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TNO report

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Systemic Innovation:
Concepts and tools for strengthening National and European eco-policies

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Summary

Background and purpose

It is widely recognized that changes in our models for production and consumption are needed if either major threats to our societies are to be prevented or significant new opportunities to be seized. Eco-innovations have a crucial role to play for realizing the kind of changes needed. Still, so-far, the more radical innovations tend to diffuse only slowly and gradually over time due to the (positive) lock-in effects of our incumbent fossil based systems. In order for eco-innovations to substantially contribute to a sustainable development, these lock-in effects have to be circumvented or broken. This implies a fundamental change of the structures, and even cultures, that lie at the basis of our production and consumption systems. The Dutch ministry of Infrastructure and Environment has asked TNO to provide an overview of concepts, examples and tools for promoting a so-called systemic approach in research and innovation that may guide policy-makers in programming ambitious and effective research.

Concepts and tools for strengthening EU eco-policies

This paper centers on the following definition of systemic innovation: Systemic innovations lead to fundamental changes in both social dimensions (values, regulations, attitudes etc.) and technical dimensions (infrastructure, technology, tools, production processes etc.) and, most importantly, in the relations between them. There are two strands of literature, which have been developing in the last ten years or so, that provide a more integrated perspective on systemic innovation and sustainable development. This is the innovation systems literature and the socio-technical transitions literature.

Socio-technical transitions

- Socio-technical transitions are defined as large-scale transformations within society during which the structure of the societal system fundamentally changes. A transition involves a shift of a relatively stable system (dynamic equilibrium) undergoing a period of relatively rapid change, during which the system reorganizes irreversibly into a new (stable) system.

- Socio-technical transitions are studied by primarily considering the interplay of processes at three different levels of aggregation: micro (niche), meso (regime) and macro (landscape). The Multi-Level-Perspective explains how systemic changes occur as the result of interacting dynamics on three system levels.

- The meso-level (regime) represents the socio-technical system that is currently dominant in serving a societal need, and which is the subject of transition. The regime is characterized by strong lock-in effects. Depending on the context, a regime can be defined on the level of a sector, a region or even a city.

- For a transition to happen, innovations on the niche level need to gain internal momentum through learning processes, price-performance improvements, the support from powerful groups and through establishing market niches.

- At the same time, there should be sufficient pressure from the landscape level on the regime in order to destabilize current practices and to create opportunities for the niches to 'break through'.

Technological Innovation Systems Approach

- Systemic innovation involves a multitude of complex processes evolving on macro-, meso- and micro level. A Technological Innovation Systems (TIS) is defined on a narrower, and more specific, level, typically somewhere at the micro and meso level of the MLP.

- A TIS can be defined as a network of actors (operating within a context set by institutional rules) involved in the development and implementation of a particular (set of) innovation(s). Examples are 'thin GISG solar energy' technology (specific), semiconductor technology (broad) or even the (still) rather conceptual notion of a biobased chemistry sector.

- The approach focuses on actors and institutions. Also, the approach stresses the interaction between numerous processes, with R&D, production and market formation reinforcing each other. If these systemic feedbacks are neglected by policy makers, this is likely to result in the failure of innovation processes.

- The application of the TIS concept in policy making, involves analyzing the interdependencies of actors, institutions and technologies. This typically results in insights with respect to drivers and barriers related to the innovation.

- A TIS approach also reveals seven key innovation functions. This is important since for many technologies, especially emerging ones, structures are not yet (fully) in place. Important system functions involve knowledge development, but also entrepreneurial activities, market formation and advocacy.

- Policy makers may support systemic innovation by supporting the innovation system functions of one or more Technological Innovation Systems.

Recommendations

On the basis of two strands of scientific literature, the paper provides:
- Cases and examples that clarify how systemic innovations work in practice.
- Policy lessons of value to the members of the Eco-Innovera network.
- Recommendations on the preparation of a European research strategy and a call-for-tender on systemic innovation.

Key insights involve:

- Disrupt the existing regime dynamics by softening the sources of lock-in.
- Organize transition arena's, set up experiments and support (market) niches.
- Foster the development of innovation systems and their functioning.
- Systemic innovation requires new forms of monitoring and evaluation.

Contents

1 Introduction

1.1 Background

Ever since the Club of Rome published its “Limits to Growth” study (Meadows, 1972), more than 40 years ago, the idea that we need to make our industrial societies more sustainable has gained broad support amongst academics, policy makers and (increasingly so) industries. Fundamental to this idea is that changes in our models for production and consumption are needed if either major threats to our societies are to be prevented or significant new opportunities to be seized (Weber & Rohracher, 2012). See Figure 1.1 for an overview of threats.

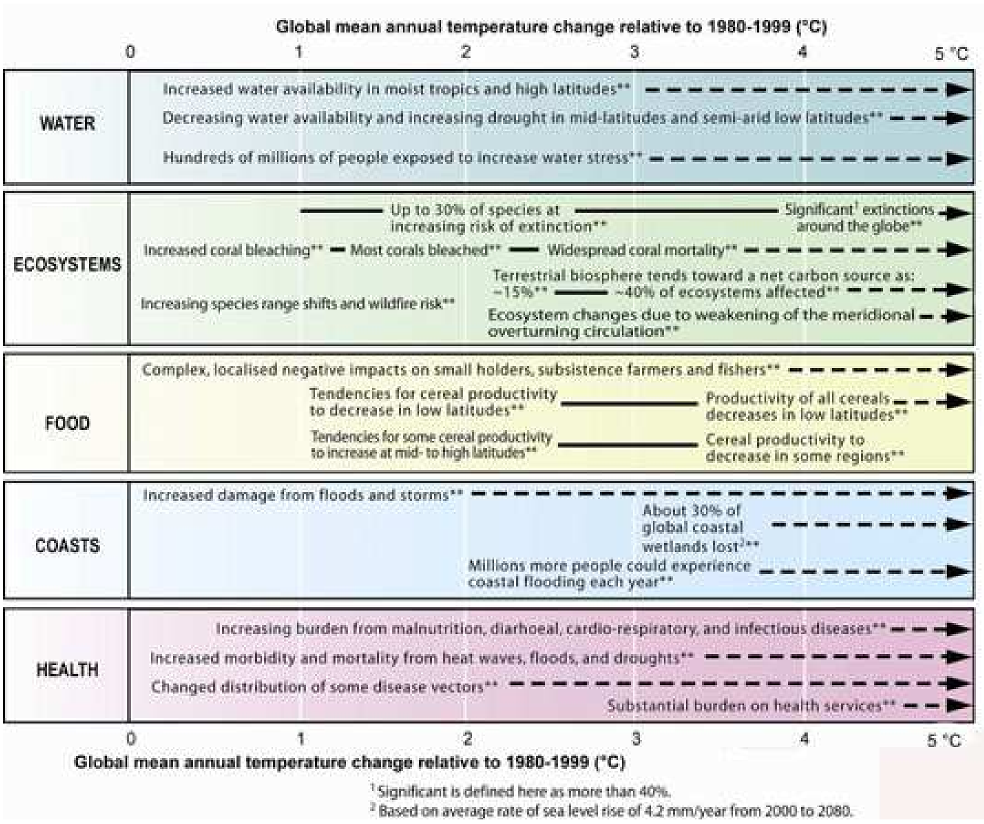

Figure 1.1: Threats of global warning (www.global-greenhouse-warming.com).

It is widely recognized that innovation in its various forms has a crucial role to play for realizing the kind of changes needed. In transport systems, energy systems, agricultural systems etc., there are numerous promising (technological) innovations with the potential to increase our environmental performance. Still, so-far, such innovations tend to diffuse slowly and gradually over time. For example, it took the OECD world more than 40 years of development in sustainable energy technologies to establish a 10% share of modern renewables (REN21, 2013). Despite double digit growth rates of PV and wind energy technologies, current energy systems are still largely based on fossil and nuclear fuels.

Unruh (2000; 2002) explains the stability of our energy system through a causal mechanism that he calls carbon lock-in. He shows how, over the past decades, an energy system has evolved into a tightly interlinked network of actors, technologies and institutions (rules, regulations). This network provides reinforcements – e.g. through accumulation of knowledge, economies of scale, network effects, consumer habits – to the preservation and improvement of carbon based technologies (see Table 1.1). Obviously these factors are reflected by a low price and high market value of these technologies. Even governments tend to exacerbate this situation, e.g. through carbon subsidies (Jacobsson et al., 2004; Jacobsson and Lauber, 2006).

Table 1.1: Sources of lock-in (based on Unruh, 2002).

Technological	Dominant design, standard architectures and components, compatibility
Industrial	Industry standards, technological inter-relatedness, co-specialized assets
Organizational	Routines, departmentalization, customer-supplier relations, training, capacity building
Institutional	Policies, legal frameworks, departments/ministries, educational programs
Socio-cultural	Social norms, values, preferences, expectations, behavioral habits

In order for environmental innovations to substantially contribute to a sustainable development, these forces of inertia have to be circumvented or even broken. This implies a reorganisation of the structures, or even cultures, that lie at the basis of the production systems of modern industrial societies. In this light, and with this societal challenge in mind, a growing community of researchers, policy makers and entrepreneurs has recently developed a body of knowledge that specifically looks into the dynamics of socio-technical transitions and systemic innovations.

1.2 Purpose

The Dutch ministry of Infrastructure and Environment is currently a leading member of an international ERA-network on eco-innovation (see www.eco-innovera.eu). National and regional policy makers active within this network are struggling with sustainability challenges on various levels (from city to nation) and in a multitude of domains (from agriculture to chemical industry). Policy-makers in programming Horizon2020 research for sustainability face similar challenges. The ministry has asked TNO to provide an overview of concepts, examples and tools for promoting a systemic approach in research and eco-innovation that may guide European en national/regional policy-makers in programming ambitious and effective research. The paper should contain the following elements:

- Overview of conceptual building blocks related to scientific literature;
- Cases and examples that clarify how systemic innovations work in practice;
- Policy lessons of value to the members of the Eco-Innovera network;
- Recommendations on the preparation of a European research strategy and a call-for-tender on systemic innovation (directed to programming in the Eco-Innovera network and at European level).

Two target audiences:
This paper is written with the members of the Eco-Innovera-network in mind as a first target-audience. It is meant to support the network in its mission to strengthen the EU's eco-innovation policies on various policy levels. A second important target audience for this paper is the European Commission DG Research and Innovation. Last but not least, the paper is meant to inspire other DGs of the European Commission in their systemic approach of innovation.

Scoping and terminology:
This paper works with the following definitions:

Eco-innovation *is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to alternatives* (Kemp, 2011).

Systemic innovation *is a re-arrangement, and improvement in terms of one or more societal values (e.g. people, planet, profit), of the structures and cultures that lie at the basis of the production and consumption systems of society.* Systemic innovation is not necessarily directed towards environmental causes.

Systemic eco-innovation*, hence, targets the development of alternative systems of production and consumption that are more environmentally benign than existing systems, e.g. biological agriculture, renewables-based energy systems.*

The remainder of the paper focuses on systemic eco-innovations. A more elaborate explanation and refinement of terminologies used is provided in the next chapters.

1.3 Reading guide

Chapter 2 provides an overview of conceptual building blocks. Chapter 3 introduces three main policy perspectives on the basis of these building blocks. In Chapter 4, recommendations are given for programming ambitious and effective research. Throughout the paper, examples from policy practice are provided to clarify the lessons and insights drawn from the literature.

2 Conceptual building blocks

2.1 Defining systemic innovation and socio-technical transitions

In the scientific literature, the term 'systemic innovation' is relatively new. The established literature of innovation studies has mainly focused on the development of new products and processes on the level of the firm. National or sectorial studies have long focused on aggregated data on R&D or economic impact. The last two decades a growing community of researchers has started to study innovation processes on a societal level, considering also the impact on the environment. Figure 2.1 provides one such classification.

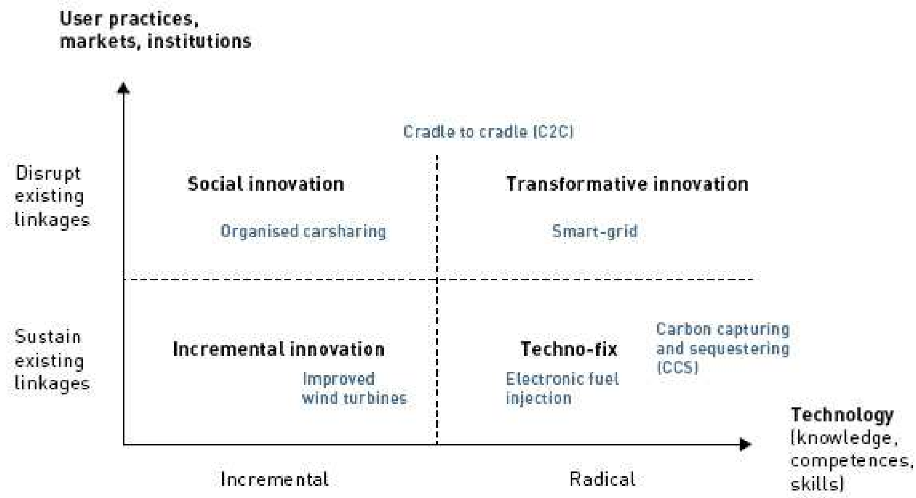

Figure 2.1: A typology of societal innovations (Kemp, 2011).

The figure distinguishes innovations (on a societal level) in terms of impact. The horizontal axis indicates the technological fit with the current infrastructure, knowledge, competences and skills. The vertical axis indicates the current societal fit in terms of practices, rules, markets. The term ‘systemic innovation’ refers to changes that belong in the upper right quadrant of the figure. (Here called ‘transformative innovation’).

Systemic innovations lead to fundamental changes in both social dimensions (values, regulations, attitudes etc.) and technical dimensions (infrastructure, technology, tools, production processes etc.) and, most importantly, in the relations between them. Vice versa, from a historical perspective systemic innovations are also the result of the interplay between technological and societal change. Systemic innovations may include elements or combinations of all types of innovations and are, by definition, developed and implemented by many actors. In fact, systemic innovations may even develop from (a combination of) other types of innovation. Hence innovations may move through different quadrants of the figure.

Systemic eco-innovations are bound to have more impact on society and therefore come with a promise of breaking free from the unsustainable lock-in of our current production and consumption structures.

It is important to consider that eco-innovations are not necessarily systemic innovations. This is illustrated by the MEI classification given in Figure 2.2. The figure shows how eco-innovations actually cover all quadrants of Figure 2.1. In the remainder of this text we will focus entirely on systemic eco-innovations (called 'green system innovations' in the MEI classification).

Box A. MEI classification of eco-innovation

A. Environmental technologies
- Pollution control technologies including waste water treatment technologies
- Cleaning (clean-up) technologies that treat pollution released into the environment
- Cleaner process technologies: new manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives
- Waste management equipment
- Environmental monitoring and instrumentation
- Green energy technologies
- Water supply
- Noise and vibration control

B. Organizational innovation for the environment:
- Pollution prevention schemes
- Environmental management and auditing systems: formal systems of environmental management involving measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste. Examples are EMAS and ISO 14001.
- Chain management: cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave)

C. Product and service innovation offering environmental benefits:
- New or environmentally improved products (goods) including eco-houses and buildings
- Green financial products (such as eco-lease or climate mortgages)
- Environmental services: solid and hazardous waste management, water and waste water management, environmental consulting, testing and engineering, other testing and analytical services
- Services that are less pollution and resource intensive (car sharing is an example)

D. Green system innovations:
- Alternative systems of production and consumption that are more environmentally benign than existing systems: biological agriculture and a renewables-based energy system are examples

Source: Kemp and Pearson (2008)

Figure 2.2: Classification of eco-innovations by Kemp (2011).

There are two strands of literature that provide a more integrated perspective on systemic eco-innovation. This is the **innovation systems literature** and the **socio-technical transitions literature**. Both literature strands employ the perspective of a societal system in which important structural problems arise that cannot be dealt with by market forces alone. As such, this literature provides a solid foundation for policies aiming at a long-term transformation of our production and consumption structures (Markard and Truffer, 2008; Weber et al., 2006; Weber & Rohracher, 2012). For the remainder of this chapter we will elaborate on some key elements of each of these two seminal frameworks.

Evolutionary theory and systemic innovation:
The literature on systemic innovation and socio-technical transitions has taken many ideas from evolutionary economic theories. In evolutionary economics, change is considered as unfolding according to a mechanism characterized, as in biology, by the interplay of three principles; variety, retention and selection. Variety is created through innovation processes that arise in a population of heterogeneous actors. Retention is maintained through the presence and inertia of routines, as well as technological and institutional structures. Selection is conducted through a so-called selection environment. A distinction can be made between the internal and external environment. The internal selection environment involves the selection (usually by firms) of technological options to be developed. The external selection environment may be considered as ‘the market'.

2.2 The literature on socio-technical transitions

Systemic innovations are often called 'socio-technical transitions'. Examples are the transitions from an industrial to a service economy, from extensive to intensive agriculture, and from horse-and-carriage to individual car-mobility" **(Geels, 2002a; 2002b)**. Figure 2.3 provides a graphical representation of different transitions as they have historically occurred in the energy domain.

Note that these representations do not provide insights in the underlying causes, nor do they reveal the true impact on society. The literature on socio-technical transitions attempts to fill exactly this ‘knowledge gap’.

Socio-technical transitions are defined as large-scale transformations within society during which the structure of the societal system fundamentally changes (Geels, 2002). A transition involves a shift of a relatively stable system (dynamic equilibrium) undergoing a period of relatively rapid change, during which the system reorganizes irreversibly into a new (stable) system (Rotmans, 2003).

Characteristics of socio-technical transitions:

Transitions are co-evolutionary and multi-dimensional: Technological developments evolve intertwined with economic and societal developments. Innovations emerge where new combinations are formed. These involve 'boundary spanning' across knowledge domains, sectors and communities.

Multiple actors are involved: A wide range of actors is involved. This includes businesses, policy-makers, NGOs, special interest groups, and others.

Transitions are long-term processes: A complete system change takes time and may take decades. Historical case studies indicate 40 to 90 years (see Figure 2.3).

Change is non-linear: The rate of change varies. For example, the pace of change may be slow in the beginning but rapid when a breakthrough is occurring.

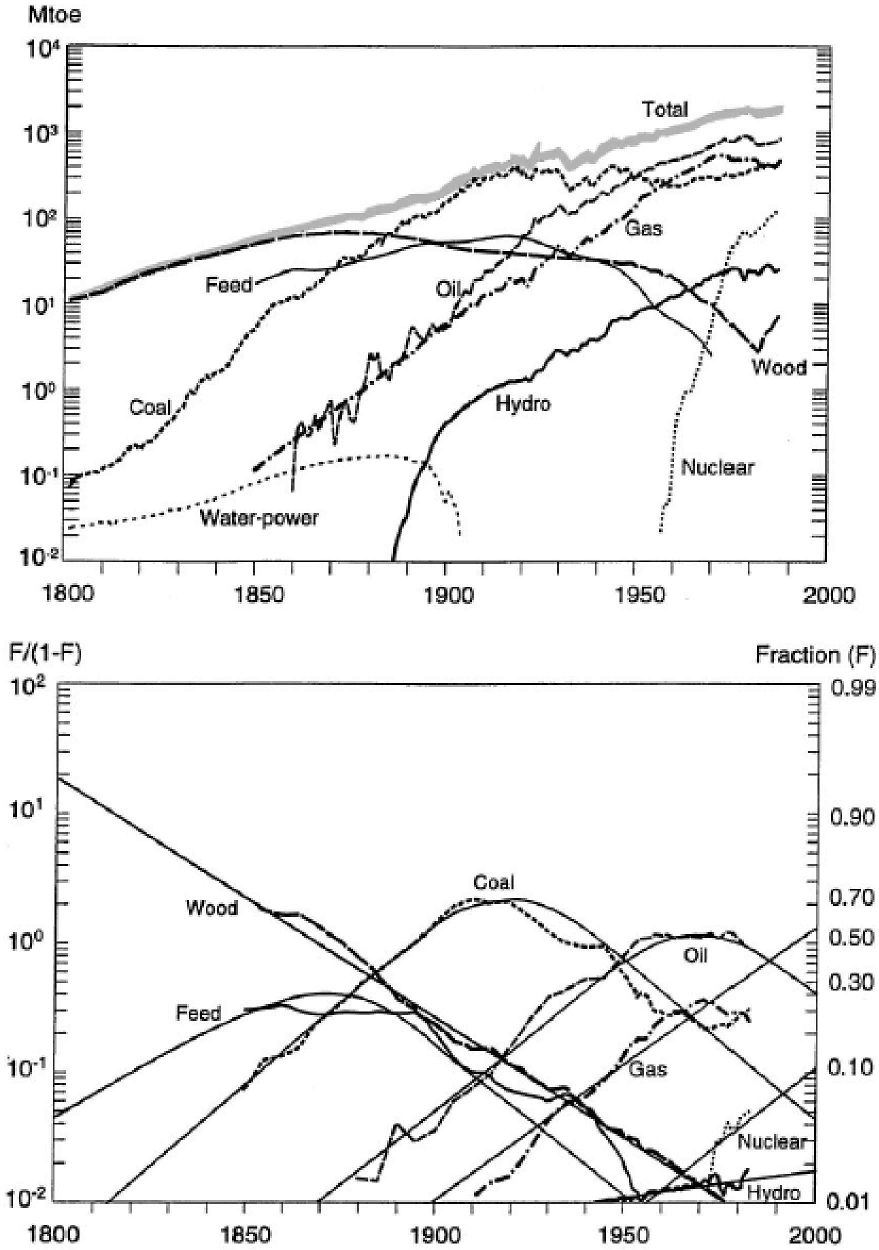

Figure 2.2: Transformative innovations, or 'socio-technical transitions' as represented by the diffusion of various energy carriers over time in the USA (Grübler et al., 1999).

Transitions are studied by primarily considering the interplay of processes at three different levels of aggregation **(Geels, 2002a; 2002b)**: micro (niche), meso (regime) and macro (landscape).

The meso-level (regime) represents the socio-technical system that is currently dominant in serving (a subset) of societal need(s), and which is the subject of transition. The regime is characterized by strong path dependence and lock-in effects. Depending on the context of study, a regime can be defined on the level of a sector, a region or even a city. Figure 2.4 shows, for example, how the road transportation system is made up of an intricate network of 'locked in' elements.

Analysing a regime:

A regime can be analysed by considering the following dimensions:

- material and technical elements; for example, in the case of electricity systems, these include resources, grid infrastructure, generation plants, etc.;
- network of actors and social groups; in the electricity regime important actors are utilities, the Ministry of Economic Affairs, industrial users, households;
- formal, normative and cognitive rules that guide the activities of actors; for example regulations, belief systems, search heuristics, behavioural norms.

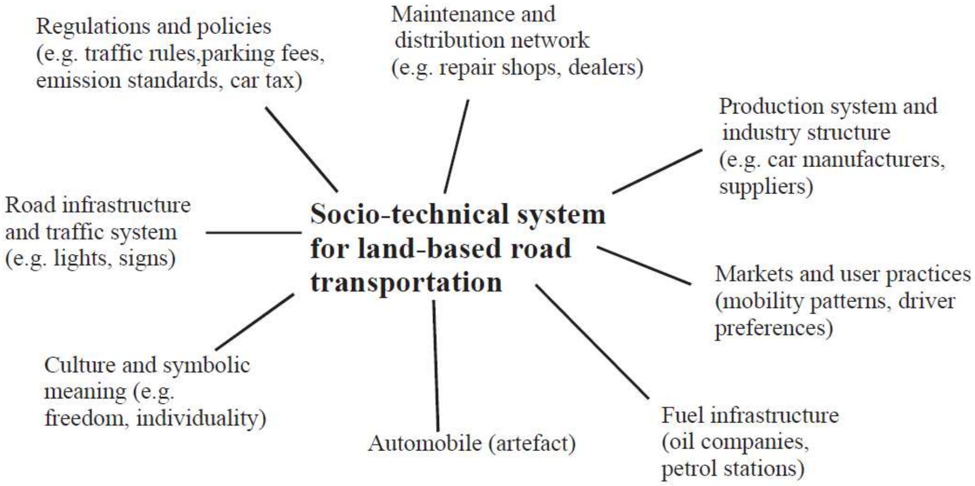

Figure 2.4: Example of a socio-technical regime (Geels, 2004).

The macro-level, the so-called landscape, comprises slowly changing factors such as demographics, climate change, geopolitics. The landscape shapes the direction and speed of innovation or transition processes but is hardly (or only in the long run) affected by these processes themselves.

The micro-level represents the secluded margins within the socio-technical system where novelties emerge. These protected spaces relate to market niches or technological niches that function as ‘incubation rooms’, shielding new technologies from the mainstream market forces of the socio-technical regime. This is important since new technologies initially tend to have a low price/performance ratio.

In Figure 2.5, the levels are represented in what has come to be known as the Multi-Level-Perspective (MLP). The MLP explains how transitions occur as the result of interacting dynamics on three system levels. For a transition to happen, niche innovations need to gain internal momentum through learning processes, price-performance improvements, the support from powerful groups and through establishing market niches. At the same time, there should be sufficient pressure from the landscape level on the regime in order to destabilise current practices and to create opportunities for the niches to 'break through'.

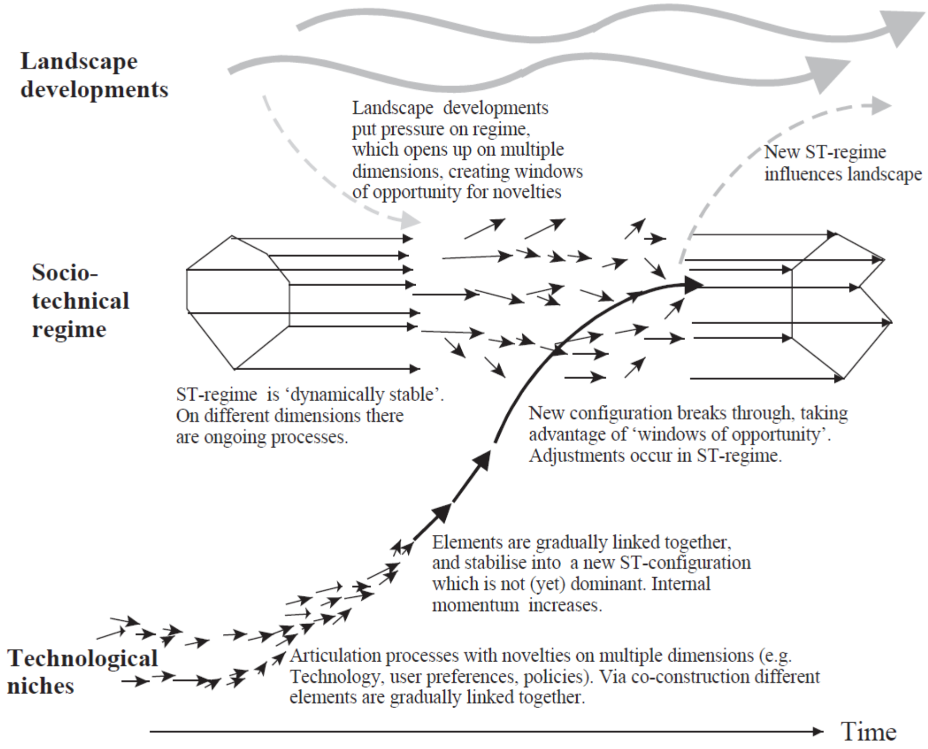

Figure 2.5: Dynamics of a socio-technical transition (Geels, 2004).

On the basis of this picture, the dynamics of transitions may seem to be relatively straightforward. Later work by Geels and Schot (2007) shows a more refined typology of four transition pathways (see Box).

Four ideal-typical transition pathways:

1) **Transformation of the system** This pathway is characterised by external pressure (from the landscape level or outsider social groups) and a gradual adjustment and reorientation of existing regimes. Although external pressures create 'windows of opportunity' for wider change, niche innovations are insufficiently developed to take advantage of them. Change is therefore primarily enacted by regime actors, who reorient existing development trajectories. Outside criticism from social movements and public opinion is important, because it creates pressure on regime actors, especially when they spill over towards stricter environmental policies and changes in consumer preferences. Although regime actors respond to these pressures, the changes in their search heuristics, guiding principles and R&D investments are modest. The result is a gradual change of direction in regime trajectories. New regimes thus grow out of old regimes through cumulative adjustments and reorientations. Radical innovations remain restricted to niches.

2) **Reconfiguration** In this pathway, niche-innovations are more developed when regimes face problems and external landscape pressures. In response, the regime adopts certain niche-innovations into the system as add-ons or component substitutions, leading to a gradual reconfiguration of the basic architecture and changes in some guiding principles, beliefs and practices. In the reconfiguration pathway, the new regime also grows out of the old regime it differs from the transformation pathway in that the cumulative adoption of new components changes the basic architecture of the regime substantially. The main interaction is between regime actors and niche actors, who develop and supply the new components and technologies.

3) **Technological substitution** In this pathway, landscape pressures produce problems and tensions in regimes, which create ‘windows of opportunity’ for niche-innovations. Niche-innovations can use these windows, when they have stabilised and gathered momentum. Diffusion of these new technologies usually takes the form of ‘niche-accumulation’, with innovations entering increasingly bigger markets, eventually replacing the existing regime. In this pathway newcomers (niche actors) compete with incumbent regime actors.

4) **De-alignment and re-alignment** Major landscape changes lead to huge problems in the regime. The regime experiences major internal problems, collapses, erodes and de-aligns. Regime actors lose faith in the future of the system. The destabilisation of the regime creates uncertainty about dimensions on which to optimise innovation efforts. The sustained period of uncertainty is characterised by the coexistence of multiple niche-innovations and widespread experimentation. Eventually one option becomes dominant, leading to a major restructuring of the system (new actors, guiding principles, beliefs and practices).

Source: Verbong & Geels, 2010; Geels & Schot, 2007.

It should be stressed that it is impossible to predict the course of a transition and it is even hard to assess its nature while it is still unfolding, not in the least because these patterns remain ideal types. Nevertheless policy makers may benefit from the historical insights captured by this typology. Verbong and Geels (2010) suggest that the typology allows for a systematic exploration of pathways and related policy goals / strategies (see the box below).

Policy relevance of transition pathways within the context of the energy transition:
Verbong and Geels (2010) have successfully applied the typology of transition pathways to the energy sector. They propose a set of scenario's for possible futures and consider the role of government within each of those futures:

Policy goals and transition pathways

- In terms of policy goals, our scenarios imply different goal hierarchies. The hierarchy in the ‘transformation scenario’ is: 1) cheap (cost efficiency), 2) reliability, 3) environmental issues. Market-based instruments are likely to dominate.
- The hierarchy in the ‘reconfiguration scenario’, where energy security is more important, is: 1) reliability, 2) environmental issues, 3) cheap (cost efficiency). Regulatory instruments, planning and stronger government involvement will be more important, besides market-based approaches.
- In the ‘de-alignment and re-alignment scenario’, the hierarchy is: 1) local control and reduced external dependence (which is a new goal compared to the other scenarios), 2) reliability, 3) environmental issues, 4) cheap (cost efficiency). Policy instruments that stimulate network building and learning will be more important in this scenario (public participation, experimentation, interactive scenario exercises).

The hierarchy in the first scenario is closest to the goal set that dominated electricity systems in the last two decades, and therefore requires least change. Alternative transition pathways, articulated in the other two scenarios, are thus likely to involve changes in policy paradigms. Political changes on the landscape level, like the election of Barack Obama in the US in 2008 and increasing evidence of the impact of climate change, could facilitate such shifts to other policy paradigm. Also erosion of the neo-liberal ideology, which dominated politics during the last two decades, may contribute to such shifts. The financial crisis of 2008–2009 has damaged the credibility of this ideology to some extent and made ideas around stronger government interventions and regulation more acceptable. But it remains to be seen if this really leads to a shift in policy paradigm.

Policy strategies and transition pathways

In terms of policy strategies, the pathways point to a different emphasis in the two-pronged strategy that is suggested by multi-level perspective: 1) increase the pressure on the existing regime e.g. with financial and regulatory instruments (e.g. carbon tax, emissions trading, emission norms, performance standards), 2) stimulate the emergence and development of radical innovations in niches.

- The ‘transformation pathway’, which is about reorientation of existing trajectories, places more emphasis on regime pressure than on stimulating niches.

- The ‘reconfiguration pathway’ has a more balanced approach: on the one hand, niche innovations are stimulated, e.g. through large-scale renewable projects; on the other hand, regime actors are stimulated to incorporate these niches and align national networks in a European Supergrid.

- The ‘de-alignment and re-alignment’ pathway, which assumes that regimes fall apart because of external landscape pressures, focuses primarily on policies that stimulate niche-innovations and nurture the emergence of a new system.

Source: Verbong and Geels (2010)

Summary for practitioners

- Eco-innovations can be part of systemic innovation processes, but are not necessarily radical or disruptive innovation whereas systemic innovation is. In the remainder of this text we will focus entirely on disruptive eco-innovations.

- Systemic innovations are needed to address grand societal challenges.

- Systemic innovations involve fundamental changes in both social (values, regulations, attitudes etc.) and technical (infrastructure, technology, tools, production processes etc.) dimensions and in the relations between them.

- Systemic innovation, or socio-technical transitions, occur as the result of interacting dynamics on three system levels: niche, regime and landscape.

- Systemic innovation often begins with small networks of actors who are willing to invest in the development of new technologies. These niche activities do not only encompass the innovation itself but also socio-economic and political opportunities for early deployment.

- For a transition to happen, niche innovations need to build up momentum through learning processes, price-performance improvements but also through the external support from powerful groups and market pull.

- Influencing innovation and systemic innovation means steering (i.e. policy making), at different levels.

2.3 The literature on Technological Innovation Systems

Given the holistic nature of transitions it is tempting to take the full extent of this macroscopic phenomenon into account when seeking to develop transition policies. The Technological Innovation System (TIS) literature starts from a narrower, and more specific, perspective of underlying technological innovation processes.

An innovation system can be defined as a network of actors (operating within a context set by institutional rules) involved in the development and implementation of a particular (set of) innovation(s). See Figure 2.7 for a visual representation.

Innovation has long been considered the result of a linear development, starting with basic research, followed by applied R&D, and ending with production and diffusion. With this heuristic model in mind, traditional innovation policies have largely focused on funding R&D. The idea was that production and diffusion would automatically result from a well-fed 'pipeline'. The different stages of the linear model of innovation were considered as separate, both in terms of time and in terms of the actors and institutions involved (see Figure 2.7).

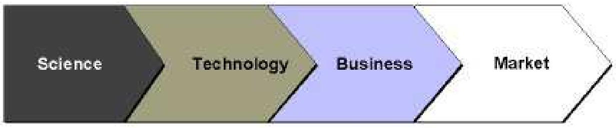

Figure 2.7: Linear model of innovation.

If the systemic feedbacks within the innovation system are neglected by policy makers, this is likely to result in the failure of innovation processes. This means the development of undesirable technologies or absence of technological development altogether. For this reason, the TIS approach rejects this model and, instead, stresses the interaction between numerous processes, with R&D, production and market formation running in parallel and reinforcing each other. For example, firms will need to cooperate with other firms and research institutes in order to develop a product. Moreover, they typically require support from governments, e.g. subsidies. Governments, in turn, require a legitimate reason for spending public money. For this, it helps that a technology has proven itself in a controlled environment. Figure 2.8 provides a representation of a systemic model of innovation.

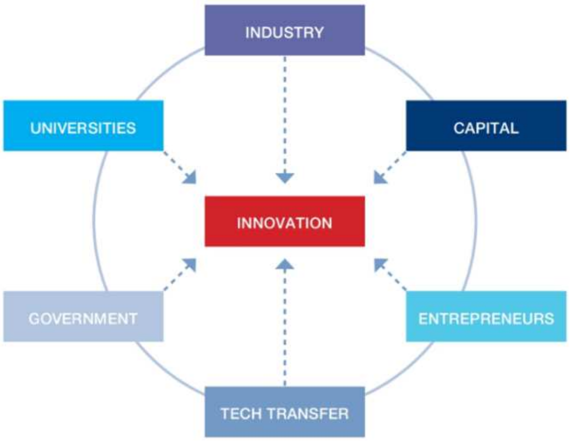

Figure 2.8: Systemic model of innovation (Source: www.isis-innovation.com).

TIS and the wider theoretical school of innovation system studies:
The concept of a Technological Innovation System was introduced as part of a wider theoretical school, called the innovation system approach. Ever since the 1980s, innovation system studies have pointed out the influence of societal structures on technological change, and indirectly on long-term economic growth, within nations, sectors or technological fields. Depending on the purpose of the research, the system may be defined on the level of a nation, a region or a sector.

TIS and eco-innovation:
The TIS framework is not necessarily used to analyze sustainable innovations but it has proven very useful to do just this. Researchers have successfully applied the framework to a large variety of eco-innovations. These scholars have focused on understanding the *development* of emerging renewable energy technologies and the innovation systems that surround them.

Source: Freeman (1995); Lundvall (1988); Suurs (2009).

The Technological Innovation System (TIS) approach focuses on a particular technology (Carlsson & Stankiewicz, 1991). A TIS consists of a variety of interdependent actors and institutions. The concept can be applied to specific technologies or broader. Examples are 'thin GISG solar energy' technology (specific), semiconductor technology (broad) or even the rather conceptual notion of a biobased chemistry sector. For practical reasons, TIS studies usually set some geographical boundaries as well. The geographical demarcation of a system can vary, ranging from global, national to regional innovation systems.

Wind energy in Denmark vs. the Netherlands
The analysis of the wind turbine innovation systems in Denmark and the Netherlands reveals how structural differences may lead to success or failure of systemic innovation attempts. More importantly, it is revealed how national innovation policies create these differences. The research shows that in the Netherlands, the R&D infrastructure was relatively well established, with high-tech companies like Fokker, aiming for large scale wind turbines. On the downside, these activities were poorly connected to the market and to relevant societal actors. In Denmark, smaller wind turbines were developed, on a trial and error basis, by a broader variety of actors. These initiatives resulted in massive opportunities for learning-by-doing. Moreover, the most successful actors gradually merged together, resulting in the build-up of a complete and well-functioning innovation system. On top of this, the Danish government actively supported market development through procurement activities.
Source: Kamp & Van der Duin (2011)

A TIS may be analyzed in terms of its system components and/or in terms of its dynamics. The system components of a TIS are called structures. Three basic structural categories are distinguished: actors, institutions and technologies.

- **Actors:** The actors involve organizations contributing to a technology. The variety of relevant actors is enormous, ranging from private actors to public actors, and from technology developers to technology adopters. The development of a TIS depends on the interrelations between actors. For example, entrepreneurs are unlikely to invest if governments are unwilling to support them financially. At the same time, governments have no clue where financial support is necessary if entrepreneurs do not provide them with the information and the arguments they need to legitimate policy support.

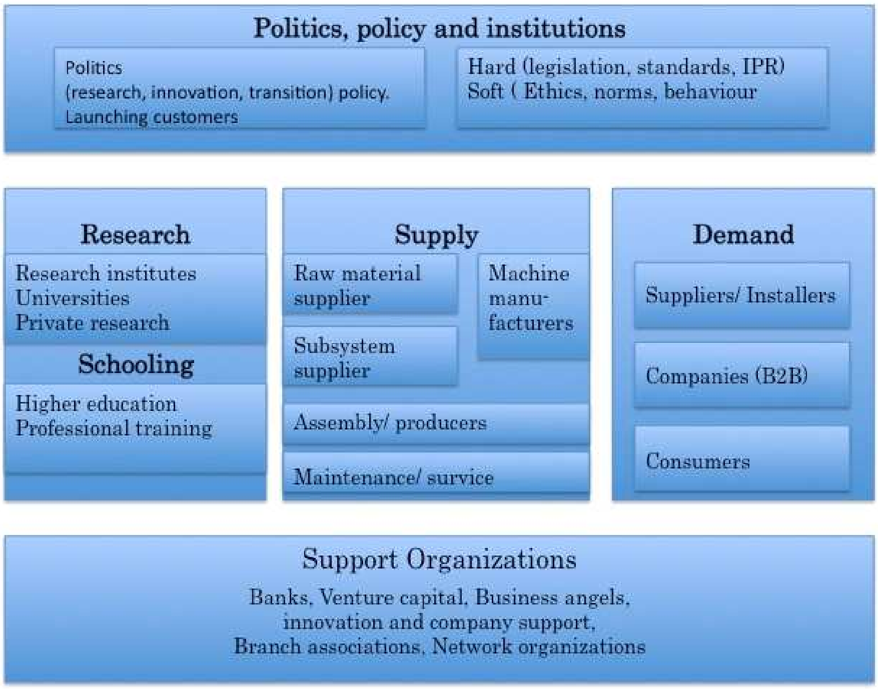

Figure 2.9: Technological Innovation System: actors and institutions.

- **Institutions:** Institutions may be considered as 'the rules of the game' in a social environment. A distinction can be made between formal institutions and informal institutions, with formal institutions being the rules that are codified and enforced by authority, and informal institutions being more tacit and organically shaped by actors. Informal institutions can be normative (social norms and values) or cognitive (collective mindframes, paradigms). Examples of formal institutions are government laws and policy decisions, firm directives, contracts. An example of a normative rule is the responsibility felt by a company to prevent or clean up waste. Examples of cognitive rules are problem-solving routines. They also involve visions and expectations held by the actors / users.

- **Technologies:** Technologies consist of artifacts and the technological infrastructures in which they are integrated. They also involve features such as costs, safety and reliability. These are crucial for understanding the interplay between technological and institutional change. For example, if subsidy schemes supporting technology development result in improvements with regard to safety and reliability, this would pave the way for more elaborate support schemes, including practical demonstrations. These may, in turn, benefit technological improvements even more.

The actors, institutions and technologies of an innovation system are to be regarded as elements that are linked to each other forming networks. An analysis of the structures of a TIS typically results in insights with respect to the systemic features of such networks. For a policy maker, this may reveal important drivers and barriers related to the technology (see the wind energy example in the box above).

A TIS may also be analyzed in terms of its dynamics. This is important since for many technologies, especially emerging ones, the structures are not yet (fully) in place. The idea here is to focus on a set of so-called innovation system functions that contribute to the development, diffusion, and use of innovations. The system functions, as defined by **Suurs (2009)**, are explained in Table 2.1 below.

System functions can be understood as key activities that contribute to the build-up of a TIS. These activities can be measured on the basis of key performance indicators. Policy makers may support systemic innovation by (additionally supporting) the system functions of one or more Technological Innovation Systems. The innovation system approach helps in determining which system functions to support with (additional) policy interventions.

Figure 2.10 provides a graph that has been used to visualize the result (see Section 3.2 for more explanation).

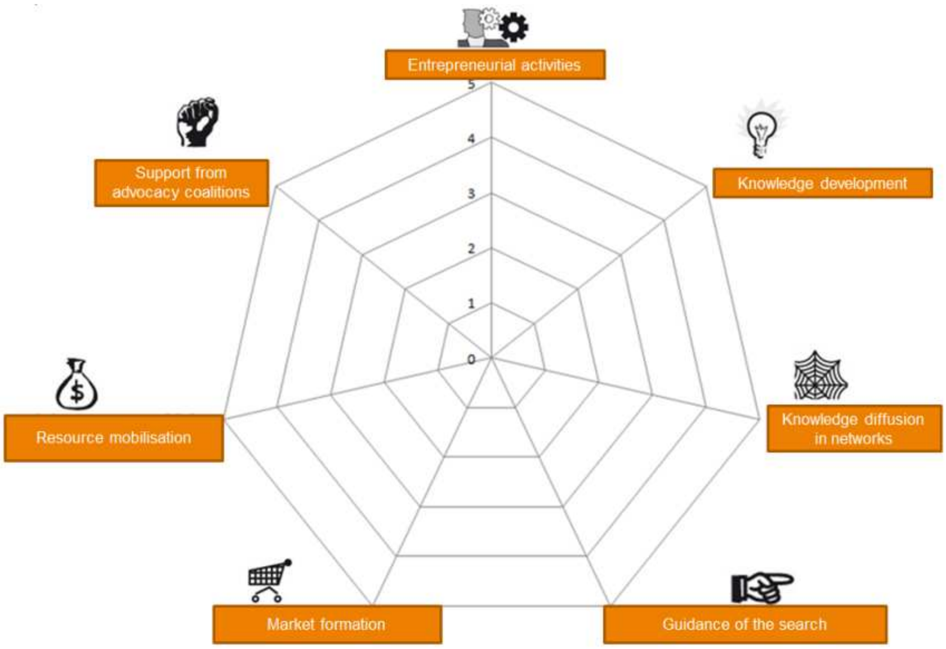

Figure 2.10: Seven functions of Technological Innovation Systems.

Motors of innovation:
A recurring theme within the literature on Technological Innovation Systems has been the notion of cumulative causation. This concept is closely related to the idea of a virtuous circle or vicious cycle, by **Gunnar Myrdal (1957)**. In the context of the TIS approach, this refers to the phenomenon that the build-up of a TIS accelerates due to system functions interacting and reinforcing each other over time. For example, the successful realization of a research project may result in high expectations among policy makers, which may, subsequently, trigger the start-up of a subsidy program, which induces even more research activities. Recently, TIS scholars have named such dynamics 'Motors of Innovation'.
Source: Suurs (2009); Hekkert et al. (2007).

Table 2.1: Seven system functions and some indicators.

System Function	**Definition**
Entrepreneurial Experimentation	Entrepreneurial activities ensure that risk is being taken in bringing new insights and scientific results to the market. Entrepreneurial activities may include: • Start-ups and spin-offs focusing on the new technology • Creating an incubator • Practical experiments and demonstration projects • Incumbent players adopting or moving towards the new technology
Knowledge Development	Knowledge development and diffusion gathers and shares new insights and technological discovery. It may entail the following activities: • Initiating research program on relevant technologies at universities and other public research institutes. • Undertaking basic R&D in (large) firms. • Cooperation between an individual firm and public research to develop new knowledge. • Undertaking a public private research program sustainable process technology, resource efficiency and/or biobased economy. • Organization of (international) gatherings to exchange ideas and present new developments
Guidance of the search	Guidance of the search influences the rate and direction of research and innovation. It may involve the following activities: • Setting collective goals for resource efficiency in the region • Sharing expectations by determining stakeholders such as government or large companies • The formulation of a vision on the future by stakeholders
Resource mobilization	Resource mobilization is needed to enable/fund all other functions. It may entail the following activities: • Subsidies by the (regional) government for sustainable chemical innovations • An investment fund for sustainable chemical innovations • Matchmaking events to bring together funds and innovative ideas. • Creation of Public Private Partnerships or other enabling platforms • Laws, standards, fiscal incentives and regulations
Market Formation	Market formation creates a demand for the technology that is developed within the system. It may entail the following activities: • Creating a niche-market within a certain region • Public procurement to stimulate market formation • Lifting impeding regulation or institutional set-up • Setting of market standards
Support from advocacy coalitions	Support from advocacy coalitions is needed to counteract an existing resistance to change by incumbents and traditional stakeholders. It can entail the following activities: • NGO’s or other non-profit organization advising for the technology • Political pressure to implement the technology • Creating advocacy coalitions to drive the technology

Summary for practitioners

- Systemic Innovation and socio-technical transitions involve a multitude of complex processes evolving on macro-, meso- and micro level. A Technological Innovation Systems (TIS) is defined on a narrower, and more specific, level, typically somewhere at the micro and meso level of the MLP (see previous chapter).

- A TIS can be defined as a network of actors (operating within a context set by institutional rules) involved in the development and implementation of a particular (set of) innovation(s). The TIS approach focuses on actors, institutions and technological features. Examples are 'thin GISG solar energy' technology (specific), semiconductor technology (broad) or even the rather conceptual notion of a biobased chemistry sector.

- Innovation has long been considered the result of a linear development, starting with basic research, followed by applied R&D, and ending with production and diffusion. With this heuristic model in mind, traditional innovation policies have largely focused on funding R&D. The TIS approach rejects this model and, instead, stresses the interaction between numerous processes, with R&D, production and market formation running in parallel and reinforcing each other. If the systemic feedbacks within the innovation system are neglected by policy makers, this is likely to result in the failure of innovation processes.

- The application of the TIS concept in policy making, involves analyzing the interdependencies of actors, institutions and technologies. This typically results in insights with respect to a variety of drivers and barriers related to the technology.

- A TIS may also be analyzed in terms of its dynamics. This is important since for many technologies, especially emerging ones, structures are not yet (fully) in place. Important system functions involve knowledge development, but also entrepreneurial activities, market formation and support from advocacy coalitions.

- Policy makers may support systemic innovation by supporting the innovation system functions of one or more Technological Innovation Systems.

3 Policy perspectives

The literature on systemic innovation and sustainability transitions has shown us that government policy has a crucial role to play, where transformative change is concerned. Classic economic theory dictates that government interventions are legitimate when the 'free market' fails to function properly. Systemic innovation scholars legitimate the active role of government by additionally referring to so-called system failures (an extrapolation of the traditional reasoning about market failures). Table 3.1 provides an overview of the most important system failures that warrant government interventions in innovation systems, markets and society. Note that, from this perspective, the government is considered part of the problem (the regime) as well as the solution.

Table 3.1: Legitimising policy intervention on the basis of market and system failures (Kemp, 2011).

Market failures	System failures
Public good nature of knowledge gives rise to problems of appropriation the benefits from innovation (e.g. risk of imitation)	Inadequacies in the technology / knowledge infrastructure
Uncertainty and incomplete information about costs and benefits of innovation	Old and rigid technological capabilities within companies causing transition failures to new knowledge bases
Market power	Insufficient entrepreneurship
Entry barriers	Not enough risk capital and high capital costs
Network externalities causing a lock-out	Regulations acting as barriers to innovate
Price gap for eco-innovations at the beginning of the learning curve	Unfamiliarity with and social resistance to certain innovations
	Actors not able to coordinate joint action

The remaining chapter introduces three policy perspectives that are specifically oriented towards supporting systemic innovation and sustainability transitions. Each perspective is described by explaining the purpose that sets it apart from other perspectives ('why') and the approach to implement it ('how to'). For each perspective, an example is provided. To render the overview complete, and in order to employ a reflective stance that fits an evolutionary and learning oriented approach, some known criticisms are listed as well.

3.1 Transition 'management'

3.1.1 Purpose

Transition management can be described as a deliberative process to influence governing activities in such a way that they enable societal processes of change towards sustainability (Loorbach, 2007). Transition management offers a steering concept that relies on 'darwinistic' processes of variation and selection rather than the 'intelligence' of planning. The framework helps different political actors to collaborate. It makes use of bottom-up developments and long-term goals both at the national and local level and is not so much concerned with specific outcomes but rather with mechanisms of change (Nill & Kemp, 2009).

3.1.2 Approach

The basic premise of the model is about creating space (institutional, technological, financial, and regulatory space) for societal innovation, as a strategy to develop alternatives to existing practices and systems. To achieve this, actors having an interest in systemic eco-innovations are brought together in so-called transition arenas. These involve a rich variety of experts, people from government and civil society. Within these virtual platforms, issues of sustainability and ideas for systemic innovation are being analysed and discussed. The analysis and discussion leads to the selection of transition paths, eligible for special support by policy. The transition arena's operate separate from regular policy arena's. But the activities are expected to influence regular policy (Nill & Kemp, 2009).

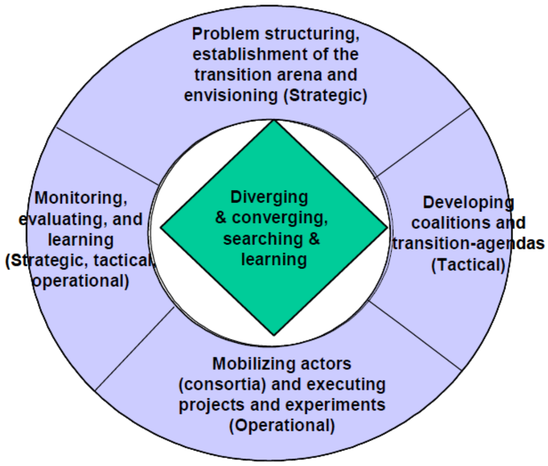

Figure 3.2: Transition management cycle (Loorbach, 2005).

The transition management model of governance relies on a cycle of problem structuring, visioning, experimentation, policy development, implementation and adaptation (see Figure 3.2). The different activity clusters of the transition management cycle can be described as follows:

1. **Strategic level:** This activity cluster starts with structuring the problem on the system level with a small group of frontrunners (start of a transition arena). This will lead to a shared picture of the system at hand and its problems.

2. **Tactical level:** This activity cluster aims at building actor coalitions (so-called transition platforms) and developing a so-called transition agenda.

3. **Operational level:** The objective of this activity cluster is to create space (niches for innovation) and to open up possibilities to set up a portfolio of experiments with all kinds of consortia. The experiments are derived from the agendas developed at the tactical level.

4. **Reflection:** The monitoring, evaluation and learning is an explicit part of transition management. It is based on the notion of social learning and can be defined as a participatory process of describing, evaluating and reflecting on ongoing activities in order to stimulate the steering of the innovation process by further refinement of and/or reorientation of the activities at all other levels.

Transition experiments play a crucial role in translating strategic and tactical results into concrete results. Transition management experts have developed a variety of tools for setting up transition experiments. Transition experiments are crucial in dealing with uncertainties. Rather than making definite choices, small-scale experiments are set up and executed from which much can be learned, so that better information is available later on the (un)sustainable aspects of pathways and the related experiments. In this respect better-defended choices can be made by better-informed actors, such as policy makers (Kemp et al, 2010).

Table 3.2 provides an overview of features that distinguish transition experiments from more classical innovation projects. Table I in Appendix I provides a set of steering principles for managing and evaluating transition experiments.

Table 3.2: Difference between innovation projects and transition experiments.

	Classical Innovation Experiment	*Transition Experiment*
Starting point	Possible solution (to make innovation ready for market)	Societal challenge (to solve persistent societal problem)
Nature of problem	A priori defined and well-structured	Uncertain and complex
Objective	Identifying satisfactory solution (innovation)	Contributing to societal change (transition)
Perspective	Short and medium term	Medium and long term
Method	Testing and demonstration	Exploring, searching and learning
Learning	1st order, single domain and individual	2nd order (reflexive), multiple domains (broad) and collective (social learning)
Actors	Specialized staff (researchers, engineers, professionals, etc.)	Multi-actor alliance (across society)
Experiment context	(partly) controlled context	Real-life societal context
Management context	Classical project management (focused on project goals)	Transition management (focused on societal 'transition' goals)

Eventually, experiments are expected to develop (deepening, broadening, scaling up) and form pathways. Some pathways will obtain extra support (from public and private sources) than others. In that sense, there will be a competition between various pathways. According to the model, the government fosters this diversity through creating space for experimentation, but refrains from 'picking winners'. Initially the competition is weak: a broad portfolio is selected. But competition will become stronger, when money is to be targeted towards a smaller set of options.

Strategic Niche Management (SNM):

The management of transition experiments is especially well described in the literature on so-called Strategic Niche Management (SNM). The SNM literature provides theoretical and practical insights in how to create and support protected spaces (niches) for promising (sustainable) technologies. It shows how policy makers (and other actors) can protect emerging (technological) innovations from the selection pressure of the regime. In that sense, SNM is a strategy to escape lock-in. The idea is to create room for experimentation with the aim of learning about the performance, effects, economic viability and social desirability of the innovation. Protection may be offered by private and public actors: by suppliers, development and regulatory agencies, local authorities and/or users.

Source: Nill & Kemp (2009).

If the selection environment at the regime level is shaped towards sustainability, winners emerge in an evolutionary way. Therefore, beyond supporting these niche level experiments, transition management experts also argue that control policies to put pressure on the existing regime are needed to bring about transitions. This calls for a policy mix of R&D support combined with e.g. tax legislation, environmental norms in order to create a ‘more level playing field’ in which different practices and technologies may compete.

3.1.3 Criticism

- The transition management approach has been criticized, saying that transitions – as processes of co-evolution – cannot be managed. This is actually accepted by Dutch authorities, who see themselves as shapers of change processes rather than as transition managers; they are avoiding the term management: they talk about the transition approach instead of transition management.

- An essential part of transition management is the upscaling of niche experiments. Often these take the form of rather isolated projects. They therefore do not add up and therefore there is no actual process of scaling up. The question is whether this can be 'fixed' by shaping better experiments according to the criteria of Table 3.2.

- In the Netherlands, scholars have claimed that the energy transition has been hijacked by the large energy companies (SHELL, NAM, NUON, Essent). Their main role is supposed to be to guard their interest not to have a system change. This might be an inherent dilemma in the transition management approach: in order to make real changes with impact one needs larger companies, with their capital, at some stage to join the process.

- Transition management is contrasted by ‘classic’ environmental policy providing norms and penalties. Transition management relies on private enterprise voluntarily acting. Some experts state that rules and bans are much more effective. On the other hand, studies have shown that norms and penalties are themselves the outcome of systemic innovation (e.g. through the interplay of technological and institutional change).

3.1.4 Summary for practitioners

- Transition management offers a steering concept that relies on ‘darwinistic’ processes of variation and selection rather than the ‘intelligence’ of planning. The framework is not so much concerned with specific outcomes but rather with mechanisms of change.

- The basic premise of the model is about creating space (institutional, technological, financial, and regulatory space) for societal experiments, as a strategy to develop alternatives to existing practices and systems. To achieve this, actors are brought together in so-called transition arenas.

- Beyond supporting experiments and new practices on the niche level, it is important to establish ‘flanking’ policy measures to put pressure on the regime. This calls for a policy mix of R&D support combined with e.g. tax legislation, environmental norms in order to create a ‘level playing field’ in which different practices and technologies may compete.

The Dutch energy transition

The transition management perspective has been applied, by the Dutch national government, to support the Dutch (renewable) energy transition. With the introduction of transition management into Dutch environmental policy a new generation of environmental policy has been introduced: While first generation environmental policy focused on mitigating the effects, and second generation policies dealt with the sources of environmental degradation, transition policy is about transforming the socio-technological systems producing the more persistent types of problems (Grin and Weterings 2005).

Since 2001, transition policy in the Netherlands resulted in a number of policy programs. The Energy Transition was one of these programs, aimed at realizing a sustainable national energy economy within 50 years. Coordinated by the Interdepartmental Project Board Energy Transition (IPE), in the Energy Transition six Ministries[1] worked together with private enterprises, NGO's and research institutes. Altogether, seven themes were defined on which Energy Transition should focus in order to realize a sustainable energy supply:

1. Biobased raw materials;
2. Sustainable mobility;
3. Chain efficiency;
4. New gas;
5. Sustainable electricity;
6. Energy in the built environment;
7. The greenhouse as energy source.

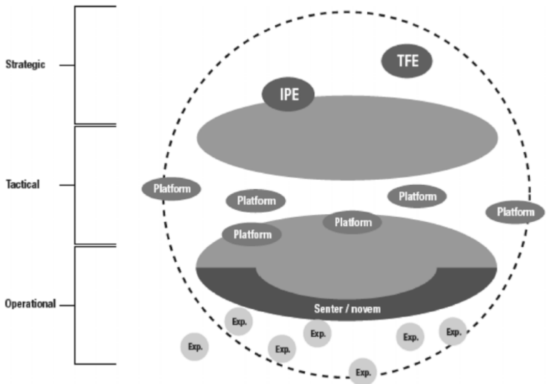

Figure 3.3: The transition management perspective as applied to the Dutch energy transition (Kemp et al., 2007).

For each theme, a so-called Energy Transition platform was set up. These public-private-platforms may be regarded as the relevant transition arena's. The platforms formulated shared visions on how to proceed along the seven themes. They all created their own thematic transition plans describing what experiments to initiate, what policy barriers to tackle, etc.

The Dutch Energy Transition has resulted in a large variety of experiments, some of which are still running up until the present day. Nevertheless, despite a myriad of experiments, the energy transition is only considered as a partial success, since it has not succeeded in actually establishing a shift in the energy regime. Transition experts say this due to vested interests being involved too soon.

[1] The six Ministries that cooperate in the Dutch Energy Transition are the Ministry of Economy Affairs, the Ministry of Housing, Spatial Planning and Water Management, the Ministry of Agriculture, Nature and Food Quality, the Ministry of Foreign Affairs, and the Ministry of Finance.

3.2 Innovation System Analysis

3.2.1 Purpose

The (technological) Innovation System Analysis (ISA) (see section 2.3.1) starts from the perspective that transitions can best be 'managed' by supporting the underlying (technological) innovation processes. The premise is that a well-functioning innovation system will increase the chance of the emerging technology coming to maturation. Once a technological innovation takes off, it is expected to replace or rearrange important structures that support incumbent technologies, thereby establishing a contribution to a socio-technical transition (see Figure 3.4).

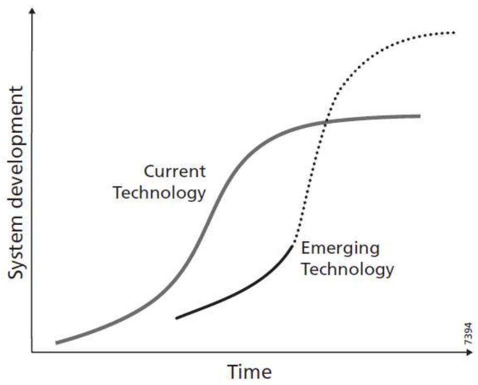

Figure 3.4: Systemic innovation from the perspective of a TIS (Suurs, 2009).

In the case of sustainable transitions a variety of technological innovations are to be generated, diffused and utilized in society in order to contribute to a transition. The purpose of the ISA is to evaluate a particular emerging technology, not primarily in terms of results and outcomes but mainly in terms of innovation system functioning (see the Box below). The evaluation reveals the intensity of seven system functions and underlying structural drivers and barriers **(Suurs, 2009; Hekkert et al., 2007)**. The result will aid policy makers in shaping their innovation agenda.

Three levels of innovation system performance:

Innovation system functions: In the early stages of a transition, technology diffusion has hardly taken place and thus it is important to consider intermediate criteria of system performance. Particular attention is provided to a set of key activities - or system functions - that are necessary for an innovation system to successfully bring a technology from the laboratory to the market / society.

Output: The output of a TIS is primarily defined in terms of technology diffusion. In the more developed innovation systems, technology diffusion may be regarded as key performance indicator.

Outcome: The contributions of a TIS to various dimension of sustainability (CO2 reduction for example) have to be regarded as performance indicators as well. This should be done very carefully since outcome measures are hard to establish for emerging technologies and may cause emerging technologies to be subjected to selection too early. In some cases, e.g. biobased products, eco-innovations are judged against stricter norms than the fossil based alternatives they seek to replace.

Source: Suurs (2009)

3.2.2 Approach

Various research methodologies exist for conducting the ISA. For the purpose of this paper we refer to an approach specifically developed by Bergek et al. (2008) for policy makers. The approach involves the following steps (see Figure 3.5):

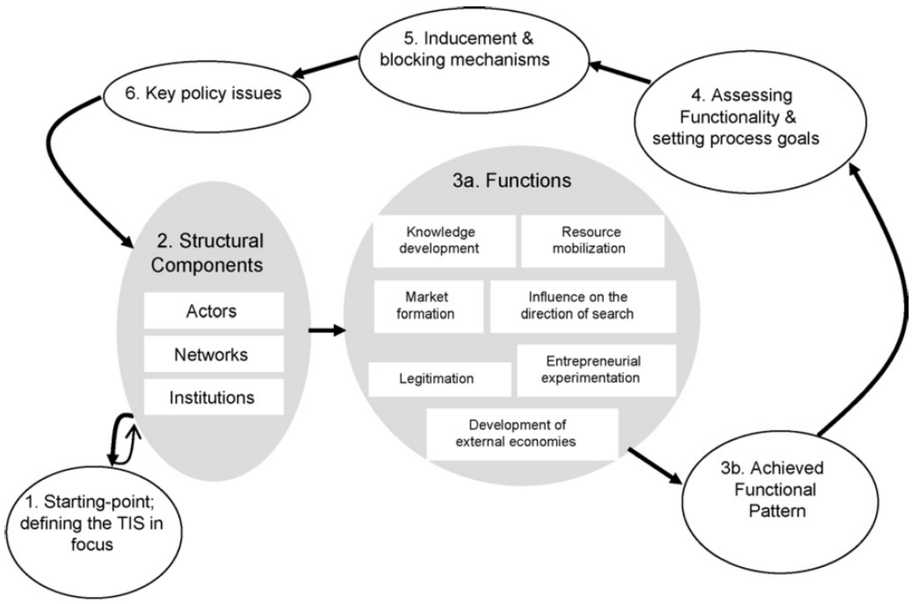

Figure 3.5: Scheme of Innovation System Analysis by Bergek et al. (2008).[2]

Step 1: The first step is the delineation of the TIS. The delineation depends on the aim of the analysis and the interests of the involved stakeholders (e.g. researchers or policy makers). Important decision to make concern:

a. the choice between a knowledge field or product as a focus
b. the choice between breadth and depth with respect to the technology
c. the choice of spatial domain (regional, national, EU)

Step 2: Having decided on the focus of the TIS (in a preliminary way), the next step is to identify and analyze the structural components of the system. First, the actors of the TIS have to be identified. Then, based on consultation of the actors, the most important institutions and technological features can be mapped.[3] The result is a picture of the TIS as seen by a group of relevant actors. Identifying the structural components of the system provides a basis for the following step, which constitutes the core of the analysis: analyzing the TIS in functional terms.

Step 3 - 4: The next step involves the analysis and assessment of innovation system functions (see Section 2.3). It is beyond the scope of this paper to explain exactly how this is done but Table 2.1 provides an overview of important activities that are typically mapped as part of such an analysis. Typically, the analysis and assessment are done on the basis of interviews or any other form of stakeholder consultation (e.g. ranging from roundtable dialogues to surveys). It is very well possible to complement this qualitative approach with a quantitative approach based on literature, database analysis and semi-quantitative surveys.

[2] Figure I in Appendix I provides an adapted version of this scheme that was applied for the purpose of establishing a joint action plan for a variety of stakeholders within a regional cluster.
[3] Note that Bergek does include networks but does not include 'technologies' as a separate component to be analyzed.

Steps 5 - 6: From a policy perspective, it is particularly important to understand the inducement and blocking mechanisms, or drivers and barriers, that shape the functional dynamics of the TIS. On the basis of these insights, policy issues may be derived. The path to achieving a higher functionality may be littered by a range of such inducement and blocking mechanisms. Hence, policy makers will usually have to support the innovation system with a mix of policy instruments. See Figure 3.6 for an example for the case of 'IT in homecare'.

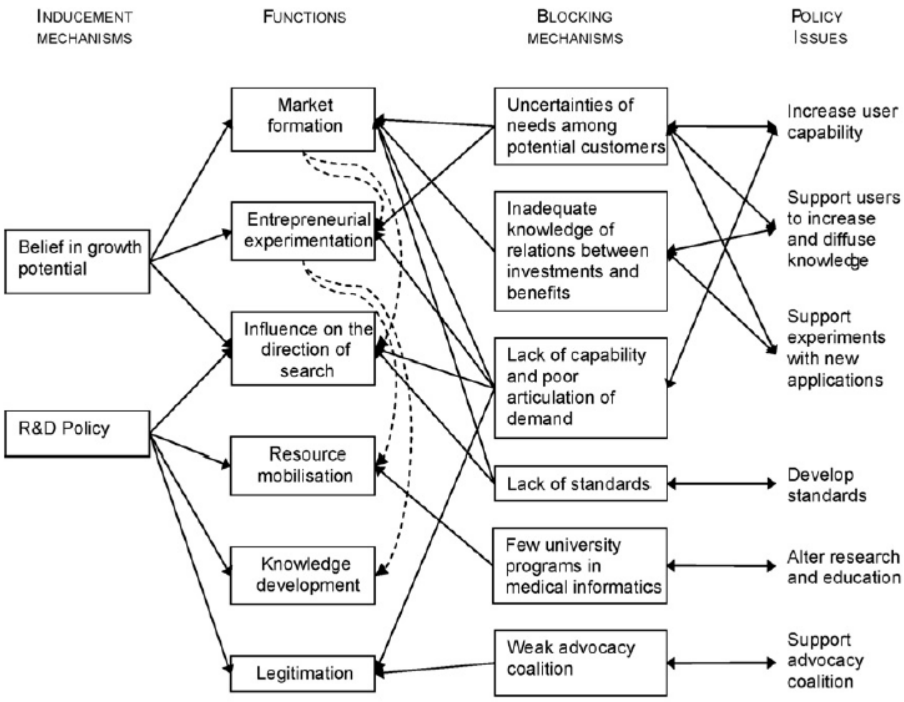

Figure 3.6: Inducement and blocking mechanisms as well as policy issues in the case of “IT in home care” (Bergek et al., 2008).

Note that the ISA approach should not be regarded as recipe but as a guideline of cyclical steps to be executed in an iterative way. Each step may need to be repeated multiple times. Eventually this will result in evidence based insights and stakeholder support for a policy agenda. The ISA may also be used for periodically monitoring the progress of a policy program (see Section 3.3.2.).

3.2.3 *Criticism*

- Scholars have criticized the ISA for assuming the existence of a system while it does not fully exist in reality. In practical terms, this should be carefully addressed by being aware of the fact that the ISA is a 'focusing device' for emerging technologies that helps scholars and policy makers to think about systemic innovation, and to shape a reality that does not necessarily exist yet.

- For emerging technologies there are inherent uncertainties, implying that the identification of structural components is thorny. It may prove hard to recognize relevant actors when directories are scarce, no industry associations exist or if the actors themselves are not aware of belonging to a certain TIS.

- For broadly defined technological fields and more mature sectors, there is the opposite challenge of information overflow. For example, the built environment case (chosen as one of the transition paths in the Netherlands, see the box below) was considered much too broad to be grasped by a single ISA.

- For practical reasons, the ISA tends to be focused on the national situation. It is methodologically quite difficult to incorporate international developments.

- Note that socio-cultural factors are not part of the ISA. Therefore the framework should be used as part of a broader perspective, e.g. Multi-Level Perspective.

The ISA as applied within the Dutch energy transition

After several years of experimentation with energy transition policy the Dutch government was in need of a method to evaluate the current state of particular transition trajectories. The ISA methodology was selected to provide this insight. The main reason to adopt it was the promise of the ISA (and the related TIS framework) to evaluate the progress of transition processes before actual technology diffusion had taken place.

At the end of 2007 over twenty transition trajectories — such as PV, wind energy, cars on natural gas, and energy efficient greenhouses — were evaluated using the ISA. This series of quick scans provided insight into the current functioning of the different technological innovation systems and which blocking mechanisms prohibited further development of the technology. Based on the results, an Energy Innovation program was formulated and 450 million euro was allocated to energy innovation activities.

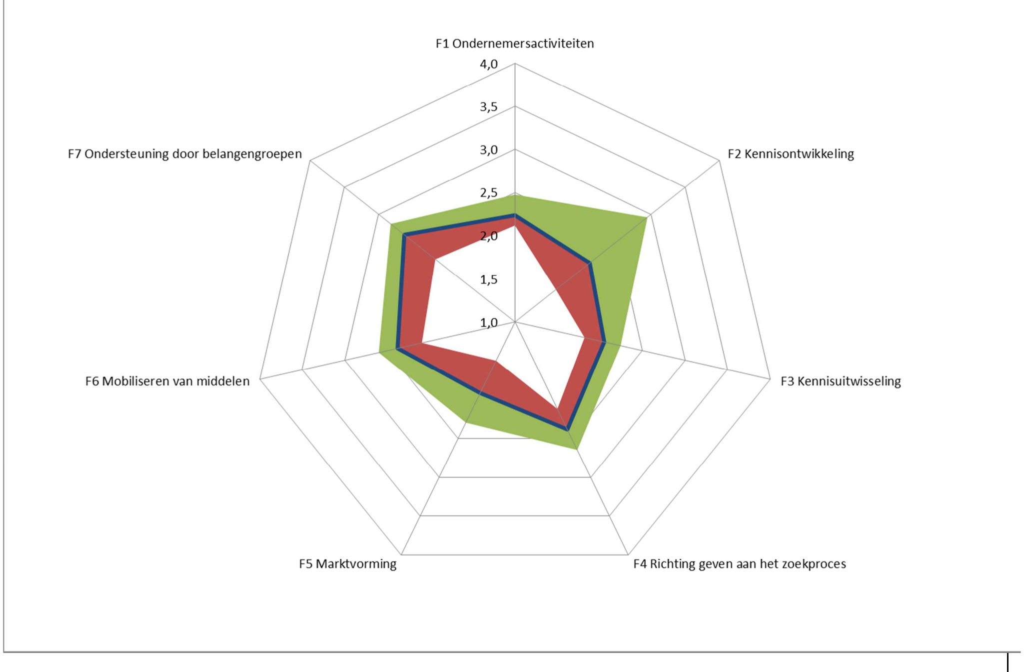

Figure 3.7: Example of a result from the analysis of the ISA around 'energy innovations' in the Built Environment (scores are given on a 4-points-scale ranging from 1 (bad) to 4 (good); colors indicated minimum (red), average (blue) and maximum (scores) provided by the expert panel.

Based on positive experiences in the energy innovation program, the ISA started to spill over to the other policy domains. Other government agencies were developing innovation programs related to other societal themes, like water, transport and agriculture.

Currently, the ISA is a well-known approach for programming and evaluating innovation programs in the Netherlands. Figure 3.7 shows a recent ISA result.

On a more critical note: because of limited time and resources available, the ISAs executed in 2007-2008 were very light quick scans. Sometimes the results would rely on a single workshop with key stakeholders. The outcome would depend on the presence of a rather small number of stakeholders.

Original developers of the ISA: Hekkert (Utrecht University), Weterings (TNO), Suurs (TNO).

3.2.4 *Summary for practitioners*

- For a socio-technical transition or systemic eco-innovation process to occur, a variety of technological innovations are to be generated, diffused and utilized in society.

- The purpose of an Innovation System Analysis (ISA) is to assess a particular emerging (technological) innovation. In the early stages of a transition, technology diffusion has hardly taken place and thus it is important to consider intermediate criteria of system performance. Particular attention is provided to a set of key activities - or system functions - necessary for an innovation system to successfully bring a technology from the laboratory to the market / society.

- The assessment reveals the intensity of seven system functions and underlying structural drivers and barriers. Typically, the analysis and assessment are done on the basis of interviews or other forms of stakeholder consultation (e.g. ranging from roundtable dialogues to surveys).

- The ISA may result in evidence based insights as well as stakeholder support for a systemic eco-innovation policy agenda. The ISA may also be used for periodically monitoring the progress of a policy program (see next section).

- Note that socio-cultural factors are not analysed as part of the ISA. Therefore the ISA should always be regarded as part of a broader perspective, e.g. the Multi-Level Perspective on socio-technical transitions.

A systems approach for the reuse of gypsum from construction and demolition waste

In 2008, the former Dutch Ministry of Housing, Spatial Planning and the Environment (VROM) and various parties in the gypsum production chain signed an agreement aimed at reusing 40% of gypsum from construction and demolition waste by 2010. This agreement sees various companies and organisations taking an important step towards a Cradle to Cradle approach to the use of gypsum in the construction branche. In the Netherlands gypsum is a frequently applied construction material in walls, ceilings (gypsum board and blocks), and floors (anhydrite floors). This results in 100 kton of gypsum in construction and demolition waste each year. To see how this agreement came about we have to go back to a systems analysis performed by TNO in 2000.

The initial foundation for the agreement was laid in 2000 with the start of a systems analysis. The result gave insight in the structure and cooperation in the gypsum production chain. The production system fell apart in two integrated parts. The first part concerned the parties involved in the production of gypsum, the manufacturing of gypsum products and the application of those in the construction sector. The second part of the system entailed the parties involved in demolition, sorting and breaking of construction and demolition waste and the further treatment of this type of waste. The multinational gypsum manufacturers in the first part of the system operated independently of the second part of the chain up till then. Gypsum was being reused by the gypsum manufacturers but in small amounts. This concerned only the gypsum originating from production spill overs and the relatively clean construction waste. Besides that, a large part of the gypsum containing demolition waste was being exported to Germany in order to be applied in filling old mines. This was legal, however not very sustainable.

In the following years TNO contacted different parties in the gypsum production system to start a jointly financed feasibility study. The study showed that reusing gypsum from demolition and construction waste was economically and technically viable. Also, it became clear that in Canada and Denmark two companies had a technology available to treat the gypsum from construction and demolition waste to make reuse in the manufacturing of gypsum products possible. But the first and most important result of this project was the fact that the first part of the system (gypsum manufacturers and their sector association NBVG) and the second part of the system (the demolition-, sorting- and breaking companies and their sector associations BABEX and BRBS) started to know each other and developed a common language. In the beginning of the project the different parties simply did not understand each other. They used different terms, different criteria for discussing the reuse of gypsum. Trust building also played an important role in this process. If you do not know the supplier of your secondary raw material and its way of doing business, the risk of introducing this material into your sensitive manufacturing process is high.

In the period of 2004-2007 several parties started to take initiatives to reuse gypsum. In December 2007 the Ministry of Environment and Spatial Planning launched a Cradle to Cradle programme in which various materials were explored in terms of their possibilities for a ‘Cradle to Cradle’ approach. One such material was gypsum. By then, about 20% of the gypsum present in construction and demolition waste was already being reused. The subsequent step for the agreement was then quickly made: the setting of a reuse target for 2010 which was feasible and challenging at the same time. Most of the collaborating parties signed the agreement for the reuse of gypsum.

An important lesson from this example is the fact that R&D efforts, in this case a feasibility study, can be very important in paving the way for a multi-actor driven systemic eco-innovation effort. In fact, shared research activities can play a pivotal role in the formation of networks and the shaping of advocacy coalitions.

Source: Elsbeth Roelofs (TNO)

3.3 Perspective on monitoring and evaluation

3.3.1 Purpose

Monitoring the impact of transition policy raises several methodological problems, because of the characteristics of both transitions and transition management. Systemic innovation is so complex that we simply cannot grasp what is ahead of us. Although a couple of things we can be sure of: it will be a complex, uncontrollable road full of uncertainty. A case of ‘crossing the river while searching for the stones to step on’.

A policy perspective that aims for systemic innovation will therefore run into difficulties with traditional ways of monitoring. The first difficulty in monitoring systemic innovation is the timeframe in which they take place. Some transitions take place well within a decade, but more often the change takes place over a period of one or two generations. This poses the second difficulty for transition monitoring: the dynamics of the system are the result of complex patterns of interaction between actors, institutions, etc. These complex patterns influence the innovation but many of these patterns cannot be influenced directly by governmental policy. Besides, these elements cannot easily be distinguished beforehand or even during the process of monitoring (Taanman et al, 2008).

So, what would then be a smart strategy for monitoring systemic innovation? To start with, the purpose of monitoring is threefold:

- reflection: lessons learnt should strengthen the innovation process.
- communication: make explicit and share the results and lessons learnt.
- legitimation: political legitimation of the public money spent.

Various methods of monitoring exist. Here we will introduce two approaches that are complementary in terms of their purpose. The *Learning Histories approach* is especially suitable for reflection and communication, whereas the *Reflective Monitoring* approach particularly focuses on reflection and legitimation.

3.3.2 Approach: Reflective Monitoring

Reflective Monitoring is used to benefit innovation programs characterized by:

- Setting long term goals related to societal values, e.g. people, planet and profit;
- The focus on systemic innovation as a means to achieve these goals;
- Policy interventions directed towards shaping favorable framework conditions and learning more than direct results in terms of e.g. technology diffusion;
- Multi-stakeholder approach (government, industry and knowledge institutes).

Reflective Monitoring starts from the assumption that an innovation program has a purpose of influencing / contributing to the development of weak innovation system functions. Reflective Monitoring therefore focuses on the program level (including projects and other activities depending on the required detail) but also on the innovation system level. See Table 3.3. Periodically, with intervals of typically a year, Reflective Monitoring results aid in updating the innovation program in terms its activities but also in terms of its goals.

The Reflective Monitoring methodology helps to keep the innovation program in line with quickly changing realities of the innovation system it tries to influence. The results of the monitor are primarily meant as a compass for the (government) agencies responsible for managing the innovation program. Additionally, the results can be used for communicating results and lessons learnt to stakeholders and political actors (parliament).

Tabel 3.3: Reflectieve Monitoring framework.

	Step	Activity	Focus of result
Program level	Status report	• Describe the long term vision and goals of the innovation program in terms of innovation system functions to be improved. • Describe / update activities to be executed • Describe / update stakeholders involved.	• **Goals** • **Approach**
	Progress report	• Update on output in terms of activities, publications, events. • Update on deviations / barriers within the program.	• **Output**
Innovation System level	System scan	• Update on relevant trends within the innovation system • Analysis of key drivers and barriers, related to seven system functions, within the innovation system.	• **Outcome**
	Reflection	• Assess contribution of program activities to the innovation system trends. • Assess the relevance of program goals. • Consider whether it is desirable / sensible to adapt the innovation program to fit the current state of the innovation system.	• **Impact on the innovation system** • **Adaptation of the program**

Sources: Taanman et al. (2008), Suurs et al. (2011).

Reflective Monitoring for Energy Innovation in the built environment:

The Reflective Monitoring Framework has been applied, since four years, within the context of the Dutch Innovation Agenda Energy in the Built Environment (IAGO in Dutch). The identification and quantification of innovation system performance was done with the aid of a dedicated expert panel that was specifically established for the purpose of monitoring the government's innovation programming activities. This panel consists of about 60 representatives covering industry (architects, construction companies), government (municipalities, ministry), knowledge institutes, branche organisations and other actors (e.g. a bank, investment funds).

The expert panel served, and still serves, as a mirror of the innovation system for 'energy-innovation in the built environment'. The panel aids in identification of trends, as well as more specific drivers and barriers related to the seven system functions. This is done by means of an web-based survey. Once a year the expert panel gathers for a Reflective Dialogue to exchange ideas on the most important topics. The survey provides a semi-quantitative image of the innovation system based on a aggregation of the experts' perceptions. The Reflective Dialogue is crucial in getting to the bottom of these perceptions, especially when conflicts of opinion exist.

Among other things the monitor results have over the years resulted in the following recommendations:

- Support educational curricula on 'energy neutral building approaches'.
- Make sure that successes of the IAGO program (tools, manuals, courses, business models) are actively shared with entrepreneurs and other target groups not currently participating in the program or its projects.
- Connect the program's demonstration projects (buildings being renovated) to so-called communities of practice (learning networks consisting of users and producers).
- Pay attention to the need for 'flanking' innovation policies, i.e. energy taxes and other incentives for real estate owners to invest in energy neutral innovations.

3.3.3 *Approach: Learning Histories*

The Learning History is a method developed by MIT researchers Roth and Kleiner (Roth, Kleiner, 1995) in the tradition of 'organizational learning' (Roth & Senge) and action research. The method aims at supporting organizations in learning from their own change and innovation processes (‘create a collective history’). It can be considered as an organizational reflection and documentation process in which researchers and the stakeholders in the organisation work together as an insider/outsider team. ‘The learning history approach help the subjects to assess and evaluate themselves as researchers capture the data which also allows the larger learning process to be documented.’ (Roth, Senge, 1996).

The way of working in the Learning History process creates ‘jointly told tales’ that describe work issues and learning experiences from multiple and sometimes contradictory perspectives. As Roth and Senge state it: ‘Learning Histories are proven to be effective in engaging and influencing readers, because of the extensive use of participants’ own narratives to capture their own coherent stories about complex realities.’ (Roth & Senge, 1996). A Learning History focuses not so much on accountability of the involved, but rather on the ways of improving processes and ways of working.

In a Learning History three levels can be distinguished:

- factual events;
- perceptions of these events by the various involved stakeholders;
- reflection on these events and perceptions by the researchers and other non-involved experts.

The Learning Histories as applied within the Dutch energy transition

The Dutch Ministry of Economic Affairs assigned TNO to make the first step in evaluating the policy making process of the Energy Transition by making four Learning Histories. The objectives of this project were:

- Exchanging and documenting lessons learned in the development of the innovation programs of the Societal Innovation Agenda Energy;
- Making accessible the lessons learned in the development of the innovation programs to the program teams of other innovation programs and to the management;
- Formulating ‘ Best Practices’ in the development of the innovation programs.

The Learning Histories were initially focused on the policy making process of formulating the innovation programs of the Societal Innovation Agenda Energy (June 2008-December 2008). However, after the first contacts with the civil servants involved in the development of the innovation programs, it was concluded that it was impossible to comprehend the lessons learned without understanding what happened before. Therefore, the period was extended to the start of the vision and strategy development in the transition platforms (see Section 3.1).

Four innovation programs were selected for monitoring: the innovation program Biobased Raw Materials, Experiments for Sustainable Mobility, Energy in the Built Environment and Precision Agriculture. The selection criteria for the innovation programs were 1) that the innovation program was developed, so the development process could be studied; 2) the development process seemed to have successful elements which would be interesting to study; 3) coverage of all six Ministries involved.

3.3.4 *Criticism*

- The value of lessons learnt, as captured by Learning Histories or Reflective Monitoring efforts, is undeniable. Nevertheless it is a challenge to capture the negative lessons and not merely the 'success stories'.

- In spite of many efforts on behalf of researchers, the outcomes of policy programmes aiming for systemic innovations remain hard to grasp in quantitative terms. This is at least partially due to the nature of these programs. After all, due to the long term and the indirect way of aiming for results, a lot of the effects are hard to attribute to particular policy efforts.

- The critical potential of Reflective Monitoring approaches is ultimately derived from expert judgement. This implies that the approach is susceptible to interpretation bias. It is the responsibility of the evaluator to be transparent about this.

3.3.5 *Summary for practitioners*

- Monitoring and evaluation serves the following purposes:
  - reflection: lessons learnt should strengthen the innovation process.
  - communication: make explicit and share the results and lessons learnt.
  - legitimation: political legitimation of the public money spent.

- Still, a policy perspective that aims for systemic eco-innovation will run into difficulties with traditional ways of monitoring.
  - A first difficulty in monitoring systemic eco-innovation is the timeframe in which socio-technical transitions they take place.
  - A second difficulty: the dynamics of the systems are the result of complex patterns of interaction between actors, institutions and technologies.

- This chapter introduces two approaches that are complementary in terms of their purpose. The *Learning Histories approach* is especially suitable for reflection and communication, whereas the *Reflective Monitoring* approach particularly focuses on reflection and legitimation.

- Key features of both approaches is that:
  - they focus on different levels of performance, ranging from facts to interpretation and reflection.
  - they focus on results as well as lessons learnt.
  - they focus on updating goals as well as updating activities.

4 Recommendations for research and policy programming

The following sections provide key lessons for policy makers aspiring to design policy programmes in support of systemic (eco-)innovation. The lessons are based on the three policy perspectives elaborated upon in the previous section.

Disrupt the existing regime dynamics and lock-in.

- Systemic eco-innovation implies a (partial) destabilization of the current socio-technical regime. There is no *direct* way to achieve this destabilization, or, in any case, it is usually not politically viable to do so. Nevertheless, A systemic eco-innovation program should have the ambition to disrupt the status-quo of e.g. the energy system or the chemical industry. This implies that the program should be somewhat decoupled from vested political institutions. In the formative stage of the program, incumbents with an interest in the status quo should be excluded altogether.

- Systemic eco-innovation programs should adopt a steering philosophy, such as the Transition Management Policy cycle, that acknowledges complexity and the fundamental uncertainties that come with it (see Figure 3.1 in Section 3.1). A systemic eco-innovation program should allocate time and budget for mobilizing relevant stakeholders and for setting up a process that involves vision building, coalition building, experimentation and (reflective) monitoring (see Section 3.1).

- Systemic eco-innovation is about fundamental changes in both social (values, regulations, attitudes etc.) and technical (infrastructure, technology, tools, production processes etc.) dimensions and the relations between them. A systemic eco-innovation program should acknowledge this by supporting technology development in relation to societal factors. This implies that:
  - Program goals are directed towards improving a societal function, e.g. mobility, covering environmental aspects but also business and well-being.
  - R&D projects will involve societal goals besides just technology.
  - R&D support will have to be part of a broader policy mix. This requires harmonisation with tax legislation, environmental norms, etcetera.

Lessons on involving SMEs:

Systemic eco-innovation programs do well to target ongoing practices, for example on the level of self-organizing communities, regional industry networks and other initiatives. It is important to consider the incentives of companies and people involved when setting up a program around such initiatives. In some cases an asymmetry between funded project partners and non-funded local partners can lead to a lack of commitment, even if the innovation program has a clear added value.

Care should be taken not to lose interest from small innovative companies. Participation in subsidized projects often requires a time investment. Also, it is common practice to require co-funding from participating actors. A downside is that SMEs are often unable or unwilling to put in such investments (of time and money) if outcomes are uncertain.

Organise transition arena's and set up transition experiments (niches)

- Start by structuring the policy challenge on the system level with a small group of leading frontrunners (start of a transition arena). Consider this transition arena as the main organisational unit for the systemic eco-innovation program.

- Build actor coalitions (so-called transition platforms) and develop a so-called transition agenda. Systemic eco-innovation requires thinking in terms of multiple domains (e.g. energy, transport and waste), lack of silo's and a broad variety of stakeholders.

- The support of systemic eco-innovation requires a long-term perspective (25 years). Nevertheless, usually the time period for the innovation program will be limited to four years or less. The systemic eco-innovation program should nevertheless develop a vision for a longer time period, along with a set of milestones that show how its ambition / vision may be realised.

- The systemic eco-innovation process should be supported by setting up transition experiments. A systemic eco-innovation program will create and foster a large variety of such niche experiments. Various niches are to be explored simultaneously to avoid lock-in for the future.

Lessons from previous policy successes:
Systemic eco-innovation programs should not reinvent the wheel. After all the systemic nature is about combining and integrating more than about generating completely new ideas. And in fact, policy makers from all over the world have developed powerful instruments that may play a key role as part of a systemic policy mix. For example, the SBIR program, originally developed by the American government in the 1980s, commissions small companies to conduct societal relevant innovative research – and with great success. Leading companies have been established as a result of an SBIR assignment; examples include telecom company Qualcomm and software producer Symantec. Inspired by American successes, the Dutch government has started its own SBIR program in 2005. The Dutch Government has used its procurement power to mobilize the innovative capacity of Dutch companies to solve major societal challenges, such as mobility, sustainability, safety and health. At the same time, the SBIR promotes innovation, especially in small and medium-sized companies, strengthens the business climate and increases the competitiveness of Dutch companies.
Source: http://www.rvo.nl/

- Consider the 'transition experiment' as the operational unit of the systemic eco-innovation program (i.e. instead of projects). Note that projects are not transition-experiments. For one thing, transition experiments are part of a broader societal movement / process and linked to a long term vision. Experiments are to be considered as:
    - practical applications
    - socially embedded, e.g. living labs
    - stepping stones leading to follow-up / scale-up / spin-off

- Ideally, transition experiments make up a connected set of related projects that complement each other. A systemic eco-innovation program facilitates the exchange of information and lessons learnt between experiments. See Table I in Appendix 1 for some principles for setting up and steering these experiments.

- For a transition to happen, a variety of niche innovations need to build up momentum through learning processes, price-performance improvements and, eventually, also through the external support from powerful groups and market pull. See Table II in Appendix 1 for a set of steering principles.

Lessons on shaping interdisciplinary networks and preventing silo's:
One way of making sure the program does not fall subject to tunnel visions is to include actors from various parts of industry (SMEs, large companies from different sectors) and also from government and research organizations. For example, the Dutch 'Duurzaam Door' program only funded projects when stakeholder participation from the so-called 5 O's is guaranteed: Overheid (government), Ondernemers (entrepreneurs), Onderzoek (research), Onderwijs (education) en Onderop (civil society).

Linking actors in a formal program does not automatically result in cooperation and learning. It is therefore crucial to put a serious effort in selecting the right people and keeping a close eye on the process of cooperation during the course of the program. A good example here is the Dutch 'Energiesprong' program which works with professional process directors. These people have knowledge of the field but are also strong networkers with a keen eye for social processes. Another possibility is to support so-called pre-project path finding. The idea here is that actors are supported, with funding and other forms of support, to develop a joint project proposal.

Innovation programs, like FP7 projects, tend to be subdivided in sub-structures like work packages where individual actors carry responsibility for separate tasks. The evaluation of the Dutch 'Gebieden Energie Neutraal' (Energy Neutral Districts) program has revealed that such structures ten to result in silo-thinking, thereby hampering development of interdisciplinary solutions. Such disciplinary silo's may be useful but only at the start of a project, for example to generate and share a state of the art knowledge position for all actors involved.

Foster the development of innovation systems

- Traditional innovation policies have largely focused on solely funding R&D, thereby neglecting the systemic nature of innovation. A systemic eco-innovation program should consider innovation as an inherently systemic process.

- This means that the systemic eco-innovation program should identify a series of promising (key enabling) technologies that may benefit the transition envisioned (determined through negotiations within the transition arena). Ideally, the transition experiments are related to these technologies, although this is not necessary.

- The systemic eco-innovation program will support these technologies by developing a mix of policy instruments that target seven innovation system functions (see Table 2.1).

- The premise is that a well-functioning innovation system will increase the chance of the technologies coming to maturation. Once a technological innovation takes off, it is expected to replace or rearrange important structures that support incumbent technologies, thereby putting pressure on the incumbent regime and establishing a contribution to a socio-technical transition.

Systemic eco-innovation requires new forms of monitoring and evaluation, covering goal searching and focusing on results as well as lessons learnt

- The purpose of monitoring is threefold:
    - reflection: lessons learnt should strengthen the innovation process.
    - communication: make explicit and share the results and lessons of the innovation process.
    - legitimation: political legitimation of the public money spent

- In the face of fundamental uncertainties, lessons learnt are as important as outcomes. Learning is also about adjusting 'goals', doing things better or more effective. Use *Learning Histories* and *Reflective Monitoring* methodologies to make these results explicit (see Section 3.3).

- Monitoring and learning takes place at various levels of the systemic eco-innovation program.
    - The experiments should be complemented by activities focusing on learning and monitoring.
    - The overall direction of the program may be monitored by periodically using the Innovation System Analysis (ISA). The result will aid in adjusting the vision and milestones of the systemic eco-innovation program.

Lessons on evaluation and monitoring:

Monitoring and evaluation can be tricky for a policy program where actual outcomes are not precisely determined beforehand. This requires a new approach to measuring outcomes and impact that leans on various forms of expert judgment (are we doing the right things?) more than simple facts (did we do the things we promised to do?). This implies that monitoring and evaluation are not entirely neutral activities. The experts will start out as independent from the innovation program. But over time they will get to know each other and they will grow more familiar with the goals and activities of the program. In some instances they may be or become participants in projects of the program. This should be treated with care and transparency.

More importantly it should also be considered as an opportunity to incorporate monitoring activities as part of a broader learning process. For example, the Dutch ‘Gebieden Energie Neutraal’ (Energy Neutral Districts) program was originally monitored very strictly, using a list of specified deliverables as performance indicators. It turned out, during the course of the program, that these deliverables were not actually helping innovation. As a solution to this problem the ministry decided that a more general set of goals should be used. Moreover, program management may deviate from the goals if properly motivated. This is where Reflective Monitoring is important as this methodology makes sure that the innovation program is monitored in terms of (changes to goals), results and lessons learnt.

A classic problem for innovation programs and projects is the phenomenon that knowledge developed remains enclosed within the boundaries of the project and actors involved. Even worse, insights tend to stick to particular people / single (R&D) departments of an organization. A systemic eco-innovation program should make sure that attention is paid to dissemination of results and lessons learnt. This may be supported by making use of Reflective Monitoring results, as well as by developing Learning Histories.

A note on leadership:
Setting up the structure and content of a program is one thing. But in the end, like many things, the development of systemic eco-innovation revolves around people. Systemic eco-innovation requires a sustained effort that can only be provided by people with a strong personal drive to bring about change. Transition leaders should be equipped with a skill-set that fits this challenge. Think of:

- General project management skills
- In-depth understanding of relevant domains / technologies
- Empathic, good at networking and overseeing stakeholder relations
- Communicative, especially with respect to managing of expectations
- Flexible, responsive to change

At the same time systemic eco-innovation programs do require different types of leaders depending on particular roles and also on the development stage of the program:

Niche leaders / experiment level:
The leaders of transition experiments should focus on learning and development of out-of-the-box solutions. Typically these people have an entrepreneurial attitude. They work on practical solutions and are able to motivate others to work with them. They tend to ignore administrative boundaries / silo's.

Innovation System leaders / program level:
Program leaders should develop a portfolio of viable transition experiments / niches. Therefore these people should understand the nature and dynamics of the innovation systems relevant to the program they are part of. Typically these people take responsibility for facilitating organizational processes and exchange of knowledge. They are good at communicating results as well as in explaining setbacks. These people should be able to connect the experiment level with the government level.

Regime leaders / governance level:
Regime leaders are usually the 'owners' of the systemic eco-innovation program. These people are responsible for funding and authorizing policies. They usually also play a key role in maintaining incumbent societal functions. Think of ministers or CEOs of large companies. These people tend to minimize risk and to maintain a balance in the existing status quo, e.g. serving industry interests. The more developed a systemic eco-innovation program will be, the more important it is to involve regime leaders in the systemic eco-innovation program. Vice versa, a successful systemic eco-innovation program may be able to put forward new leaders to (over)take a position in the regime.

Source: Roald Suurs (TNO), loosely based on ideas from Caluwé & Vermaak: www.decaluwe.nl/articles/ChangeParadigms.pdf

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Appendix I : Overviews, schemes, tools

Table I: Steering dimensions for transition experiments.

Steering dimensions / Success criteria	Deepening actions aimed at learning as much as possible from the experiment in the specific context	Broadening actions aimed at repeating the experiment in other contexts or connecting to other functions and domains	Scaling up actions aimed at embedding the experiment in dominant ways of thinking, doing and organizing
Process			
Room in budget and planning	- allocating resources (time, money, knowledge, etc.) to an open search and learning process;	- allocating resources to interaction with other domains and partners;	- allocating resources to (early) involvement of key actors at a strategic level;
Space in the process	- building in space for reflection on and adjustment of the vision and learning goals;	- building in space for reflection on the connection to the broader context;	- building in strategic reflection on barriers and opportunities in dominant ways of thinking, doing and organizing;
Quality of learning process	- organizing a broad, reflexive and social learning process;	- focusing the learning process on how experiments can reinforce each other;	- focusing the learning process on how learning experiences can be embedded in dominant ways of thinking, doing and organizing;
Supportive incentives / assessment mechanisms	- developing supportive incentives / assessment mechanisms that increase the quality of learning;	- developing supportive incentives / assessment mechanisms that stimulate interaction with other domains and partners;	- developing supportive incentives / assessment mechanisms that stimulate feeding back results to key actors at a strategic level;
Competences of project participants	- selecting project participants with an open mind and willingness to learn;	- selecting project participants that are able to look outside the borders of their discipline and are strong 'connectors';	- selecting project participants that are able to communicate and 'anchor' project results at a strategic level;
Strategic management	- the management guarantees that project results are related to the societal challenge;	- the management guarantees the interaction with other domains and partners;	- the management guarantees connection to key actors and developments at strategic level;
Substance			
Connection to societal challenge	- connecting project goals explicitly to societal (transition-)goals;	- cooperating with partners and developing new partnerships to realize shared societal goals;	- adapting to sense of urgency with regard to societal challenge;
Sustainability vision / future perspective	- project participants share a long term sustainability vision;	- developing an overarching sustainability vision to provide guidance to different experiments;	- drawing attention to the sustainability vision at a strategic level;
System analysis (dominant culture, practices, structure in sector)	- project participants share perspective on dominant ways of thinking, doing and organizing in the sector (from which the experiment deviates);	- identifying similar experiments and potential new partners, application domains and functions;	- identifying key actors with power and willingness to influence dominant culture, practices and structure;
Learning goals/ desired changes (innovation)	- formulating explicit learning goals with regard to desired (interrelated) changes in culture, practices and structures;	- repeating the experiment in other contexts and experimenting with new functions is part of the learning goals;	- anticipating and learning about barriers and opportunities in dominant culture, practices and structures is part of the learning goals;
Intended results	- distinguishing results in generic and context specific;	- sharing results with other experiments and potential application domains;	- stimulating structural (regime) support and resources for results;

Source: Van de Lindt; Kemp & Van den Bosch (2006)

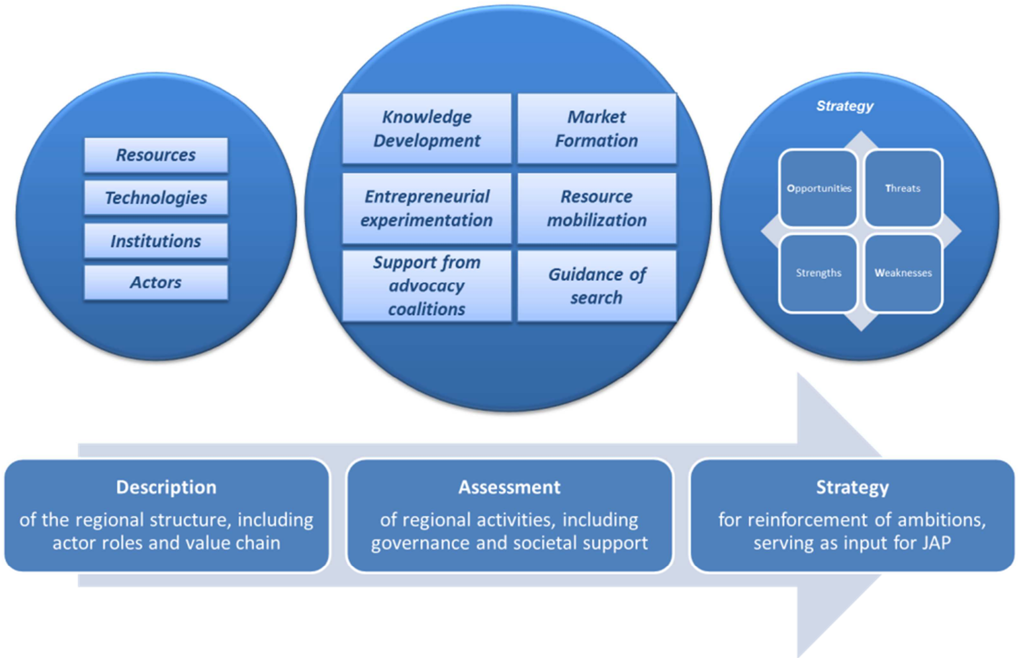

Figure I: Innovation System Analysis as applied within the context of a regional resource efficiency challenge. The picture shows how the analysis consists of an analysis of structures (description), system functions (assessment) and evaluation (strategy) (Source: FP7 project R4R).

Table II: Key processes relevant for policy makers (Kern, 2012).

Niche	Learning processes E.g. learning processes have stabilised in a dominant design	Price–performance improvements E.g. price–performance improvements have been made and are believed to continue to improve	Support from powerful groups E.g. powerful actors have joined the support network	Establishing market niches E.g. innovation is used in market niches
Regime	Changes in rules E.g. belief systems, problem agenda's, guiding principles, search heuristics; relationships, behavioural norms; regulations, standards, laws	Changes in technologies E.g. in the case of electricity: resources, grid, generation plants	Changes in social networks E.g. new market entrants gain in importance compared to incumbents	
Landscape	Macro-economic trends E.g. globalisation, oils crisis	Socio-economic trends E.g. recessions, unemployment developments	Macro-political developments E.g. the 'philosophy' behind policy making	Deep cultural patterns E.g. trend towards more 'individualization'