

Review of System Innovation and Transitions Theories

*Concepts and frameworks for understanding and enabling
transitions to a low carbon built environment*

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Executive Summary

- This report reviews the literature on innovation and transition theory with a view to gaining a greater understanding of the nature of innovation processes, particularly those involving disruptive change and systems transformation. The report has been commissioned by the *Visions and Pathways 2040* project for the CRC for Low Carbon Living. A key aim of the review is to supply insights and frameworks to assist the visioning, pathway analysis and policy work of the project.
- There are a number of variations in the use of the term “innovation”. These variations depend on, for example, where the innovation is located in the value chain (e.g. product, process or organisational innovation), the novelty of the knowledge underlying the innovation, or the extent of the economic /market impact of the innovation. Confusingly, the idea of “incremental” versus “radical” innovation is often applied to both the second and the third of these situations. The move to a low carbon urban future will most likely not rely on one or even a small number of technological innovations, but is likely to arise from a constellation of interacting systems of innovations, some involving radical knowledge-based innovation and some involving incremental and “recombinative” innovations. Another term commonly used interchangeably with systems innovation is “transition”.
- The theory of innovations and transitions is not based on any single discipline or school of thought. Rather, the concepts and insights draw upon a broad range of disciplines and practices going back to the first half of the 20th century. Early economic theories viewed the innovation process as a relatively simple, one-directional process from invention to commercial development to diffusion into the market place. A consequence of this linear model was a strong prioritisation of either supply–push factors such as research and development (R&D) or demand–pull factors such as relative prices as the drivers of innovation.
- Modern thinking on innovation has a more nuanced and richer picture, with a wider set of implications for those hoping to assist, shape or direct the innovation process and system change. Key ideas include appreciating the importance of actor networks; the role of institutions; the co-evolutionary nature of the technologies, institutions, social practices and business strategies; the role of feedback and path dependency in socio-economic systems; and a greater understanding of the different types of knowledge and learning processes.
- Technological innovation systems (TIS) theory is a useful heuristic framework that uses many of these concepts for analysing the success or failure of a technology on the basis of the performance of the surrounding technological system. It includes identifying the key structural elements of a TIS (e.g. actors, institutions, interactions and infrastructures) and key functions of a TIS (e.g. entrepreneurial activity, knowledge development and diffusion, market formation, expectations and goal formation, resource mobilisation and the formation of advocacy coalitions).
- The multi-level perspective (MLP) is another heuristic framework, which takes a broader approach than TIS theory by looking at transformative societal processes. These may include a variety of innovations. It is part of the socio-technical transitions theory pioneered by Dutch researchers. The MLP posits three levels to aid understanding transitions: a landscape (macro) level that encompasses the dynamics of deep cultural, economic and political patterns; a regime (meso) level that refers to the current practices, routines and dominant rules that prevail in a socio-technical system; and a niche (micro) level which represents the space where actors experiment with radical innovations that may challenge and break through into the prevailing regime.
- These concepts and frameworks have been used to support the formation of innovation and transitions policies. By focusing on systems and the dynamics and drivers of change, they allow for a perspective on fostering innovation that goes beyond mere diagnosis of “externality” market failures, which is the main basis of innovation policy grounded in neoclassical economics. The TIS policy approach involves monitoring the key structures and functions of a technological system to see whether weaknesses exist in the system and to pinpoint where improvements could be made. Strategic niche management (SNM) and transition management (TM) have evolved as policy-centric frameworks in the Dutch socio-technical transitions tradition and also use MLP. Their advice includes paying attention to the role of visions, the development of actor networks, facilitating learning, creation of nurturing spaces for niche innovations, and strategies for up-scaling niche innovations.

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1. Introduction

As cities and urban lifestyles account for three quarters of global energy demand and greenhouse gas emissions, it is generally agreed that they will play a crucial role in any attempt to reduce energy use and greenhouse gas emissions to the extent that scientists say is required (Bicknell et al 2009; UNEP 2011; Newton 2011). However, there is less agreement as to whether such reductions can be achieved by means of incremental improvements in efficiency and waste reduction (by means, for example, of technical improvements to products and processes) that keep our lifestyles and physical and social infrastructures relatively unchanged. Increasingly, the view is that a radical and transformative restructuring is needed of our most fundamental systems for urban living (Ryan 2013).

Radical systems innovations or transitions involve “innovations that are directed to redesigning entire systems of practices and provisions, instead of individual products or processes” (Sterrenberg et al 2013: 9). These include the domains of housing, mobility, food, community practices, city infrastructures and urban form. Widening the boundaries to include entire systems makes possible gains in sustainability that are potentially much greater than those from single product or process innovations, which are the focus of traditional eco-design or end-of-pipe innovations.

This report reviews the literature on innovation and transition theory with a view to gaining a greater understanding of the nature of innovation processes, particularly those involving

disruptive change and systems transformation. The report has been commissioned by the *Visions and Pathways 2040* project for the CRC for Low Carbon Living. A key aim of the review is to supply insights and frameworks to assist the visioning, pathway analysis and policy work of the project.

The literature on innovation and transitions is enormous and this review will only cover key concepts and frameworks that are particularly relevant in the area of sustainability. As mentioned already, a particular focus is on system changes (macro- and meso-level). However, given that system changes usually involve a constellation of lower-level innovations, and indeed are often initiated by the emergence of niche innovations, we will also be covering some key understandings of the micro-level.

The literature we draw upon may be described as innovation theory, systems innovation theory and transition theory. However, this does not imply that the concepts and frameworks for understanding disruptive change are contained in a single discipline or school of thought. Rather, the insights presented here draw upon a broad range of disciplines.

A significant feature of the development of modern innovation thinking, particularly in the area of sustainability, has been a gradual broadening of the scope of both problem framing and analytical framing (Smith et al 2010). That is, first, the object of innovation has been extended from the 1980s focus on cleaner technologies towards interest in the entire system of production and consumption. Second, the analytical frames and considerations that have been used to study innovation processes have been enlarged from a focus on the role of the inventor (supply side) or price signals inducing innovation (demand side) to include a much broader set of systemic issues that may propel or impede the development of an innovation or set of innovations (including the role of networking and coalition building, mechanisms of knowledge diffusion, processes of legitimation and social acceptance, and so on).



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In this review we first look at a number of key ideas and concepts that have emerged in innovation thinking over the last half-century, and then examine two prominent frameworks for understanding innovation, particularly system change. The *Innovation Systems* approach, particularly the *Technological Innovation Systems* version, is an influential analytical framework that emerged in the 1990s for identifying the structure and functions of innovation systems and has been applied in a number of areas. The *Socio-Technical Transition* approach, particularly the *Multi-Level Perspective*, is a framework that developed out of historical studies of transitions in areas such as energy and transport, and is particularly powerful in understanding the complex interplay of different forces at the macro-, meso- and micro-level in creating disruptive change.

The literature does not provide consensus on the best approach, and each of the frameworks discussed here has its critics. However, we hope to give the general reader who is unfamiliar with innovation and transition theory a flavour of the complex web of elements and issues involved in understanding innovation and systems change. This includes dispelling the myth that transformative change will be driven exclusively by scientists and engineers. Rather, the perspective adopted here argues that any potential disruptive system change will likely be the outcome of a large set of multiple actors (public and private) interacting on multiple levels and operating under a web of multiple technological, economic and social dynamics.

These theories have been applied across a large number of industries and technologies, some of which have been related to sustainability issues but less in specific application to the built environment. Side boxes throughout this report present examples of the application of concepts and frameworks to cities and sustainable urban living. Given the multi-modal complexity and scale of a city, the applicability of some of these frameworks to cities is still up for debate (e.g. Naess and Vogel 2012) and an important ongoing research goal of the *Visions and Pathways*

2040 project is to determine the strengths and weaknesses of these frameworks in relation to urban settings.

Section 2 of this report provides a few clarifying comments on the somewhat confusing terminology relating to the different types of innovations referred to in the literature. Section 3 presents a number of key concepts and insight that have emerged in innovation thinking over the last half century. Section 4 examines two specific frameworks that incorporate these ideas into systems approaches for understanding innovation and transition. Some of the potential policy implications that emerge from these frameworks are presented in section 5. Section 6 concludes the report.

2. Incremental, radical and systems innovation

The literature on innovation contains many categorisations of innovation along many different dimensions. One survey by Garcia and Calantone (2002) found 15 different constructs for categorising innovation from only 21 studies. There is little consensus on the correct use of such terminology, with many terms having strongly overlapping meanings while the same term is often used in different ways. Typical distinctions one encounters in the literature are *incremental vs. radical* innovation (Dewar and Dutton, 1986), *evolutionary vs. revolutionary* innovation (Tushman and O'Reilly 1996), *sustaining vs. disruptive* innovation (Christensen 1997), and *product vs. process vs. organisational* innovation (OECD, 1997). Some typologies are orientated towards a firm or managerial perspective whereas others are orientated towards more macroeconomic or systems research perspective.

Two of the most common terms – incremental and radical innovation – are often distinguished using one or both of the following criteria (Bell 201226):

1. The novelty of the knowledge base underlying the innovation.

Here we can think of a “radical” innovation as involving a considerable discontinuity in the knowledge base underlying the technical system (whether the product, production process, administration, etc). Whereas incremental innovations have a greater continuity in the type of knowledge employed.

2. The scale and significance of the economic (and other)

consequences of the innovation. The idea here is that the impacts and effects of radical innovation are much greater and probably more “disruptive” than those of incremental innovations.

Unfortunately for the purposes of terminological clarity, as Bell (2009) has noted, differences between innovations in terms of their market or economic impact does not always align well with their technological novelty. Christensen (1997), for example, in his case study research on the computer disk drive industry, found that many of the innovation that led to significant new markets and overturned existing markets or value networks (what Christensen terms “disruptive innovation”) were not always “radical” in the sense of a novel discontinuity in the underlying knowledge base; rather, they often amounted to repackaging off-the-shelf components so as to create a new value proposition to customers. The implication for low carbon pathways, which is concerned with end-result impacts on emissions, is that we do not necessarily have to rely on “radical” innovation in the sense of an abrupt discontinuity in the underlying knowledge of the relevant system. Ryan (2004) coined the term “recombinant innovation” to capture the idea that the next (sustainable) industrial revolution may be located significantly within the progressive and cumulative transformation of existing systems of production and consumption to make them more resource efficient and less polluting.

As alluded to in the introduction, the transition to a low carbon urban future will most likely not depend on one or even a small number of technological innovations, but is likely to arise from a constellation of mutually interacting systems of innovations. In moving from a single innovation, to a cluster, to a system of innovation, perhaps the most well known taxonomy is the one developed by Freeman and Perez (1988) based on empirical research conducted at the influential Science and Technology Policy Research Unit (SPRU) at the University of Sussex, UK. Table 1 (see next page) presents their four level taxonomy of innovation.

Table 1. Freeman and Perez (1988) Taxonomy of innovations

Type of innovation	Description
Incremental innovations	Innovations that occur continuously, that are not the result of deliberate R&D, but outcomes of inventions and improvements suggested by the production people or proposals by users (“learning-by-doing” and “learning-by-using”).
Radical innovations	Discontinuous events, usually as a result of deliberate R&D in an enterprise or university. They lead to growth of new markets and investments, but are relatively small in aggregate economic impact
Changes of technology systems	These are far reaching changes in technology, affecting several branches of the economy, as well as giving rise to entirely new sectors. They are based on a combination of radical and incremental innovations affecting more than one or a few firms.
Changes in “techno-economic paradigm” (“technological revolutions”)	A major influence on the behaviour of the entire economy (“pervasive effects”). Created through many clusters of radical and incremental innovations. Not only create a new range of products, services, systems and industries, but also affect almost all the other branches of the economy. The changes involved go beyond engineering trajectories for specific product or process technologies and affect the input cost structure and conditions of production and distribution throughout the system.

A feature of the last two categories, which involve clusters or aggregation of innovations, is that they rely on both incremental and radical innovation. It is therefore a mistake to underestimate the importance of cumulative, incremental innovation in our understanding of major transformative change. Indeed, the benefits of many radical innovations – including the automobile and airplane – have only been recognised through a series of supporting incremental improvements (Geels 2005; Dolata 2011).

Another commonly used term in the literature is “system innovation”. Depending on the writer, this can refer to either

of the last two categories of Freeman and Perez’s typology. In most cases, the term covers not only product and process innovations but also changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle and management of firms (see, for example, Berkhout 2002; Kemp & Rotmans 2005; Geels 2006). Another common term, “transition”, is often used interchangeably with the term “systems innovation”, either at the technology system or society-wide level. Kemp and Rotmans (2005), however, argue that “For the purposes of managing change processes to sustainability it is useful to use the concept



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of a ‘transition’ rather than system innovation” since it brings into focus the new state, the path towards the end state, the transition problems and the wide range of internal and external developments which shape the outcome (36). Also note that sometimes the term “transitions theory” is used to refer to “transition management”; the latter is usually associated with a specific research stream in the EU (mainly in the Netherlands). However, in this report we will continue to attach a more generic interpretation to the term “transition theory”.

3. Selected key insights from modern innovation and transition theory

Schumpeter (1934, 1942) is often identified as the first to feature innovation as a central driver of the economy and to reject neoclassical economics' idea of a static equilibrium. His idea that the process of innovation "incessantly revolutionises the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (Schumpeter 1942:83) continues to be influential to this day. However, Schumpeter and his followers employed a rather simple, one-directional perspective of the innovation processes. The so-called "linear model" of innovation begins with an invention (perhaps from a scientific discovery), is developed into a commercially viable technology in a firm, and is then diffused into the market place. A consequence of this model was a strong prioritisation of research and development (R&D) and the entrepreneur as the driver of innovation. This is sometimes referred to as the technology- or supply-push perspective of innovation. An alternative perspective put forward in the 1950s and 60s, but still within the linear model approach, was that demand for products and services is more important in stimulating innovation activity and is known as the demand-pull perspective (Schmookler 1966). The idea of introducing carbon pricing, with its subsequent effect on relative prices, as a means of bringing cleaner technologies and products to the market, follows this logic.

Over the last fifty years, a more nuanced and richer picture of the innovation process has emerged, with a wider set of implications for those hoping to assist, shape or direct it. In the following subsections we review a selection of key insights that have emerged over this period and look at two approaches that incorporate many of these ideas into a heuristic framework for understanding system innovations and transitions.

3.1 Multiple actors and networks

Modern innovation theory has moved towards the recognition that innovation is a joint activity involving a large number of actors with different interests, perceptions, capabilities and roles. In particular, it removes the prejudice that the economy is entirely made of entrepreneurs. In particular, the technological innovation systems approach (see below) pays much attention to understanding the structure and networks of actors. The heterogeneity of actors, including differences in risk averseness, perceptions of the economic environment and imperfect abilities to imitate the innovations of others, also provides a theoretical underpinning for explaining why there is any innovation at all (which is less easily explainable under neoclassical assumptions).

A particularly interesting development is the growing recognition of the importance of users (firms and individual consumers) in the innovation process. It is not just that product and service developers are more sensitive to the wants and needs of users, but rather that users are increasingly developing or adapting their own goods and services, sometimes aided by the availability of improvements in computer and communication technology (Bogers et al 2010; von Hippel 2005). This has led in many areas to thriving user innovation communities and rich intellectual commons, which also feed back to manufacturers to mass produce new products and services. Product innovation by users has been shown to be especially prolific in the field of sporting devices such as kiteboarding (Franke et al 2006) and mountain-biking (Liithje et al 2005) as well as juvenile products (Shah and Tripsas 2007) and music devices and software (Faulkner and Runde 2009).

In the context of the *Visions and Pathways 2040* project, having a wide set of participants has been deemed central to the potential success of the project. Participants in the project are to include industry (property developers, materials suppliers, energy specialists, architects, planning, urban design and engineering service companies and built environment related peak bodies), state and federal governments, city councils, universities from Australia and Europe, public utilities, planning agencies, the national standards organisation, TAFE and CSIRO.

3.2 Interactivity, feedback and complexity

Compared to the linear model, an important feature of the modern approach to innovation is the interactivity among agents and feedbacks between different stages of the innovation processes (Kline and Rosenberg 1986). Like the previous theme, this resonates strongly with the field of complexity science which investigates how relationships between parts give rise to the collective behaviours of a system, and emphasises non-linear dynamics, heterogeneous agents, networks, evolution and the emergence of system properties (Mitchell 2011).

The idea of the economy as a complex adaptive system has been developed into so-called "complexity economics" (Arthur 1999) and complexity system tools such as agent based modelling are increasingly being applied to economics. Such tools may be particularly useful in modelling discontinuous, disruptive systems change (versus the marginal, incremental approach usually implicit in neoclassical economics). The complexity of interaction and interdependence also occurs between (as well as within) systems and, as Foxon et al (2013) note, this is highly relevant to analysing sustainability issues in which there are complex interactions between economic, social and ecological systems.

3.3 Institutions and culture

Whereas neo-classical economics has a minimal understanding of institutions, evolutionary economics and modern innovation theory give institutions a central role in enabling, constraining and shaping our behaviours and practices. Indeed, it may be argued that many of the limitations of neoclassical economics result from considering interaction of rational agents with no meaningful analysis of the institutional environment in which business and policy decisions are taken (Foxon et al 2013). The atomistic nature of this model also under-appreciates the role of culture – the ideas, customs, and social behaviour of a particular people or society – which belies the idea that people are born with given “preference functions” or behavioural practices that are not historical and culturally contingent and open to change (Ormerod 1998).

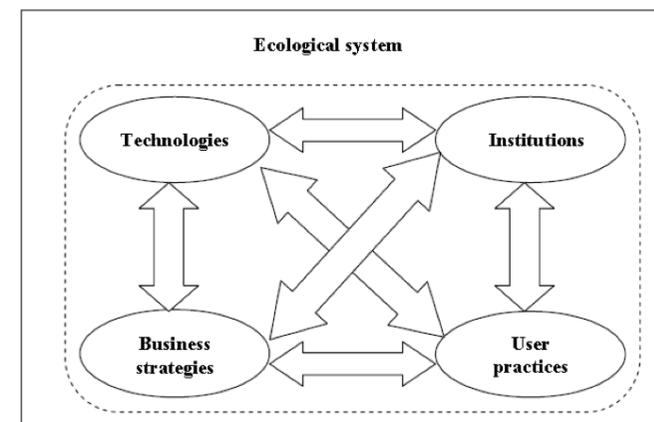
Institutions are sometimes divided into hard and soft institutions. Hard institutions are explicit and codified and include laws, rules, regulations and instructions. Soft institutions include customs, habits, routines, established practices, traditions, ways of conduct, norms and expectations. In the context of the *Visions and Pathways 2040* project, identifying both the hard and soft institutions that underlie our urban systems will be crucial, particularly in conducting the pathway analysis of how to enable change.

3.4 (Co-)evolutionary

A co-evolutionary approach to innovation is an overarching theme in modern innovation theory. Co-evolution occurs when different sub-systems have mutual interactions which affect the development of each system. In particular, analysing transition pathways calls for a co-evolutionary understanding of the development of technologies, institutions, social practices and business strategies (Geels 2005; Foxon 2008, see figure 3). The co-evolutionary understanding is an attempt to overcome the dichotomy between the two dominant approaches advocated to achieve sustainability – technology-oriented versus behaviour-oriented approaches (Brand 2003).

Sartorius (2006) states that “co-evolution implies that successful innovation in general and successful sustainable innovation in particular, has to acknowledge the involvement of, and mutual interaction between, more than the mere technical and economic spheres” (274). Therefore, to understand the dynamics of technological change so as to plan for and develop sustainable technologies, particularly in a complex sphere such as urban living, a co-evolutionary approach which acknowledges the interaction between all components of socio-technical system is essential (Gaziulusoy 2010).

Figure 1. Co-evolution of technologies, business strategies, institutions and user practices (Foxon 2010)



3.5 Path-dependency and lock-in

Technological change tends to proceed incrementally along fixed paths due to the risk reducing behaviour of companies. This phenomenon is known as path dependency of innovation (Arthur 1989). Path dependency creates technological lock-in, which act as a barrier against disruptive innovation (Nelson & Winter 1982). Co-evolutionary and feedback processes also point to how path dependencies can arise in the trajectories of socio-technological systems. In the context of sustainability, it explains the presence of the carbon “lock-in” of our energy systems, in which a centralised, fossil-fuel based system has arisen through the co-evolution of technological, institutional and user practices, and has created significant barriers for the diffusion of decentralised and renewable based systems (Unruh 2000). Another example is the case of automobile dependence and development of urban form (see Box 1).

3.6 Uncertainty

Implicit in a number of the above considerations is the presence of uncertainty, particularly fundamental or intrinsic uncertainty. Fundamental uncertainty refers to situations that are not – or cannot – be known in advance, because they are outside existing conceptual models. In some characterisations, fundamental uncertainty is due not so much to the limits of imagination as to the possibility of creativity and non-predetermined structural change, making prediction inherently impossible. Thus, a full list of possible outcomes is not predetermined or knowable *ex ante*, as the future is yet to be determined (Dequetsh 2008).

One particularly important implication of the uncertain nature of innovation is that firms’ and investors’ *expectations* of future markets, technologies and policies are a crucial influence on their decisions about which technologies to invest in and develop. Expectations are often implicitly or explicitly shared among

different firms in the same industry, giving rise to trajectories of technological development which resemble self-fulfilling prophecies (Dosi 1982). One of the goals of the *Visions and Pathways 2040* project is to co-create new shared futures that become self-fulfilling.

3.7 Knowledge and learning

Knowledge is often claimed to be the most fundamental *resource* in an innovation system, while learning is the most important *process* (Lundvall 2007; Wieczorek 2012). As innovation theory has developed, the understanding of different kinds and forms of knowledge (e.g. tacit as opposed to explicit knowledge) and learning (e.g. learning-by-doing, Arrow 1962; learning-by-using, Rosenberg 1982; learning-by-interacting, Lundvall 1988; single loop and double loop learning, Argyris and Schon 1978) have expanded our insights into the development and diffusion of innovations.



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Box 1: Automobile dependence and urban form lock-in

In urban studies, the concept of automobile dependence is a well known path-dependence phenomenon where institutions and structures (e.g. car based suburban shopping malls, dispersed locations of new urban developments) encourage, reinforce and entrench high levels of private motor vehicle use and low usage of alternative modes of transport (Newman and Kenworthy 1999).

In the aftermath of World War 2, when Australia experienced significant population and economic growth, combined with cheap fuel and increasing car affordability, many Australian cities rapidly transformed from modest, medium density centres supported by public transport to suburban, car-dominated cities with large residential suburbs with relatively poor public transport infrastructure. Along with the increasingly dispersed population came a correspondingly higher carbon footprint. Given that so many of our structures and practices are now embedded in a car dominant culture, the task of urban planners to slow, let alone reverse, this path dependency momentum is a daunting one.

4. Frameworks of systems innovation and transition

In this section we examine two complementary bodies of literature that provide frameworks for analysing radical innovation and system innovations: the innovation systems approach and the socio-technical transitions approach. Although these perspectives have developed to some extent independently, there has been cross fertilisation of ideas and they largely share most of the innovation concepts and insights of the previous section. Furthermore, there have been recent efforts towards integrating these perspectives (Markard and Truffer 2008; Meelen and Farla 2013).

There are other relevant frameworks that we will not discuss here, partly because of space considerations but also because they have many overlapping characteristics with the two frameworks examined here. These include macro theories such as long wave theory on techno-economic paradigm shifts (Freeman and Perez 1988) and technological discontinuity (Anderson and Tushman 1990), as well as more organisational focused theories such as disruptive innovation theory (Christensen 1997).

4.1 Innovation systems

Innovation systems (IS) theory is a heuristic framework that starts from the basis that it is not entrepreneurs or firms alone that innovate. Rather, innovation occurs in the context of an entire system. In particular, a core tenet is that technologies, actors and institutions co-determine each other and need to be analysed conjointly. The innovation systems approach has been applied at national (Freeman 1995), regional (Cooke and Uranga 1997), sectoral (Malerba 2002) and technological levels (Bergek et al 2008). It is on this last, technological innovation systems (TIS), that we will focus on here.

A TIS has been defined as “a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilisation of a technology” (Carlsson and Stankiewicz 1991: 111). The TIS approach usually starts with a specific technology and seeks to understand its success or failure on the basis of the performance of the TIS. The detection and investigation of so-called system failures (a concept more encompassing than the idea of market failure in neoclassical economics) and the creation of appropriately targeted policy responses is a major theme of this approach.

The early literature focused on identifying the structure of a TIS. Table 2 shows a classificatory system developed by Wieczorek and Hekkert (2011) based on four key structural dimensions: actors, institutions, interactions and infrastructure. An analysis of structures typically yields insight into systemic features – complementarities and conflicts – that constitute drivers and barriers for technology diffusion at a certain moment or within a given period.

Table 2. Structural dimensions of Technological Innovations Systems (Wieczorek and Hekkert 2011)

Structural Dimensions	Subcategories
Actors:	<ul style="list-style-type: none"> • Civil society • Companies: start-ups, SMEs, large firms, multinational companies • Knowledge institutes: universities, technology institutes, research centres, schools • Government • NGOs • Other parties: legal organisations, financial organisations/banks, intermediaries, knowledge brokers, consultants
Institutions:	<ul style="list-style-type: none"> • Hard: rules, laws, regulations, instructions • Soft: customs, common habits, routines, established practices, traditions, ways of conduct, norms, expectations
Interactions:	<ul style="list-style-type: none"> • At level of networks • At level of individual contacts
Infrastructures:	<ul style="list-style-type: none"> • Physical: artefacts, instruments, machines, roads, buildings, networks, bridges, harbours • Knowledge: knowledge, expertise, know-how, strategic information • Financial: subsidies, financial programs, grants etc.

More recently, attention has turned to the dynamics of innovation and the so-called functions of innovation systems. The main purpose of this approach is to consider all the activities that contribute to the development, diffusion, and use of innovations as system functions. Table 3 provides an example of seven functions as analysed by Bergeck et al (2008). The premise is that, in order to properly develop, the system should positively fulfil all system functions. There is usually more than one way to achieve function success.

In general, the TIS has been used as a heuristic tool for analysing nascent innovations at an industry level and focuses attention on the arrangement of structures and activities. In section 5 we will examine more closely the policy applications of this approach. However, while the TIS framework has been applied in a number of technology case studies, the approach has not been without criticism (Smith et al 2010; Geels, 2006, 2011). Lachman (2013) has summarised some of the main criticisms:

- Though co-evolutionary in nature, the TIS approach tends to marginalise cultural and demand side aspects.
- The TIS approaches do not typically address the forces that come into play when a new technology attempts to supplant a dominant technology.
- The approaches focus more on the functioning of systems, viz. the element weaknesses, rather than system changes.
- Though emphasis is placed on identifying system weaknesses, less attention is paid to their development, and the reasons behind them, and therefore little attention is paid to system dynamics.
- TIS approaches focus on large actors, such as dominant institutions and firms, and tend to neglect smaller ones, such as grassroots movements and individuals (Lachman 2013:273)

In the next sub-section we look at a broader, social-systems approach for analysing systems innovations.

Table 3. Functions of technological innovation systems (Bergeck et al 2008; Suurs 2009)

System Function	Description	Typical events
F1. Entrepreneurial activities	The existence of risk taking entrepreneurs is essential as they translate knowledge into business opportunities by performing commercial experiments.	Commercial projects, demonstrations, portfolio expansions.
F2. Knowledge development	R&D and knowledge development mostly on emerging technology, but also on markets, networks, users etc.	Studies, laboratory trials, pilots, prototypes developed.
F3. Knowledge diffusion / knowledge exchange	Using networks and other interactions to facilitate the exchange of knowledge between all the actors involved in the TIS.	Conferences, workshops, alliances between actors, joint ventures, setting of platforms or branch organisations.
F4. Guidance of the search	Activities within the TIS that shape the needs, requirements and expectations of actors with respect to their (further) support of the emerging innovation.	Expectations, promises, policy targets, standards, research outcomes.
F5. Market formation	Activities that contribute to the creation of a demand for the emerging technology.	Regulations supporting niche markets, generic tax exemptions, "obligatory use".
F6. Resource mobilisation	Facilitating access to financial, material and human capital.	Subsidies, investments, infrastructure developments.
F7. Support from advocacy coalitions	Forming advocacy coalitions to counteract institutional inertia by urging authorities to reorganise the configuration of the system.	Lobbies, opinion pieces, advice.

Box 2: Photovoltaic Technological Innovation Systems – A comparison between Japan and the Netherlands

Kamp et al (2009) is an interesting case study that compares the successful development and diffusion of PV (photovoltaic) power in Japan with the problematic situation of PV in the Netherlands using the Technological Innovation Systems (TIS) framework. They looked at the fulfilment of each of the seven system functions and also examined the interactive dynamics between them. In particular, positive interactions between system functions can lead to a reinforcing dynamic within the TIS, creating virtuous cycles that promote the development and diffusion of the technology. On the contrary, vicious cycles, which result from negative interaction between system functions, lead to reduced activities in relation to other system functions, thereby slowing down or even stopping the progress. By observing positive and negative interactions, it is possible to determine the presence of self-reinforcing virtuous and vicious cycles which respectively support or hinder the functioning of the TIS.

The authors found that different functional patterns were indeed occurring in the PV innovation systems. In the Japanese case,

they found that all system functions were being fulfilled and were interacting with each other in a positive way, setting in motion virtuous cycles that enabled the implementation of PV. The main system functions that triggered the positive build-up of the Japanese PV innovation system were guidance of research, as policies were based on a shared vision, and policies were for the long-term, thereby providing certainty and support to entrepreneurs and investors in order to set up projects and invest in PV technology. Furthermore, there was strong support from advocacy coalitions and market formation. In the Netherlands not all system functions were fulfilled and a vicious cycle resulted, so that the Dutch PV innovation system collapsed as soon as institutional conditions changed. Due to the lack of guidance of research and market formation, the entrepreneurial activities and resource mobilisation declined, resulting in the end of many projects; this in turn led to a loss of knowledge and skills as there was no feedback from practice, resulting again in a lack of human capital for the installation of projects.

4.2. Socio-technical transition theory

The socio-technical transition approach is another heuristic framework that is part of an ongoing research program pioneered by Dutch researchers (Elzen et al 2004; Kemp 1994 Geels 2005; Rotmans et al 2000). The socio-technical transition approach is an umbrella term that includes the multi-level perspective (MLP) and multi-phase model, transition management (TM) and strategic niche management (SNM). The last two approaches emerged partly from MLP and have a more normative and governance orientated focus for supporting radical innovations and system transformations. We explore the MLP here, and will examine SNM and TM in Section 5, 'Policy and Strategy Implications'.

The MLP approach differs in focus and scope from the TIS approach, as summarised in Table 4. The MLP research emerged partly from historical studies of system changes and evolutionary economics. The approach is conceived in a societal context that is broader than the Innovation Systems approach. The first version was introduced by Rip and Kemp (1998) and was refined and developed in the 2000s by the empirical research of Frank Geels (2005). A central theme is the recognition of the co-evolutionary development of technologies, institutions and social and economic subsystems.

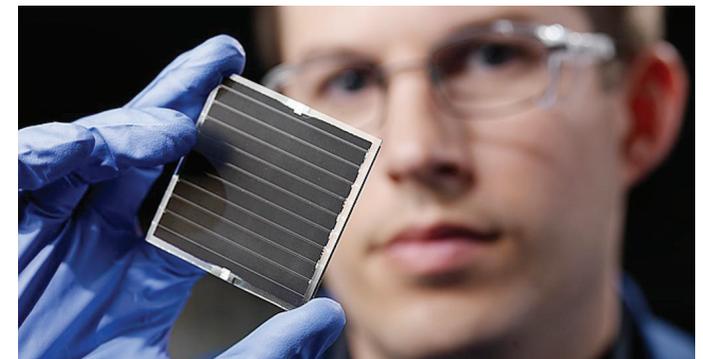


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Table 4: Technological Innovation Systems (TIS) and Multi Layer Perspective (MLP) compared

	Technological Innovation Systems	Multi Level Perspective
Focuses on:	Prospects and dynamics of a particular innovation	Prospects and dynamics of broader transition processes/variety of innovation
Concerned with:	Successful diffusion of a particular technology or product	Successful transformative societal processes

The MLP posits three levels to aid in understanding transitions: landscape (macro-level), regimes (meso-level) and niches (the micro-level).

- **Landscape level (macro)** is the overall socio-technical setting that encompasses the dynamics of deep cultural patterns, macro-economics and macro-political developments that make up the environment or context of socio-technical transition. It is the backdrop to the regime and niche levels, which stimulates and exerts pressure on the socio-technical regime and the technological niches and so plays an important role in stimulating socio-technical transitions.
- **Regimes level (meso)** comprises the structures that represent current practices and routines, including the dominant rules and technologies that provide stability and reinforcement to the prevailing socio-technical systems. The regime is also a presents a barrier to change, including new technological and social innovations (see Box 3).
- **Niches level (micro)** is the level in which space is created for experimentation and radical innovation. The niche level is more loosely structured than the regime and is less subject to market and regulation influences. There is much less co-ordination among niche actors than among regime actors, but this allows for the emergence of new interactions between actors that may support innovation.

The strength of the MLP approach is that transitions can be explained by the interplay of stabilising mechanisms at the regime level, combined with destabilising pressure from the landscape and radical innovations at the niches (Markard and Truffer 2008). In particular, the breakthrough of innovations is dependent on multiple processes in the wider context of regimes and landscape. A graphical interpretation of these dynamics is shown in Figure 4.

Box 3: Mobile phone contracts as unsustainable regime practices

An example of a dominant regime practice that leads to millions of mobile phone handsets being prematurely disposed of every year is plan-based contracts. These are usually offered with highly subsidised or free handsets bundled into the contract. When the contract has expired customers are usually offered a new contract with the sweetener of the “latest” handset. Under such circumstances the previously existing handset becomes seemingly worthless. Crocker (2013) has noted that the justification given by phone service providers that the rapid churn of handsets is due to either the pace of technological change or to consumer preference is largely disingenuous. There are usually few practical contract alternatives available and the consumer is actively encouraged to dispose the old handset, even when the new one has only marginal improvements. As with driving to work when no alternatives are provided, the system becomes compulsory.



The niches are loosely structured and there is much less co-ordination among actors than there is among the regime actors. The regimes are more structured than niches and the rules of the regimes have co-ordinating effects on actors through a strong guidance of the actors' activities. Landscapes are even more structured than regimes and are more difficult to change (Geels 2005). Nevertheless, as Figure 4 suggests, landscapes influence change both on niches and regimes; in return, niches (may) change the regimes and a new regime changes the landscape in the longer term. The socio-technical landscape in this model is relatively static, stands for the external context and represents the physical, technical and material setting supporting the society, and cannot be changed by the actors in the short term (Geels & Schot 2007). Landscapes are constituted by rapid external shocks, long-term changes and factors that do not change or change only very slowly (Van Driel & Schot 2005).

Kemp et al (2001) identify three strategies for changing regimes. The first strategy, promoted by economists, calls for changing the structure of incentives and allowing market forces to function. This strategy is problematic especially when used in relation to environmental improvements. In order for policies targeting market forces to have an impact, these policies have to be drastic. For example, although the dramatic rise in the market price of crude oil from US\$3 a barrel in 1973 to US\$30 in 1983 resulted in stagnation, fossil fuels continued to be the dominant energy sources (Farrell 1985). In addition, the use of economic incentives may lead to temporary windfall profits for manufacturers and dead weight losses for consumers. A further problem is that the incentives need to be supported by corrective measures to counter possible harmful effects of the innovations favoured by the incentive.

The second strategy Kemp et al (2001) identify is "to plan for the creation and building of a new sociotechnical system based on an alternative set of technologies, in the same fashion as decision makers have planned for large infrastructure works, like coastal

defence systems or railway systems" (279). This approach is also problematic because in advanced, modern and pluralistic societies a new technology system cannot be completely planned due to emergent properties stemming from co-evolutionary dynamics between technologies and social systems.

The third strategy they identify is to "build on the ongoing dynamics of sociotechnical change and to exert pressures so as to modulate the dynamics of sociotechnical change into desirable

directions. For this strategy, the task for policy makers is to make sure that the coevolution of supply and demand produces desirable outcomes, both in the short run and in the longer term" (280). Kemp et al (2001) prefer this third strategy since it appears to be the only feasible one in contemporary society. In order to manage transitions through this strategy, the lowest level of MLP model, i.e. the niches level, plays an important role since niches are where radical innovations emerge (Geels 2002).

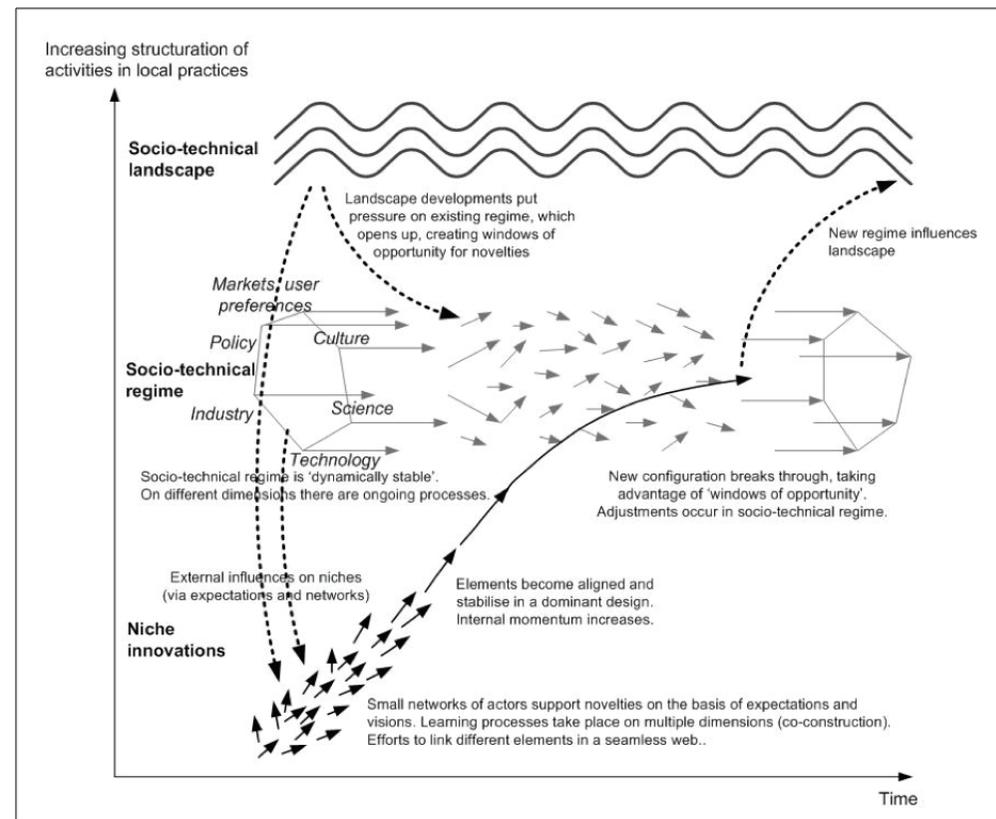


Figure 4. Multi-level perspective on transitions (Schot and Geels 2008)

Sustainable transport and the Multi-level Perspective

Geels (2012) gives an example of an application of the MLP approach to the auto-mobility systems in the Netherlands and UK, where most sustainability experts agree that transition to new kinds of transport systems is necessary. To understand the dynamics of such a transition, Geels uses a socio-technical approach which goes beyond seeking a simple technology fix or behaviour change. Systemic transitions entail co-evolution and multidimensional interactions between industry, technology, markets, policy, culture and civil society and Geels uses the multi-level perspective to identify and analyse these interactions

Geels reviews promising niche developments (e.g. inter-modal travel schemes; travel demand management initiatives; public transport innovations; green propulsion technologies), landscape pressures (e.g. climate change public concerns; peak oil; diffusion of ICT) and discusses whether these pressures are enough to create cracks in the current transport regime given the many stabilising and lock-in mechanisms in place (e.g. sunk investments in road, urban and spatial infrastructures; consumer preferences such as convenience and speed that benefit cars; vested interests such as the car making industry; beliefs from established actors that take existing practices for granted and legitimate the status quo.) The MLP does not provide a crystal ball on what is likely to happen to our transport system or on what niche development should be promoted, but rather is useful for making a comprehensive analysis of the possibilities, barriers and drivers of transitions towards sustainable transport.



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5. Policy and strategy implications

The frameworks discussed above have been used to support the formulation of innovation policies. By focusing on the dynamics of change and their drivers they allow for a perspective on fostering innovation that goes beyond mere diagnosis of externality market failures, which is the main feature of innovation policies based on neoclassical economics. In this section we briefly consider some of the potential policy and strategy implications of three policy approaches based on the previous section. The first is based around the technological innovation systems framework. The second and third, which have a heritage in the socio-technological transitions literature, are strategic niche management and transitions management.

The examination of policy and strategies for fostering low carbon innovations and transition will be a major aspect of the *Visions and Pathway 2040* project and will be pursued more deeply in later reports and other outputs. The purpose of this section is to give a flavour of the methods and scope of policy interventions and insights that arise from the systemic views that characterise the theories we have been examining.

The effectiveness of these approaches in initiating or fostering radical or systemic changes is still to be proven. This is partly due to the relatively recent development of these frameworks and their moderate uptake by governments so far, the Netherlands being the most notable exception. Nevertheless, the way these policies have been theoretically conceived and initial experiences do hold promise that they can contribute to radical and systems innovation. Further research and experience will be required to fully understand the strengths, complementarities and weaknesses of these approaches (Nill and Kemp 2009).

5.1 Technological innovation systems policy implications

The technological innovation system approach has been used for investigating emerging sustainable technologies such as electric vehicles (Hekkert and Negro 2009), biofuels (Suurs and Hekkert 2008) and hydrogen fuel cells (Suurs 2009). As discussed above, the key idea is that for a technological system to flourish there should exist a set of key structural elements that are interacting successfully, such that certain key activities or functions are being fulfilled in the system. The policy approach is therefore to monitor these structures and functions to analyse what weakness exists within the system and thus propose recommendations on how improvements could be made. A key point is that different types of system problems are likely to require different types of instruments.

The most systematic policy framework to methodically identify structural and functional weaknesses has been proposed by Wieczorek and Hekkert (2011). They use a five stage process:

3. **Mapping the structural dimensions and their capabilities.**

The analysis starts with mapping and identifying the structural elements of the analysed system, as in Table 2.

4. **Coupled functional-structural analysis.** Using the seven functions of innovation systems classification scheme (see Table 3), each function is evaluated on a 1–5 scale using a set of diagnostic questions for each function as a guide. For example, with Function 1 (entrepreneurial activities):

- Are there enough entrepreneurs?
- What is the quality of entrepreneurship?
- What types of businesses are involved?
- What are the products?

- To what extent do entrepreneurs experiment?
- What variety of technological options are available?
- Are any entrepreneurs leaving the system?
- Are there new entrepreneurs?

Wieczorek and Hekkert (2011) recommend analysing each function from the perspective of the four major structural elements (actors, institutions, interactions and infrastructure) and identifying which of these elements are causing the weakness or absence of function.

5. **Identification of system problems.** This stage involves summarising the problems that hinder the development of the system in terms of functions evaluation (absent, weak, etc.), reasons why the specific function is absent, weak, etc. (“blocking mechanisms”) and classifying the systems problem in terms of whether it is an actor problem, interaction problem, institutional problem or infrastructure problem.

6. **Systemic instruments goals.** Having precisely identified systemic problems, the next stage is to align these problems with the systemic policy instrument goals that would address the problem. A scheme for potential systemic instrument goals associated with each systemic problem is presented in Table 6.

7. **Systemic instrument design.** Finally, an instrument or set of instruments can be chosen from a set of standard tools available in the policy field (or perhaps the creation of a new policy instrument to address the policy goal). The chosen instrument(s) must not only address the goals of the systemic instrument but must also be chosen with sensitivity to the interaction with other instruments, socio-political constraints, and impact of other, perhaps competing TISs. An overview of standard instruments to address different system problem goals is presented in Table 7.

Table 6: Goals of systemic instruments per (type of) systemic problem

Systemic problem	(Type of) systemic problem	Goals of systemic instrument
Actor problems	Presence?	Stimulate and organise participation of actors
	Capabilities?	Create space for actors' capability development
Interaction problems	Presence?	Stimulate occurrence of interactions
	Intensity?	Prevent too strong and too weak ties
Institutional problems	Presence?	Secure presence of (hard and soft) institutions;
	Capacity?	Prevent too weak/stringent institutions
Infrastructural problems	Presence?	Stimulate physical, financial and knowledge infrastructure
	Quality?	Ensure adequate quality of infrastructure

Source: Wieczorek and Hekkert (2011)

The result of these five stages should be an integrated and coherent portfolio of instruments that address the identified systemic problems of the given technological system. Its purpose is to create opportunities and conditions for system formation that would not emerge spontaneously. Since policy making is a cyclic process, over a period of time the evaluation of the effectiveness of the policy instrument should later serve as an input into a new iteration of the above five stage policy design process.

Table 7 Innovation systems targeted policy goals and instruments

Goals of systemic instruments	Examples of individual instruments
1. Stimulate and organise participation of actors	Clusters; new forms of public private partnerships, interactive stakeholder involvement techniques; public debates; scientific workshops; thematic meetings; transition arenas; venture capital; risk capital
2. Create space for actors' capability development	Articulation discourse; backcasting; foresights; road-mapping; brainstorming; education and training programs; technology platforms; scenario development workshops; policy labs; pilot projects
3. Stimulate occurrence of interactions	Cooperative research programs; consensus development conferences; cooperative grants and programs; bridging instruments (centres of excellence, competence centres); collaboration and mobility schemes; policy evaluation procedures; debates facilitating decision-making; science shops; technology transfer
4. Prevent too strong and too weak ties	Timely procurement (strategic, public, R&D-friendly); demonstration centres; strategic niche management; political tools (awards and honours for innovation novelties); loans/guarantees/tax incentives for innovative projects or new technological applications; prizes; Constructive Technology Assessment; technology promotion programs; debates, discourses, venture capital; risk capital
5. Secure presence of (hard and soft) institutions;	Awareness building measures; information and education campaigns; public debates; lobbying, voluntary labels; voluntary agreements
6. Prevent too weak/stringent institutions	Regulations (public, private); limits; obligations; norms (product, user); agreements; patent laws; standards; taxes; rights; principles; non-compliance mechanisms
7. Stimulate physical, financial and knowledge infrastructure	Classical R&D grants, taxes, loans, schemes; funds (institutional, investment, guarantee, R&D), subsidies; public research labs
8. Ensure adequate quality of infrastructure	Foresights; trend studies; roadmaps; intelligent benchmarking; SWOT (strengths, weaknesses, opportunities and threats) analyses; sector and cluster studies; problem/needs/stakeholders/solution analyses; information systems (for program management or project monitoring); evaluation practices and toolkits; user surveys; databases; consultancy services; tailor-made applications of group decision support systems; knowledge management techniques; Technology Assessments; knowledge transfer mechanisms; policy intelligence tools (policy monitoring and evaluation tools, systems analyses); scoreboards; trend charts

Source: Wieczorek and Hekkert (2011)

5.2 Strategic niche management

Strategic niche management (SNM) highlights the importance of protected spaces and of user involvement in early technological development. It can be seen as focusing on the niche level of the MLP framework discussed in Section 4. The aim is to create new technology pathways which are able to penetrate the prevailing regime (or be part of a realignment of the regime) so as to replace unsustainable technologies as part of the dominant regime (Kemp et al 1998) .

The approach was partly inspired by historical studies showing that many successful innovations started as a technological niche and only gradually overturned a dominant regime (e.g. Geels and Schot 2007). Historical studies have also shown that potentially valuable sustainable technologies have often failed to develop fully, or to catch on in the market, even though they may had superior performance characteristics. Thus the approach attempts to purposefully craft and guide such niches to give promising technologies time to develop.

SNM is a process orientated approach with a focus on experimenting and learning. The objective is not to achieve a particular outcome in terms of use, since the desirability of a new technology cannot be taken for granted. Rather, the major concern with SNM is to establish processes by which experiments can evolve into viable market niches and ultimately contribute to a shift towards a more sustainable socio-economic environment. If after a sufficient period of incubation, a technological niche has not evolved into a commercially sustainable market niche, then support of the policy experiment may be discontinued.

SNM as a policy tool is not exclusively a government top-down process for creating niches. Rather, the niche creation and nurturing can be steered by a range of actors, including users and societal groups, and have been defined as a form of reflexive governance (Schot and Geels 2008).

Depictions of the SNM approach often include a five phase process (Kemp et al 1998; Kemp et al 2001; Weber et al 1999): (i) the choice of technology; (ii) the selection of the experiment; (iii) the set up of the experiment; (iv) scaling up of the experiment and

(v) breakdown of the protection. Across these phases a number of guidelines have emerged. We summarise some of them and associated potential policy dilemmas in Table 8.

Table 8. Strategic niche management guidelines and potential dilemmas

Policy area	Policy guidelines and potential dilemmas
Expectations, visions	<ul style="list-style-type: none"> • Be flexible, engage in iterative visioning exercises; adjust visions to circumstances and take advantage of windows of opportunity • Be persistent, stick to the vision, persist when the going gets tough
Learning	<ul style="list-style-type: none"> • Create variety to facilitate broad learning • Too much variety dilutes precious resources and prevents accumulation. It also creates uncertainty and may delay choices/commitments (by consumers, policy makers)
Upscaling	<ul style="list-style-type: none"> • Stepwise learning and bricolage strategy. Disadvantages: (1) slow, (2) incremental steps • Breakthrough strategy and big leaps to achieve success rapidly. Disadvantages: (1) danger of failure, (2) misalignment with selection environment
Network	<ul style="list-style-type: none"> • Work with incumbent actors, who have many resources, competence and “mass”. Try to change their agenda, visions • For radical innovations, it is better to work with outsiders, who think “out of the box” and have new ideas. Incumbents have too many vested interests and will try to hinder or encapsulate radical innovations
Protection	<ul style="list-style-type: none"> • Protection is needed to enable nurturing of niche-innovations • Do not protect too long and too much. This might lead to limited exposure to selection pressures (and the danger of creating white elephants)
Niche–regime interaction	<ul style="list-style-type: none"> • Wait for cracks in the regime, and vigorously stimulate niche-innovations. Until such windows of opportunity arise, niches should be nurtured to facilitate stabilisation. • Use niche experiences to influence perceptions of regime actors and actively create cracks in the regime.

Source: Schot and Geels 2008.

As with the other policy approach, SNM has not been without criticism. Some have criticised it for being too much of a bottom-up strategy (e.g. Berkhout et al 2004) and focusing on internal niche processes (such as learning, networking, visioning) at the expense of external niche processes. Furthermore, there is as yet scant evidence of consciously designed SNM initiatives becoming major learning vehicles for wider change towards new socio-technological regimes (Caniëls and Romjin 2008). Most SNM experiments have remained at the stage of single activities. However, SNM can still be viewed as a useful framework for generating learning about needs, technology imperfections and strategies to overcome them, and for building actor networks (Nill and Kemp 2009). A policy approach with a greater focus on the role of external niche processes can be seen in transition management.

5.3 Transition management

The transition management (TM) policy approach adopts a broad systems perspective that embraces all three levels of the MLP framework. It is concerned with the dynamics of structural change in society and when and how transformation can be initiated, facilitated, and shaped. As in SNM, the importance of experimenting and learning is central. However, the starting point of TM is not a technological innovation but a societal challenge, such as how to meet the need for energy, transportation or housing in a sustainable way (van der Bosch and Rotmans 2008). As a reflexive and participative mode of governance, TM aims to steer our socio-technical systems towards desirable social outcomes, with engagement with stakeholders at multiple levels and testing the practicality of ideas through experimentation, learning and adaptation as the primary motors of change.

Conceptually, the TM framework comprises two key lenses: a descriptive distinction into strategic, tactical, and operational innovation spheres, and a prescriptive cyclical framework of co-evolving activities that connect these spheres (Loorbach 2007, 2010).

The three spheres of activities in TM are:

- **Strategic activities.** These involve the formation of long term goals and vision development that will lead to changes in the culture of a societal system. This includes dialogues on norms and values, identity, ethics or sustainability. This focus coincides with the landscape level in the MLP framework.
- **Tactical activities.** These involve activities directed at implementing a transition agenda towards the desired goal and relate to interactions between actors that can build and align the new vision into the regime level. This can include activities relating to changes in structures, such as investments and other resource distributions, rules, incentives and underlying infrastructure. Negotiations regarding interests are more common in this sphere. It also involves understanding barriers that may inhibit the advancement of the visions and propose adjustments that may be needed.
- **Operational activities.** These activities relate to the experiments and learning-by-doing at the niche level, often with an emphasis on radical and disruptive innovations that may filter up into the regime and landscape levels.

An essential mechanism in this approach is the *transition arena*, a setting that provides an informal but well-structured space to a small group of change-agents from diverse backgrounds (businesses, government, research institutes, community organisations and citizens) (Roorda et al 2012). This is organised

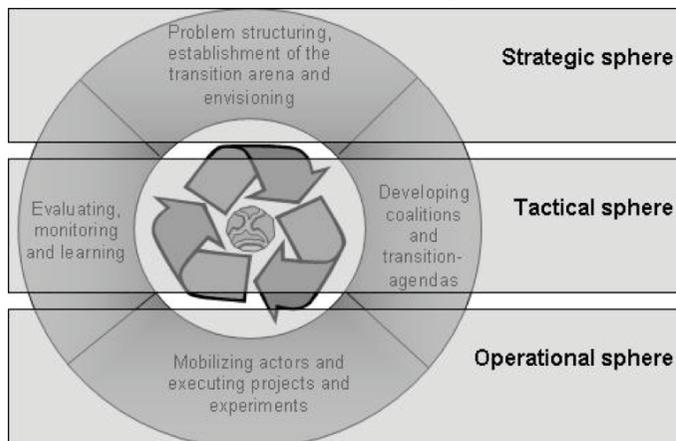
in such a way that it helps to build a group of ambassadors who are inspired to go beyond current interests and daily routines. The participating change agents engage in a series of meetings to develop a new, shared visionary story which they can directly link to their own everyday practice. The *Visions and Pathways 2040* project is an example of such an arena in pushing for the transitions to a low carbon and resilient built environment in Australia.

At all three levels, but particularly at the strategic level, an important conceptual tool that is increasingly highlighted in the literature is the creation of “transition scenarios” which are plausible, coherent narratives of pathways that could bring about the desired end state. Transition scenarios can help engage and align stakeholders, but can also help prepare more resilient strategies by anticipating deviations from trends (Sondeijker 2009),

In the TM literature, these three spheres of activity are connected in a cyclical path as illustrated in Figure 7 (Loorbach and Rotmans 2006):

- Problem structuring and the establishment and development of a transition arena
- the development of a long-term vision, transition pathways and agenda for sustainable development
- the mobilisation of actors and knowledge development through experimentation
- the monitoring, evaluation and learning from the transition process.

Figure 7 Activity clusters in transition management



Source: Loorbach and Rotmans (2006) and van der Brugge and van Raak (2007)

Since the TM approach is relatively new, with only a handful of case studies to draw from, the methodology is still under debate (Lachman 2013). Some criticisms include: current practices focus mostly on the niche-regime dynamics (e.g. SNM) to the neglect of the broader transitions process; there has been an inherent bias in TM implementation towards incumbent actors, which may have inhibited new players' ability to break through into the regime (Smith and Kern 2009); Shove and Walker (2007), casting doubt on societies' ability to transform themselves, criticise the social-engineering tint of TM and the central role given to technical change in societal transitions (arguing that culture and social practices have been neglected in TM practice).

Box 5: Cities transition management and the MUSIC project

The adaptation of Transition Management to the urban context and its transnational application constitute an important part of a European project named MUSIC (Mitigation in Urban Context, Solutions for Innovative Cities). This Interreg-funded project is a co-operation between five cities in north-western Europe and two research institutes – the Dutch Research Institute For Transitions (Drift), Erasmus University, Netherlands, and and Public Research Centre Henri Tudor (Luxembourg).

The overall aim of the MUSIC project is to catalyse and mainstream carbon and energy reduction in urban policies, activities and the built environment. The MUSIC cities will use the transition management method developed by DRIFT to guide this process. This method includes a series of workshops with several stakeholders (businesses, government, research institutes, citizens) resulting in a local sustainability vision and action plan.

The local action plans and energy planning tools being tested in pilot projects include:

- Aberdeen: renovation of a school to become more energy efficient and at the same time increasing the energy efficiency awareness of students and parents
- Rotterdam: development of new cooperation models between public and private sectors to make public buildings less energy consuming. These models will be applied to swimming pools and smart roofs
- Ludwigsburg: building of an energy neutral community centre in a socially and economic weak district, where local residents will be informed on energy reductive measures
- Montreuil: building of an energy generating school building. Local residents and students will be involved and informed during the whole building process
- Ghent: developing a participation project to receive support from the users and inhabitants of the city. Also, Ghent will do a major pilot of a GIS support tool by proclaiming the energy saving message during several events.

6. Conclusion

The creation of a more sustainable urban environment is likely to require radical or disruptive innovations that will result in a system transformation in the way we organise our economy and society. Such change may not be easy to achieve as there are various forces of inertia in our infrastructure, institutions, social practices, laws and regulations and vested interests which will resist such change (Unruh, 2000). This review has pointed towards some of the concepts and frameworks that may help analysing and prescribing the types of policies and strategies that will help initiate and foster such radical innovations and system transformation.

The modern theory of innovation and transitions provides a number of related concepts and insights. It presents a nuanced and rich picture of the innovation and transition process, with a wide set of implications for those hoping to assist, shape or direct the innovation process and system change. Key ideas include appreciating the importance of actor networks; the role of institutions; the co-evolutionary nature of the technologies, institutions, social practices and business strategies; the role of feedback and path dependency in socio-economic systems; and a greater understanding of the different types of knowledge and learning processes. Frameworks such as technological innovation systems (TIS) and the multi-level perspective (MLP) have provided useful analytical structures for developing innovation and transition policies and strategies.

Perhaps the most basic but significant finding from this literature review is that facilitating transformative change requires acknowledging that it is an emergent, collaborative, multi-actor and multi-level process that will involve business, government, research and civil society. By bringing together stakeholders in dialogue to develop visions and pathways for a more sustainable future, the *Visions and Pathways 2040* project and the CRC for Low Carbon Living can hopefully contribute to this transformative task for Australia.



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