Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy

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This article discusses empirical findings and conceptual elaborations of the last 10 years in strategic niche management research (SNM). The SNM approach suggests that sustainable innovation journeys can be facilitated by creating technological niches, i.e. protected spaces that allow the experimentation with the co-evolution of technology, user practices, and regulatory structures. The assumption was that if such niches were constructed appropriately, they would act as building blocks for broader societal changes towards sustainable development. The article shows how concepts and ideas have evolved over time and new complexities were introduced. Research focused on the role of various niche-internal processes such as learning, networking, visioning and the relationship between local projects and global rule sets that guide actor behaviour. The empirical findings showed that the analysis of these niche-internal dimensions needed to be complemented with attention to niche external processes. In this respect, the multi-level perspective proved useful for contextualising SNM. This contextualisation led to modifications in claims about the dynamics of sustainable innovation journeys. Niches are to be perceived as crucial for bringing about regime shifts, but they cannot do this on their own. Linkages with ongoing external processes are also important. Although substantial insights have been gained, the SNM approach is still an unfinished research programme. We identify various promising research directions, as well as policy implications.

1. Introduction

Following Mokyr, we can describe new technologies as 'hopeful monstrosities' (Mokyr 1990, 291). They are 'hopeful', because product champions believe in a promising future, but 'monstrous' because they perform crudely. As Rosenberg (1976, 195) argues: 'most inventions are relatively crude and inefficient at the date when they are first recognised as constituting a new invention. They are, of necessity, badly adapted to many of the ultimate uses to which they will eventually be put.' This means that new technologies cannot immediately compete on the market against established technologies. This problem is pivotal for many new technologies

with sustainability promise for energy, transportation, agriculture, etc. There is no lack of such new technologies, which are developed in R&D laboratories and put to use in demonstration projects. They have a hard time, however, bridging the 'valley of death' between R&D and market introduction. Building on Van de Belt and Rip (1984), Schot, Hoogma, and Elzen (1994) and Kemp, Schot, and Hoogma (1998) introduced the strategic niche management perspective (SNM) to address this problem.[1] Hence, much of the SNM literature focuses on understanding the early adoption of new technologies with high potential to contribute to sustainable development.

A core assumption of the SNM approach is that sustainable innovation journeys can be facilitated by modulating of technological niches, i.e. protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices, and regulatory structures. Radical innovations therefore never serve as a simple technological fix in an SNM approach. It is not a technology push approach. Instead, SNM scholars argue that sustainable development requires interrelated social and technical change. In that respect, they build on the work of sociologists of technology who argue that technological and social change are interrelated.[2] They also recognise that the rise of modernity created conditions in which technology actors usually focus on developing, testing and optimising technology, but neglect the embedding in broader societal goals, or leave it to a later stage. Confronted with relatively fixed technical designs, governments often take on the role of mitigating and/or compensating for the impacts. This historical diagnosis has been the background for the development of new thinking about technology policy and Constructive Technology Assessment of which SNM is an offspring.[3]

While early SNM scholars had normative concerns, subsequent research did not focus primarily on the development of SNM as a policy tool, although some work has been done in that direction. Instead, SNM scholars began investigating which processes determine successful niche development. This research direction was based on the idea that strategies such as SNM can only work well when they modulate on-going dynamics. Consequently, SNM as a policy tool does not suggest that governments create niches in a top–down fashion, as is sometimes assumed by commentators, but focuses instead on endogenous steering, or steering from within.[4] Such steering can be enacted by a range of actors, including users and societal groups. Steering can address many parts of the process, by adding a new actor, a specific learning process or a set of demonstration projects which may redirect evolving dynamics toward a desired path. Niches are not inserted by governments, but are assumed to emerge through collective enactment. Nevertheless, their (future) course can be modulated into more sustainable directions. Because of these characteristics, we would like to define SNM as a form of reflexive governance (see Voss, Bauknecht, and Kemp 2006; and in particular, see Grin 2006).

During the last 10 years, many new studies and articles have appeared, which have reported empirical findings and suggested further elaboration. In this article, we review and discuss the results of this research and show how the research agenda has evolved. The article is structured as follows. In Section 2 we provide the theoretical background of SNM and introduce some basic concepts. In particular we discuss a specific conceptualisation of the role of niches in technical change. In Section 3 we discuss the main body of SNM research that focuses on niche-internal processes. In Section 4 we broaden our scope and look at conceptualisations that connect niche-internal to external processes. In Section 5 we address policy implications of SNM research. Finally, the concluding section brings together the results of this discussion and articulates a future research agenda. Throughout the article we distinguish between 'early' SNM research which mainly focuses on niche-internal processes and 'later' SNM research which provides a more elaborate analysis of the interaction between niches and their broader environments.

2. Theoretical background of SNM research

The theoretical background of SNM consists of an attempt to import insights from constructivist science and technology studies into evolutionary economics as developed by Nelson and Winter (1982) and Dosi (1982). This effort led to the formulation of a quasi-evolutionary perspective on technical change by Rip (1992, 1995) and Schot (1992, 1998). They argue that variation is not blind, as is assumed by many evolutionary economists, but directed to some extent. Technology actors not only anticipate future selection, but also try to shape the selection process itself by setting up special programmes in R&D settings or demonstration projects. These are spaces in which radical novelties are tried out and developed further, while they are sheltered from mainstream competition. This way, firms and governments develop variations, which do not (yet) fit in the existing selection environment. Rip and Schot referred to such spaces as (technological) niches.[5] In their view, these niches could be used not only for testing the design of the technology, but also for mutual articulation (and alignment) of technology, demand and broader societal issues, including sustainable development. The niche provides a protected space that nurtures a specific set of interactions between issues, but also between actors representing these issues. The additional hypothesis was that such niches function as 'proto-markets' which may jumpstart the development of market niches (i.e. niches in which technology design and user demands have become stabilised). Technological niches often involve policy makers, but they do not do so necessarily. Users and societal groups can also invest their time and resources to construct niches.[6] One important reason for governments to subsidise and nurture not yet profitable innovations is the expectation that they will become important for realising particular societal and collective goals in the future.[7] Because of these expectations, governments and other actors operating in the niche may accept disadvantages in the present and invest resources in upgrading and developing a 'hopeful monstrosity'.

The notion of 'niche' was already present in the innovation literature but was not focused on inducing sustainable development. Evolutionary economists (Saviotti 1996; Windrum and Birchenhall 1998; Frenken, Saviotti, and Trommetter 1999) and management scholars have emphasised the importance of market niches for radical innovations (Astley 1985; Lynn, Morone, and Paulson 1996). In particular, Levinthal's (1998) path-breaking article argues that radical change may occur as a result of distinct selection criteria operating in a niche. In his conceptualisation the initial speciation event is minor in the sense that the technology does not differ substantially from its predecessors, but different selection pressures in the niche subsequently trigger a divergent evolutionary path. His idea of a market niche thus rests on the assumption that selection environments are not homogenous and consist of several different niches. While Levinthal and others usually take the existence of market niches for granted, and assume that minor variations of prevailing technologies are tried out in such niches, SNM scholars argue that for many innovations, especially with sustainability promise, market niches and user demand are not readily available because the innovations are not minor variations from the prevailing set of technologies, but differ radically from them.[8] SNM was thus developed to serve the management of a particular type of innovations: (1) socially desirable innovations serving long-term goals such as sustainability, (2) radical novelties that face a mismatch with regard to existing infrastructure, user practices, regulations, etc. It is precisely for this reason that SNM scholars see real-world experimental projects as important devices that precede market niche development. Such proto-markets can be exploited to explore possible alignments of technology, user demands and sustainability issues.

3. Niche internal processes

In early SNM work the idea is that the selective exposure of new (sustainable) technologies to the market through a process of niche development can eventually lead to the replacement of the dominant (polluting) technologies. This replacement would take the form of the development of a new socio-technical regime that carries and stores the rules (partly embodied in standards, skills, designs, and government regulations) for how to produce, use and regulate the new technology. Early SNM work conceptualised the process as a bottom–up process, in which novelties emerge in technological niches, then conquer market niches, and eventually replace and transform the regime (Figure 1).

The main research question was: how and under what circumstances is the successful emergence of a technological niche possible? Success was defined in terms of transformation of a technological niche into a market niche and eventually a regime shift. Based on a range of insights from innovation studies, including STS, evolutionary economics and history of technology, three (internal) processes were distinguished for successful development of a technological niche (Elzen, Hoogma, and Schot 1996; see also Kemp, Schot, and Hoogma 1998):[9]

(1) The articulation of expectations and visions. Expectations are considered crucial for niche development because they provide direction to learning processes, attract attention, and legitimate (continuing) protection and nurturing.
(2) The building of social networks. This process is important to create a constituency behind the new technology, facilitate interactions between relevant stakeholders, and provide the necessary resources (money, people, expertise).
(3) Learning processes at multiple dimensions:

   (a) technical aspects and design specifications
   (b) market and user preferences
   (c) cultural and symbolic meaning
   (d) infrastructure and maintenance networks
   (e) industry and production networks
   (f) regulations and government policy
   (g) societal and environmental effects

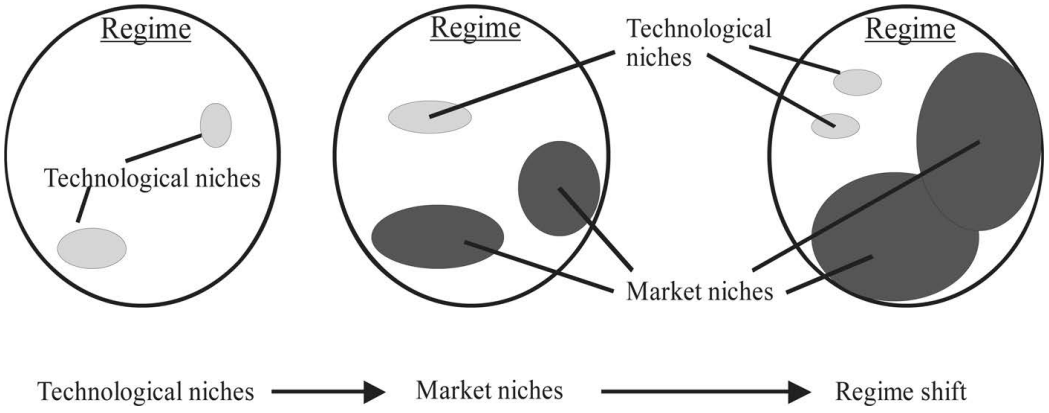

Figure 1. From niche dynamics to regime shift (adapted from Weber et al. 1999, 22).

Subsequently, more specific hypotheses were formulated for each process (Elzen, Hoogma, and Schot 1996, 76–78; and Hoogma et al. 2002, 28–29):

(1) Expectations would contribute to successful niche building if expectations were made: (a) more robust (shared by more actors), (b) more specific (if expectations are too general they do not give guidance), and (c) have higher quality (the content of expectations is substantiated by ongoing projects);
(2) Social networks are likely to contribute more to niche development if: (a) the networks are broad, i.e. multiple kinds of stakeholders are included to facilitate the articulation of multiple views and voices; the involvement of relative outsiders may be particularly important to broaden cognitive frames and facilitate second-order learning; (b) the networks are deep, i.e. people who represent organisations, should be able to mobilise commitment and resources within their own organisations and networks;
(3) Learning processes would contribute more to niche development if they are not only directed at the accumulation of facts and data, i.e. first-order learning, but also enable changes in cognitive frames and assumptions, i.e. second-order learning (derived from Grin and Van de Graaf 1996).

These hypotheses were tested in a European Union project,[10] three PhD theses (Hoogma 2002; Van Mierlo 2002; Raven 2005) and discussed, criticised or amended in several other studies.[11] These studies contained empirical (case) studies of finished and/or ongoing experiments in a range of fields, from transport to energy to agriculture and sanitation, mainly in (Western) European contexts, but also in Tanzania and South Africa. They investigated if the identified success conditions explained outcomes. The case selection included some examples of market niche development, but many cases featured a limited outcome in terms of inducing further niche development into a sustainable direction.

The results showed that many demonstration projects were organised in an overly contained way. Networks tended to be narrow and projects tended to focus on first-order leaning. Consequently, many demonstration projects followed too much of a technology push approach. The narrow focus came through in the way users were included in the demonstration projects that were studied. They were mainly perceived as consumers with given needs and preferences. Hence, the aim of many demonstration projects was to discover (mis)matches between technology features and these (assumed) needs. Standardised surveys and usability trials and panels were used to investigate these (mis)matches. Failed niche developments could often be related to either minimal involvement of outsiders in the experiments and a lack of second order learning, or to minimal involvement of regime actors which resulted in lack of resources and institutional embedding. Another recurring finding is that the nature of social networks determined the depth and breadth of learning processes. Networks that were broad and contained outsiders provoked more second-order learning. These studies show that SNM is a useful *ex-post* analytical framework. The demonstration projects in these studies did not use SNM prescriptively as a management tool. So the real-life problems in these projects are not indicative for theoretical failures in SNM, as some commentators have suggested.

Some of these studies highlight shortcomings of the SNM approach as defined in Kemp, Schot, and Hoogma (1998) and Hoogma et al. (2002). For instance, Brown et al. (2004) and Harborne et al. (2007) stress that involvement of outside actors and second-order learning do not happen easily and by themselves. It requires the presence of particular drivers and contexts. They point to the importance of a sense of urgency and the role that a process of structured repeated visioning

could play. In similar vein, Hegger, van Vliet, and B.J.M. van Vliet (2007) argue that the strong focus on experiments with technology in many demonstration projects is not conducive to broad learning and outsider involvement. It might reinforce the technology push character of actual experiments. They propose to redirect the focus of niche experiments towards concepts, visions and guiding principles rather than technologies, and toward experimenting with social aspects first, albeit without neglecting the socio-technical character of the change process. Finally, the transition management (TM) approach advocated by Rotmans, Loorbach and others, which like SNM highlights the importance of experiments, emphasises the importance of creating visions before starting experiments (Rotmans, Kemp, and van Asselt 2001; Loorbach 2007; Kemp, Rotmans, and Loorbach 2007).[12] TM promotes envisioning practices in so-called 'transition arenas', which consist of regime actors, niche actors and outsiders. TM thus actively aims to influence the regime, using niche experiences and alternative visions to influence the cognitive frames of regime actors. Grin (2006) makes similar points about the transformative power of influencing cognitive frames, which he sees as an important aspect of reflexive governance (see also Bos and Grin 2008, forthcoming). Grin argues that biases and limitations in existing institutions can be overcome by providing actors with a meta-vision that helps them deal with the challenge of creating fundamental change.

On the one hand, we acknowledge that TM addresses some factors that SNM underplays. While SNM develops an evolutionary approach that builds on and leverages the dynamic forces of market competition, aimed at overcoming lock-in and promoting socio-technical diversity, TM suggests a more ambitious approach of goal-oriented modulation that places more emphasis on the role of strategic envisioning. In that respect, TM introduces the notion of 'transition experiment' which is supposed to be different from regular innovation experiments (Van den Bosch and Taanman 1996).

On the other hand, in practice there are too many fruitless scenarios and visioning exercises, with few substantive follow-up activities. In a critical interpretation, one might say that many of these exercises have become rituals, where actors express good intentions as a form of public 'impression management'. While we recognise that reproductions of rituals may sometimes provide conditions for change, there are many instances where they have little real influence. Hence, SNM scholars have stressed the importance of 'hands-on', real-life experiences in demonstration projects; SNM assumes that actual implementation and specification of visions in experimental settings is most conducive for niche development. We are not yet convinced that there is much to gain from visioning beforehand in transition arenas. Still, we also recognise that SNM's assumptions may need to be reconsidered: empirical research of sequences of experimental projects indicates that visions and expectations do not evolve as much as we expected in response to learning processes in the projects. Several critical sympathisers (e.g. Hegger, Harborne, and Brown 2007) have argued that visioning prior to experimentation does help to broaden networks and learning processes.

In our opinion, this controversy touches upon a central problem of technology development in modern societies. Technology actors such as firms and governments introducing new technologies tend to exclude certain actors and focus on optimising the technological side first while neglecting other social aspects. It remains to be seen whether introducing some structured process of visioning (as in transition management) in arenas arranged by policy actors, or forms of conceptual niche management as proposed by Hegger, Harborne, and Brown (2007), could indeed help to overcome this modernist bias. Early SNM put its cards on influencing the actual design and implementation of a range of new varieties. Below, we show that later SNM suggests that such a strategy needs to complemented with other measures which modulate emerging windows of opportunity external to the niche.

A lot of the cited research focuses on explaining the limited success of the experiments studied. Conclusions point to the conditions that would better encourage particular types of learning, networking and visioning. Hommels, Peters, and Bijker (2007) have argued that part of the problem might be that SNM focuses too much on providing protection. In their view innovations have a better chance of success if made vulnerable by subjecting them to risks and oppositions from the outset. They developed a management tool (PROTEE) to arrange for learning process about the context in which the innovation will be embedded. This tool might indeed be useful for an SNM approach. Contrary to what Hommels, Peters, and Bijker (2007) argue, controlled exposure to selection pressures has been central to SNM research from the start. Yet we agree that more attention should be devoted to ways in which protection is provided and can be lifted in a phased way. The managing of selective pressures is not only an issue of specific measures, such as subsidies, but also one of niche expansion and the emergence of a new set of stable rules and routines.[13] Yet, innovations in SNM are of a particular nature (see above) that requires some form of protection. Otherwise the journey would not begin at all since market demand does not pull and firms and other technology actors are not pushing for market introduction, as Harborne, Hendry, and Brown (2007, 184) formulated the problem.

Many of the studies discussed can be seen as inquiries into understanding the failure and successes of the journey from technological niche to market niche, and eventually to a regime shift. On this point, Raven (2005) and Van Mierlo (2002) made a crucial contribution by signalling the need for distinguishing between local socio-technical projects and the niche level which consists of an emerging community that shares cognitive, formal and normative rules (Figure 2).

Niche development can then be conceptualised as progressing at two levels simultaneously: the level of projects in local practices and the global niche level. Sequences of local projects may gradually add up to an emerging field (niche) at the global level (Figure 3). Using the work of Deuten (2003), Geels and Raven (2006) conceptualised this aggregation process as follows: developments may start with one or a few projects, carried by local networks of actors, who are interested in innovations for idiosyncratic or local reasons. The cognitive rules (such as expectations) that guide these projects are initially diffuse, broad and unstable. Local projects form test beds for these diffuse ideas and spaces for the elaboration of new ideas. If learning processes in local projects are compared and aggregated, the cognitive rules at the more global niche level may gradually become more articulated, specific and stable. In this conceptualisation, a technological niche is not only characterised by protection (which tends to be phased out slowly), but also by the locality and instability of rules and networks. The movement to a market niche does not only entail a movement to more exposure to selection pressures, but also to more stable shared rules (e.g. dominant designs).

This conceptualisation shifts the attention from single projects and their success or failure to sequences of projects, which can accumulate into learning trajectories, while also the notion

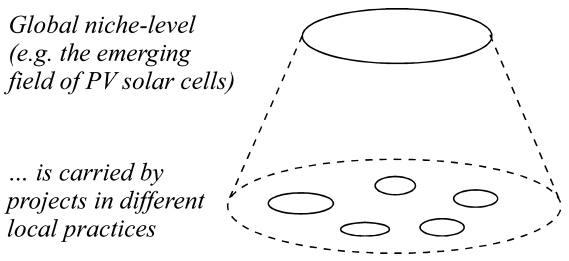

Figure 2. Local projects and global niche-level (Geels and Raven 2006, 378).

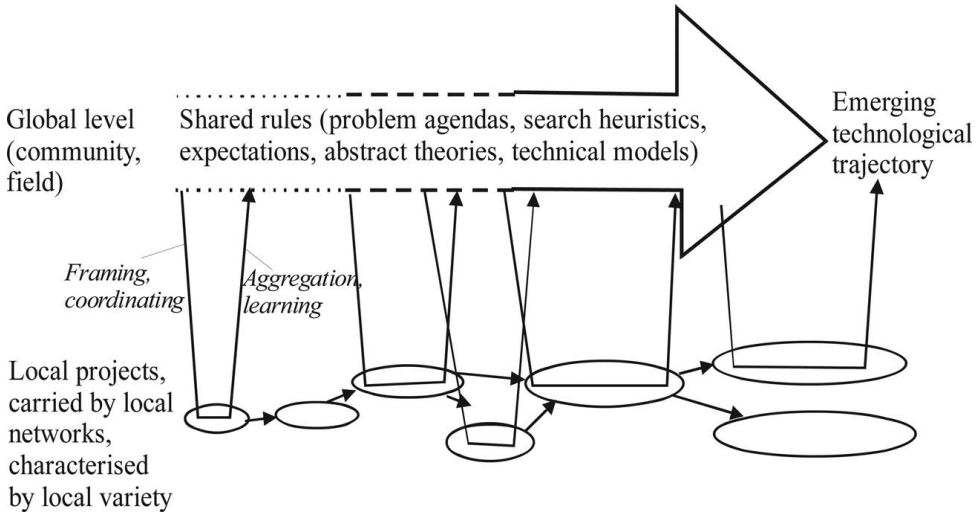

Figure 3. Emerging technical trajectory carried by local projects (Geels and Raven 2006, 379).

of failure itself becomes more layered since failed projects can contribute to the success of the overall sequence. This point is reinforced by Van den Bosch and Taanman (1996) who discuss the importance of a cyclical pattern of learning and networking that would help to create a set of more global rules, and by Van Eijck and Romijn (2008) who stress the importance of organising sequences which take into account changes needed in the entire production chain. This line of research opens up a range of new topics and questions that require further investigation, in particular in two areas: (1) mechanisms and factors that make sequences of projects gel into niche development; (2) contributions of interactions among between multiple regimes and niches towards regime shifts.

These areas have been explored in some recent papers. Geels and Raven (2006) argue that sequences of projects are guided by cognitive rules and expectations, thus restating the importance of visions, albeit not for developments within projects but between projects. They also point to changes in external circumstances such as oil prices and the liberalisation of the electricity sector that influence the adoption and direction of developments. Geels and Deuten (2006) emphasise the role of intermediary actors at the community level (e.g. branch organisations, professional societies), who monitor multiple local projects, aggregate generic lessons, and circulate knowledge through journals or dedicated workshops and conferences. Earlier, Van Mierlo (2002) found that Shell was involved in most projects with solar photovoltaics in the Netherlands in the late 1990s. This professional actor brought lessons from one project along to the next project. Different projects, however, also compete with other, so actors may not be willing to share learning experiences. Secrecy may hamper circulation of lessons and experiences. This issue of competition leads to a bigger issue. SNM assumes that diversity is productive for niche development, because it enhances learning and network development, but too much diversity may hamper developments, because it creates uncertainty (which prevents full commitments), fragments resources and hampers the emergence of a stable set of rules. This dilemma needs more attention in future research.

These findings and discussions suggest that the journey from experiments to regime shift is more complicated than was previously assumed. In 2002, Hoogma et al. acknowledged this:

> For one thing, 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 . . . . The experiments were relatively isolated events. It seems difficult for the actors to build bridges. Although more could perhaps have been done and achieved, there are limits to the power of experiments. Only occasionally will an experiment be such a big success that it will influence strategic decisions. Experiments may tip the balance of decision-making, but they will not change the world in a direct, visible way . . . . Experiments influence the world but do not bring particular futures about. Their influence is more indirect. (Hoogma et al. 2002, 195–196)

In sum, SNM has identified and empirically investigated important niche-internal mechanisms in sustainable innovation journeys. While SNM research provides evidence that there is a correlation between the design of experiments and outcomes in terms of technological and market niche development, it is also clear that internal niche developments are not the only important factor. External factors also play a crucial role. Niche innovations are rarely able to bring about regime transformation without the help of broader forces and processes. This conclusion led to a search for conceptualisations that linked niche internal and external processes. This search was done under the heading of the multi-level perspective, and developed in parallel with much of the SNM work discussed above.

4. Niches and multi-level analysis

A broader, contextualised view of the role of niches in technical change was developed in the context of a number of research projects, in particular: (a) a literature review and synthesis about technological change, performed for the Batelle Memorial Institute funded by the US Department of Energy (Rip and Kemp 1998); (b) a major research programme about the history of technology in the Netherlands in the nineteenth and twentieth century,[14] and (c) PhD research by Geels (2002, 2005) into technological transitions and regime shifts, based on historical case studies. This work culminated in a multi-level perspective (first formulated by Rip and Kemp 1998) that distinguishes three analytical levels. Niches form the micro-level where radical novelties emerge. The socio-technical regime forms the meso-level, which accounts for the stability of existing large-scale systems (in transport, energy etc). The socio-technical regime is an extended version of Nelson and Winter's (1982) technological regime, which referred to shared cognitive routines in an engineering community and explained patterned development along 'technological trajectories'. Sociologists of technology broadened this explanation, arguing that scientists, policy makers, users, and special-interest groups also contribute to patterning of technological development (e.g. Bijker 1995). The socio-technical regime concept accommodates this broader community of social groups and the alignment of activities. Regimes not only refer to cognitive routines and belief systems, but also to regulative rules and normative roles. The macro-level is formed by the socio-technical landscape, an exogenous environment beyond the direct influence of niche and regime actors (e.g. macro-economics, deep cultural patterns, macro-political developments). Changes at the landscape level usually take place slowly, in the order of decades.[15] Figure 4 indicates that the three levels form a nested hierarchy with regard to local practices. Niche actors hope that novelties will eventually be used in the regime or even replace it. This is not easy, because the existing regime is stabilised and entrenched in many ways (lock-in).

The core notion of the multi-level perspective (MLP) is that transitions come about through interactions between processes at different levels: (a) niche innovations build up internal momentum, (b) changes at the landscape level create pressure on the regime, (c) destabilisation of the regime creates windows of opportunity for niche innovations (Figure 5).

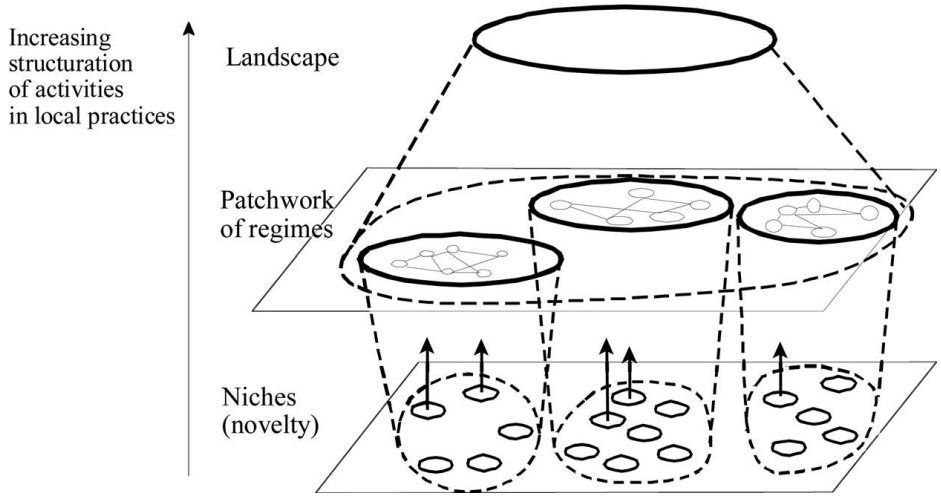

Figure 4. Multiple levels as a nested hierarchy (Geels 2002, 1261).

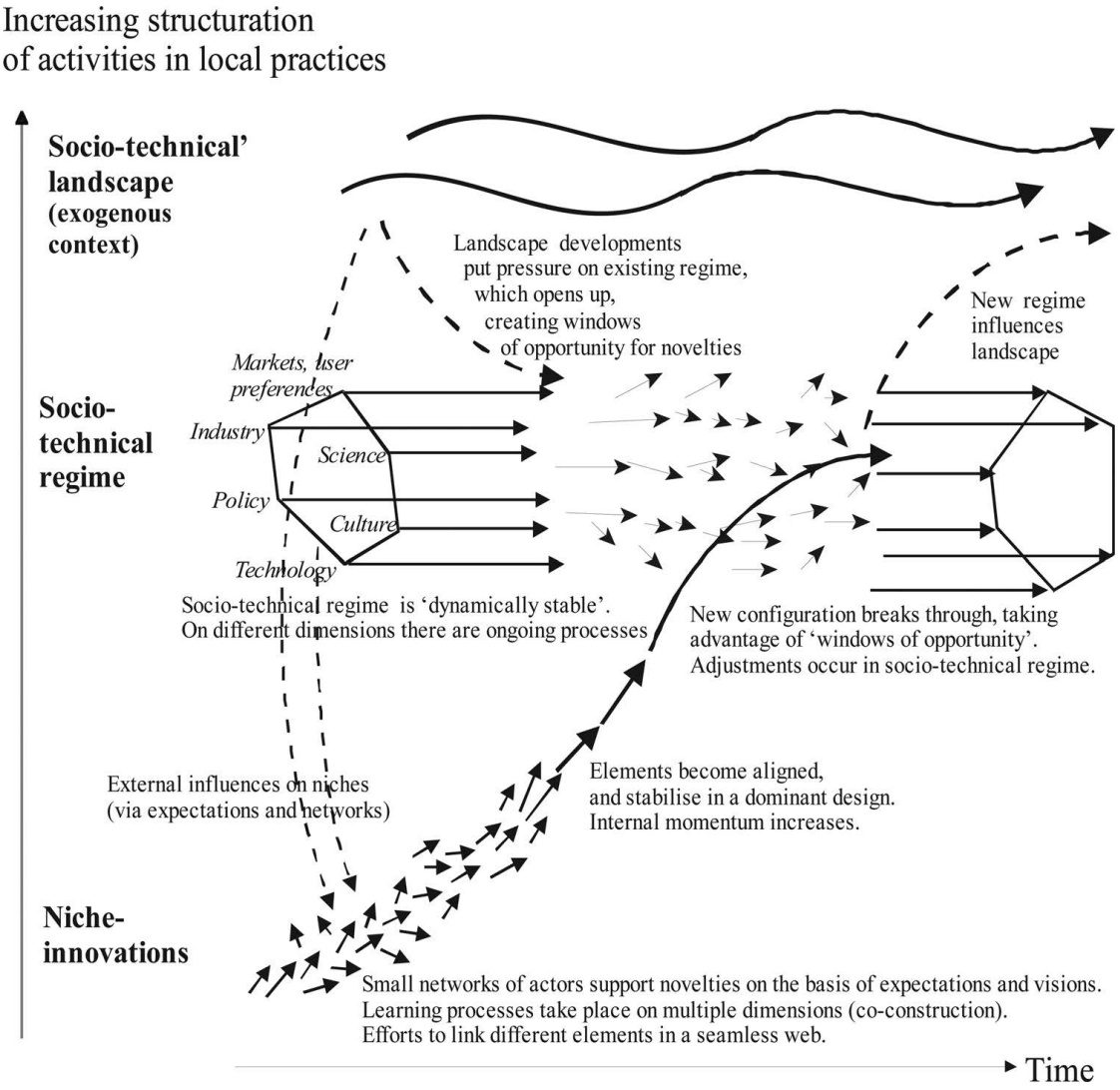

Figure 5. Multi-level perspective on transitions (adapted from Geels 2002, 1263).

The MLP thus corrects the suggestion of the early SNM literature that regime shifts would come about through bottom–up processes of niche expansion (see Figure 1). Instead, alignments of processes at multiple levels are now emphasised. Niche innovations are still important, but they can only diffuse more widely if they link up with ongoing processes at regime and landscape levels. As Shove and Walker (2007, 764) formulated it: 'the key idea is that change takes place through processes of co-evolution and mutual adaptation within and between the layers'.

Recent work distinguishes various types of co-evolution. Raven (2006) found that niche innovations may be adopted from the start within the regime to solve certain problems. Subsequently, further learning processes may lead to more substantial reconfigurations of the regime. Niche innovations thus need not always compete with and substitute for the prevailing regime, as was assumed in earlier SNM work. They may also be incorporated and transform the regime from within. Raven analysed how biomass was incorporated in the electricity production regime through co-firing with coal. Ongoing learning processes and stricter regulatory pressure subsequently triggered further reconfigurations in the electricity regime. Another co-evolution pattern, translation from niche experiences to the regime, was found by Smith (2007) in a study of organic food and green housing in the UK. He found that new practices were initially pioneered by niche actors in relatively secluded spaces (dedicated green activists or architects). Broader regime changes occurred, however, when the niche lessons were translated and picked up by regime actors.

In both co-evolution patterns, the dynamic is less about substitution and more about how niches may branch, pile up, and contribute to changes in the behaviour, practices and routines of existing regime actors. This more differentiated view of niche–regime interaction is fruitful terrain for further research. It also shows that niches can play different roles. They can grow and become a new regime that eventually replaces the old one, but they can also be incorporated into existing regimes. This conclusion led to various systematic attempts to distinguish various types of niches and different transition pathways (Berkhout, Smith, and Stirling 2004; Geels and Schot 2007). Because this is not the right place to elaborate on this work, we only conclude that a next step would be to incorporate the idea of transition pathways more explicitly into SNM work (which may also lead to differentiated policy suggestions).

While the MLP helped to further develop the SNM perspective, SNM research also contributes to the MLP. Most of the MLP studies focus on one regime, but Raven found that niche developments may be influenced by multiple regimes (Raven 2005, 2007; Raven and Verbong 2007).[16] This influence can be beneficial when a niche innovation becomes linked as solution to multiple regimes, but it can also create new problems and uncertainties about regulations, definitions, technical linkages, and responsibilities. The burning of waste in electric utilities, for instance, involved struggles over emission regulations (regarding mercury and other heavy metals), which were stricter for the waste regime than for the electricity regime. There were also struggles over the question of whether organic waste should be defined as biomass (which would make it eligible to renewable energy subsidies) or as waste. Another way to broaden the analytical scope is to study interactions between multiple niche innovations. Sandén and Jonasson (2005), for instance, studied interactions between multiple types of alternative transport fuels. This broader attention to multiple regimes and multiple niches may also lead to modifications in the existing pathway typologies, which are limited to transitions from one regime to another.

5. SNM and its policy implications

The research discussed shows that, contrary to what SNM approaches would favour, many experiments are organised to push for a certain technology and neglect the necessary co-evolutionary

dynamics. Furthermore, experiments are often isolated local projects that are not connected to a broader strategy to develop a (global) niche. An important policy question is: how can this structural technology push bias be overcome?[17] This is not an easy question, since the bias is deeply embedded in the modernist way of managing the introduction of technology in society. Ultimately, it would require not only a change in the specific practice of organising experiments, but also broader institutional and cultural changes, particularly in the distribution of responsibilities and the organisation of relations between state, market, civil society and science and technology. This article is not the place to discuss this issue at length (see Schot 2003). We only point to the overlap with Grin's diagnosis, which calls for a new reflexive governance model that appreciates the profound changes that are occurring in the relations between these areas, and conclude with him that to evaluate the policy relevance of SNM and TM, the question needs to be asked to what extent and in what ways they would benefit from, or be hindered by, these profound changes (see Grin 2006). In the remainder of the article, we restrict ourselves to some comments about the nature and limitations of the policy advice generated within SNM research.

SNM was developed to find ways of coping with the policy challenge of nurturing sustainable innovation journeys and transitions. Building on findings of the last 10 years, we conclude that hypotheses about the importance of identified niche internal assumptions are sustained when outcomes of experiments are evaluated *ex-post*. Building on these findings, SNM research has generated a lot of policy advice aimed at creating appropriate processes of network development, learning and visioning. This advice often focuses on generating more appreciation and reflexivity about the ongoing dynamics. It does not result in clear-cut recipes, but helps identify a number of dilemmas. We list of number of them in Table 1. An important contribution of SNM research may thus consist in helping policy makers build competences in recognising and dealing with these policy dilemmas. For this reason we support the initiative of the Dutch Competence Centre for Transitions, in collaboration with the Knowledge Network on Systems Innovations and Transitions, to develop a so-called 'competence kit' on experimentation, which is to be used in real life (Dutch) transition practices (see Raven et al. 2007).[18] It remains to be seen, however, if such instruments actually work in practice and have the intended effects. So far, SNM has been used primarily for *ex-post* evaluations of case studies. It has not been applied prescriptively in ongoing processes.

The research discussed indicates that SNM is not a silver bullet solution that will bring about transitions towards sustainable development, if only because experimenting will not be sufficient. SNM should be seen as a useful addition to existing policy instruments that have neglected the value of experiments. Other more traditional instruments for inducing sustainable innovation, such as market incentives, various forms of regulation, and technology forcing, also have to play a role. Elzen, Hoogma, and Schot (1996) have formulated some initial ideas about the relative influence of different policy strategies on niche-internal development (see also Van der Laak, Raven, and Verbong 2007).

We would like to add a final comment on the position of researchers in this type of action oriented research. SNM suggests that researchers can act as mobilisers, advisors, mappers of change dynamics, and change agents in the name of sustainable development. While SNM recognises that different definitions of sustainable development exist, it is based on the assumption that sustainable development captures enough common ground to act upon. In reaction to this active involvement of SNM (and TM scholars), Shove and Walker have critically asked:

> What are the everyday politics of such an enterprise? When and how are the goals of transition management subject to critical scrutiny, and by whom? Equally important, who wins and who loses out as transition are guided in one direction but not another? (Shove and Walker 2007, 765)

Table 1. Policy dilemmas for niche development.

Expectations, visions	Be flexible, engage in iterative visioning exercises; adjust visions to circumstances and take advantage of windows of opportunity.	Be persistent, stick to the vision, persist when the going gets tough.
Learning	Create variety to facilitate broad learning.	Too much variety dilutes precious resources and prevents accumulation. It also creates uncertainty and may delay choices/commitments (by consumers, policy makers).
Learning	Upscaling through bricolage strategy and stepwise learning. Disadvantages: (1) slow, (2) incremental steps.	Upscaling through breakthrough strategy and big leaps to achieve success rapidly. Disadvantages: (1) danger of failure, (2) mis-alignment with selection environment.
Network	Work with incumbent actors, who have many resources, competence and 'mass'. Try to change their agenda, visions.	For radical innovations, it is better to work with outsiders, who think 'out of the box' and have new ideas. Incumbents have too many vested interests and will try to hinder or encapsulate radical innovations.
Protection	Protection is needed to enable nurturing of niche-innovations.	Do not protect too long and too much. This might lead to limited exposure to selection pressures (and the danger of creating white elephants).
Niche-regime interaction	Wait for 'cracks' in the regime, and then vigorously stimulate niche-innovations. Until such windows of opportunity arise, niches should be nurtured to facilitate stabilisation.	Use niche experiences to influence perceptions of regime actors and actively create cracks in the regime.

These are good questions, because there are politics and power play in SNM processes, the depth of which are easily underplayed. There is no clear solution, however. Independent 'outside positions' do not exist. This is one reason why open-ended learning processes are emphasised in SNM. From this perspective, resistance and conflict is to be expected, and should also be embraced since it may enhance learning processes and allow for the exploration of different futures. Finally, the work on SNM (and TM) originates from a particular assessment of the socio-political situation. While it is clear that investments in R&D and pilot projects for promising sustainable development have increased substantially in the last five years in many sectors (transport, energy, agri-food), at the regime level sustainability is not (yet) the main driver or concern. In the transport regime, for instance, congestion and safety are higher on the agenda than sustainability, even though multi-million R&D programmes are conducted on fuel cells and biofuels. Major car manufacturers also face strong competition, hostile takeovers and rising costs (e.g. pension problems at GM), which receive more attention than sustainability issues. In the electricity regime, liberalisation and privatisation are leading concerns for regime actors. Environmental issues have also appeared on the agenda, but still rank lower than other criteria such as low cost, reliability of supply, and diversification (Verbong and Geels 2007). These regime diagnoses imply that, at the moment, sustainability (still) faces an uphill battle. Although warnings about the political dimension of the SNM and TM research are welcome, the dilemma is that too much reflexivity may lead to paralysis. Political actors who try to deal with the challenge of

sustainable development are in need of ideas and approaches that provide handles for addressing the required fundamental changes in the way we live and work. SNM is an answer to this need.

6. Conclusions

We have discussed empirical findings and conceptual elaborations of the last 10 years in SNM research. This discussion has showed that concepts and ideas evolved over time. The internal analysis of crucial niche processes (expectation dynamics, learning, network building) was increasingly complemented with attention to external processes. Particularly, the multi-level perspective proved useful for contextualising SNM. This led to modifications in claims about the breakthrough of sustainable innovation journeys. Niches and experiments are to be perceived as crucial for bringing about regime shifts, but not as the sole forces in doing so. Linkages with ongoing processes at broader regime and landscape levels are important. With regard to interactions between niches and regimes, initial work only focused on technological substitution, but recent work also distinguishes other types of interaction (e.g. incorporation, translation) and more differentiated transition pathways (e.g. reconfiguration, transformation). In sum, the understanding of niche dynamics has become increasingly complex compared to simple technical substitution ideas in the mid 1990s.

Although substantial insights have been gained, the SNM approach is still an unfinished research programme. Therefore, we would like to end by listing a number of promising research issues identified in this article:

- The role of visions in the process of niche formation, including their influence on the building of positive feedbacks between changes at the niche, regime and landscape level;
- The nature and source of protection of niches that is conducive to its further development, as well as the management of selective exposure;
- The mechanisms that make sequences of projects gel into niche development;
- The way interactions among multiple niches and multiple regimes influence niche development patterns;
- Action research of prescriptive applications of SNM;
- A systematic comparison SNM, TM, and other policy measures.

In seems fair to conclude that SNM has already become a niche in policy studies about sustainable innovation journeys, but further work and implementation is needed to enhance the prospect of sustainability transitions and the larger issue of transforming the modernist approach of regulating impacts and correcting market failures through subsidies (see also Nill and Kemp 2008, forthcoming).

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Notes

1. Van de Belt and Rip (1984) did not address sustainable development and regime change, but nurturing, survival and robustness. They introduced SNM as a combination of protection against too harsh selection at an early stage and subsequent controlled exposure to selection pressures.
2. For a nice overview, see Williams and Edge (1996).
3. For this historical analysis, see Schot (2003).
4. See Rip and Kemp (1998) for the idea of modulating ongoing interactions; for the notion of steering from within, see Rip (2006). Kemp developed the idea of modulating ongoing dynamics into an evolutionary policy approach; see Nill and Kemp (2008, forthcoming).
5. When Rip (1992, 1995) introduced the niche concept, he used the example of the R&D programme on the Stirling engine inside the Philips Company. His basic point was not that niches are internal to firms, however, but that radical novelties initially have low legitimacy and require protection and nurturing to survive (e.g. dedicated product development programmes). See also Van den Belt and Rip (1987). Schot, Hoogma, and Elzen (1994), expanded the idea and introduced the distinction between technological and market niche, and proposed to use the notion of technological niche to refer to societal experiments with new technologies outside the laboratory in a user context.
6. On this point, see Verheul and Vergragt (1995).
7. On the role of expectations, see Brown and Michael (2003); see also Van Lente (1993).
8. For an overview of various conceptualisations of niches in radical change see Schot and Geels (2007).
9. This division in three processes has been much discussed, leading to various proposals. For example, Hoogma et al. (2002) propose to distinguish two main processes; learning processes and institutional embedding, with further subdivisions (pp. 28–29).
10. In 1998, the European Union funded an SNM research project within the 'Environment and Climate' RTD programme. Through this project, scholars in several countries worked on SNM. They investigated fourteen innovative transport projects in different European cities (ranging from electric vehicles to car sharing schemes). This collaborative project resulted in a work book for practitioners on how to do SNM (Weber et al. 1999), and an academic book (Hoogma et al. 2002).
11. The following articles explicitly applied the SNM perspective: Brown et al. (2004), Ieromonachou, Potter, and Enoch (2004), Truffer, Metzner, and Hoogma (2004), Kivisaari, Lovio, and Väyrynen (2004), Harborne, Hendry, and Brown (2007), Hendry (2007), Van Eijck and Romijn (2008) and Hegger et al. (2007). Two other PhD theses that discuss SNM are Lane (2002) and Adey (2007). Finally SNM is central to Wiskerke and Van der Ploeg (2002).
12. TM partly draws on SNM. Kemp has been the intermediary between the two approaches. Another approach that highlights the role of visions is backcasting (see Quist 2007). For a reflection on SNM and TM, see Loorbach and Van Raak (2007).
13. This is the theme of a thesis under preparation by Ulmanen. For first results see Ulmanen, Raven and Verbong (2007).
14. For results published in English, see Schot (1998) and Van Driel and Schot (2005).
15. For a further discussion on the nature of this macro-level, see Van Driel and Schot (2005) and Geels and Schot (2007).
16. For multi-regime interaction in the multi-level perspective, see Geels (2007).
17. Policies induced by Transition management encounter a similar problem, see Kemp, Rotmans, and Loorbach (2007).
18. Two other books have been produced for practitioners but with less direct involvement of them (Kemp and Van den Bosch 2006; Weber et al. 1999). Insights of the later working book are elaborated in Weber and Dorba (1999). More information on www.transitiepraktijk.nl and www.ksinetwork.nl

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