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Multi-level sociopolitical institutional support systems for decentralized small-scale bioenergy systems in Finland

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Summary

The objective of the study is to define some solutions for integrating distributed bioenergy production into current energy systems, and to define the factors hindering small-scale production from connecting to the system. Integration of distributed energy production into the current energy regime requires careful attention to the institutional fit of new technological systems, regulatory concerns, as well as existing social, economic, and governance networks.

The study draws on multiple perspectives in social science energy and innovation research to map the characteristics of successful niche technology systems in a desk study. The combination of Technological Innovation Systems theory, Socio-Technical Transitions theory and Strategic Niche Management theory highlights the importance of multi-actor dynamic networked models for success, from a variety of perspectives. Whether the perspective is at the policy level, national innovation system level, sectoral or regional networks level or local project setting level, similar predictors of success come up. Bottom-up, dynamic, multi-stakeholder but structured interactions are important. Policy, funding, innovation and stakeholder involvement should all focus on structures that allow and enhance learning.

This report concludes by mapping what the BEST project can learn from other innovation systems and discusses learning in the project from a variety of perspectives. A reader mostly interested in the results can focus on section 7, which can be considered a results summary and does not necessarily require familiarity with the earlier sections.

CONTENTS

1 Introduction

This report provides an overview of sociopolitical support systems for decentralized small-scale bioenergy. The theoretical backbone of the report builds on three theories: Technological Innovation Systems (TIS) (Bergek et al. 2008a; del Río 2012)[1], Strategic Niche Management (SNM) (Van der Laak et al. 2007), and Socio-Technical Transitions Theory (STTT) (Geels 2002).

All three theoretical frameworks focus on three key concepts, albeit from different perspectives: actors, networks, and institutions or the rules that manage the interactions between actors. For the current energy system, it is fairly well known who knows how to do what, who to go to when you need information or collaboration, how to interact with policy-makers and so forth. For a novel system, the technologies are different, but so are the actors, their roles and perspectives, and how these interact. To change a system, actors will have to learn these new roles, rules and practices. They are also context-dependent and simply reproducing a new system from another country is not enough: everything has to be adapted to local circumstance.

What needs to be learned for our context? Decentralization of the energy system is usually associated with increased use of renewable energy sources, but it goes beyond what the eventually selected technologies would be. Decentralization means more inclusiveness in deciding on the goals of the system and how to reach them (Ratinen and Lund 2015) and less ability by particular actors to define the conditions for entry, whether into actual energy production through grid connection (Verbong and Geels 2007) or the societal debate. How such inclusive process works is not known: there are no available best practices for doing multi-actor energy regimes, so they need to be learned.

The practices are also somewhat specific to technologies. This report pays special attention to small-scale bioenergy use, without focusing on any particular type of biomass or biomass use, or without explicitly defining what is small for bioenergy production. Smallness is defined in the context of novelty: any bioenergy technologies with little market diffusion currently can be seen to work in similar niches, whether the operative scale or energy produced is large, or whether the actors involved are large or small companies. The challenges and learning requirements do vary by type of biomass and final product (transport fuels depend on different operating schemes compared to electricity and heat). We present research from multiple technologies and discuss the differences.

The structure of the report is as follows: we present out theoretical orientation in some more detail in the next section. Most of the research we present has also been done within these theoretical traditions so the section also discusses the terminology for the latter parts of the report.

2 Theoretical framework

2.1 Technological innovation systems

In the TIS perspective, the three key elements of an innovation system are the technologies and related knowledge, social networks and institutions or the rules that enable and constrain interactions between actors (del Río 2012). The analysis in this paper focuses on the latter two: institutions are focal as the formal rules or the policies and regulations in place, but also the social and economic practices, norms and values people use, while social networks are reviewed both in the governance and local settings. Barriers to entry are not simple cost questions, but complex systemic and dynamic issues.

The TIS perspective pays special attention to learning effects. Stakeholders learn the application of technology by doing, by using and by interacting (del Río 2012), with particular focus on learning in actual interactions. Decentralized systems in particular will need to draw on such learning, as they involve many users not accustomed to working in the energy sector, including households, small and medium-sized enterprises from non-energy sectors, and government and third sector organizations whose primary interest is not in the energy sector. Even incumbent regime actors will to learn new mental models for dealing with decentralization, as technology search has at times been limited to similar options in price and size per unit (Negro et al. 2010)

A TIS is made of three elements: actors (networks and other organizations), networks, and institutions (rules and practices) Jacobsson (2008). TIS have seven key functions: entrepreneurial activities, knowledge development or learning, knowledge diffusion, search guidance, market formation, resource mobilization, and advocacy coalition support (Hekkert et al. 2007) or legitimation Bergek et al. (2008b). Additionally, positive externalities are sometimes added as an eight function to highlight the collective dimensions in diffusion and innovation processes through mutually beneficial co-evolution and knowledge spillovers (Bergek et al. 2008b). These functions work in a self-reinforcing cycle (Negro et al. 2008), where the central function of entrepreneurial activity is supported by loops of activities of networks of governmental and non-governmental actors.

Legitimacy, or the attainment of social acceptance from the general public and fitting into the institutional scheme overall, is a prerequisite for political strength and even the formation of new industries (Bergek et al. 2008b). However, social acceptance is a complex issue involving organizational trust, cultural features, and other beliefs, and legitimacy cannot be attained by simple knowledge diffusion (Karimi and Toikka 2014). Delegitimation can also happen, and is often related to three processes: unit performance, overall potential, and proven functionality (Negro et al. 2010).

For the TIS, a measurement scheme exists that enables the quantification and tracking of the seven functions (Table 1). Of course, these indicators only serve as rough proxies of all the different phenomena the functions represent, but they should be useful for tracking changes over time or comparing between technologies and countries.

Table 1: Quantifying the Systems of Innovation Indices

Function	Measures
Entrepreneurial activities	# of entrants, diversification activities, experiments
Learning	# of R&D projects
Knowledge diffusion	# of workshops and conferences
Search guidance	# of government targets, # of articles in professional journals
Market formation	# of niche market initiatives, specific tax regimes
Resource mobilisation	# of statements regarding resource availability
Advocacy coalition	# of interest group statements
Based on Negro et al. (2007)	

Relationships between the functions and measures are empirical questions to be evaluated on a case-by-case basis, but some knowledge about how they work general exists. For example, search guidance is often linked with entrepreneurial activity, and legitimation usually requires institutional change in market formation and such Bergek et al. (2008b).

TIS have also been analyzed from a system failure perspective (Woolthuis et al. 2005). TIS can fail in four ways: through infrastructure failure, institutional failure, interaction failure, or capabilities failure. Infrastructure refers to the physical artefacts, institutions to laws and regulations but also norms and practices, interaction to lack of interaction, but also network effects in strongly connected TIS, including myopia due to internal orientation, dependence on dominant partners, and lack of weak ties that connect network substructures to

2.2 Socio-Technical Transitions Theory

The STTT is based on the work of Frank Geels and co-workers (Geels 2002, 2012). In this tradition, energy regimes in particular but other technical systems as well are seen to work in a three-level socio-technical setting, each with interacting social networks, technological artefacts and institutional or rule systems. The three levels are landscape, regime, and niche. The regime is a dynamically stable or resilient collection of actors, technologies and processes. The regime responds to and feeds into the landscape level of exogenous events and the niche level of disruptive innovations.

The STTT framework has been criticized for the rigidity of the levels it sets and the bias towards niche-innovation that results. It would benefit, in our view, from considering the levels as nested holons, in other words, the idea that the processes at each level are actually similar, and the levels are not related to size but just the scope of the observer. Landscapes, regimes and niches all consist of actors constrained and enabled by policies, available technologies, economic opportunities, and social pressures and the actors' beliefs of such. For example, in an analysis of Finnish energy markets, the EU might appear as an exogenous governance landscape and peat producers as key economic agents in the regime: in contrast, for an European climate policy analysis EU will be the regime, Kyoto protocol the landscape, and Finnish peat a niche innovator (possibly innovative only in lobbying for peat to be considered renewable).

2.3 Strategic Niche Management

SNM is a key approach for understanding market penetration in many sustainable innovations (Van der Laak et al. 2007). Sustainable innovations are often characterized by the lack of a pre-existing market niche - there is some demand for sustainable energy and some willingness to pay a premium, but the main product is still just electricity, heat, or transport. Thus, the niches have to created and maintained. New technologies emerge in 'protected spaces' Geels and Raven (2006) that may be either market niches, formed by customers with different selection criteria compared to the regime, or technological niches, with resources provided by public subsidies or strategic company investments.

The phase between R&D and market diffusion happens in this niche and conventional economic theory does not capture all important factors affecting development there. Multiple factors interact and produce complex, non-linear trajectories that are hard to predict. SNM understands these interactions as three interdependent processes: voicing and shaping expectations, building of social networks, and a good learning process (Raven 2005). Articulating

expectations attracts partners and enables collaboration, but also directs development: the expectations act as a cognitive frame or a mental model that defines what kinds of questions make sense and what options are evaluated against each other. A good SNM process is characterized by shared expectation based on tangible results from experiments, a broad and regularly interacting network, and a broad and reflexive learning process. Although SNM started with analysis of individual projects and products, the principles do apply at a variety of scales from local to global (Geels and Raven 2006).

The SNM explains non-linearity and changes in the direction of technological trajectories through changes in cognitive rules and expectations, which are in turn influenced by the interactions of the three process (Geels and Raven 2006). Cognitive routines such as search heuristics, exemplars and guiding principles orient perceptions and actions. A local-global loop connects learning and aggregating from individual projects and building institutionalized practices on these lessons at the global level and then assigning resources and refining requirements on further projects.

The dynamics of established regimes have been suggested as a fourth variable in the SNM (Raven 2005).

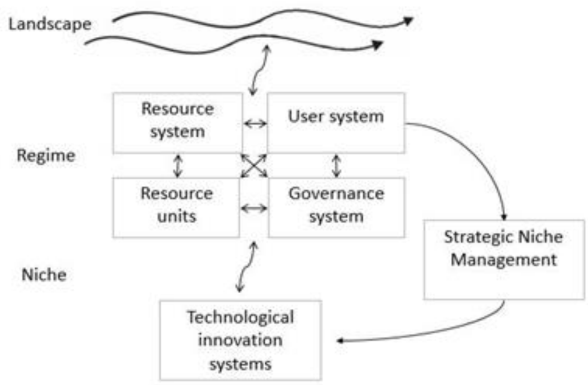


Figure 1. Theoretical synthesis

2.4 Theoretical Framework

In the sections reviewing research done using these theoretical frames, we will refer to research using the terminology they use. In 1, the flow between the theoretical viewpoints is visualized. The orientation is that the existing system, consisting of actors and their networks as well as the physical artifacts, is changed in interactions with niche TISs, pressures from the societal landscape, as well as in a managed way by creating niches and allowing them to become innovation systems.

The framework points four interesting learning processes: first, the regime itself is under constant evolution. Regime-controlled niche development (Ratinen and Lund 2015), however, is unlikely to bring out radical change and can be characterized as 'changes for sameness'. Second, learning can mean understanding how potential niches fit existing regimes. Third, learning can mean how niche management can spur a whole innovation system. Fourth, learning can mean how innovation systems grow, stabilize, and eventually change existing regimes.

3 Bioenergy policy and it’s support mechanisms

Policy instruments can differentiated by whether the state specifies the particular goals of policy, and whether it specifies how that goal is to be achieved Jordan et al. (2005). In environmental policy in general, there has been a shift from state-centric regulation to new types of policy instruments, such as market mechanisms through tradable permits, eco-taxes, eco-labels and so forth. In energy policy, there has been a shift in emphasis from R&D stimulation towards dissemination and market application Gan et al. (2007).

This adds an important temporal aspect to non-state actor influence. In the context novel budding technologies and future technologies, the social support mechanisms that enable stakeholders to find the best technologies and solutions are not in place, and simple market-mechanism based search does not necessarily find the best options. This phase just before large-scale market introduction has even been called the Valley of Death (Negro et al. 2010), as uncertainties about market potential are still high, costs to build at scale are high, and political support is weak. The Valley of Death metaphor often refers to the longer period of development from an idea in a research lab to the marketplace (Weyant 2011), but it has been applied to novel applications of more mature technologies as well. For example, Foxon et al. (2005) identify gaps in the support systems in the demonstration and pre-commercial stage for a range of technologies in the UK.

The state stepping out from its traditional role as a network builder has not been unproblematic, as it has introduced new types of uncertainties into investment processes Raven and Gregersen (2007) and the new market mechanisms are stronger in picking technologies ’from the shelf’ rather than ’filling the shelf’ Bergek et al. (2008b). This section reviews the types of policy tools used in Europe for promoting renewable energy use that do not involve much stakeholder inclusion, while the next section shows how governments and private actors have worked in and with networks to discuss policy goals and design solutions.

In the EU, the two major support mechanisms for renewable energy are feed-in tariffs and tradable green certificates (Fouquet and Johansson 2008), also called renewable portfolio standards (Jenner et al. 2013). With tradable certificates, the regulator sets a goal for emission reduction or technology market penetration (such as share of renewables of final energy consumption), but the market sets the price. With feed-in tariffs, the regulator sets the price, but the amount can be whatever the market supplies, although there are often capacity gaps as well (del Río 2012). Feed-in tariffs have been more successful in increasing market share of renewables overall, as investor risks are lower and investment incentives can be higher (Fouquet and Johansson 2008). However, feed-in tariffs can be economically inefficient by promoting by allowing poorly performing units to remain on the market, which can lead to higher consumer prices, and the perverse incentives can also result in lower investment as feed-in tariffs may reward the use of current technology (Lesser and Su 2008).

Feed-in tariffs are, usually, technology specific, and have so far focused more on wind and solar power, although biomass schemes are in force in many jurisdictions. The following section will discuss these two mechanisms from the point of view of small-scale bioenergy.

Feed-in tariff systems are also connected to the size of projects - sometimes explicitly, as was the case in Germany (Couture and Gagnon 2010). The overall effects of maximum plant sizes on the adoption of technologies are unclear: they do limit technological competition, but that may be balanced by promiting investment, technological diversity and learning effects (del Río 2012).

Even when not explicitly regulating on the size, the rules of the tariff affect the types and sizes of projects. So-called market independent or fixed price tariffs have attracted smaller, more risk-averse and non-traditional investors, especially when coupled with a purchase obligation (a commitment of the utility to buy the electricity produced).

Market dependent or variable price tariffs reward producers who are able to meet hour-to-hour market demand and thus offer advantages to biomass and biogas over wind and solar where supply cannot be easily varied (Couture and Gagnon 2010). Currently, fixed price tariffs are more common in Europe Kitzing et al. (2012).

Technological lock-ins are of crucial importance in designing support mechanisms. Bad designs, even if small, can lead to the dominance of an incumbent but less efficient technologies on very long time scales (Kalkuhl et al. 2012) The current dominance of fossil fuel technologies can be seen as an example of this, . A good support mechanism should have a clear goals and an explicit time-line – including an exit strategy defining when support will be withdrawn from a particular projects or technologies that fail to progress towards commercialization (Foxon et al. 2005).

Evaluating the effectiveness of renewables support mechanisms is often done with case studies, especially the leading example of Germany.However, this is problematic, as the same characteristics of a country and it’s culture can lead to the adoption of renewables and renewable policies - in other words, it can be hard to tell if a policy instrument was effective, because countries where renewables are popular also adopt pro-renewables policies (Jenner et al. 2013). Comparative statistical research with fixed effect models makes it possible to differentiate the country effect and the actual policy effect. Both renewable portfolio standards and feed-in tariffs (Jenner et al. 2013) have been found to increase the share of renewables, but the results are somewhat ambiguous. For biomass, studies have found feed-in tariffs both effective (Jenner 2012) and ineffective while porfolio standards were effective (Bolkesjø et al. 2014).

Advocacy in political processes is important, but how the process is influenced can be hard to predict. For example, the first German feed-in tariffs were the results of small-scale hydropower advocacy, but led to massive benefits to the wind power industry Bergek et al. (2008b). A robust advocacy program should be designed to allow for potentially surprising trajectories.

In the future, it remains to be seen whether the European support scheme systems sees convergence or divergence and whether that happens through national mechanisms becoming more similar or different or through international collaborative methods (Kitzing et al. 2012). Still, stability of policy instruments remains a big issue in renewables adoption at the national scale (Negro et al. 2010). Instruments such as the European Investment Fund may enable technology adoption that surpasses national support schemes and potentially also generate much needed stability.

4 National and international issue networks

This section focuses on the collaborative tools and networks of companies, policy-makers and other stakeholders. The theoretical framework highlighted the importance of multi-sectoral networks from a variety of perspectives to get the benefit of 'running in packs' (Bergek et al. 2008b). Early stage competition between potential new technologies instead of allying against the incumbents can generate uncertainty and legitimacy issues (Negro et al. 2010). Partnerships should also span national and sectoral boundaries, including those between companies and end-users (Foxon et al. 2005). Regulatory frameworks that allow coalitions of technologies with potential for functional and structural overlaps to pass the formative phase in parallel are the most efficient in promoting new technologies. This section reviews experiences from such European coalitions.

Networks have been found to be most successful when connections between subgroups are short, but not too strong - weak links allow for information to travel but not overload, and capacity to innovate at various parts of the network are not stifled (Toikka 2010). Being too strongly connected or with too many active links can lead to strategic conformity (Negro et al. 2010).

Thus, the relationships between related technologies and their TISs is key. For biomass, it is not clear how and when related technologies form separate innovate systems and when separate systems support each other. In the UK, distinct TISs exist for different end products or for heat and electricity production and transport fuels, despite sharing some resources and some conversion technologies (Foxon et al. 2005). It should be existed that the most successful technologies are those that are able to exploit shared knowledge and resources and thus build on the weak links.

A successful SNM process will have to involve relevant regime actors. For example, in the Dutch transport biofuels case, the lack of participation from important actors in the transport and agricultural sectors was found to be problematic (Van der Laak et al. 2007).

The SNM review on Dutch transport biofuels SNM revealed several key factors for successful management of shared expectations (Van der Laak et al. 2007). First, stimulating visions with concrete action was important. An example was a fleet of cars, buses and garbage trucks that showed they were part of a project and made it tangible for stakeholders and the general public. Second, shared expectations did not mean a consensus of goals, but rather experimenting to learn about the feasibility and desirability of different expectations. Third, expectations tend to follow a hype-disappointment cycle and failure to reach initial goals led to disappointment and shifts in attention. Fourth, the vision should not be committed to particular technologies or regions. Locking-in given technological choices or ’technology forcing’ led to failure, and lack of international understanding led to lessened learning opportunities. Fifth, visions should not be rigid in order to allow learning.

The keys to a good learning process in the Dutch transport biofuels SNM (Van der Laak et al. 2007) were the creation and stimulation of a variety of designs (whether technological or socio-technical), aiming to learn simultaneously about different dimensions, reflecting on the underlying assumptions, creating opportunities to share lessons between experiments and types of actors, and reformulating your vision based on the lessons.

A review of the Dutch biomass digestion TIS revealed that the failure of the TIS to grow was explained in terms of sporadic entrepreneurial activity not being able to establish a ramp-up of support from the other system functions (Negro et al. 2007). Especially, the lack of a persistent group of actors pushing the technology forward was to be problematic. The review suggested that policy-makers should focus on three system functions: search guidance, market formation, and resource mobilization. Individual key blocking mechanisms were the absence of a clear and consistent national policy and the failure of biomass digestion to achieve the status of proven technology in a key legislative process (Negro et al. 2008).

The development of biogas plants in Denmark is often recognized as a success story, and three factors were important for the expansion (Raven and Gregersen 2007). First, a governmental bottom-up strategy stimulated interaction and learning between social groups. Second, a dedicated social network enable continuity in development until the 1990s. Third, a good fit between biogas and other local social, political, technological and economic factors was important. These included support for decentralized Combined

Heat and Power (CHP) systems, early adoption of energy taxes, and existing collaborative structures in the social networks of farmers. Especially, like in the Netherlands, biogas was able to grow by offering a solution besides just energy, as it solved multiple manure-related issues in the agricultural sector.

In Sweden, a biopower (basically, any biomass electricity and heat solutions) TIS has been successful (Jacobsson 2008). In the formative phase, a good fit between existing paper and pulp industries and more demand for CHP systems and less use of fossil fuels resulted in the establishment of an important home market that acted as a seedbed for entrepreneurial experimentation, where new technologies could be tried out. These seedbeds were supported by the creation of special academic-industrial collaborative units.

Managing attention shifts and cycles is crucial for issue networks. For bioenergy, two types of cycle are especially common: first, technological hype-and-disappointment cycles, and second, changing policy objective cycles (Negro et al. 2010).

5 Learning in sectoral, regional and industrial networks

Innovation in modern industry often happens through collaborative or collective learning in innovation networks. This section reviews how and when meso-scale (smaller than national, but not bound to particular localities) networks allow learning. These networks are defined variously by the geographical, industrial or sectoral focus. Sectors where innovation requires an understanding of regulation and industrial networks in addition to understanding the market demand and the industrial processes often requires a collective learning process, where issues are reframed by combining and comparing different perspectives (Levänen 2015).

Collective learning can be conceptualized as a systemic multiple-loop process, where first-order learning is simply changing practices from outcomes, second-order learning adjusts intentions or corrects values and policies based on outcomes and third-order learning adjusts governance by learning design of norms and protocols from outcomes (Armitage et al. 2008). Alternatively, these loops can be conceptualized as operational-level learning (learning about the concrete practices), collective-choice learning (learning how to efficiently make decisions within a setting), and constitutive-choice learning (learning how to design the decision-making situations to allow efficient learning). For example, in Levänen (2015)'s study on waste management and Finnish industrial networks, first-order learning would be finding processes that produce less waste, second-order would be redefining processes to reclassify waste to a byproduct that can be used somewhere else, and third-order would be redefining the actual process of how something is classified as waste or a byproduct (for example, whether it is defined in advance in an environmental permit, or during the process in collaboration with public authorities) in a way that helps enable better use of resources.

At each level, actors learn by transformative reflection, mutual sharing and experimental learning (Cheng et al. 2011). Learning within organizations and in networks of organizations can similarly benefit from classical learning by being taught by someone else, but also goal-oriented reframing of practices and values.

Improving outcomes in established industries can be simply fine-tuning a process, but an emerging sector has to establish how to evaluate performance when no mature market exists to allow evaluation through competition. Changing the relevant performance criteria is an important part of TIS dynamics and generation of legitimacy. For example, shared expectations of national potential for production capacity of a technology generated through stakeholder networks and mass media can shape technological trajectories (Bergek et al. 2008b).

Local processes are crucial for enabling ’learning-by-trying’ - the path from a laboratory model to market scale involves learning about the practical issues in running and using a technology, but also about how they fit the contexts of economic sectors. Getting from learning by doing to rapid onset of market diffusion takes time - even 15-20 in many renewable energy contexts (Negro et al. 2010). In the 1980s, Dutch biomass digestion was not seen as economically feasible for biogas production. However, it came to be used for a different problem: development in the agricultural sector led to overproduction of manure (Geels and Raven 2006), and large centralized biogasification plants were attempted as a solution to this problem. This is typical of multi-sectoral network learning: often, the key for success is the integration of problems and solutions

In Sweden, the integration of TIS systems for knowledge spillovers has been key. The wood ethanol TIS and wheat ethanol TIS grew by shared expectations that led to market creation and regulative change, while benefiting from earlier methanol and biogasification TIS activities (Bergek et al. 2008b). Even though the technologies could be seen as competing alternatives, collaboration was more effective.

Levänen (2015) studied these processes in the context of waste legislation and industrial recycling and found that collective learning enabled by looking at operational systems as large-scale networks that connect different organizations and resources led to innovation. Formal institutions (rules and regulations) and informal institutions (established practices and norms) that encourage such network thinking, and are themselves flexible to change and have built-in feedback mechanisms, were successful in pushing innovation.

Anbumozhi et al. (2010) studied a Japanese wood industry cluster to understand how a successful network was established around biomass from waste products from the timber industry. They found that stimulating community-based action, providing enabling technologies, creation of social capital and policy integration were key factors for establishing the network. The establishment of a shared vision was also important. Integration of policy goals should be done in a bottom-up collaborative frame.

Policy change based on sectoral networks is often incremental and about drawing lessons rather than overhauling large systems (Secco et al. 2011). This is a feature of systemic learning through feedback mechanisms and should be encouraged: top-down initiatives for major overhaul are rarely successful.

Learning can be hindered by strong network failures (Woolthuis et al. 2005). Long established networks build habits and practices and run the risk of myopia due to internal orientation: they may lock into existing technological trajectories and miss relevant developments outside. Strong networks can also lack weak ties - ties that bridge relative strangers across a network to different industries, or educational or cultural backgrounds. Also, dominance of central partners can be a problem for learning.

6 Local social networks and the context of projects

It is important to involve users and user groups in projects for successful SNM Van der Laak et al. (2007). In the Dutch biomass digestion scene, initial expansion (in the late 1970s) was grounded in stakeholder networks, as the co-operation of farmers and academic researchers led to the installment of decentralized farm-scale plants. Ultimately, technological failures and lower than expected efficiency led to diverging expectations between the stakeholders: what the technology developers saw as part of the learning process, the farmers saw as fundamental failures, and eventually the abandonment of the decentralized technology.

The Göttingen approach to sustainable development consists of seven elements of a research cycle. In addition to the traditional role of the scientist, that of research producing scientific knowledge, the six other tasks focus more on practical problem-solving methods and activities, as well as applying the scientific knowledge learned to each stage.

The problem solving starts initially with the selection of the problem in focus. For global-level problems, however, such as climate change or water crises, the formulation of solutions under the Göttingen approach does not occur at the global level. Instead, it rather focuses more on local and regional levels, levels at which it is more feasible for scientists to affect directly. Scientists can more easily suggest and initiate research ideas in sustainable energy research with local political authorities, who are likely more willing to consider experimental techniques compared to at the global level.

Once practice partners are found, a scientifically grounded pilot project at the local level not only allows for distinguishing local priorities, but a successful realization could also support the transfer of a particular model to other regions and countries.

7 Lessons for BEST

Is the BEST project able to generate the setting needed for successful technological market integration and an innovation system? This section discusses some key lessons identified in this study and develops indicators measuring progress and system performance along the lines identified. Figure 2 shows the system conceptualized as a loop between technological innovation systems that reshape the regime configuration in a transition process - that also shapes how the novel technological niches are managed. Of course, these processes are simultaneous and regime-niche dynamics are continually played out, sometimes resulting in more stability and preservation on the status quo, sometimes resulting in systemic change. This section is organized from niche to regime back to the niche. First, what lessons can an actor hoping to improve the technological innovation system of decentralized biomass draw from experience in other countries? Second, how do these changes fit the transitioning regime and socio-technical systems technology developers, technology users, end consumers and policy-makers are embedded in? And third, how the changing regime can be expected to put pressures on the niches and how this process should be managed?

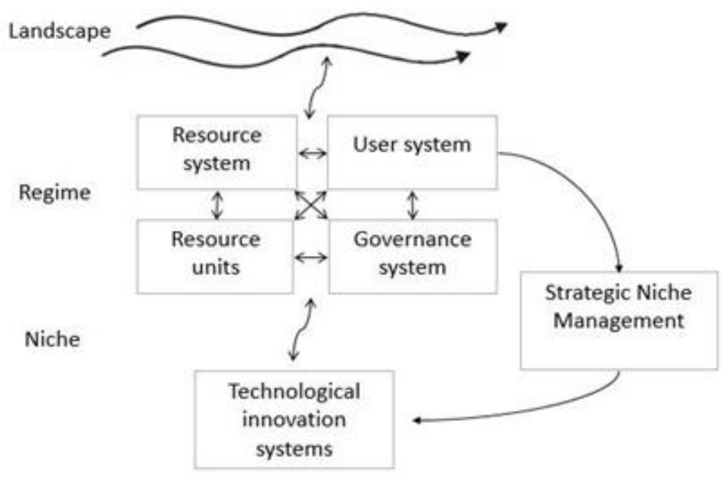


Figure 2. Feedback links between theories and subsystems

7.1 Innovation networks

Organizational networks (figure 3) that involve multiple types of stakeholders from business to research to governance to society do not work very well with a centralized hierarchical structure, but given the size of the networks and the complexity of the issues, and a completely open network dense with communication and collaboration links leads to information overload. An efficient social network is characterized by combinations of strong subnetwork cores and so-called *weak links* (Granovetter 1973): links that connect subnetworks that enable unplanned and unconstrained travel of information.

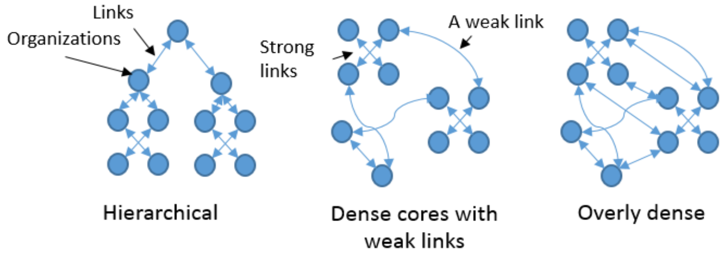


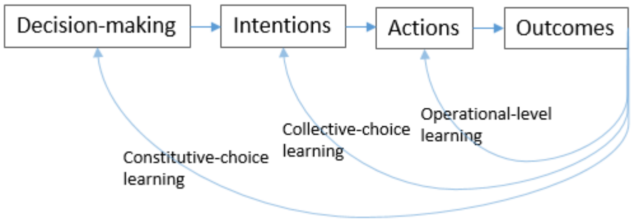
Figure 3. Network structures and weak links

Absence of weak links leads to insufficient use of complementary skills and ideas and inefficient interactive learning. Bioenergy examples are plentiful: for example, Swedish wood ethanol and wheat ethanol innovation systems depended on weak links between each other, but also to earlier methanol and biogasification systems (Bergek et al. 2008).

7.2 Collaborative learning

Collaborative network learning needs to be able to challenge even the reasons for the network's existence. Triple-loop learning (Figure 2; Armitage et al. 2008) demonstrates this: first-loop is the basic refining of processes that happens in any organization. Second-loop learning is challenging the values and goals attained by networking. Third-loop learning is learning about how setting up the decision-making architecture for a network affects those goals.

For example, in Levänen's (2015) study on waste management and Finnish industrial networks, first-order learning would be finding processes that produce less waste, second-order would be redefining processes to reclassify waste to a byproduct that can be used somewhere else, and third-order would be redefining the actual process of how something is classified as waste or a byproduct (for example, whether it is defined in advance in an environmental permit, or during the process in collaboration with public authorities) in a way that helps enable better use of resources.



Many bioenergy technologies are established and mature, but many small-scale and/or high-value technologies still remain in the niche. Even many of the concepts developed within BEST will be in the demonstration and pre-commercialization phases, and there is a need to avoid the valley of death with first, good innovation system management within the technology sector, and second, policy attention in crucial stages in niche management.

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