case difference between institutions on a provincial level explained why experiments tend to emerge in four provinces instead of others. Finally, organisational proximity in this case referred mainly to the creation of new actors – i.e. formalisation of interactions between individual persons or organisations such as the taskforce that was created in 2008.

Second, taking into account these notions of proximity helps to understand better how and why the niche evolved over time. More particular, it helps to unpack processes of aggregation and upscaling. Indeed, previous SNM literature has remained vague how exactly aggregation and upscaling occurs. This paper hints at the importance of various proximity dynamics. There is a pattern according to which aggregation and upscaling occurred in the case. Starting with cognitive proximity (articulating expectations) and social proximity (trust) the niche started quite loose and informal from an institutional perspective. Later, organisational proximity and institutional proximity became more important when interactions were formalised into newly created organisational entities and with interactions with the wider institutional context (or regime in SNM terminology). Geographical proximity turns out to be an important ‘background variable’ as the availability of natural resources was crucial for success. While the importance of natural resources is conceptually present in SNM literature (biological literature – being an important intellectual inspiration – indeed emphasises the geographical dimension and resource availability of niches), empirically this aspect is not well articulated in SNM studies. Hence, using proximity concepts holds the promise of opening up the blackbox of aggregation and upscaling and bringing back the importance of locality in SNM.

Third, the paper provides useful insights for proximity literature as well. There are several aspects to this. Proximity literature implicitly assumes the presence of proximity advantages, ready to be utilised by innovative actors. This paper, however, suggests that various forms of proximity advantages needs to be shaped rather than being present. In this case of a radical new technology, only some cognitive and geographical proximity advantages were present in the beginning (in the form of loosely coupled expectations and natural resource availability). Many other forms of proximity advantages co-evolved along the way and were actively constructed by involved actors. Agency and path creation played a crucial role in this process (Garud and Karnoe, 2001). Indeed, experimentation shaped social proximity by creating mutual trust; learning shaped cognitive proximity by aligning expectations; interactions with the wider context shaped institutional proximity and in particular with regulations; and establishing new (intermediary) actors shaped organisational proximity. Hence, there is a need for a more agency-based and dynamic perspective on proximity advantages.

Finally, this paper suggests that there is a bias in proximity literature, in the sense that proximity is not always an advantage as suggested by this literature. E.g. there were limits to geographical resources and potential environmental degradation in case of too much projects in too limited areas. Hence, proximity can also be a disadvantage for innovation processes, aggregation and upscaling.

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Figures

Figure 1. Relationships between local project and an emerging global level of shared rules. Adapted from Geels and Raven (2006).

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