Towards a strategic framework for promoting environmental innovations

Paper accepted for presentation at the 2012 Berlin Conference on the Human Dimensions of Climate Change, October 5 – 6, 2012

.

Author: Rainer Quitzow

Environmental Policy Research Centre
Otto Suhr Institute
Freie Universität Berlin
Ihnestr. 22
14195 Berlin

ABSTRACT

Studies have shown that markets for environmental innovations are highly dependent on government intervention, and, with few exceptions, markets for environmental technologies have been "policy driven". Moreover, there is widespread consensus that no individual policy instrument but rather a "smart policy mix" is needed to effectively drive the development and diffusion of environmental innovation. However, what exactly represents such a smart policy mix remains largely undefined. This paper takes this discussion a step further by developing what is called a "strategic framework" for promoting environmental innovation. Drawing on strategy concepts from the management sciences, this analytical framework provides the basis for systematizing and integrating lessons from existing evolutionary approaches to promoting environmental innovation. While individually none of these approaches provides a sufficient basis for developing a truly comprehensive policy mix, they each help to elaborate a particular element of the proposed strategic framework. Combining them in this way, therefore, represents an important step forward for developing adequate policies for the promotion of environmental innovation. Furthermore, the strategic framework not only provides a more comprehensive but also a more dynamic approach to the design of smart policies for promoting environmental innovation.

Paper accepted for presentation at the 2012 Berlin Conference on the Human Dimensions of Global Environmental Change, October 5 – 6, 2012.

Introduction

Sustainable development can only be achieved by extensive innovation in environmental technology and its rapid international diffusion. Studies have shown that markets for environmental innovations are highly dependent on government intervention, and, with few exceptions, markets for environmental technologies have been "policy driven" (Ernst&Young, 2006; Jacob et al., 2005; Jänicke & Jacob, 2004). In other words, the role of the State in stimulating and sustaining green industries is crucial. Consequently, the hands-off approach to industrial development that has dominated the economic policy debate since the late 1970's is not adequate for promoting technology development for a green economy. This does not imply a return to an old fashioned, *dirigiste* model of economic development. However, it requires a smart combination of the market and the State to steer economic development towards environmentally-friendly, resource-efficient technological solutions. But what does this mean in practice? What concrete tools does the State have at its disposal to promote green industries?

Innovation and technological change is a complex and multi-facetted process that cannot be prescribed by the State. Rather it requires a nuanced and flexible approach to policy making (Blazejczak, Edler, Hemmelskamp, & Jänicke, 1999; Ekins & Venn, 2006a; J. Hemmelskamp, 1999; J. Hemmelskamp, Rennings, K., and Leone, F. , 2000; Jänicke, Blazejczak, Edler, & Hemmelskamp, 2000; Klemmer, Lehr, & Löbbe, 1999; Oosterhuis et al., 2006). Jänicke and Lindemann (2010) call for "smart regulation" based on "instrument mixes" or "hybrid forms of governance". They state, "Innovation-oriented environmental policy is most likely to succeed if regulatory 'fine-tuning' through command and control measures (a 'regulatory core') is complemented with market-based 'trendsteering' through economic instruments." These recommendations represent basic principles for designing an appropriate policy mix. However, they leave open a host of questions about how to design and implement such a policy mix in practice.

This paper seeks to take this debate a step further by introducing the concept of "strategy". Raschke and Tils (2007, 2010) have pointed out that concepts of strategy have been conspicuously missing from the political science discipline. While the concept is well

established in the field of military strategy and in the field of business and management sciences, a corresponding discussion has not taken place in the realm of government and politics. Meanwhile, in political practice the use of formalized government strategies has become increasingly common, including the high-level strategies of the European Union (e.g. Lisbon strategy, EU 2020 strategy, etc.), national strategies for sustainable development and innovation strategies (e.g. Germany's High Tech Strategy) to name just a few examples.

This paper argues that the concept of strategy provides a useful basis for designing and assessing policies for promoting the development of environmental technologies. While the literature on policy and governance for environmental innovation offers a host of useful lessons for this purpose, none of the existing approaches offers a framework that is both comprehensive and sufficiently dynamic. In other words, none of the approaches provides a sufficient guide to policy makers faced with the challenging task of developing and implementing policies for the promotion of environmental technologies. The strategy concept that is developed below closes this gap by offering a coherent framework for combining lessons from the existing literature.

The paper proceeds in three steps. It begins with a brief discussion of the paper's underlying theoretical approach, based on evolutionary theories of innovation and technical change. Next, drawing on the strategy literature from the management sciences, a strategy concept is developed. This strategy concept serves as the basis for systematizing and integrating five existing policy approaches for the promotion of environmental innovation in one comprehensive strategic framework. Each policy approach and its specific contribution to the different elements of the strategic framework are presented. The concluding section offers a brief synthesis of the strategic framework and highlights its main advantages compared to other frameworks and its potential for further elaboration.

An evolutionary perspective on innovation and technological change

The strategic framework, which is developed below, combines policy lessons from five streams of literature. Though each approach represents a distinct contribution to the debate on policies for the promotion of environmental innovation, they all have a common basis in evolutionary perspectives on innovation and technological change. The following section briefly discusses this underlying theoretical basis of the paper. First, it briefly justifies the

chosen focus on evolutionary perspectives, which comes largely at the expense of neoclassical perspectives on the subject. Second, the section argues that this shared theoretical basis makes the chosen policy approaches compatible and enables them to be integrated in the proposed strategic framework.

The neoclassical tradition has brought forth a wealth of studies on the relationship between innovation and different types of regulatory and market-based instruments (Ambec, Cohen, Elgie, & Lanoie, 2010; Bernauer, Engels, Kammerer, & Seijas, 2006; Jaffe, Newell, & Stavins, 2005). However, for two basic reasons, this paper argues that these studies prove inadequate for informing policy making aimed at the promotion of novel environmental technologies. Firstly, neoclassical studies have focused exclusively on how individual policy measures affect innovation in polluting firms, failing to consider the development of new sectors whose innovations compete with the technologies of existing firms (Ambec et al., 2010; Porter & van der Linde, 1995). Secondly, these studies fail to consider important questions pertaining to the specific policy design, policy implementation as well as the broader techno-economic, social and institutional context. As a result, empirical results from these studies have been inclusive (Ambec et al., 2010; Jaffe et al., 2005). Even prominent neoclassical economists concede that multiple market failures may imply that "a portfolio of policies, rather than policy directed at emissions reduction alone, will offer a more complete response to environmental problems" (Jaffe et al., 2005). Apart from this acknowledgement, however, these economists offer little further guidance on how policy for the promotion of environmental innovation might be optimized. This, however, is the specific focus of this paper. It aims to develop a basis for a more systematic approach to developing an appropriate policy mix for the promotion of environmental innovation.

Evolutionary approaches to analyzing innovation and technological change seek to overcome the limitations of neoclassical theory by opening the "black box" of the innovation process and revising a number of key assumptions made by mainstream economists. At the micro-level, evolutionary economics departs from the paradigm of rational choice and profit-maximization and replaces it with the concept of "bounded rationality." This concept takes account of the fact that economic actors do not always make choices that are profit-maximizing. Routines and aversion to risk, especially under situations of uncertainty, often

favor the (technological) status quo (Beckenbach & Nill, 2005; Nelson & Winter, 1982; J. van den Bergh, Faber, Idenburg, & Oosterhuis, 2007).

At a macro-level, evolutionary economics replaces the neoclassical concept of equilibrium with an environment characterized by uncertainty and instability. Within this "selection environment" multiple factors, including the unpredictable process of learning and discovery, influence the direction of technological development. The notion that competitive forces will always select the technologies with the highest intrinsic utility is challenged. Instead, evolutionary approaches conceptualize technological innovation as a process of development, adaptation and selection, where multiple events and feedback mechanisms shape technological development. Due to "dynamic increasing returns," technological development is a highly path-dependent process. It is shaped by the existing technological regime (Dosi & Nelson, 1994) and characterized by technological lock-ins (Arthur, 1988, 1989; David, 1985, 1992). Shifts from one technological regime to another depend on a process of co-evolution, involving simultaneous developments within different realms of society (Nelson, 1994, 1995; Rip & Kemp, 1998; Jeroen van den Bergh & Stagl, 2003).

The approaches discussed below all share this common theoretical basis. The only partial exception is the literature on innovation-oriented environmental policy, which has its primary roots in the political science discipline. Nevertheless, this literature shares the basic insight with evolutionary economics that the impact of policies cannot be considered in isolation from a dynamic socio-economic and institutional context (Klemmer et al., 1999: 51-52). Although the innovation process is not treated in all its complexity, it is assumed to be shaped by multiple influences, known as the "multi-impulse hypothesis" (Jänicke et al., 2000; Klemmer et al., 1999).

From a policy perspective, the studies discussed below share the insight that the promotion of environmental innovation requires more than changes in factor prices or the introduction of individual regulatory measures. The role of policy is to provide an "extended level playing field". Externality problems coupled with path dependence and technology lock-ins justify policy interventions that subsidize learning costs and remove biases towards existing technologies or the premature lock in of new alternatives (J. van den Bergh et al., 2007). In practice, this means that an effective approach to the promotion of environmental innovation

requires a policy mix that is adapted to the particular context. How to systematically develop such a policy mix is the question to be addressed in the remainder of the paper.

Defining strategy

The concept of strategy as defined in this section is built on this same basic understanding that individual policy measures on their own do not suffice to promote innovation and technological change. From a political science perspective, this goes hand in hand with findings that the success of policies in general (Mayntz & Scharpf, 1995) and of environmental policies specifically (Gunningham & Grabosky, 1998; Jänicke & Weidner, 1995; Weidner & Jänicke, 2002) depend not only on the choice of a particular instrument but also on the broader conditions shaping their development and implementation. In practice, it reflects a shift from a government-centered planning approach, which dominated until the 1970s, to governance approaches based on less hierarchical and increasingly cooperative State-society relations (1993, 2000; Mayntz, 2008).

Rather than reducing the State's role, however, the concept of strategy proposed here seeks to strengthen the State's ability to effectively deploy policy and allocate resources to promote environmental innovation. An important point of departure for this discussion is Jänicke's (1998, 2009) call for a more strategic approach to environmental policy (see alsoTils, 2004). In his writings on ecological modernization and the role of the nation State, he demands a "a policy model that focuses the central state on strategic tasks and transfers detailed regulations more strongly to decentralized actors" (Jänicke, 2009, p. 35). Rather than representing a disillusioned acquiescence to the diminishing role of the State, this was meant as a reconceptualization of the State in more strategic and more flexible terms. He states, "The hierarchical state as an intervention authority legitimized by the whole of society needs to be considered indispensable (see Offe 1987), especially if one seeks to develop a modernization of the industrial system that can effectively balance the immense ecological impacts of global growth." (Jänicke, 2009, p.38). He calls for strategies based on precise goals, able to develop and adapt the particular mix of instruments based on the specific context (Jänicke, Kunig, & Stitzel, 2003, pp.111-112).

While Jänicke's approach stops here, the goal of this paper is to further develop and operationalize such a strategic approach to promoting environmental innovation. To do so,

this section begins by outlining a more detailed definition of strategy, drawing mainly on strategy concepts from the management sciences. The resulting strategic framework provides the foundation for integrating policy guidance from five approaches for the promotion of environmental innovation, which are presented in the next section.

One of the earliest thinkers on business strategy was Peter Drucker who established the concept of "management by objectives" (Drucker, 1954). Much like Jänicke, Drucker stresses the central role of formulating strategic objectives from which all other organizational activities and policy measures should follow. On this basis, Peter Drucker offers the following strategy definition, which will serve as the conceptual foundation for the further discussion of strategy. Drucker (1973) states that strategy is "the continuous process of making present entrepreneurial (risk-taking) decisions systematically and with the greatest knowledge of their futurity; organizing systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organized, systematic feedback." (p.120) By replacing "entrepreneurial decisions" with "policy decisions", this definition can be extended to a policy context. In the following, it provides the basis for further developing a number of basic elements of government strategies.

Firstly, a central tenet of Drucker's strategy definition is the need for systematic efforts to acquire the greatest possible knowledge about the implications ("futurity") of the (policy) decisions being taken. In other words, strategies require an analytical basis to help define what is expected from individual policy decisions. This notion has a long tradition in the field of strategy and implies the need for analytical tools to help assess external conditions for the purpose of defining the appropriate strategy (see Andrews, 1971; Mintzberg, Ahlstrand, & Lampel, 2009; Porter, 1980). It implies that the choice of individual policy measures may vary based on this assessment, rejecting the notion that any particular policy instrument might be considered as *a priori* superior. Rather strategy is developed in response to external opportunities and challenges.

Secondly, strategy is an ongoing yet systematic process. A strategy is, therefore, neither a one-off exercise, nor can it be equated to the frequently cited process of "muddling through" (Lindblom, 1959). As such, strategy as defined in this paper is a normative rather than a descriptive concept. Strategies and the associated concepts are considered devices for

improving and/or evaluating the practice of policy making (in this case specifically policies aimed at promoting environmental innovation). In other words, the concepts developed here are intended to *avoid* rather than describe a process of "muddling through".

Simultaneously, Drucker's definition proposes that strategic decision making is a continuous and reactive process, where decisions are adjusted based on new information or changes in the external environment (see also Raschke & Tils, 2007). In other words, static, one-dimensional concepts of the policy process - where analysis is followed by planning which is in turn followed by implementation - are rejected. Rather strategy development and implementation are overlapping processes, which are pursued, albeit with varying degrees of intensity, throughout the strategy process. Finally, to enable such a dynamic strategy process, Drucker suggests the need for organized and systematic efforts to measure the success of policy decisions against the expectations underlying them. In the terminology of political science, strategies should promote policy learning (Bennett & Howlett, 1992; Rene Kemp & Weehuizen, 2005).

Strategy defined in this way combines elements of what Mintzberg et al. (2009) call the planning and the learning schools of strategic management. Applying this to the public sector, Steurer and Martinuzzi (2005) point out that the planning and learning school represent ideal-types on a continuum of policy making. The planning school emphasizes the need for formalized processes of policy development, which are conducted in specialized planning departments and which are divorced from the process of implementation. The learning school on the other hand views policy making as an incremental process. It acknowledges the importance of operational knowledge gained in the process of implementation and the continuous need for adjusting and fine-tuning policy when new knowledge is acquired. The strategy concept developed here acknowledges both the need for formal processes and responsibilities for strategy making and the need for mechanisms that enable systematic feedback from implementation.

Finally, the strategy literature goes beyond the *process* of strategy making. A central question is how the internal capabilities of an organization should relate to the chosen strategy. Much debate on this subject has centred on whether strategy should follow structure or vice versa (Chandler, 1962; Hall & Saias, 1980). Fundamentally, this discussion highlights that strategy

making has to include a reflection on the internal capabilities and resources that are at the disposal of those responsible for the strategy. Both strategy objectives and related policy measures should take into account the organization's ability to implement a chosen course of action. The concept of dynamic capabilities takes this another step further. Building on concepts from evolutionary economics, it highlighs that organizations can develop and change their capabilities over time to meet the needs of their strategic objectives (C. Helfat et al., 2007; C. E. Helfat & Peteraf, 2009; Teece, 2009). In other words, strategies should reflect existing organizational capabilities, but they may also try to actively develop those capabilities, deemed necessary to achieve strategic objectives.

What is included in the required set of capabilities depends on the specific objectives and may differ across different types of organizations (i.e. different types of businesses, non-profit organizations or public sector organizations, etc.). What this might mean for strategies in the realm of politics has been explored by Raschke and Tils (2007). Their concept of "strategic capacity" is based on but extends beyond the concept of organizational capacity. Organizational capacity includes the allocation of responsibilities, access to sufficient resources to perform organizational tasks, well-established institutional rules and norms for reaching decisions, etc. While building basic organizational capacities may be beyond the scope of a strategy focused on the promotion of environmental innovation, it is possible to address capacities that are specific to the particular policy field. This might include developing the ability to assemble related knowledge or to formulate realistic policy objectives, efforts to build a network of alliances or partnerships for policy development and implementation, or building new institutional arrangements for the implementation or coordination of policy measures.

Summarizing the points developed above, the strategic framework proposed here incorporates the following elements. They are given the following labels for further reference in the remainder of the paper: the guiding principles of strategy, the analytical dimension of strategy, the process dimension of strategy and the dimension of strategic capacity:

- Strategy requires clear objectives and corresponding policy measures to achieve those goals (Guiding principles of strategy).
- To guide the choice of policy measures, strategy development requires a systematic approach to analyzing the external environment in relation to the tools and measures at

the disposal of the respective organization or decision-maker (Analytical dimension of strategy).

- The process of strategy development and implementation is an ongoing and iterative process, which requires continuous and systematic review and adaptation of policy measures (Process dimension of strategy).
- Strategy should both build on available capacities and seek to develop and expand the required capacities for strategy development and implementation (Dimension of strategic capacity).

Each of the four dimensions of strategy is considered necessary for developing a comprehensive policy mix for promoting environmental innovation in a particular sector or technology field. On their own, however, these four elements only represent a generic concept of strategy, which requires further elaboration to meet the specific challenges of promoting environmental innovations. To do so, the following section systematizes and integrates lessons from existing policy approaches for the promotion of environmental innovation, utilizing these four dimensions of strategy as an analytical framework.

Building a strategic framework for the promotion of environmental innovation

As indicated, this section reviews and systematizes policy guidance emerging from the main evolutionary approaches to studying environmental innovation. It demonstrates that each policy approach further elaborates and operationalizes a particular dimension of the strategy concept. In this way, each policy approach makes a unique contribution to the development of a strategic framework for promoting environmental innovation. On the other hand, individually none of them serves as a sufficient basis for developing a comprehensive approach to promoting environmental innovations. Combining them based on the elements outlined above, therefore, represents an important step forward for developing adequate policies for the promotion of environmental innovation.

The following five main approaches are identified in the literature:

- Innovation-oriented environmental policy, with its roots in political science;
- Sustainability-oriented innovation policy, based on studies carried out by the OECD on integrating sustainable development policy and innovation policy;
- Transition management and strategic niche management, based on the literature on sustainability transitions;
- The system functions approach based on the concept of a technological innovation system; and

- A time-strategic perspective on ecological innovation policy.

In the following, each approach and its theoretical foundation is briefly introduced. After this, its unique contribution to elaborating one or more of the four dimensions of strategy is highlighted.

Innovation-oriented environmental policy

The discussion on innovation-oriented environmental policy is based on findings from the field of policy analysis within political science. Rather than seeking to build a theory of the innovation process as a whole, this literature takes an empirical approach, focused on how government interventions have influenced the emergence of environmental innovations. The guiding question of these policy-oriented studies is: Under what conditions do policies to protect the environment promote innovation and technological change? A number of authors have investigated this question using a comparative case study approach (Ashford, Ayers, & Stone, 1985; Blazejczak et al., 1999; Ekins & Venn, 2006b; J. Hemmelskamp, 1999; J. Hemmelskamp, Rennings, K., and Leone, F. , 2000; Jacob et al., 2005; Klemmer et al., 1999; Oosterhuis et al., 2006). On the basis of best practice cases, they have been able to derive a number of general policy lessons for the formulation of an innovation-oriented environmental policy.

These policy lessons primarily suggest a number of general principles for designing innovation-oriented environmental policy. Firstly, they highlight the importance of formulating policy targets, the basic requirement for strategy development. Policy targets, when sufficiently ambitious and credible, are found to be important drivers of innovation in their own right (Jacob & Jänicke, 2005). These objectives provide the basis for developing a "smart policy mix" adapted to different phases of technological development and including measures spanning a number of different policy fields (Jänicke & Lindemann, 2010). More specifically, an innovation-oriented policy mix requires an appropriate level of stringency, appropriate timing of individual measures and overall policy coherence (Ashford & Hall, 2011; Bernauer et al., 2006; Jänicke & Lindemann, 2010). A number of studies also emphasize that traditional environmental regulation plays an important role in inducing environmental innovation, though only if designed appropriately and combined with complementary measures (Ashford & Hall, 2011). Finally, a number of authors have highlighted the importance of an innovation-friendly "policy style". A policy-style is

considered innovation-friendly "if it is based on dialogue and consensus, is calculable, reliable and has continuity, is decisive, proactive and ambitious, is open and flexible" (J. Hemmelskamp, Rennings, K., and Leone, F. , 2000, p. 135).

These findings both confirm the guiding strategy principles, i.e. the need for clear policy objectives that guide the choice of policy measures, and further elaborate them for the realm of innovation-oriented environmental policy, i.e. policy targets need to be ambitious and credible and regulatory measures need to be both sufficiently stringent and flexible to be adapted over time. Additionally, the insights from the study of innovation-oriented environmental policy include a number of process-oriented lessons. Firstly, the emphasis on dialogue and consensus requires the engagement of stakeholders in the process of formulating policies (Jacob & Jänicke, 2005). Secondly, policy coherence requires active coordination of policy across relevant policy domains (Ashford & Hall, 2011; Jacob & Jänicke, 2005). Finally, flexible instruments adapted to different phases of technological development require continuous monitoring and review of the policy mix (René Kemp, 2011). One-off policy measures are not sufficient for driving environmental innovation (Jacob & Jänicke, 1998; 2005).

Sustainability-oriented innovation policy: lessons from the OECD

In addition to these academic studies, the OECD has conducted a policy-oriented review, entitled "Governing Innovation Systems" (OECD, 2005), which offers a number of lessons for the development of sustainability-oriented innovation policy. Taking a similar case-study based approach, the study distills best practice lessons from a number of country studies on the practice of innovation policy. The review builds on work by the OECD on system-based approaches to innovation policy, referred to as a "strategic horizontal approach to innovation policy" or a "third generation innovation policy" in the review. The study outlines the key governance challenges and respective "national capabilities" required for implementing such an approach. Though these national capabilities relate to innovation policy more broadly, they also draw on a set of case studies on sustainability-oriented innovation policy and explicitly address corresponding issues. The OECD's explicit focus on capabilities is unique among the approaches described here and represents the particular contribution of the OECD study to the strategic framework. Simultaneously, the OECD's approach echoes a number of the principles and process-oriented issues highlighted in the section on innovation-oriented environmental

policy. As such, it comes close to covering the whole spectrum of strategy components, although it fails to address the analytical dimension of strategy further discussed below.

The OECD (2005) report recognizes that formulating a coherent, mutually supportive set of innovation policies requires "balancing imperatives" (p.14) and developing a "joint understanding across policy cultures and rationales" (p.11). Innovation policy should be embedded in a more comprehensive set of strategic goals addressing economic, social and environmental imperatives. To implement such an approach, the OECD calls for an adjustment of institutional structures to draw on the corresponding knowledge base for developing an appropriate vision and policy goals and to facilitate policy integration and policy learning.

This translates into the development of a number of capabilities for developing and implementing innovation policy. These capabilities include basic organizational capacities, such as establishing a clear division of labor between ministries and agencies, and highlight the need for vision and leadership as a basis for inter-ministerial coordination. Furthermore, the need for mechanisms for horizontal and vertical policy coordination are highlighted and a series of possible institutional arrangements are proposed. These include task forces, policy councils, government committees, and joint programs. Also mechanisms for monitoring and evaluation are considered, not only for the purpose of assessing progress but also as coordinating mechanisms. Moreover, developing an appropriate policy mix requires leveraging the knowledge and resources of relevant stakeholders and exploiting synergies in network structures. This implies not only the engagement of stakeholders in the policy process, but the development of "distributed network organizations of strategic intelligence, which combine different sectoral and stakeholder perspectives" (OECD, 2005, p.102). Finally, the OECD calls for "pragmatic public-private interfaces" to "manage transitions in structures and infrastructure" (OECD, 2005, p.69).[1]

[1] These recommendations are supported by a number of authors who call for "strategic policy institutions" and "systemic instruments" to appropriately intervene and respond to changes in a dynamic innovation system (Smits et al. 2010). These authors, however, do not specifically apply these lessons to sustainability-oriented innovation policy.

This set of capabilities mirrors a corresponding set of issues related to the process dimension of the strategic framework, notably acquisition of relevant knowledge, horizontal and vertical policy coordination, policy learning, and stakeholder engagement. By translating these process-related issues into capabilities, the approach helps to elaborate and adapt the concept of strategic capacity to the specific purpose of promoting environmental innovation.

Transition management and strategic niche management

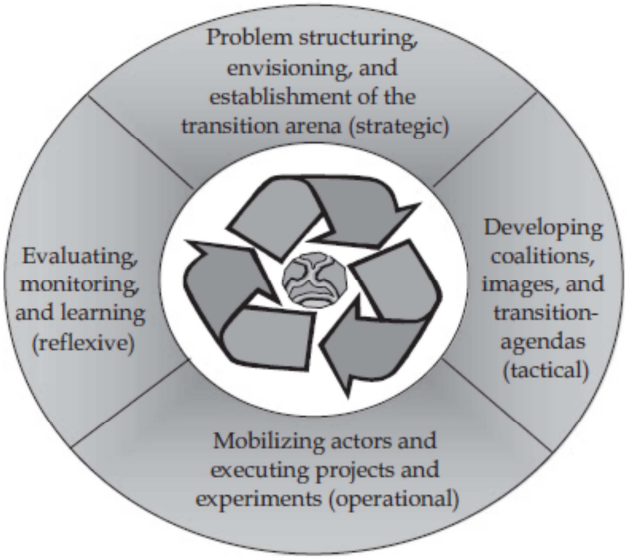
Transition management (TM) and strategic niche management (SNM) are simultaneously the broadest in terms of their underlying conceptual approach and the narrowest in terms of their contribution to a strategic framework for promoting environmental innovation. Based on the literature on sustainability transitions, this literature takes a very broad view of technological change, which is conceptualized as shifts to new technological regimes (R. Kemp, Schot, & Hoogma, 1998; Rip & Kemp, 1998) or "system innovations" (Elzen, Geels, & Green, 2004; 2004; 2010; F. W. Geels, 2002). In terms of policy, however, both TM and SNM are focused mainly on engaging stakeholders in a process of visioning and experimentation. SNM mainly offers a number of principles for setting up and implementing experiments aimed at supporting technological learning. TM goes beyond an individual experiment or niche and provides mainly process-oriented guidance for managing a broader set of experiments and facilitating visioning and networking in a broader technology field or sector. Neither of the approaches addresses how to promote the broader diffusion of environmental technologies or how to intervene at other levels of policy.

Kemp et al. (1998) define SNM as "the creation, development and controlled phase out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of a new technology, and (2) enhancing the rate of application of the new technology"(p.186). They outline a number of principles for choosing a technology to be supported through SNM, for selecting a domain for its experimental application and for applying a balanced mix of protection and selection pressure. They point out that SNM will have to address the challenges of scaling up and a timely phasing out of protection, but do not offer specific guidance on how to implement

these objectives. Instead, the focus of SNM is the promotion of learning in relation to the benefits and drawbacks of the selected technology and the formation of a network of actors. A number of authors view this narrow focus as a limitation and have criticized the fact that the approach ignores the broader selection environment (Berkhout, Smith, & Stirling, 2004; Schot & Geels, 2008).

TM is a broader concept, less concerned with supporting a particular technology than with supporting a so-called transition process based on visioning and experimentation (Jand Nill & Kemp, 2009, p.672). By combining elements of network governance, self-organization and process management, TM seeks to modulate ongoing dynamics of change to produce transitions to more sustainable socio-technical regimes. It represents a multi-level governance framework for enabling co-evolutionary processes of change. Loorbach (2007, 2009) defines the TM approach as a cyclical, multi-level framework composed of four key governance activities (see figure 1). Each of these governance activities represents a particular aspect of managing a deliberate process of promoting new technology fields.

Figure 1: Transition Management cycle



Source: Loorbach, 2009.

First, a group of frontrunners and other key individuals with different backgrounds are selected to structure the problem and develop a long-term sustainability vision. Next, this group of key individuals reaches out to other relevant stakeholders to concretize the vision into possible transition paths and possible entry points for action. This process should lead to the creation of a broader transition network with a concrete transition agenda. Sub-sets of the network then implement a number of concrete transition experiments. These may be complementary, or they may represent test cases for potentially divergent paths. Finally, a key governance activity, referred to as reflexivity, is the process of monitoring and evaluation where both progress towards the vision as well as the process itself are scrutinized. Its goal is to enable social learning and to facilitate the adaptation of both vision and process based on a process of continuous feedback.

Through this multi-level approach, TM seeks to promote the alignment of actors and processes to achieve the common goal of facilitating sustainable system innovations. It offers a process-oriented approach for engaging stakeholders in a process of visioning, experimentation and policy learning (reflexivity). Central instruments in this process are participatory scenario building and foresight exercises to promote a shared understanding of future challenges, to align actors based on a common vision and to identify novel solutions to be tested in joint experiments (R. Kemp, Loorbach, & Rotmans, 2007). An outcome of

visioning and experimentation should not only be innovation and learning but also the development of a corresponding actor network (Loorbach, 2007, 2009). Finally, the researchers who developed the approach also mention the need to promote policy integration (the better alignment of policies) and address "control policies," such as taxes and regulations, within the transition process (Rene Kemp & Rotmans, 2004, p.152). However, both conceptually (see critique in Berkhout et al., 2004) and in its application to Dutch energy policy (see critique in Kern & Smith, 2008), the TM approach has emphasized the role of so-called transition experiments or niche experiments.

Within the strategic framework, TM offers guidance for engaging stakeholders in visioning, experimentation and learning and highlights the importance of participatory scenario or foresight exercises. Both TM and SNM provide process-oriented guidance for developing and leveraging a stakeholder network within a particular technology field, similar to the distributed network of strategic intelligence suggested by the OECD.

The system functions approach and technological innovation systems

While the three approaches outlined above offered guidance on three of four strategy elements (the guiding principles for strategy, the process dimension of strategy and the dimension of strategic capacity), the last two approaches focus on the remaining strategy element: the analytical dimension of strategy development.

Like the "system failures" approach to innovation policy (Edquist, 2002; Klein Woolthuis, Lankhuizen, & Gilsing, 2005; Metcalfe, 2005; OECD, 1999; Reid, 2009), the system functions approach has emerged from the broader literature on systems of innovation. What sets the system functions approach apart from the systems failures approach, however, is its suitability for the formulation of policies aimed specifically at environmental innovation. The reasons for this are the following. Firstly, being based on the concept of a technological innovation system (TIS), the approach focuses on the promotion of a particular technology. In other words, the system boundaries may be set to focus on a specific type of environmental technology. The system failures approach is aimed at promoting innovation in a more general sense without prioritizing the promotion of individual technologies. Secondly, the system failure approach assumes that an innovation system is already pre-existing and aims at enhancing or optimizing the dynamics of these systems. The system functions approach, on

the other hand, may be applied to an emergent and not fully functional innovation system, explicitly considering how this particular system develops and changes over time. This makes it better suited for the study of environmental technologies, which require policy support to develop into viable competitors of mainstream technologies.

Within the strategy concept outlined above, the system functions approach serves as an analytical framework for the identification of entry-points for supporting environmental innovation. It identifies seven system functions (see table 1), which drive the development of technological innovation systems and which have been synthesized from existing system approaches. To apply this analytical framework to the task of policy development, Bergek et al. (2008) outline five analytical tasks leading up to the specification of policy measures tailored to the particular TIS. The process begins with the definition of the scope of the technological innovation system, followed by an identification of actors, networks and institutions that make up the system. Next the seven system functions and how they are being performed are analyzed. Finally, blocking and inducement mechanisms are identified. On this basis, policies can then be identified that might improve the functioning of the system by reinforcing functions or by removing blocking mechanisms. The ultimate goal of policy is to catalyze a process of "cumulative causation" where policy measures induce further development and positive feedbacks within the TIS (Jacobsson & Bergek, 2004).

TABLE 1: System functions

- Knowledge development and diffusion
- Influence on the direction of search and the identification of opportunities
- Entrepreneurial experimentation and management of risk and uncertainty
- Market formation
- Resource mobilization
- Legitimation
- Development of positive externalities

Source: Bergek et al., 2008

Time-strategic perspective on ecological innovation policy

Like the system functions approach, the time-strategic approach to ecological innovation policy is primarily focused on providing analytical guidance for the design of policies. However, rather than focusing on the internal dynamics of a specified TIS, it emphasizes the

dynamic interaction between competing technology trajectories. In other words, it highlights a different aspect of innovation and technological change. The approach seeks to utilize knowledge about the evolutionary process of technological innovation to make strategic use of so-called "techno-economic windows of opportunities". These windows of opportunity represent restricted time periods during which overcoming a technological lock-in and thus a shift to a different technological trajectory is particularly likely. Windows may be opened due to favorable developments in one or several sub-systems of a technological regime (see Erdmann, 1999; Jan Nill, 2009; Jand Nill & Kemp, 2009; Jan Nill, Sartorius, & Zundel, 2005; Jan Nill & Zundel, 2001; Sartorius & Zundel, 2005).

In terms of policy guidance, the focus of the time-strategic perspective on ecological innovation policy is on how to determine the appropriate timing of individual policy measures, one of the principles mentioned in 4.1. It provides an analytical framework for developing and adjusting policy measures to different phases of technological development. The goal is to optimize policy design by preparing and utilizing windows of opportunities. For instance, introducing a new environmental regulation or tightening existing standards may accelerate the innovation process if a window of opportunity has opened, e.g. an ecologically superior technological alternative has reached sufficient maturity and investment-cycles favor its adoption by companies. Conversely, a premature tightening of environmental standards may induce investments in expensive end-of-pipe technologies thus further strengthening technological lock-ins and slowing down technological change (Erdmann, 1999). To enable policy makers to take advantage of these "techno-economic dynamics", Zundel et al. (2005), propose different policy priorities for the phases of window preparation, creation and utilization (see table 2).

TABLE 2: Taxonomy of techno-economic dynamics and related policy objectives

Status of the techno-economic system	Status of technological alternatives	Kind of technological competition	Policy strategies and objectives
Stable	Only theoretical alternatives exist	Not applicable	Demonstration of technical feasibility
(Still) stable	Promising solutions	Only new-vs-new	"Window preparation": diversity and development
Stable (but strong social pressure for quick path change)	Promising solutions	Not applicable	"Window creation": handling of political pressure
Unstable (window)	At least one solution is competitive	Old-vs-new and new-vs-new	"Window utilisation": making transition easier and avoiding rush selection
Unstable (window)	Only one alternative solution is competitive, but other promising solutions for the future	Mainly old-vs-new	"Window utilisation": making transition easier
Unstable (window)	Several alternative solutions are competitive	Mainly new-vs-new	"Window utilisation": avoiding rush selection
Stable	Transition takes place	Not applicable	Restoring selection function of markets

Source: Nill and Kemp (2009).

Conclusion

To briefly summarize, the strategic framework developed here proposes the following four defining components of strategy: guiding principles, an analytical dimension, a process dimension and the dimension of strategic capacity. Accordingly, a policy approach to promoting environmental that fails to explicitly address any one of these components does not represent a truly comprehensive approach and is not considered a *strategic*. Based on this definition, none of the five approaches outlined above provides a sufficient basis for developing a strategy for the promotion of environmental innovation in a particular sector or technology field. Each approach only offers a partial guide to designing and implementing a strategy for promoting environmental innovation. Rather each approach provides guidance for further elaborating one or two of the key components of a strategic framework for the promotion of environmental innovation. The table in the annex provides an overview of how the different approaches contribute to elaboration of the strategic framework.

The four components of strategy provide the basis for systematizing and integrating the five policy approaches in one comprehensive and coherent framework. It is argued that their common foundation in - or at least compatibility with - evolutionary concepts of innovation and technological change ensure that their respective contributions are complementary. The distinctiveness of each approach is not based on underlying conceptual differences, but on the chosen focus area. Each approach considers different aspects of the innovation process and/or provides guidance on different components of the strategic framework. The time-strategic perspective on innovation policy and the system functions approach both provide analytical guidance aimed at informing policy design, which sets them apart from the other three approaches, which do not address this dimension of strategy. Differences between the two approaches relate to the particular aspect of the innovation process that each approach highlights. While the former focuses on the dynamics of technological competition and the challenge of overcoming technological lock-ins, the latter provides entry-points for supporting the various functions of a TIS. The findings on innovation-oriented environmental policy highlight a number of guiding principles for policy design along with process-oriented lessons. The OECD offers process-oriented lessons combined with corresponding lessons on capabilities for sustainability-oriented innovation policy. Finally, TM and SNM focus on process-oriented steps for engaging stakeholders in visioning and experimentation, while highlighting the need to develop actor networks for innovation and learning.

By combining the guidance from these different approaches to promoting environmental innovation, an approach emerges that is comprehensive, coherent and dynamic. It is comprehensive because it combines all the main evolutionary approaches to promoting environmental innovation in a common framework. It is coherent, as it is based on a clearly defined strategy concept adapted from the well-established business management literature on the topic. Each contribution from the different streams of literature is placed in relationship to the four components of strategy. It is dynamic because it not only provides analytical entry-points for adapting policy over time, but it also offers the perspective of adjusting capacities to meet the needs of policy objectives. In other words, policy measures may evolve in relation to changing external conditions, but also in relation to dynamic capacities. It, therefore, challenges the idea that policy options are only a function of a given policy paradigm and a given set of external conditions. Rather the set of feasible policy options can be developed over time by developing strategic capacity.

Finally the strategic framework developed in the paper is itself dynamic and provides entry-points for its further development. Firstly, the four components of strategy provide a structure for systematically integrating further policy guidance aimed at the promotion of environmental innovation. Findings from compatible policy approaches may further elaborate the four strategy elements. Secondly, it offers a structure for integrating findings from the theory and practice of strategy making in the public sector. In particular, the concept of strategic capacity; as developed by Raschke and Tils (2007), offers potential for the further elaboration of the strategic framework. The work of Raschke and Tils provides a number of entry-points for addressing political factors in the context of strategy making, albeit with a focus on high-level political strategies. They go into great detail about the need to establish a strong and coherent leadership that spans key positions within the party, the government and the relevant parliamentary group. Moreover, they point out the need to have a clear set of political objectives that transcend immediate electoral goals. While these concepts cannot be transferred directly to more policy-focused strategies for the promotion of environmental innovation, they offer a starting point for a more detailed reflection on how political factors might be addressed more explicitly in the context of policy making for the promotion of environmental innovation.

Annex: Overview of the strategic framework for promoting environmental innovation and the contributions of the different streams of literature

Approach	Guiding Principles	Analytical dimension	Process dimension	Strategic capacity
Innovation-oriented environmental policy: Identification of best practice in promoting environmental innovation	Highlights the importance of ambitious policy targets, coherence across different policy domains, flexibility, stringency in regulatory measures		Highlights the importance of dialogue and stakeholder involvement, coordination of policy and reflexivity/policy learning	
OECD study on Governing Innovation Systems: Lessons for governing (sustainable) innovation systems	Highlights the need for a comprehensive set of strategic goals, addressing economic, social and environmental imperatives		Highlights the need for stakeholder engagement, policy coordination and policy learning	Defines national capabilities, including M&E arrangements, strategic councils, networks of strategic intelligence and public-private interfaces
System functions approach: Operationalizing a system perspective to support technological innovation systems		Definition of entry points for identifying policy interventions in support of a technological innovation system		
Time-strategic approach: Guidance for adjusting policies to the phases of technological development with a focus on competing technological trajectories		Definition of policy options for preparing, creating and utilizing "techno-economic windows of opportunity" in the context of competing technological trajectories		
Strategic niche management: Niche development and learning			Basic procedural steps for implementing the SNM approach	Highlights the importance of creating actor networks
Transition Management: Visioning, experimentation and learning for early innovation phases			Multi-level, cyclical governance framework for engaging stakeholders; highlights the importance of foresight exercises	Creation of a transition platform and networks

References

Ambec, S., Cohen, M., Elgie, S., & Lanoie, P. (2010). The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness. Chair's Paper at the Porter Hypothesis at 20 Conference, Montreal, Canada, June 27-28, 2010. Accessed on March 4th, 2011 at http://www.isc.hbs.edu/pdf/PorterHypothesis_at20_Montreal.pdf.

Andrews, K. (1971). *The Concept of Corporate Strategy*. Homewood, IL: Irwin.

Arthur, B. (1988). Competing Technologies: An Overview. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg & L. Soete (Eds.), *Technical change and economic theory* (pp. 590-607). London: Frances Pinter.

Arthur, B. (1989). Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *The Economic Journal, 99*(1), 116-131.

Ashford, N., Ayers, C., & Stone, R. (1985). Using Reugulation to Change the Market for Innovation. *Harvard Environmental Law Review, 9*(2

), 419-466.

Ashford, N., & Hall, R. (2011). The Importance of Regulation-Induced Innovation for Sustainable Development. *sustainability, 3*, 270-292.

Beckenbach, F., & Nill, J. (2005). Ökologische Innovationen aus Sicht der evolutorischen Ökonomik *Jahrbuch Ökologische Ökonomik 4: Innovationen und Nachhaltigkeit* (pp. 63-86). Marburg: Metropolis Verlag.

Bennett, C. J., & Howlett, M. (1992). The Lessons of Learning: Reconciling Theories of Policy Learning and Policy Change. *Policy Sciences, 25*(275-294).

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy, 37*(3), 407–429.

Berkhout, F., Smith, A., & Stirling, A. (2004). Socio-technological regimes and transition contexts. In B. Elzen, F. W. Geels & K. Green (Eds.), *System Innovation and the Transition to Sustainability*. Cheltenham, UK: Edward Elgar.

Bernauer, T., Engels, S., Kammerer, D., & Seijas, J. (2006). Explaining Green Innovation. Ten Years after Porter's Win-Win Proposition: How to Study the Effects of Regulation on Corporate Environmental Innovation? Zürich: ETH Zürich.

Blazejczak, J., Edler, D., Hemmelskamp, J., & Jänicke, M. (1999). Umweltpolitik und Innovation: Politikmuster und Innovationswirkungen im internationalen Vergleich. *Zeitschrift für Umweltpolitik & Umweltrecht, 22*(1).

Chandler, A. D. J. (1962). *Strategy and Structure: Chapters in the History of the American Industrial Enterprise*. Cambridge, MA: MIT Press.

David, P. (1985). Clio and the Economics of QWERTY. *The American Economic Review, 75*(2), 332-337.

David, P. (1992). Heroes, Herds and Hysteries in Technological Histroy. Thomas Edison and 'The Battle of the Systems' Reconsidered. *Industrial and Corporate Change, 1*(1), 129-180.

Dosi, G., & Nelson, R. (1994). An introduction to evolutionary theories in economics. *Journal of Evolutionary Economics, 4*(3), 153-172.

Drucker, P. (1954). *The Practice of Management*. New York: Harper and Row.

Drucker, P. (1973). *Management: Tasks, Responsibilities, Practices*. New York: Harper & Row.

Edquist, C. (2002). Innovation Policy—A Systemic Approach. In D. Archibugi & B.-Å. Lundvall (Eds.), *The Globalizing Learning Economy*. Oxford: Oxford University Press.

Ekins, P., & Venn, A. (2006a). Assessing innovation dynamics induced by environmental policy. Report of Workshop at the European Commission, Brussels, 21 June 2006.

Ekins, P., & Venn, A. (2006b). Assessing Innovation Dynamics induced by Environmental Policy. Combined Methodological and Case Study: Synthesis Discussion Paper. Discussion paper for project "Assessing Innovation Dynamics Induced by Environment Policy, EU DG Environment: London: Policy Studies Institute.

Elzen, B., Geels, F., & Green, K. (Eds.). (2004). *System Innovation and the Transition to Sustainability*. Cheltenham, UK: Edward Elgar.

Erdmann, G. (1999). Zeitfenster beachten. *Ökologische Wirtschaften*.

Ernst&Young. (2006). Eco-industry, its size, employment, perspectives and barriers to growth in an enlarged EU. In D. E. European Commission (Ed.).

Geels, F. (2004). From sectoral systems of innovation to socio-technical systems. Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*.

Geels, F. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy, 39*(4), 495–510.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes. A multi-level

perspective and a case study. *Research Policy, 31*, 1257–1274.

Gunningham, N., & Grabosky, P. (1998). *Smart Regulation. Designing Environmental Policy*. Oxford: Oxford University Press.

Hall, D. J., & Saias, M. A. (1980). Strategy Follows Structure! *Strategic Management Journal, 1*(2), 149-163.

Helfat, C., Finkelstein, S., Mitchell, W., Peteraf, M., Singh, H., Teece, D., & Winter, S. (Eds.). (2007). *Dynamic Capabilities: Understanding Strategic Change in Organizations*. Malden, MA: Blackwell.

Helfat, C. E., & Peteraf, M. A. (2009). Understanding dynamic capabilities: progress along a developmental path. *Strategic Organization, 7*(1), 91-102.

Hemmelskamp, J. (1999). *Umweltpolitik und technischer Fortschritt. Eine theoretische und empirische Untersuchung der Determinanten von Umweltinnovationen*. Heidelberg: Physica-Verlag, 1999.

Hemmelskamp, J., Rennings, K., and Leone, F. (Ed.). (2000). *Innovation-Oriented Environmental Regulation. Theoretical Approaches and Empirical Analysis*. Heidelberg: Physica-Verlag.

Jacob, K., Beise, M., Blazejczak, J., Edler, D., Haum, R., Jänicke, M., . . . Rennings, K. (Eds.). (2005). *Lead Markets for Environmental Innovations*. Heidelberg: Physica-Verlag.

Jacob, K., & Jänicke, M. (1998). Ökologische Innovationen in der chemischen Industrie: Umweltentlastung ohne Staat? Eine Untersuchung ind Kommentierung von 182 Gefahrstoffen. *Zeitschrift für Umweltpolitik & Umweltrecht, 21*(4), 519-547.

Jacob, K., & Jänicke, M. (2005). Umweltintegration und Umweltinnovation *Jahrbuch Ökologische Ökonomik 4: Innovationen und Nachhaltigkeit*. Marburg: Metropolis.

Jacobsson, S., & Bergek, A. (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change, 13*(5), 815-849.

Jaffe, A., Newell, R., & Stavins, R. (2005). A tale of two market failures. Technology and environmental policy. *Ecological Economics, 54*(2-3), 164-174.

Jänicke, M. (1998). Umweltinnovationen aus der Sicht der Policy-Analyse: vom instrumentellen zum strategischen Ansatz der Umweltpolitik. In W. Jann, K. König, C. Landfried & P. Wordelmann (Eds.), *Politik und Verwaltung auf dem Weg in die transindustrielle Gesellschaft* (pp. 323-338). Baden-Baden: Nomos Verlagsgesellschaft.

Jänicke, M. (2009). On Ecological and Political Modernization. In A. P. J. Mol, G. Spaargaren & D. Sonnenfeld (Eds.), *The Modernisation Reader. Environmental Reform in Theory and Practice* (pp. 28-41). New York: Routledge.

Jänicke, M., Blazejczak, J., Edler, D., & Hemmelskamp, J. (2000). Environmental Policy and Innovation. An International Comparison of Policy Frameworks and Innovation Effects. In J. Hemmelskamp, K. Rennings & F. Leone (Eds.), *Innovation-Oriented Environmental Regulation. Theoretical Approaches and Empirical Analysis*. Heidelberg: Physica-Verlag.

Jänicke, M., & Jacob, K. (2004). Lead Markets for Environmental Innovations: A New Role for the Nation State. *Global Environmental Politics, 4*(1).

Jänicke, M., Kunig, P., & Stitzel, M. (2003). *Umweltpolitik. Politik, Recht und Management des Umweltschutzes in Staat und Unternehmen*. Bonn: Dietz.

Jänicke, M., & Lindemann, S. (2010). Governing environmental innovation. *Environmental Politics, 19*(1), 127 - 141.

Jänicke, M., & Weidner, H. (Eds.). (1995). *Successful Environmental Policy. A Critical Evaluation of 24 Cases*. Berlin: Rainer Bohn Verlag.

Kemp, R. (2011). Ten themes for eco-innovation policies in Europe. *S.A.P.I.E.N.S., 4*(2).

Kemp, R., Loorbach, D., & Rotmans, J. (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. *Journal of Sustainable Development and World Ecology, 14*, 78-91.

Kemp, R., & Rotmans, J. (2004). Managing the transition to sustainable mobility. In B. Elzen & F. W. Geels (Eds.), *System Innovation and the Transition to Sustainability*. Cheltenham, UK: Edward Elgar.

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation. The Approach of Strategic Niche Management. *Technology Analysis & Strategic Management, 10*(2), 175-195.

Kemp, R., & Weehuizen, R. (2005). Policy learning, what does it mean and how can we study it? PUBLIN Report No. D15, Working paper produced by the PUBLIN research project.

Kern, F., & Smith, A. (2008). Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. *Energy Policy, 36*, 4093– 4103.

Klein Woolthuis, R., Lankhuizen, M., & Gilsing, V. (2005). A system failure framework for innovation policy design. *Technovation, 25*, 609–619.

Klemmer, P., Lehr, U., & Löbbe, K. (1999). *Umweltinnovationen: Anreize und Hemmnisse* (, Analytica, 1999. ed.). Berlin: Analytica.

Kooiman, J. (1993). *Modern Governance: New Government – Society Interactions*. London: Sage.

Kooiman, J. (2000). Societal Governance: Levels, Models and Orders of Social-Political Interaction. In J. Pierre (Ed.), *Debating Governance: Authority, Steering and Democracy* (pp. 138–164). Oxford: Oxford University Press.

Lindblom, C. (1959). The Science of Muddling Through. *Public Administration Review 19*(2), 79-88.

Loorbach, D. (2007). Transition Management. New mode of governance for sustainable development. PhD manuscript.

Loorbach, D. (2009). Transition Management for Sustainable Development. A Prescriptive, Complexity-Based Governance Framework. *Governance: An International Journal of Policy, Administration, and Institutions, 23*(1), 161–183.

Mayntz, R. (2008). Von der Steuerungstheorie zu Global Governance. In G. F. Schuppert & M. Zürn (Eds.), *Governance in einer sich wandelnden Welt, Politische Vierteljahresschrift Sonderheft 41/2008*. Wiesbaden: Verlag für Sozialwissenschaften.

Mayntz, R., & Scharpf, F. (Eds.). (1995). *Gesellschaftliche Selbstregelung und politische Steuerung*. Frankfurt: Campus.

Metcalfe, J. (2005). Systems Failure and the Case for Innovation Policy. In P. Llerena & M. Matt (Eds.), *Innovation Policy in a Knowledge-Based Economy. Theory and Practice*. Berlin: Springer.

Mintzberg, H., Ahlstrand, B., & Lampel, J. (2009). *Strategy Safari. Your Complete Guide Through the Wilds of Strategic Management*. London: Financial Times Prentice Hall.

Nelson, R. (1994). The Co-evolution of Technology, Industrial Structure, and Supporting Institutions. *Industrial and Corporate Change, 3*(1), 47-63.

Nelson, R. (1995). Co-evolution of Industry Structure, Technology and Supporting Institutions, and the Making of Comparative Advantage. *International Journal of Business, 2*(2), 171-184.

Nelson, R., & Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA: Harvard University Press.

Nill, J. (2009). *Ökologische Innovationspolitik. Eine evolutorisch.ökonomische Perspektive*. Marburg: Metropolis.

Nill, J., & Kemp, R. (2009). Evolutionary approaches for sustainable innovation policies: From niche to paradigm? *Research Policy, 38*(4).

Nill, J., Sartorius, C., & Zundel, S. (2005). Zeitfenster vorbereiten, öffnen und nutzen. Strategien ökologischer Innovationspolitik. In F. Beckenbach, U. Hampicke, C. Leipert, G. Meran, J. Minsch, H. Nutzinger, R. Pfriem, J. Weimann, F. Wirl & U. Witt (Eds.), *Innovationen und Nachhaltigkeit*. Marburg: Metropolis.

Nill, J., & Zundel, S. (2001). Die Rolle von Vielfalt für Zeitstrategien ökologischer Innovationspolitik. In H. Spehl & M. Held (Eds.), *Vom Wert der Vielfalt. Diversität in Ökonomie und Ökologie*. Lüdenscheid: Analytica.

OECD. (1999). *Managing National Innovation Systems*. Paris: OECD.

OECD. (2005). *Governance of Innovation Systems. Synthesis Report*. Paris: OECD.

Oosterhuis, F., Kuik, O., Berkhout, F., Venn, A., Ekins, P., Anderson, J., . . . ten Brink, P. (2006). Innovation dynamics induced by environmental policy *IVM Report E-07/05*. Amsterdam: Institute for Environmental Studies.

Porter, M. E. (1980). *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: Free Press.

Porter, M. E., & van der Linde, C. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives, 9*(4), 97-118.

Raschke, J., & Tils, R. (2007). *Politische Strategie. Eine Grundlegung*. Wiesbaden: VS Verlag für Sozialwissenschaften.

Raschke, J., & Tils, R. (Eds.). (2010). *Strategie in der Politikwissenschaft. Kontouren eines Forschungsfelds,* . Wiesbaden: VS Verlag für Sozialwissenschaften.

Reid, A. (2009). *Systems failure and innovation policy. Do national policies reflect differentiated challenges in the EU27*. Position paper presented to the 6 Countries Programme workshop on New Economic for innovation policy.

Rip, A., & Kemp, R. (1998). Technological Change. In S. Rayner & E. Malone (Eds.), *Human Choice and Climate Change*. Columbus, OH: Battelle Press.

Sartorius, C., & Zundel, S. (Eds.). (2005). *Time strategies, Innovation and Environmental Policy*: Edward Elgar.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys. Theory, findings, research agenda, and policy. *Technology Analysis and Strategic Management, 20*(5), 537–554.

Steurer, R., & Martinuzzi, A. (2005). Towards a new pattern of strategy formulation in the public sector: first experiences with national strategies for sustainable development in Europe. *Environment and Planning C: Government and Policy, 23*, 455-472.

Teece, D. (2009). *Dynamic Capabilities and Strategic Management*. Oxford: Oxford University Press.

Tils, R. (2004). *Politische Strategieanalyse. Konzeptionelle Grundlagen und Anwendung in der Umwelt- und Nachhaltigkeitspolitik*. Wiesbaden.

van den Bergh, J., Faber, A., Idenburg, A., & Oosterhuis, F. (2007). *Evolutionary Economics and Environmental Policy. Survival of the Greenest*. Cheltenham, UK: Edward Elgar.

van den Bergh, J., & Stagl, S. (2003). Coevolution of economic behaviour and institutions: towards a theory of institutional change. *Journal of Evolutionary Economics, 13*(3), 289–317.

Weidner, H., & Jänicke, M. (Eds.). (2002). *Capacity Building in National Environmental Policy. A Comparative Study of 17 Countries*. Berlin: Springer.

Zundel, S., Erdmann, G., Kemp, R., Nill, J., & Sartorius, C. (2005). Conclusions - a time-strategic ecological innovation policy. In C. Sartorius & S. Zundel (Eds.), *Time strategies, Innovation and Environmental Policy*. Cheltenham, UK: Edward Elgar.