The contribution of local experiments and negotiation processes to field-level learning in emerging (niche) technologies

Meta-analysis of 27 new energy projects in Europe

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Abstract

This paper examines how local experiments and negotiation processes contribute to social and field-level learning in emerging (niche) technologies. The analysis is framed within the niche development literature and in particular the dynamics of socio-cognitive technology evolution as elaborated by Geels and Raven (2006). This literature offers a framework for analyzing the relation between individual projects in local contexts and the transfer of local experiences into generally applicable rules on the 'global niche level'. We address this question by examining two case studies drawn from a meta-analysis of 27 new energy projects throughout Europe. These two case studies, both pertaining to biogas projects for local municipalities, illustrate the diversity of applications introduced into a generic technology through processes of local variation and selection. We examine the diversity of expectations, and the negotiation and alignment of these expectations, underlying the diversity of local solutions. Moreover, we address how the transfer of lessons from individual local experiments can follow different pathways, but always requires due attention to the social and cultural limits to the transferability of solutions.

1. Introduction

Renewable and sustainable energy technologies, with an average European market share of 6.38% in 2005 (EurObserv'ER 2006), are in a crucial phase of development. Much work has been done in the past in terms of research, development and deployment projects, providing financial resources, developing new knowledge infrastructures, adjusting legal and regulatory frameworks and finding early niche markets. At the same time renewable and sustainable energy technologies are - apart from a few notable exemptions - far from being the dominant practice in mainstream European energy systems. This makes current renewable energy projects interesting topics of research as they are part and parcel of an emerging technological trajectory that seems to be at the verge of breakthrough.

A particularly interesting question in emerging trajectories is how individual projects interact with other projects within the same emerging trajectory, e.g. in terms of knowledge, competences and practices developed in earlier (similar) projects. How do new projects use the generic, non-specific knowledge and competences pertaining to the emerging technology? How are they adjusted into something useful for the specific characteristics of the new project and its location? But also: how do new projects contribute to the emerging trajectory? How are lessons learned in a project made 'mobile' and transferable to other locations and projects? These are the type of questions we will address in this paper. We will address them by drawing upon a meta-analysis of 22 new energy projects throughout Europe including a variety of technologies: wind turbines, bioenergy technologies, solar systems, energy efficiency technologies, carbon capture and sequestration (CCS), hydrogen technologies, salinity power and geothermal technology. The meta-analysis was carried out in the context of a European research project on societal acceptance of new energy technologies called 'Create Acceptance'.[1]

We frame the analysis within the niche development literature and in particular Geels and Raven (2006) and Raven and Geels (2007). This literature offers a framework for analyzing the relation between individual projects in local contexts and the translation of local experiences into generally applicable 'rules' on the 'global niche level'. The niche development perspective has been developed on the basis of a large number of case studies of sustainable technologies such as wind turbines (Kemp et al., 2001), battery powered vehicles (Kemp et al., 1998; Hoogma et al., 2002; Truffer, 2002), fuel cell vehicles (Lane, 2002), photovoltaic cells (Van Mierlo, 2002), organic food (Smith, 2003, 2006), energy efficiency (Kivisaarie et al., 2004), renewable energy technologies (Tsoutsos and Stamboulis, 2005), biogas plants (Raven, 2005), biomass co-firing (Raven, 2005, 2006) and biofuels (Van der Laak et al, 2007). Its theoretical foundation comes from a variety of literature and in particular evolutionary theories on technical change - emphasizing variation, selection and retention mechanisms and the role of niche markets as proto-test beds for new and emerging 'technological species' - and socio-cognitive theories - emphasizing the relation between learning in social networks and changing content of cognitions, and in particular expectations.

We will not repeat the full argument behind the niche development model, because this has been done elsewhere (see the above references). Instead we selectively focus on the issues that offer insights for the topic of this paper (section 2). We then continue with an operationalisation of the niche model into a research

[1] See http://www.createacceptance.net

strategy (section 3) that enables us to understand the translation of generic rules into local, practical variations and the translation of local experiences back into general applicable lessons in a selected number of individual projects (section 4). We end with conclusions and discussions in section 5.

2. The niche development perspective: arguments and concepts

The niche development model emerged from the insight that many sustainable innovations never leave the laboratory or showroom. Building upon evolutionary theories of technical change (and in particular evolutionary economics) Kemp et al. (1998) argue that an important notion for understanding this is the regime concept, which was originally developed by evolutionary economists Richard Nelson and Sidney Winter (1981). Regimes are a set of stabilized routines that tend to make engineers blind to radical variations. They are retention mechanisms in the minds of engineers like genes are in biological variation. Rip and Kemp (1998) and Geels (2004), building upon institutional theory, widen the regime concept and argue that the general concept of ‘rules’ can better explain path dependence and stability in technological change than just the engineering routines. In contemporary societies innovation processes and technological change are widely embedded in society. A wide variety of rules - including formal ones like regulations and informal ones like normative roles, expectations and routines of many social groups - enable and constrain the development and adoption of socio-technical variations. On an even wider scale, development is conditioned by socio-technical landscapes - referring to slowly changing developments such as demographic trends or international policies as well as sudden events like wars.

Kemp et al. (1998) argue that for radical variations to develop successfully (or even become acknowledged at all), ‘protected spaces’ are necessary. They provide learning platforms for new social networks to emerge. Those new and emerging networks can negotiate, struggle, learn and experiment in a partially shielded environment provided by, for example, subsidies or strategic investments by powerful actors. Regime rules only partially apply, making the emergence of new practices possible. In these protected spaces, experimental projects such as pilot, and demonstration plants can be developed.

These projects do not emerge in a vacuum but build upon experiences from past (similar) projects. Building upon Hård (1994) and Deuten (2003) this is conceptualized in the niche model as a ‘global niche level’ that forms a reservoir of rules and represents a context-independent structure. Examples of such rules are general organizational models, financing structures, technical standards, shared ideas about what users want, best-practice publications etc. Such rules guide local projects in terms of design specifications, market choices, type of partnership, etc, but leave room for local variations as local actors reinterpret and reinvent them for local circumstances. The articulation of expectations is an important mechanism in the translation of generic rules into site-specific ones, in particular in the period before the project is actually realised. Expectations enable local actors to articulate how they interpret generic rules and how they expect to benefit from (or be harmed by) the project (Van Lente, 1993; Brown and Michael, 2003; special issue in TASM, 2006, No. 3). Project managers also use expectations strategically and rhetorically when they make promises to attract attention and resources from sponsors and try to persuade potential partners and stakeholders to participate. This indicates that reinterpretation and reinvention requires dedicated work and efforts, because it is likely that in many cases potential partners and stakeholders hold different interpretations and thus articulate different expectations. Successful negotiation of expectations about the future project is thus at the heart of successfully implementing a local project variation of an emerging niche technology.

So new projects are not literal reproductions of the emerging niche trajectory; projects are not determined by the trajectory. Rather, they are local variations of a generic design. Similarly, each project yields new results and new lessons, which - through interpretation and social learning - can be selected and aggregated into generic lessons for the emerging niche trajectory. This does not happen automatically, but requires dedicated activities by dedicated actors (Geels and Deuten, 2006). Aggregation activities include a range of (formal and informal) activities such as standardisation, model building, handbook writing, internet forums, site visits and excursions. They may be performed by a variety of actors including intermediary actors (professional societies, industry associations, standardisation organisations), large firms with multiple projects in different locations, research organisations, governmental project coordinators, etc. Initially these activities may only result in ad-hoc *interlocal learning* as follow-up projects copy successful elements of a previous project and leave out unsuccessful elements, but can transform into global niche learning as lessons turns into generic rules with an increasing structuring effect on new projects.

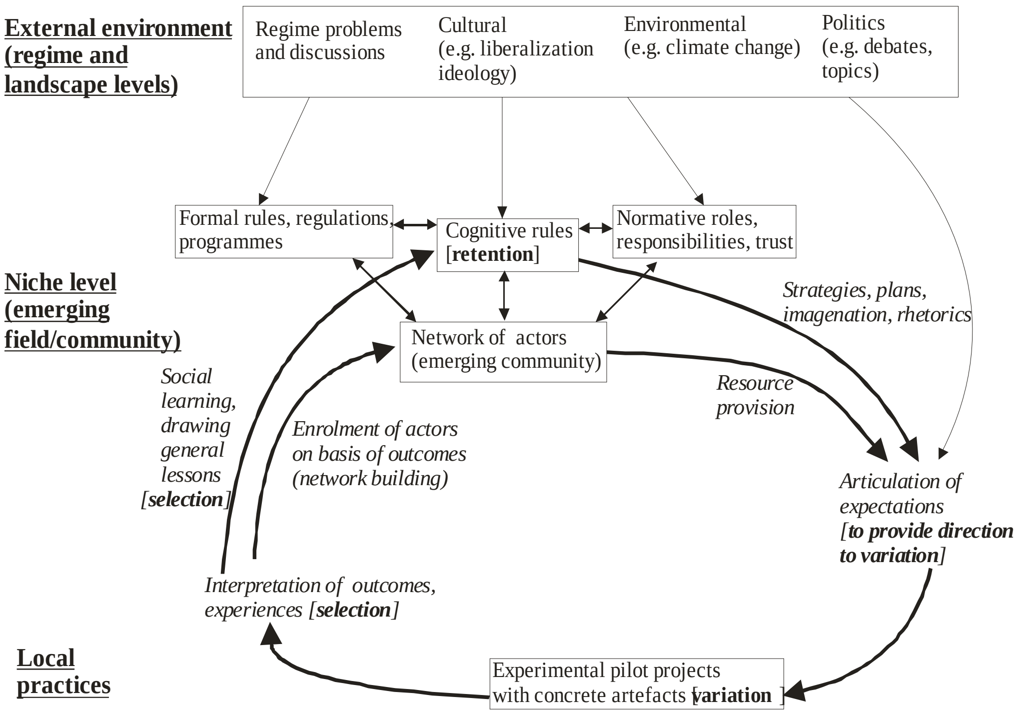

Figure 1. Dynamics in the relation between projects and socio-cognitive technology evolution (Geels and Raven, 2006; Raven and Geels, 2007)

Figure 1 presents the perspective outlined above. To use this perspective for analysing our case studies we will translate this perspective in the following section into a three step research strategy.

3. From local variation to inter-local transfer? Developing a framework for research

The niche development model is useful for analysing the relationship between processes of the local embedding of technologies and the lessons that can be taken from this at the level of emerging niche trajectories. To do so we have developed a three step research framework, which we outline below (adapted from Hodson et al, 2007):

(1) Variation through local contextualisation of a niche innovation
(2) Negotiation and alignment of expectations
(3) Retention and transfer to the inter-local level

Variation through local contextualization of a niche innovation

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Niche innovation occurs in relation to a particular local context. In this respect socio-technical innovation and the particular context within which it takes place are mutually shaping (Hodson and Marvin, 2007). Although the niche-development perspective above does not make it explicit, there is the potential for a wide variability of expectations of the possibilities of niche innovation in relation to local context. This may include, for example, a variety of expectations, of multiple social interests, from different perspectives (e.g. the expectations of a local official may be different from a private technology developer and they may contrast with, national politicians, local residents, local and national media and so on).

Moreover, these expectations may not have equivalence. Some are more influential in shaping projects in a local context than others. In particular, the terms of the debate are framed by the initial expectation of the project manager, or organisation(s) or individual(s) responsible for the initial development of a project initiative. To distinguish between the initial expectation expressed by the project initiator and the (more reactive) responses of actors that become involved subsequently we term these initial expectations as the project vision. Project visions offer prospective views on the form, features, functions and benefits of technologies in relation, here, to local contexts of application. In this sense, visions articulated at an early stage of project initiation can be viewed as highly aspirational and be seen largely in terms of their articulation of a future. Visions and the goals they outline provide a reference point through which networks can be built, gaining commitments to ‘participate’, orientating the actions of potential participants and constituencies (Russell and Williams, 2002).

Our first step is therefore to analyse the initial project vision as it is an indication of the local contextualisation of the generic characteristics of a niche innovation.

Negotiation and alignment of expectations

Formatiert: Nummerierung und Aufzählungszeichen

Project visions are not fixed and will change over time with the variety of social interests that become involved and the expression of a variety of alternative expectations. Given the potential variability of expectations of the relationship between niche innovation and local context, from different positions, this raises the issue of how particular sets of expectations dominate and the processes through which negotiation and alignment of expectations occur in local project-context variations. This should not be seen merely as administrative process but is potentially deeply political and embedded in power relationships. It is influenced by processes of 'participation' and 'engagement' of stakeholders, their expectations and particular social interests and the ways in which they shape and reshape the initial vision of the project.

We focus on the formal and informal processes of 'participation' and the methods mobilised in coordinating and aligning differing expectations. The types of methods that are mobilised, the questions asked, by whom, the timing of their mobilisation, the alignment of social interests and the concomitant resources they can draw upon highlight the politicised extent of 'participatory' methods which are often viewed as de-politicised and neutral. With this background in mind, views of what might constitute 'effective' public participation are not only unclear (Rowe and Frewer, 2005; Rowe and Frewer, 2004) – despite a long history (see Arnstein, 1969) - but require a sensitivity to the local context within which they are mobilised. This captures the importance of context in not only being shaped by socio-technical innovation but also in actively shaping it (Hodson and Marvin, 2007).

The next step in our analysis is therefore to open up the black box of participation and engagement and deconstruct the ways and mechanisms through which expectations were negotiated.

Towards retention and transfer to the niche level.

Formatiert: Nummerierung und Aufzählungszeichen

The issue that a concern with variability and selection and local contexts raises is related to what the 'transferable' lessons are that can be taken from particular local contexts and how they become generic and institutionalised into general rules on the global niche level. We can distinguish between inter-local transfer of lessons and translation and institutionalisation of lessons into rules at the global niche level. In this paper both are captured with the phrase 'retention and transfer to the niche-level'. This will be examined in the following case study sections, where empirical examples of niche innovations in different local contexts are analysed to inform the development of an understanding of retention and transfer to the niche level and to examine the implications of the lessons of projects at a level beyond that of the immediate project level.

4. Local variation and inter-local transfer – evidence from a meta-analysis of recent European case studies

In the following, we discuss the questions raised in the previous sections in the light of an ongoing meta-analysis of recent European projects. The dataset was collected in order to enable an analysis of factors influencing the social acceptance of a range of new energy technologies in different parts of Europe (North, West, Central and South Europe). In particular, we focused on analysing both more and less successful projects – from the project managers' perspective, and from those of stakeholders (Table 1). A meta-analysis of the cases has been conducted (Create Acceptance 2007), focusing on (a) specific characteristics of various new energy technologies, (b) characteristics of the national and local context and (c) procedures for stakeholder participation and project management. On the basis of this analysis, we have developed recommendations for management procedures that promote the societal acceptance of new energy technologies in their local contexts.

Table 1. Overview of case study projects: successfulness in terms of outcome (project managers' perspective) and process (stakeholders' perspectives).

Stakeholders' perspectives / Project manager's perspective	Process largely successful	Process mixed or uncertain	Process largely unsuccessful
Outcome largely successful	Bioenergy Village Jühnde Västerås Biogas project Pannon Power biomass conversion Pommerania solar project Barcelona Solar Ordinance PV Accept solar project ECTOS hydrogen project CRUST CO_2 capture & storage project	Hannover social marketing for energy efficiency Berlin H2Accept hydrogen bus trials EOLE 2005 wind energy programme London CUTE hydrogen fuelling station	
Outcome mixed or uncertain	Suwalki wind energy Szelero Vep Solar Water Heaters	Low-energy housing, Finland Trinitat Nova Ecocity energy-efficiency project Snohvit CO_2 capture & storage project Podhale region geothermal project Solar Home Systems	Cap Eole
Outcome largely unsuccessful		Bracknell Biomass CHP Energy Centre Blue Energy	Lund Biogas project Umbria local bioenergy (early projects) Crickdale Bioenergy Power Station

A central outcome of our meta-analysis was that sensitivity to local context and the local embeddedness of the project were key aspects determining the immediate successfulness of the project. The most successful projects devoted intensive efforts toward 'local re-invention' of the new energy technologies in terms of their linkages to locally available resources and local concerns. We have thus suggested that successful projects should be locally embedded, provide local benefits, establish continuity with existing physical, social and cognitive structures, and apply locally appropriate communication and participation procedures.

Yet our analysis of successfulness did not extend beyond the project level, and thus we have not hitherto considered a broader kind of successfulness: how well did the projects promote learning on the wider emerging niche community level? The focus on local embeddedness in our recommendations may thus raise a legitimate concern: will projects developed according to this 'formula' for success be able to provide useful contributions to the emerging niche community level? Do they provide lessons that have relevance for other applications?

In the following, we focus on two of the cases termed 'successful' from both local perspectives – the project managers' and stakeholders': a biomass project in Germany and one in Sweden. This focus enables us to consider how the negotiation of different kinds of local expectations contributes to a diversity of social, economic and technical solutions for a generic technology. Both cases deal with biogas – but with different systems and technology backgrounds. While the diffusion of biogas based on liquid manure and biogenic wastes is not novel, the use of energy crops for anaerobic fermentation is quite new in Europe. The questions of success factors and setbacks of different biogas technologies are currently under study for Germany (Öko-Institut et al. (2007); see also Raven and Gregersen (2007) for Denmark). Our cases highlight the innovative socio-technical solutions for large-scale biogas production and use developed in two very different contexts. Both involved local residents, farmers and government, but in different ways and with different implications for project design, feedstocks and outputs. Moreover, we consider the way in which these solutions, in turn, provide lessons for other projects or are even transferred to general rules for the level of the niche community.

We describe the cases in three stages (1) variation through local contextualization of a niche innovation (2) selection and alignment of expectations and (3) retention and transfer to the niche level. Through these cases, we illustrate a phenomenon that can be observed in many of the other case studies as well. Retention does not merely pertain to cognitive rules, but also to normative issues such as cultural meanings and beliefs or administrative and participatory practices. Such 'lessons' seem to diffuse through different kinds of communities and pathways than the more technical knowledge developed in the project. Apart from scientific and technical forums and communities, the cases show that there are also user-to-user diffusion pathways.

4.1 Bioenergy Village Jühnde: biogas for local energy independence

The concept of a Bioenergy Village was coined by a group of social scientists from the University of Göttingen (IZNE), who wished to develop an energy strategy linked to societal and economical welfare in rural areas (Brohmann et al. 2006). A central idea in the model is a complete shift of an entire village away from fossil energy sources to renewable bioenergy, mainly based on biogas. Jühnde, a village of 750 inhabitants in Lower Saxony, Germany, was selected out of 17 volunteering villages in the region to pioneer the implementation of the concept. The entire project has been based on a strong participatory ethic aimed to combine ecological goals and energy independency with the development of the local economy, the preservation of the local cultural heritage and a strengthening of the local community spirit.

(1) Variation through local contextualisation of a niche innovation

The local variation on the biomass concept relates to the specific purpose of the facility – the independent production of electricity and heat by and for an entire village – and to the governance model selected. Besides the use of biogas as the main form of bioenergy, one of the conditions was to avoid mono-cultivation of energy crops by using an innovative farming scheme (double cropping), wood chips from forest residues, and liquid manure, thus preserving local environmental quality. Another design solution contributing to environmental quality was the choice of combined heat and power generation (co-generation). This required the massive conversion of individual home heating systems to local district heating. Hence, securing the co-operation of local residents (users) was crucial for the design of the Bioenergy Village concept.

The technical core of the bioenergy concept is a 500 kW_{el} biogas plant (Brohmann et al. 2006). The biogas is burnt in an internal combustion engine which generates enough electricity for the entire village; the co-generated heat is mainly used for space heating via a newly constructed district heating system (supplement with a 550 kW_{th} wood chip boiler during the winter months).

The innovative aspect of this case is the large-scale and voluntary conversion of an entire village to bioenergy, mainly based on biogas derived from residues from local farming. The technical concept was strongly grounded in local values, local participation and local ownership. The energy system in the Jühnde model is operated by a local cooperative, which was launched by inhabitants and local farmers, and in which 70% of the residents are members. The technologies applied in the project are not radically new, but as an energy system, the project represents an extremely rapid (4 years) and comprehensive local conversion from fossil to renewable energy supply. This radical process was made possible by a participatory decision process, into which all inhabitants were invited.

(2) Selection and alignment of expectations

The project involved a range of different local and non-local actors with different, yet mostly compatible expectations (Table 2). The original vision of the project, as formulated by IZNE, were (1) protection of climate and resources (2) soil and water protection (3) plant diversity (4) positive contribution to the regional business cycle and economy (5) participation (6) decentralisation of energy supply and (7) quality of life. This vision resonated with local concerns, such as the desire for increased regional economic and energy independence, represented by the Mayor of Jühnde and members of the County, for example. Moreover, two local farmers in Jühnde had plans to diversify and become energy suppliers. They were the first to be involved in a local co-operative, and a number of other local residents invested in the launch of the project, thus becoming the first of many local members of the co-operative.

Table 2: Actors and expectations involved in the Jühnde project

Actor	Expectation
Funding Ministry	Implementation of biomass technology Societal welfare, economic welfare of rural areas
University – IZNE (7 different disciplines)	Interdisciplinary research in agriculture, ecology and (cultural) life sciences Empirical evidence on hypotheses regarding life-style shifts, sense of community, ecological diversification
Mayor of Jühnde (and County of Göttingen)	Economic and environmental welfare, gaining funds, future oriented decision (self-sufficiency) stabilization of the farming structure (safeguarding employment)
Cooperative/local farmers	Business success, energy and economic independence
Members of the cooperative/investors	Saving money in the long-term, becoming independent energy producers

Local residents	Cheap energy, environmental protection, stabilization of the farming structure, strengthening the local position
Engineering	Image building, new employment opportunities
Construction firms	Enhanced capabilities, ensuring employment
Committee of external experts	Professional and scientific information transfer

Significant effort when designing the project was placed on aligning expectations. The entire bioenergy system was grounded in the local residents' expectations and a combination of local knowledge and external competences. The participatory process was designed to secure compatibility with local needs. Eight working groups were set up for residents to participate in the planning of various aspects of the project, including the design of the operating company, the biogas facility, the supply of energy plants, the heating plant and the district heating system. Moreover, a system of coordination and information among the groups was established in the form of planning workshops and village meetings. Joint forums for learning were created, providing local people with the self-confidence and new competencies to operate the system. Many of the participatory and alignment-creating features were present already in the design stage and in the way the project was adapted to the local context through technological refinement (e.g. the double cropping system is not yet common practice) and through organisational solutions (e.g. the founding of a cooperative as system operator was elaborated by the locals). Nonetheless, the project increased its popular support and social embeddedness by organizing both formal channels for residents' influence and informal and emotionally appealing communications (e.g., festivals and events for children), which engaged an ever-widening local network of support.

(3) Retention and transfer to the niche level

From the start, the project involved a number of mechanisms for interlocal transfer, among others, a 'Committee of External Experts'. An important element was the active role of the research institute, IZNE, with its specific focus on transdisciplinary research with a strong social science component. Hence, many of the lessons derived from the project pertain to the governance structure of the project, the integration of the project in the local economy and culture, and the identification of appropriate forms of participation and communication. Moreover, already during the planning phase, the project involved a dedicated Round Table for other communities in Southern Lower Saxony, with the explicit purpose of gaining and transfer of information. The regional level has, in fact, been the most visible form of interlocal transfer for the project. Other neighbouring villages have been eager to join the project and become energy independent, too. The project has also provided references and recommendations for local project partners (e.g., engineering services). Since the inauguration of the local energy facility, large numbers of visitors from other communities have been hosted on study tours.

One of the important general rules transferred in this project is a *cultural and normative one*, linking local bioenergy (including biogas) production to *energy independence and local self-sufficiency*. Alongside this, technical lessons and expertise, as well as rules pertaining to local governance and participation are transferred. Important lessons have been gained concerning the mode of local organization, which is based on a local co-operative, broad participation in decision making, local customers and local ownership (Brohmann et al. 2006). The transfer to the interlocal level has hitherto been most visible within the region, and has concerned the unique way in which the Jühnde model combines technological change with local participation and infusion with cultural meaning. Yet visitors eager to learn from Jühnde have also arrived from abroad. The concept may have broader lessons for community-based energy projects elsewhere (in particular, in rural areas), but is likely to require a degree of adaptation.

4.2 Växtkraft biogas plant in Västerås: creating new marketable products from waste

In Sweden, co-digestion of municipal and agricultural waste has featured as part of the country's Eco-Cycle Society strategy, and more recently, biogas has also become a valuable transport fuel as the country has pledged to become fossil fuel free (Heiskanen 2006). In the late 1990s tens of municipalities were granted support for constructing biogas plants under the government programme for sustainable development (Thyselius 1999). One of these was Västerås, a town with 100 000 inhabitants, which successfully established a local biogas facility by finding synergies among a range of local interests.

(1) Variation through local contextualisation of a niche innovation

Although biogas production was in the 1990s a fairly established technology, large-scale co-digestion of different kinds of organic matter was still fairly new. Different plants employed different technologies, and much research was ongoing to optimize processes. The use of the digested material as fertilizer presented problems due to consumer and NGO concerns about heavy metal buildup and the risk of spreading pathogens (Bengtsson and Tillman 2004). Another set of problems related to the local impacts of biogas plants, most importantly the issue of odour, which sometimes provoked local opposition (Khan 2004a). The sector was fairly dependent on financial support from the state, and most biogas plants have been financed by municipally-owned waste companies making use of generous state grants (Khan 2004a). The Västerås biogas project was jointly initiated by three different partners (Khan 2005): local farmers investigating options to grow ley crop and to digest the crops in a common biogas plant, the regional waste company investigating alternative forms of biological waste treatment for organic household waste after having instituted a system for source separation of organic household waste some years earlier, and the municipal energy company.

(2) Selection and alignment of expectations

A joint project was started in 1995 for a plant that would produce biogas from silaged ley crops and organic household waste. During the long and explorative planning process (Khan 2005), common design solutions were sought that would combine the interests of the three different partners and their stakeholders. Many basic design issues were altered during the project in order to make it fit into local circumstances. The original location of the project had to be abandoned when the local energy company decided to build another type of district heating system in the area. This change of location gave rise to the decision to upgrade the gas produced to vehicle fuel quality, and thus find a new market for the product. The project team also had to ensure that the digested sludge would be acceptable as a soil improvement medium for organic production. Finally, local residents' concerns needed to be addressed, and this was done by locating the plant on an existing landfill site and ensuring improved odour control. Regional and national authorities also had an important role in the selection process, as they very critically reviewed the emission levels (Khan 2004b).

Alignment was promoted through a co-operative work process involving a number of permanent working groups of key stakeholders (Khan 2005). Multiple linkages were established with ongoing change processes, such as local sustainability efforts and the institution of a system for source separation of organic waste in Västerås. Even though public participation was limited to mandatory public hearings, the waste management company interacted with local residents on an ongoing basis in the context of waste management (management of the landfill site, introduction of the source separation process). As the project evolved, the notion of the plant as an exchange point between town and countryside gained ground, and the facility was linked to the idea of the local recycling of resources. Moreover, as the project proceeded toward completion, interest in biogas as a vehicle fuel grew, and the project was thus able to offer the local benefits of a fuelling station for the public and fuel for local public transport buses. The biogas plant was opened in 2005, processing annually about 14 000 tons of sorted organic household waste, about 4000 tons of fatty sludge and 5000 tons of ley crops and producing an amount of biogas equivalent to 15 000 MWh. The plant includes a facility for upgrading the gas to vehicle fuel quality. The gas is used by buses in the urban transport system, other urban service vehicles, as well as sold to the general public.

Table 3. Actors and expectations in the Växtkraft project

Actor	Expectations
Regional waste management company, VaFab	Investigate alternative forms of biological waste treatment for household waste Improve environmental image Recover resources from waste Develop a new line of business
Municipality	Improve local environmental quality Make use of separately collected household waste Contribute to national aims
Local farmers	Grow and digest ley crops for crop rotation Utilize digested material as fertilizer
Energy company	Experiment with biogas production First: use gas for district heating Later: upgrade gas to vehicle fuel quality
Government (as grant provider)	Support local change processes toward sustainability Provide good examples for other municipalities Promote diffusion and further refinement of biogas technology
Environmental NGOs	Mildly in support Little active engagement
Local residents	Improved waste management (source separation, odour control

	at landfill site) Little active engagement

(3) Retention and transfer to the niche level

The project started out as a local or regional project, albeit through government funding was aimed to promote learning about biogas co-digestion at the national level. Toward the completion of the project, however, a number of information transfer mechanisms set in. One important form of information transfer was the decision in 2003 to join the Agroptigas project funded by EU FP5. As a consequence, the Federation of Swedish Farmers, as well as a number of national and international research institutes and consultancies joined the project, and a special dissemination activity was launched in Bulgaria. Research has focused on technical optimisation of the feedstock logistics, plant operation and overall assessment of socio-economic impacts. Moreover, a communication and information forum model has been developed for rural-urban communication (Agroptigas 2005). Other media for communicating the project have included professional associations, conference papers and international seminars, national research projects and study visits by various groups from Sweden and abroad (Agroptigas 2006a)

The project made a number of technical design changes that have subsequently contributed to broader innovation processes (Agroptigas 2006b). One is the development of improved technology for air and groundwater quality, which is important when applying biogas co-combustion in a suburban setting. Another is the shift from using biogas for district heating to reformulating and upgrading the biogas to vehicle fuel quality, which has significantly increased interest in the technology within the Swedish agricultural sector, as well contributed to standards for gas filling stations. Finally, the measures taken to ensure that the digested material meets national standards for organic farming fertilizers also have wider applicability. The organizational lessons mainly pertain to the way in which a range of local actors were engaged in the technology development process, and they have been transferred, e.g., through research conducted in Sweden by Khan (2004a; 2005) as well as seminars organised by the Agroptigas project. VaFab, the project manager, has also gained valuable technical and organizational lessons for further projects.

5. Conclusions and discussion

The two biogas cases discussed above illustrate a key finding from the entire meta-analysis, which is the way in which local project variations are derived from a more generic, mobile concept of a particular emerging niche trajectory. The two biogas projects represent very different applications of the same basic technology, i.e., the controlled production of fuel methane through anaerobic digestion of organic matter. Although the two cases applied similar production technologies, they used different feedstocks and used the fuel produced in very different applications, one pertaining to a rural, the other to an urban context. This finding is also representative for many of the other case studies examined in the dataset. Most projects were highly innovative in their local contexts, and illustrate how – even in the ‘protected spaces’ of local experiments – extensive alignment of a range of different expectations is required. As a diversity of local expectations are aligned to the vision of the project, the new technologies take on a lot of local character. Our first conclusion is thus that the cases have a good fit with the conceptual framework and show how new projects are local reinterpretations and reinventions of a more generic, mobile concept of an emerging niche trajectory.

Second, these local project variations are to a large extent the result from differences in contextual conditions and the way potential partners and stakeholders (are able to) bring the requirements of these conditions into the negotiation process. In the Jühnde project, many partners and stakeholders linked biogas production to the goal of local energy independence – the aim was to use local agricultural feedstocks to create a local fuel economy. In this context, producing electricity locally was important because residents wanted to be independent of the large energy producers. In contrast, the Växtkraft project – as a result of local variation – eventually took on the aim to create a new marketable product, i.e., produce transport fuel for urban transport and for marketing beyond the region. It also promotes fuel independence, but more on the national level, in connection with Sweden's plan to become fossil fuel free. Another important difference in the cases was the local setting – the one rural and the other urban. These local contexts provided different possibilities and constraints for the project. The rural context of Jühnde provided the possibility for intensive local participation and ownership, which might not be equally easy to accomplish in on an urban scale. Moreover, the limited economic and employment prospects present in a rural setting motivated residents to make a large effort to support the project. Finally, environmental and sustainability motives were strongly present among the residents in Jühnde, and created support for the project. In the urban settings of Västerås, the problems of urban waste management and the potential of urban transport shaped the project design. Similar processes for aligning expectations were not available on the scale of the entire population, nor was there an equal level of interest present among the general public. Yet the project managed to find a number of synergies and diverse 'local loops', i.e., local nutrient recycling between town and country, and provision of fuel for the local transport system as well as for the national market. Nonetheless, the alignment of expectations in the Växtkraft project took much longer and was much more complicated, in spite of an initial interest by project actors.

Third, not only did the context properties result in a project variation, but the implementation of the project also changed the context. Project and context co-evolved. Through the negotiation of expectations, the biogas projects incorporated a number of social interests, and contributed to the emergence of new ones. Thus, local farmers' interests evolved into the much wider cultural processes of supporting energy independence in Southern Lower Saxony and the waste company's interest to upgrade of urban waste management practices evolved to contribute to an 'exchange of resources between town and country'. At the same time, a range of new institutions emerged to govern the new technologies, such as the local energy co-operative model in Jühnde or the development of a joint-stock company owned by farmers, a waste management company, a local energy company, and an institutional investor in the case for the Växtkraft facility.

Fourth, the cases also show that in spite of their local embeddedness, the two projects examined here – as well as a number of other projects examined in the meta-analysis – provided more generic lessons that were aggregated for use at other sites and project variations. Yet, the nature of these rules and their transfer mechanisms are quite diverse, as the two cases examined here illustrate. In the Jühnde project, diffusion has been most visible and forceful on the regional level, whereas in the Växtkraft project, it has been more diffuse and has occurred more on the national and international level. In addition to scientific and technical transfer mechanisms, such as standards and technical literature, also user-to-user transfer was evident in the form of study visits and regional co-operation networks. They exemplify thus that it is not only the biogas developer community that can learn from local experiments, but also user groups such as urban planners or rural communities. Nonetheless, it is important to note that not all lessons are transferred, while there is still social learning on the local level. Such ‘lessons’ are not self-evidently transferable beyond their local context as such, but are an important part of the local embedding process.

Fifth, taking the above conclusions into account we can now elaborate on the ‘local practices’ element in the research framework concerning the dynamics in socio-cognitive technology evolution presented by Raven and Geels (2007). The two cases examined in more detail above illustrate how variation and selection in local experiments, in itself, involves a number of stages (Figure 2). Variation is present in the potential for a range of applications (‘affordances’) in the generic technology (i.e., biogas production through anaerobic digestion). Variation in also introduced through the different expectations present in different local contexts (i.e., urban waste management vs. economic self-sufficiency and energy independency). Selection occurs when technology developers select sites for application, and when local people select technologies to solve their problems. Here, expectations meet, or fail to meet. The third process, i.e., social learning, occurs when the variety of expectations are negotiated, technology and contextual needs are adjusted to one another (alignment of expectations) and the project is implemented, resulting in changes in both technology design and local context. Some of these changes remain idiosyncratic customisation while others feed back into the emerging niche trajectory. These lessons are translated into rules when they have become standard practice in new projects. In our cases, the translation of lessons into niche rules points more to an extension of the competencies and potential applications of the technology, rather than to the classical narrowing down into a dominant design. The projects provided exemplars for other projects rather than that becoming evidently the way to do things. However, it is likely the result from the project perspective and limited time frame taken in the Create Acceptance project, and a hypothesis would be that when investigating a larger number of subsequent projects, translation of local lessons into niche rules will become more visible. Some of the contextual changes (e.g., ideological meanings attached to a technology, or supporting institutions) may also diffuse beyond the immediate context, but the diffusion pathways are more diverse than those of the technological design changes.

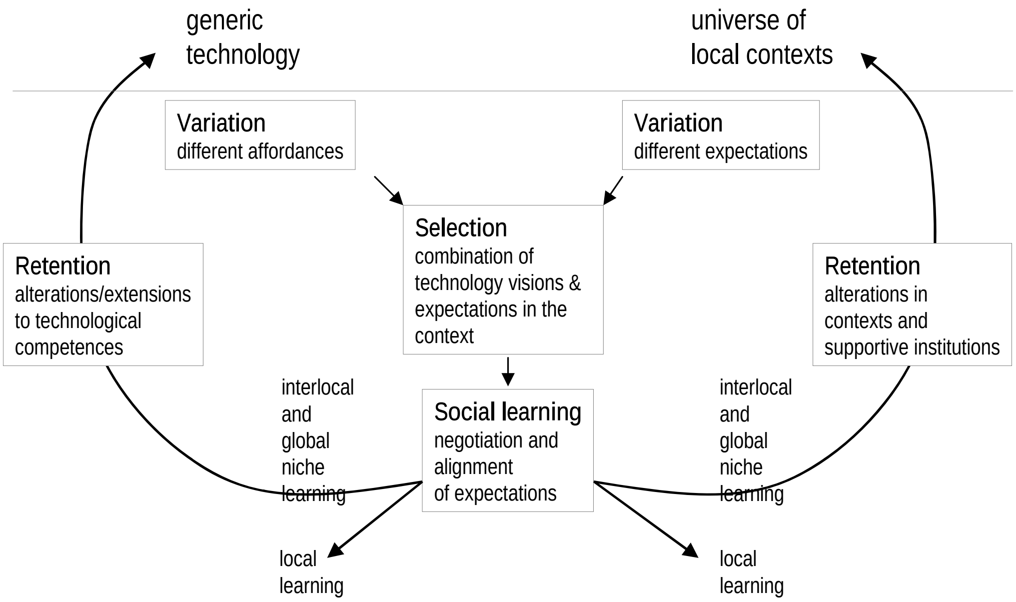

Figure 2.Variation, selection and retention in the interplay between technology and context

In sum, we can conclude that both the translation of a generic concept into a local project variation as well as the transfer of local lessons into global rules occur, but are difficult and require dedicated work. The case studies in our meta-analysis produced a range of ‘rules’ that may be applied in other contexts, such as organisational models, financing structures, technical solutions and ideological meanings. In this sense, each process of local embedding has the potential to increase the diversity of the social and cultural affordances of the generic technology, for example, by suggesting different local embedding processes and institutional solutions for rural and urban contexts. Yet, our findings concerning the amount of energy devoted to local embedding of concepts in each and every successful project that we analysed in the Create Acceptance (2007) project provide a warning: ready-made solutions cannot be ‘dropped’ into a context without local negotiations.

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