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Towards an integrated framework for sustainable innovation policy

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Abstract

An integrated framework for the analysis and development of sustainable innovation policy was developed, based on a combination of the transition management framework, the strategic niche management approach, and policy recommendations resulting from technological innovation system (TIS) studies. In the framework, the multilevel view from transition management has been integrated with the functions approach from the TIS literature. The integrated policy framework shows that specific policy goals and measures can be found at the specific points of intervention related to landscape, regime, TIS and niches. The integrated framework suggests that stimulation of a TIS only makes sense when this is well aligned with landscape and regime developments. The framework also suggests that the three TIS functions entrepreneurial activities, knowledge development and knowledge diffusion can be seen as policy *goals*, whereas the four other TIS functions are more directly linked to policy *measures*.

Keywords: transition management, strategic niche management, technological innovation systems, sustainability, innovation policy.

Introduction

Climate change, air pollution, and the dependency on fossil fuels from politically instable countries are seen as persistent sustainability problems in modern society. To overcome such problems, the use of specific, radical innovations is advocated (like for instance the electric vehicle or photovoltaic solar panels). However, implementation of such 'sustainable' innovations is difficult because fossil fuel-related technologies benefit from many years of experience, economies of scale, optimal institutional arrangements and vested interests (Unruh 2000). Van den Bergh, Truffer and Kallis (2011) argue that the double externality problem of sustainable innovations is a reason that policy action is required in order to introduce sustainable innovations. They state that research is needed about which policy (or policy package) is most suitable to escape lock-in.

In the past decades we have witnessed the emergence of two broad approaches of analysing the dynamics of radical innovations related to (environmental) sustainability problems. One approach is related to a multi-level perspective on technological change (Rip and Kemp 1998; Geels 2002), and is based on co-evolutionary development of technologies, institutions and social and economic subsystems. Another approach is based on the systems of innovation perspective (Lundvall 1992; Edquist 1997). Studies on 'sustainable innovations', which start from an innovation system perspective, generally take the development of a specific technology as a starting point. The technological innovation systems (TIS) literature describes how different actors, networks and institutions form a system around a technology (Carlsson and Stankiewicz 1991; Carlsson 1995; Hekkert et al. 2007). The success of a new technology can then

largely be explained on the basis of the performance of this technological innovation system.

From the analysis of innovation dynamics to the design of adequate policies that support radical innovation and system transformation is a big step. However, two (governance) approaches have been described that are based on the multi-level perspective (MLP): strategic niche management and transition management[1]. Strategic niche management (SNM) focuses on the (policy) actions that can help the development of radical innovations in technological or market niches, in relation to the development of new institutional arrangements, user preferences, etc (see for instance (Hoogma et al. 2004; Kemp, Schot, and Hoogma 1998; Raven 2005)). Transition management (TM) takes a broader perspective and includes the developments outside the niches in which technologies are nurtured (Rotmans, Kemp, and Van Asselt 2001; Kemp and Loorbach 2003; Kemp and Loorbach 2006). The TIS literature has provided policy makers with a tool for identifying system weaknesses, which could then be corrected with environmental regulation and technology-specific policies (Johnson 2001). However, policy recommendations from TIS studies (See e.g. (Hekkert et al. 2007; Negro, Hekkert, and Smits 2008; Bergek, Jacobsson, and Sandén 2008)) also seem to be rather erratic and lack a coherent view on the governance of sustainable innovations as it is present in the SNM and TM frameworks.

Even though the analytical frameworks of the multilevel perspective and technological innovation systems have developed quite separately in the past decade, they largely share the same conceptual basis. Both are rooted in evolutionary economics and use concepts like path dependency, lock-in and non-linearity. Moreover, the approaches are complementary, as important shortcomings of each of the two analytical frameworks are covered by concepts of the other framework (Coenen and Lopez 2010). Markard and Truffer (2008) therefore use the commonalities of the two frameworks to suggest an integrated framework. This integrated framework is interesting for analytical purposes, but also gives the opportunity to bridge another important gap in the innovation literature: it enables us to integrate policy approaches related to the multilevel perspective (transition management and strategic niche management) with the policy recommendations that result from the many analyses based on the TIS framework. An integrated policy framework could make use of the complementarities of both models and therefore be valuable for policy analysis and development.

The aim of this paper is thus to integrate the policy approaches related to transition management and strategic niche management with the policy recommendations resulting from the TIS literature into one framework for policy analysis and development. Weber and Hoogma (Weber and Hoogma 1998) already argued that innovation activities at the micro level (niches) can be understood better by also looking at the macro level of the national innovation system; both levels influence the innovation success. Hillman et al. (2011) argue along the same line in their study that integrates the MLP and TIS

[1] Van den Bergh, Truffer and Kallis (2011) argue that transition management can be understood as the policy view related to the Complex systems approach. However, since MLP also borrowed from complex systems theory, this distinction is not relevant for our argument.

approaches, giving specific attention to the governance of TISs, resulting in a theoretical framework. Both studies support our idea that it is useful to study governance strategies in a combined framework that takes all levels (from macro to micro) into account. Whereas Hillman et al. (2011) end with a theoretical framework, in this paper we take it one step further by including actual steering guidelines and policy measures that we derived from the respective literatures.

Starting point for this study is the integrated framework by Markard and Truffer (2008). Based on that framework and a critical review of (a part of) the TIS literature, we will develop a policy framework that matches the integrated analytical framework by Markard and Truffer (2008). This endeavour is meant as a theoretical contribution to the 'sustainable transitions' literature, and possibly a starting point for empirical case studies. Schematically our contribution can be positioned in the literature as follows:

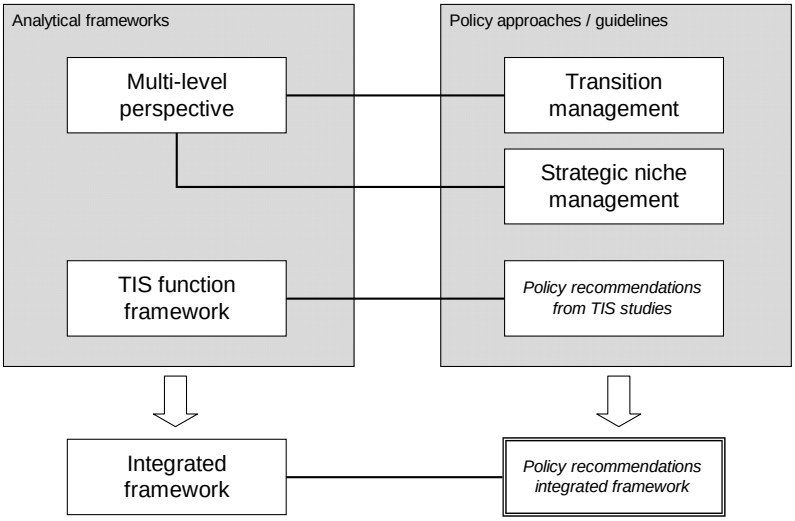

Figure 1. Schematic presentation of the work in this paper.

The left-hand side of Figure 1 shows the analytical frameworks, with the integrated framework by Markard and Truffer (2008) at the bottom. At the right-hand side, the related policy recommendations are integrated; the double-framed box at the bottom of Figure 1 indicates the contribution of this paper.

The paper is structured as follows. First an overview of the TIS framework and the policy recommendations given by TIS scholars will be provided. The policy recommendations were derived from a sample of empirical TIS studies that use the functions approach (Hekkert et al. 2007; Bergek, Hekkert, and Jacobsson 2008). Second, the MLP framework and the related policy approaches TM, and SNM are briefly discussed. We then integrate the different policy approaches into one comprehensive model. In the final section the application possibilities and limitations of our model are discussed and suggestions for further research are given.

Theoretical background

Technological innovation systems and related policies

Innovation system theorists state that companies do not innovate on their own, but in the context of a system (Lundvall 1992; Nelson 1993). Companies innovate together with other companies, universities and research institutes. Furthermore, laws, rules and routines can stimulate or hamper the innovation process (Edquist 2005). A distinction can be made between national (Nelson 1993; Freeman 1995)**,** regional (Cooke and Uranga 1997; Braczyk, Cooke, and Heidenreich 1998), sectoral (Breschi, Malerba, and Edquist 1997; Malerba 2002) and technological innovation systems (Carlsson 1995; Carlsson and Jacobsson 1997). Carlsson and Stankiewicz (1991) define a TIS as 'a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of a technology'. The TIS approach is suitable for investigating emerging technologies like for instance the electric car (Hekkert and Negro 2009).

It is essential for the success of a TIS that certain activities take place in the system. These activities are often called 'functions' of innovation systems and contribute to the development and diffusion of the innovation (Hekkert et al. 2007; Johnson 2001; Bergek et al. 2008). Although broad agreement seems to exist about which functions are important, the naming and definitions of these innovation system functions differs between authors. In this paper we use the list of functions from Hekkert et al. (2007) which has been verified by extensive empirical research (Hekkert and Negro 2009). A description of the seven system functions according to Hekkert et al. is given in Table 1.

Table 1. Functions of innovation systems (Hekkert et al. 2007)

#	Function name	Description of the system function
F1	Entrepreneurial activities	Entrepreneurs are at the basis of the innovation system. These risk-takers perform commercial experiments and see and exploit business opportunities.
F2	Knowledge Development	Learning is important for the development of innovations. It can take place in the form of classical R&D projects, but also learning by doing is important.
F3	Knowledge diffusion in networks	The typical organizational structure of an emergent innovation system is the knowledge network that facilitates the exchange of information.
F4	Guidance of the search	A selection process is needed for a convergent development in the TIS. It consists of policy aims and the outcome of technical and economical studies and the expectations about technological options.
F5	Market formation	New technologies are often unable to beat the existing technology. For the stimulation of innovation the creation of niche markets is important.
F6	Resource mobilisation	Financial, material and human factors are necessary for the development of a TIS. Investments can come from venture capitalists or the government.
F7	Creation of legiti-macy/ counteract resistance to change	The development of a new technology often encounters resistance from the current socio-technical regime. A lobby to generate support for the technology is necessary.

Paredis (2009) states that when the TIS around a certain technology only exists in plans or visions, all of the seven functions should be supported in order to start up an embryonic TIS. When a TIS grows, the development of the seven functions can be monitored (e.g. by event analyses (Negro, Suurs, and Hekkert 2008)) and the results of these analyses can be used for the development of policies aiming at the improvement of weak system functions (Bergek et al. 2008). TIS scholars have stressed the need for empirical analysis of many different TISs before policy recommendations can be given, because of the large differences between TISs (Hekkert 2010). However, they acknowledge that the variety in evolution patterns of TISs is probably not infinite and that it should therefore be possible to determine 'generic' policy recommendations after review of many different empirical studies (Bergek et al. 2010).

Policy recommendations found in TIS studies

In articles using the TIS (functions) approach, policy recommendations are given for almost all of the functions of the innovation system. A notable exception is entrepreneurial activities (F1); these will result when the other functions are stimulated (Hekkert et al. 2007). However, it is acknowledged that entrepreneurs should be more involved in innovation policy making because their interests are often neglected (Hekkert 2010).

Knowledge development (F2) can be stimulated by financing and facilitating R&D (Negro, Hekkert, and Smits 2008) and by learning from (niche) experiments (learning-by-doing) (Negro, Hekkert, and Smits 2008; van Alphen, Hekkert, and Turkenburg 2009). Van Alphen et al. (2010) advise demonstration of technologies at commercial scale to trigger learning-by-doing instead of learning-by-planning.

For the diffusion of knowledge in networks (F3), cross-linking platforms can be stimulated (Smits, Kuhlmann, and Teubal 2010). International collaborative networks may have an important role (Van Alphen et al. 2010). Van Alphen et al. (2010) also state that intellectual property rights sometimes hinder knowledge diffusion; coordination in the network is mentioned as a solution. Van Alphen et al. (2010) mention full-scale demonstrations as a means to make hidden knowledge deficits visible. The issuing of best practices by a public or private coordinating organization is another means to stimulate knowledge diffusion (Van Alphen et al. 2010).

Bergek, Hekkert and Jacobsson (2008) state that governments can provide guidance of the search (F4) by setting short-term and long-term policy goals in relation to the technology and by expressing positive expectations about the technology. The same is argued by van Alphen et al. (2010) under the heading "regulate and communicate", in which they also include standard setting. At one hand Van Alphen et al. (2010) propose regulatory flexibility around demonstration projects; on the other hand they propose a "strong regulatory framework" to minimize concerns in the public at large (related to F7: legitimacy).

Function five, the creation of markets can be supported by the installation of favourable tax regimes or minimal consumption quotas (Hekkert et al. 2007). Van Alphen et al. (2010) state that temporal subsidies and tax credits can be a first step, but that this should be done in combination with changes in the institutional infrastructure: […] government […] should change 'the rule of the game'.

The provision of resources (F6) is a general activity to support the other functions. Van Alphen et al. (2010) argue that public-private partnerships may be a means of providing certainty for investors. Hudson, Winskel and Allen (2011) mention support for training activities as a means to increase the skills of technicians related to a specific technology.
Function seven of the TIS framework, the creation of legitimacy can be supported by changing institutions (laws, rules, routines, etc.) in order to make them more compliant with the technology of the TIS (Bergek, Hekkert, and Jacobsson 2008). Also, open communication about a technology can help creating legitimacy for the technology (van Alphen, Hekkert, and Turkenburg 2009). Hudson, Winskel and Allen (2011) argue that setting technology specific targets may increase legitimacy and that technology specific (trade) organisations may be used to focus and unite interests.

In addition, Hekkert (2010) gave more general policy recommendations after empirical analysis of emerging TISs. He makes a plea for consistent and long term innovation policies that put pressure on (the lock-in of) the current technological regime. Furthermore, the need for international collaboration for effective stimulation of innovations is stressed, because TISs cross national boundaries. Finally, Bergek, Jacobsson and Sandén (2008) state that policy makers can make use of the positive externalities between TISs, by stimulating complementary TISs in parallel.

Multi level perspective and transition management

The multilevel perspective provides a (heuristic) model of how innovations in niches can enter the existing socio-technical regime, with the help of societal pressure on the so-called landscape level (Rip 1995). The successful introduction of an innovation that leads to a major change in the existing socio-technical regime is called a transition in the multilevel perspective. As innovations can enter the current socio-technical system in various ways, transitions may follow different pathways (see (Geels and Schot 2007)).

From historic transitions described with the multilevel framework, the idea of transition management was deduced (Rotmans, Kemp, and Van Asselt 2001; Smith, Stirling, and Berkhout 2005; Loorbach 2007). Transition management theory states that transitions towards sustainable development may be initiated, sped up and steered 'by coordinating and enabling the processes that occur at different levels in a more systemic and evolutionary way, which leaves room for variation, selection and innovation' (Kemp and Loorbach 2006). In transition management, governments can be active at three different levels: the strategic, tactic and operational level (Rotmans, Kemp, and Van Asselt 2001; Loorbach 2007; Loorbach 2009).

At the *strategic level* the creation of visions and setting of long term goals is important. Transition management argues that normal policymaking is focusing too much on short-term and mid-term goals because of political cycles. Transition management tries to incorporate long term processes more actively in policy development with the creation of so called 'transition arenas' in which innovative people from governments, NGO's, academia and industry work together on long term visions. Eventually these transition visions should lead to the formulation of different transition paths to reach the transition vision (Loorbach 2007). For instance, electric cars can be a formulated as a transition path in a vision to reach sustainable mobility.

At the *tactical level* a so-called transition agenda should be defined with intermediate policy objectives (Kemp and Loorbach 2003). At this level, the complex task is to prepare the existing socio-technical regime for the introduction of a technology from a niche. Structures of the old socio-technical regime, which may hamper the introduction of the innovation, should be adapted. These structures include predominant rules, institutions, organizations, infrastructures, routines and habits (Loorbach 2007). Furthermore, at this level the pressure on the current regime should be increased, making use of landscape developments and internal regime contradictions (Kemp and Grin 2009). Landscape developments can – for instance – support actions aimed at reducing climate change. An example of an internal 'regime contradiction' is a high oil price that can disturb the current socio-technological regime of gasoline cars.

At the *operational level* experiments should be carried out. These experiments are innovation projects that have to be in strong accordance with the vision defined at the *strategic* level and the transition paths chosen at the *tactical* level (Loorbach 2009).

Critical reflection on and monitoring of both the transition process and transition management itself at the different levels is of foremost importance. Evaluations should be done in such a way that transition policies can be adapted to the on-going transition developments (Kemp and Loorbach 2006; Taanman 2008).

Strategic Niche Management

Strategic niche management (SNM) is a steering approach that is also related to the multi-level perspective (Kemp, Schot, and Hoogma 1998; Schot and Geels 2008). Strategic niche management specifically describes how protected spaces can be created in which experiments with a promising technology can be carried out. The knowledge resulting from the experiments is used to scale up the niche experiments in such a way that the technology is eventually ready to diffuse from the niche into the prevailing socio-technical regime.

In the basis, SNM consists of five phases (Kemp, Schot, and Hoogma 1998): 1) the choice of the technology; 2) the selection of the experiment; 3) the set up of the experiment; 4) scaling up the experiment, and 5) breakdown of the protection. For each of the five phases guidelines have been developed. In the first phase, the choice should be made for a technology that a) has large possibilities for future technological development,

b) has learning economies, c) is compatible with the actual institutional structure and user needs, and d) is already attractive in certain applications where the disadvantages of the technology count less and its advantages are highly valued. With regard to the selection of an experiment (phase 2), an experiment setting should also be chosen in which the advantages of the technology are highly valued, and the disadvantages are of less importance. For the set-up of an experiment, a balance should be found between protection and selection pressure. Activities should focus on the barriers that hinder the introduction of the technology, which can either be technical, economic or institutional (Kemp, Schot, and Hoogma 1998). In the phases (4) and (5) the experiment should be scaled up and make its way into the current socio-technological regime. In later SNM literature more attention is given to the interaction of niches from the same technology, which can reinforce each other due to mutual influences on the so-called 'global niche level' (Geels and Raven 2006).

The goals of SNM are to learn about the social desirability of a specific technology, to stimulate its development (by achieving cost efficiency and alignment of/with the institutional framework), and to build a constituency – of firms, researchers and public authorities – behind a technology (Kemp, Schot, and Hoogma 1998). Another important aspect of SNM (as well as TM) is higher-order learning: in higher-order learning processes the ideas about a technology, user demands, regulations, etc. are not tested, but questioned and explored (Hoogma et al. 2004).

Towards an integrated framework

In their effort to integrate the 'Technological innovation systems' and the 'Multi level perspective' approaches, Markard and Truffer (2008) came up with an integrated model in which one TIS interacts with existing regimes, with other TISs and with the landscape. Within the TIS several niches can be found. For example, in the electric vehicle TIS niches may exist for the application of electric cars as taxis and as vehicles for inner city mail delivery. A schematic presentation of the integrated framework is given in Figure 2.

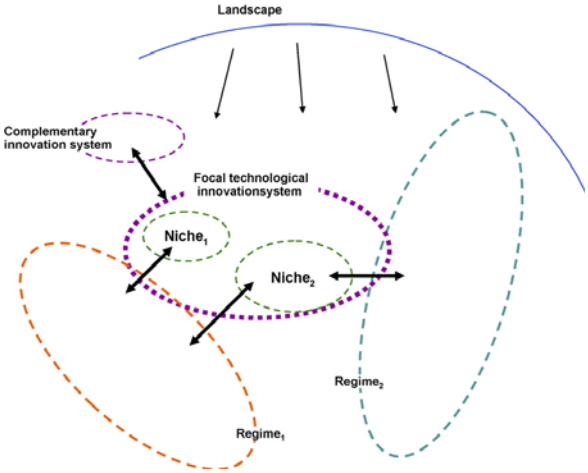

Figure 2: Integration of the MLP and TIS frameworks (Markard and Truffer 2008).

The strength of the combined model is the complementariness between the approaches. In the MLP, the roles and strategies of the different actors, the interactions between actors and institutions and the agency of the different actors are given less attention (Smith, Stirling, and Berkhout 2005). The TIS approach, on the other hand, claims to be more powerful for analysing the dynamic processes with the function framework (Hekkert et al. 2007). However, the TIS approach may have a perspective that is too much inward looking (Coenen and Lopez 2010; Geels, Hekkert, and Jacobsson 2008).

In the TIS perspective the current socio-technical regime and landscape and their influences on the TIS are less rigorously analysed, whereas this is one of the strengths of the MLP (Markard and Truffer 2008). The combined model by Markard and Truffer (2008) is used by us as a basis to combine policy concepts derived from both the TIS and MLP perspectives.

The MLP and TIS approaches differ on the point of incremental and radical innovations. In the MLP, radical innovations come from niches, whereas incremental innovations originate from the regime. However, in the original literature on technical innovation systems no difference is made between radical and incremental innovations. The TIS framework comprises both the production and innovation part and is thus applicable in both niche and regime like situations (Markard and Truffer 2008). The TIS articles that we studied for policy recommendations all look at the dynamics of a growing TIS, which has not yet reached a regime like status. Our policy framework is thus specifically applicable to growing TISs.

We should notice here that the TM, SNM and TIS approaches have been criticized for paying limited attention to users (see e.g. (Shove and Walker 2007; Spaargaren 2011). This lack of attention can not be fixed in this article, but it implies that our combined policy approach framework will also lack the specific attention to users in sustainability transitions.

Fitting policy approaches in the integrated framework

In this paragraph we integrate the goals and steering/policy advices from the previously described approaches. This integration is modelled along the interfaces between regime, TIS and niches that can be seen in Figure 2. Our effort cumulates into a new, combined model in Table 2.

In the model by Markard and Truffer (2008) system innovations are (as is the case in the multi level perspective) supported by developments at the landscape level. Landscape developments may open ‘windows of opportunity’ for promising technologies. For the identification of promising technologies, transition managers should thus be aware of the trends at the landscape level. The TM literature stresses the need for a long term vision that is in accordance with the slow trends at the landscape level. The ‘transition arena’ is a platform where such a vision can be arrived at (Loorbach 2009). TM scholars state that after the creation of a transition vision, transition paths can be created: possible routes starting from the present which can realize the transition vision. The choice of a transition

path thus implies the choice for stimulating specific technologies/TISs. In the transition path, (positive) expectations and short-term and mid-term policy goals regarding the use of the technology of the TIS are included. So the transition path contributes to the fulfilment of function four of the TIS framework: guidance of the search. Following the policy recommendations resulting from the TIS framework, entrepreneurs should take part in developing the transition path(s). Reflexivity is a key element in TM and SNM literature. The monitoring and evaluation of the developments at the different levels is stressed as well as a reflection on the effectiveness of activities that were undertaken, so that these can be adapted if necessary (Loorbach 2009; Schot and Geels 2008). In transition management, the concept of 'development rounds' expresses the idea that a critical reflection is necessary after every few years to re-align the transition activities with the changing environment (Rotmans, Kemp and Van Asselt 2001).

The TIS in the model by Markard and Truffer (2008) is interacting with the existing socio-technical regime(s). To stimulate the success of the developing TIS, regime-TIS interactions should be influenced. Weakening the existing regime to create more space for the innovation from the TIS can be a strategy to achieve this. TM literature states that policy measures should increase the pressure on the current regime, using landscape developments and internal regime contradictions (Kemp and Grin 2009). TIS literature states that neoclassical, non-systemic policy measures (e.g. tax measures, consumption quotas) can be useful for this purpose (Hekkert 2010). Both TIS and TM scholars state that the institutions (laws, rules, routines etc.) of the current socio-technical regime should be changed, in order to make them more compliant with the technology of the TIS (Bergek, Hekkert, and Jacobsson 2008; Loorbach 2007). Broad societal support for a technology is seen as an important prerequisite for its success in TM literature. TIS scholars state that for the creation of societal support an open, interactive communication strategy about the technology is useful (van Alphen, Hekkert, and Turkenburg 2009). Hillman et al. (2011) state that a TIS can also be supported by drawing on resources of aligned regimes. Weakening the regime, opening the regime for a new technology and active support for a new technology can also be seen as creating legitimacy for the TIS in focus.

In the model by Markard and Truffer (2008) the TIS also interacts with other TISs. Bergek, Jacobsson and Sandén (2008) state that positive externalities can result from TIS-TIS interactions. Therefore it can be useful for actors to identify and support TISs that are complimentary to the TIS in focus. The idea that one TIS can be strengthened by another, related TIS is more-or-less equivalent to the idea from Hillman et al. (2011) that a TIS can be strengthened by an aligned regime.

At the TIS internal level, knowledge development and diffusion (functions 2 and 3 of the TIS framework) are the main goals that must be supported. TIS scholars mention financing and facilitating R&D or training as a policy instrument for knowledge development (Negro, Hekkert, and Smits 2008; Hudson, Winskel, and Allen 2011). Van Alphen et al. (2010) stated that co-ordination of intellectual property rights and the issuing of best practices will support knowledge diffusion. For sharing the knowledge of all the different (niche) experiments, cross-linking platforms are said to be of major

importance (Smits, Kuhlmann, and Teubal 2010). Here the TIS becomes rather similar to the 'global niche level' as postulated by Geels and Raven (2006). The TIS level, as indicated in Figure 2, is the level where knowledge and information from the niches can accumulate. The creation of (TIS-internal) networks supports the transmission and retention of knowledge. As niche markets grow, positive externalities may arise at the TIS level (Bergek et al. 2010) which strengthen the growing TIS. Over time, the development of institutions within the TIS will be a sign of the maturation of the TIS.

At the niche level actors contribute to the fulfilment of function five of the TIS framework: the creation of markets. For the proper choice of niche experiments, the policy guidelines of strategic niche management, as described before (Kemp, Schot, and Hoogma 1998) should be taken into account. Niche experiments require that actors/entrepreneurs are enrolled. Several means of financial and institutional (policy) support may stimulate actors to start their activities in a technological or market niche. TM and SNM scholars stress the importance of learning from niche experiments (learning by doing); knowledge development (function 2 in the TIS framework) can be seen as the main goal of technological and market niches. Learning in niches – if successful – will result in the (mutual) alignment of a technology with producer, user and institutional set-up around the technology. SNM scholars also stress the importance of higher-order learning in niche experiments (Hoogma et al. 2002; Brown et al. 2003).

The integration of the goals and (policy) instruments from the TIS, SNM and TM literature leads to the conceptual framework shown in Table 2. It should be noted that the policy instruments indicated are not the only possible instruments, but merely examples.

Conclusions, discussion and suggestions for further research

In this study we presented a new framework for the analysis and development of sustainable innovation policy. The framework is based on the Transition management framework, the Strategic niche management approach, and policy recommendations resulting from TIS studies. By integrating these three approaches, optimal use can be made of the complementary strengths of each of the approaches.

We want to stress that our framework should not be seen as a recipe with which one could force the adoption of sustainable technologies. Rather, it should be read as an integration of what different streams in literature state about policies and steering guidelines for the stimulation of sustainable innovations. Because the frameworks underlying the integrated framework focus on environmental innovations, our framework is only useful for studying (policy) guidelines related to these specific innovations. Our framework can be used analytically to categorize existing policies, and (prescriptively) to make suggestions for policy improvement, for instance if policy in a certain category of the framework is missing.

Table 2. Integrated framework for sustainable innovation policy

Point of intervention	**Policy goals**	**Policy instruments / guidelines**
Landscape – TIS interaction	- Goal-oriented modulation (Kemp, Loorbach and Rotmans 2007) using landscape developments - Use regime weaknesses and internal regime contradictions (Kemp and Grin 2009) - Provide guidance of the search - Reflexivity	- Develop long term visions and long term policy goals (in transition arena) (Rotmans, Kemp and Van Asselt 2001) - 'Development rounds' to reflect on past and future of the goals and activities - Set short-term and long-term policy goals, technology targets and express positive expectations (Bergek, Hekkert, and Jacobsson 2008) - Include entrepreneurs in innovation policy making (Hekkert 2010)
Regime – TIS interaction	- Weaken existing regime - Prepare regime for new technology - Create broad societal support - Use resources from aligned regimes (Hillman et al. 2011) - Create legitimacy for new technology	- Tax policies to put pressure on regime (Kemp and Grin 2009; Hekkert 2010) - Minimal consumption quotas (Hekkert et al. 2007) - Adapt regulations / institutions: change 'rule of the game' (Van Alphen et al. 2010) - Open and interactive communication with stakeholders (van Alphen, Hekkert, and Turkenburg 2009)
TIS – TIS interaction	- Use positive externalities between TISs (Bergek, Hekkert, and Jacobsson 2008)	- Identification & support of complementary TISs
TIS internal	- Knowledge development - Knowledge diffusion - Create networks - Create institutions - Development of positive externalities (Bergek et al. 2010)	- Financing and facilitating R&D (Negro, Hekkert, and Smits 2008) - Stimulate cross-linking platforms (Smits, Kuhlmann, and Teubal 2010) - Co-ordinate intellectual property rights (Van Alphen et al. 2010) - Issue best practices (Van Alphen et al. 2010) - Training activities (Hudson et al. 2011)
Niches	- Enroll actors / entrepreneurs; build a constituency (Kemp, Schot and Hoogma 1998) - Knowledge development - Higher order learning - Create alignment (technology-user / technology-institutions / producer-technology, etc.)	- Mobilize resources for experiments - Choose technologies and experiments with criteria from SNM (Kemp, Schot and Hoogma 1998) - Commercial-scale demonstrations (Van Alphen et al. 2010) - Public-private partnerships (Van Alphen et al. 2010) - Favourable tax regimes (Hekkert et al. 2007) - (Temporarily) adapt regulations and institutions in niche: regulatory flexibility (Van Alphen et al. 2010)

Because of the complementariness between the different approaches that underlie the integrated framework in this paper, we think that a more complete policy analysis can be performed on the basis of this framework. The combined policy framework can be strengthened and improved further by performing multiple (empirical) case studies on the basis of this framework; this is an important possibility for further research.

From the integrated framework in Table 2 we can also learn something about the TIS functions in relation to the point(s) of intervention. At the landscape-TIS and regime-TIS interfaces the policy measures largely relate to the functions four and seven: guidance of the search and creation of legitimacy. Including a specific technology (TIS) in a future vision or imposing measures on the existing regime all support the expectations that a specific technology should be stimulated. The functions entrepreneurial activities (F1), and knowledge development and diffusion (F2 and F3) only play a role at the TIS and niche levels. Interestingly, these functions are not steered directly but only indirectly, by policies and measures related to market formation (F5) and resource mobilization (F6).

At this point we can also compare the role of the government in the different policy approaches underlying the integrated framework. Transition management and Strategic niche management stress the multi-actor characteristics of stimulating sustainable innovations; TM and SNM seem to regard public authorities as one of the many actors involved. However, it is clear that both TM and SNM critically depend on at least some stimulating efforts by public authorities. The TIS literature with its functional analyses of growing technological innovation systems focuses on the system dynamics, leaving out of sight who has to do what. When system functions are measured to be weak, policy measures are suggested, although the steering philosophy behind these suggestions remains inarticulate. In looking at the policy recommendations in the TIS studies, it becomes clear that some of the TIS scholars indicate a rather large role for ‘government’. Government should provide financial means and create supportive legislation, including ‘game-changing’ institutional changes. This seems to imply that government can and wants to change regulations, and that government can select specific technologies that it wants to support. However, our integrated framework teaches us that stimulation of a certain TIS will only make sense if this stimulation is well aligned with developments at the landscape and regime level. Further, TIS studies also imply government to be a single, rational actor, an idea that can not be supported from political science studies (Flanagan, Uyarra, and Laranja 2011). We conclude that TIS studies largely overestimate the role that government(s) can play, whereas TM and SNM scholars currently give the government a (somewhat) more modest role. The understanding of the actual position of public authorities and the role they can and want to play in the process of sustainable innovation remains an interesting starting point for further empirical and theoretical research.

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