# SYSTEM INNOVATION: SYNTHESIS REPORT

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# System Innovation:
# Synthesis Report

# FOREWORD

This synthesis report was developed as part of the CSTP activity on 'System innovation' carried out under the auspices of the Working Party on Innovation and Technology Policy (TIP) as part of its contribution to the CSTP's Intermediate Outputs 1.3 and 1.4. The goal of this activity was two-fold: 1) to improve policy makers' understanding of the concept of system innovation as a tool for orienting innovation policy and decision making; and 2) to foster mutual learning between policy makers, researchers, and business representatives based on case studies of system innovations in specific sectors/technologies, in areas such as e-mobility, sustainable building and housing, smart cities, and technology platforms for health and green growth initiatives. The case studies commissioned for the project are a way to learn how other countries are using concepts and policies based on system innovation thinking to meet societal challenges. This work builds on the OECD Innovation Strategy and the OECD Green Growth Strategies, which were released in 2010 and 2011 respectively. A central policy challenge identified by both the Innovation and the Green Growth Strategies has been bringing together policy domains that are often kept separate, notably economic (including innovation), environmental and social.

The project on system innovation is an on-going project to develop new innovation policies for innovation alongside the traditional policies such complements other work of the TIP and the CSTP on public/private partnerships, demand-side innovation, the next production revolution and related work across the OECD on green innovation, eco-innovation, systemic innovation and smart cities. The synthesis report was prepared by the OECD Secretariat [Dimitrios Pontikakis (OECD DSTI until December 2014, presently European Commission, Joint Research Centre, and Institute for Prospective Technological Studies), Mario Cervantes and Daniel Kupka]. Marion Robert, intern at the OECD's Science and Technology Policy Division, provided research and editorial assistance while Katjusha Boffa provided secretarial support. In addition, the Secretariat acknowledges substantive inputs from leading innovation policy experts: Professor Dirk Meissner, Moscow National Research University Higher School of Economics; Wolfgang Polt, Joanneum Research; Matthias Weber, Austrian Institute of Technology; Jan Larosse, Flanders Department for Economic Policy; Göran Marklund, Vinnova, Sweden; and Christopher Palmberg and Kirsti Vilén, Tekes, Finland. The synthesis report distils the findings from analytical work of the last two years, which includes:

- A review of the concepts and definitions of system innovation, drawing on the national innovation systems theory and transition management literature. The review System Innovation: Concepts, Dynamics and Governance (OECD, 2013) was undertaken by Professor Frank Geels of Manchester University, consultant to the OECD Secretariat, and is the basis of the material contained in Chapters 1 and 2 of the report.

- A case study on sustainable housing and buildings in Flanders, Belgium (Erik Paredis, Centre for Sustainable Development, Department of Political Sciences, Ghent University) as well as case study on sustainable materials (Frank Nevens, Nele D'Haese and Marian Deblonde, VITO: the Flemish Institute for Technological Research).

- A case study on sustainable renovation of multi-family housing in Sweden (Liselott Bergman, Karla Anaya Carlsson and Lennart Stenberg, Vinnova). It is gratefully acknowledged that Lennart Stenberg could carry out part of his work as a visiting researcher in Kitamori Lab, School of Engineering, University of Tokyo.

- A case study on sustainable building and retrofitting in Austria (Björn Budde, Matthias Weber, AIT – Austrian Institute of Technology and Andreas Niederl Wolfgang Polt, Joanneum Research).

- Case studies on “smart cities” in Finland (Kirsti Vilén and Pirjo Kutinlahti, Ministry of Employment and Economy and Christopher Palmberg, Tekes) and in Germany (Jan Wessels and Katrin Schumann, VDI/VDT Innovation).

- A case study on e-mobility in Austria (Björn Budde, Matthias Weber, Austrian Institute of Technology (AIT), and Andreas Niederl and Wolfgang Polt, Joanneum Research), and another case study on electric vehicles in China (Xiaoyong Shi, National Center for Science and Technology Evaluation).

- A case study on green growth in Korea (Joo Sung Hong and Jeong Hyop Lee, STEPI) and the bio-based economy in the Netherlands (Peter Besseling, Ministry of Economic Affairs, Harriëtte Bos, Wageningen University and Research Center).

- Case studies related to long-term care/assisted living in the United Kingdom (Alex Mace, Department for Business Innovation and Skills), and on technology platforms in the Russian Federation (Yuri Simachev and Vladimir Kiselev, Interdepartmental Analytical Centre, Moscow, Russia).

- A case study on cluster policies in the Russian Federation (Dirk Meissner and Evgeny Kutsenko, National Research University Higher School of Economics, Moscow).

- Several expert workshops held in Paris (March 2013), Stockholm (September 2013), Helsinki (November 2013) and Berlin (April 2014). Oliver Bott of VDI/DTI Berlin was rapporteur at the Berlin workshop and provided a summary of the discussions. In addition, an OECD-BIAC Business Symposium was held on 17 November 2014 at the Joanneum Research, Graz (Austria) where Wolfgang Polt and Matthias Weber provided the rapporteur's summary.

The synthesis report has benefited from discussions and input from members of the TIP Steering Group on System Innovation and invited experts including Professor Marko Hekkart, Chair of Dynamics of Innovation Systems at Utrecht University in the Netherlands, Dr. Eckhart Hertzsch, Fraunhofer Institute for Building Physics, Professor Dr. Bertil Haack, Technische Hochschule Wildau, Professor Knut Blind, Berlin University of Technology, Dr. Wolfgang Schade, Technische Hochschule Wildau, Johannes Hartwig and Florian Senger, Business Unit Transportation Systems Fraunhofer Institute for Systems and Innovation Research (ISI) and by national delegates to the OECD Working Party on Innovation and Technology Policy (TIP) at plenary meetings in 2013 and 2014. Several member countries provided in-kind support for the preparation of case studies and the participation of experts at workshops. The Secretariat gratefully acknowledges research funding for the project from Vinnova. This report was declassified by the Committee for Scientific and Technological Policy on 30 January 2015.

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## EXECUTIVE SUMMARY

**The interdependency of the opportunities and challenges faced by OECD countries require a re-think in policy making if governments are to deliver on growth and well-being**

1. OECD countries face a number of challenges but also opportunities. Some of these challenges are well known, such as climate change, energy shortages, food security, ageing populations, environmental pollution, and the challenge is to find win-win solutions that both help meet these grand challenges and lead to sustainable economic growth. Innovation and technology are clearly part of the solution to transition modern economies on a more sustainable path but as this report shows they are not, in and of themselves, sufficient. In fact, technology must go hand-in-hand with new approaches and tools for addressing economic and social challenges, such as smart regulation, circular economy, innovative public-private partnerships and new business models, including in the public sector, to meet the social, economic and environmental challenges of the day.

2. Turning challenges into opportunities for sustainable and inclusive growth is not a straightforward task. Firstly, societal challenges may be inter-linked or have unexpected knock-on effects. For example, ageing societies can lead to a reduced labour force, increases in health care costs and a reduction in the tax base. And short term policies to limit labour migration may aggravate ageing-induced labour force reductions in the longer term. Second, some challenges also have a global dimension, which means that national policies alone will be insufficient to solve them. Current government policy structures and policies, including in R&D and innovation policy, are ill-adapted to tackle such complex challenges characterised by interdependencies that while not new, have been intensified by globalisation and ICTs, including, more recently, big data and social media. Therefore, a re-think in government policy making that takes a more systemic view of problems and an inclusive and holistic approach to innovation policy is the only way forward.

**System innovation is a horizontal policy approach to tackle problems that are systemic in nature; it involves actors outside government and is longer term in its planning**

3. System innovation is a concept used to illustrate a horizontal policy approach that mobilises technology, market mechanisms, regulations and social innovations to solve complex societal problems in a set of interacting or interdependent components that form a whole 'socio-technical system'. In some ways it is similar to "whole-of-government-policy" approaches that aim to enhance coherence (or in the best case align policies in different domains), but system innovation aims to achieve much more than coherence or policy alignment since it involves actors outside government – notably firms and civil society - and takes a longer term view. System innovation is problem oriented and focused on addressing systemic problems in particular sectors/technology areas. Implementing a system innovation policy requires sophisticated analytical tools and processes in governments to model systemic problems, to understand casual relations among different elements of the system (e.g. between traffic, private car use and public transport), barriers and obstacles, and to design policy responses be they changes to legislation, regulations, standards or fostering technology platforms and public-private partnerships.

4. System innovations are thus defined as radical – insofar as they alter existing system dynamics - innovations in socio-technical systems that fulfil societal functions, entailing changes in both the components and the architecture of systems. They are characterised by three main features: 1) disrupting or complementary types of knowledge and technical capabilities; 2) fundamental changes in consumer practices and markets; and 3) novel types of infrastructures, institutional rules and skill sets. Examples of such systems include an e-mobility urban transport system, a sustainable public housing system, or an e-

health care system. System innovations take time, sometimes decades, and are therefore best thought of as periods of *transition*. The purpose of public policy in this setting varies; in cases where transition paths are well-defined and momentum has gathered pace, necessary policy interventions may be limited and confined to managing aspects of the transition (e.g. accelerate it or offset some of its distributional impacts); in other cases the role of policy is much more substantial and extensive and may include shaping visions, mobilising resources, setting standards and helping create markets where none exist.

**OECD countries are actually already implementing system innovation in a range of areas such as smart cities, sustainable building, healthy ageing, or green innovation initiatives.**

5. Today, even if the concept of system innovation, which has been around for more than a decade, is still debated from a theoretical perspective, OECD countries are actually already implementing system innovation approaches in a range of areas such as smart cities, sustainable building or green innovation initiatives. However, as the case studies have also shown, policy success in fostering systemic innovation is hampered by an over reliance on single market failure rationales, short-term political processes (i.e. election cycles), and fragmented governance structures and processes. Other barriers include: 1) technological trajectories and lock-in; 2) market power and political clout of incumbents; 3) lack of consumer acceptance/ adoption; and 4) institutional inertia and path dependency (Polt and Weber, 2014). There are two implications arising from this. First, government's role must become quite different from one focused on solving pure market failures. It must not only play its role as a co-ordinator and facilitator but it must also change to become more entrepreneurial and engaged in enabling transitions that deliver on social needs. The second implication is that system innovation is not just an economic, technological or managerial process, but also a political and cultural project that will require leadership, inclusiveness and a shared societal vision to drive it. Among the key findings of this report are the following.

- System innovation is likely to have lasting impact since the change resulting from it is major, e.g. in the sense of radical innovations with many outreach channels.

- Access to and cost of capital is a central determinant for the initiation of system innovation. Beyond incentivising investments through tax policies or subsidies, financial innovations will be needed to help to cut the cost of funds raised for investment and to raise funds more securely and quickly.

- Redefining the structure of the system – understood as the prevalent relationships between economic and social stakeholders – is an at least as, if not more, important contribution of public policy to system innovation than the provision of funding. Carefully crafted regulations, the facilitation of standards and the creation of mediating bodies can help 'couple' henceforth disparate parts of the system (e.g. electricity distribution and transport systems), adding to the momentum of the transition.

- Technological innovation is necessary (in areas such as energy, materials, and collective goods systems) but successful transitions will require complementary innovations in organisations and institutions to implement them as well acceptance by consumers/citizens.

- Improved governance mechanisms, better means of engaging a range of stakeholders and lengthened decision-making horizons are needed to facilitate system innovations, especially because such innovations take time and sustained commitment from stakeholders.

- System innovation requires the transformation, replacement or establishment of complementary infrastructures. Too often investment is drawn towards traditional infrastructures in transport and energy due to large sunk capital investments and technology and institutional lock-in.

- National strategies for innovation can help articulate and be vehicles for implementing system innovations. However, the multiplication and multi-layering of national innovation strategies with thematic objectives (new industrial strategies, research strategies, and smart specialisation strategies) raises problems of co-ordination and overall accountability of the outcomes of such strategies.

- Transitions can also be fostered by improving efficiency in existing systems-specific incentives for investment, funding for research and innovation, changes in vocational education and a more intense dialogue with industry.

- Legislative and regulatory initiatives can also facilitate transitions and system innovation, such as changes in procurement legislation. Regulations to reduce $CO_2$ emissions in the transport, energy and building sectors have also been major drivers of innovation.

- System innovation can be met with resistance to change; therefore understanding, and where appropriate, managing resistance, is a key role of policy.

- The complexity of system innovation requires a more holistic and systemic design and analysis of the STI policy mix. However, this is no easy task as public agencies face constraints in terms of the skills of programme managers and the famous 'silo' effect in government. Multi-stakeholder engagement and technology foresight can play an important role in overcoming some of these obstacles and creating shared visions of transitions.

- Foresight and technology road mapping can be especially important in helping to better identify the critical transitions points that are amendable to policy action (e.g. infrastructure). Technology platforms that bring together large and small firms, universities, regulatory and standard settings agencies and innovation agencies can also help overcome resistance and increase the scale of system innovations.

6. The appeal of system innovation today is closely linked to the pressing issue of meeting the 'grand' or global challenges of today. These global challenges require policy actions across technological, economic and social structures and boundaries, as well as national borders. For example, system innovation in the green space, known as systemic eco-innovation, is increasingly considered a cornerstone for the green economy as it may help society exit its current hydrocarbon-based technology regimes (OECD, 2012). Other policy domains are also embracing a systems approach to policy making that combine market-based instruments, technology, innovation and institution building to deliver on public missions whilst promoting greener growth.

7. Traditionally public policies have aimed to address social problems through discrete interventions but many societal problems are of systemic nature and discrete policy interventions on their own may not be sufficient, or may be too short-term oriented. Even when they do succeed they may result in unintended consequences and shift the problem elsewhere in the system. A classic example is the case of housing markets. Governments often intervene on the supply side (i.e. building social housing or facilitating private market access to lower income groups (through rent controls) but they also intervene on the demand side through fiscal and tax policy to stimulate property ownership which may lead to rent seeking and bidding-up of prices. In turn this can lead to additional supply-side interventions with unintended consequences and the persistence of the initial problem (lack of affordable housing) together with the creation of new ones (housing bubbles, urban sprawl). Social housing may also be constructed without a long-term vision of sustainability or without consultation with the very societal groups which are the targeted population; this can result in unstainable housing environments, economic inefficiencies, erosion of the environment and large costs to tax payers.

**System innovation requires a combination of innovations as well as the tools and processes of management. It also requires sequencing of policies with the different stages of the transition.**

8. Innovation policies are no exception; many policies have tended to foster the generation of knowledge and spill-overs across the board rather than directing such processes, the notable exception being public research in health, energy, and military R&D, so called 'mission-oriented' research. So while policies to stimulate public and private investment in R&D and innovation matter immensely, solving complex problems will require a combination of innovations, a combination of policies – far beyond innovation policy - on the supply and demand-side (e.g. public procurement, standards), and tools and processes of management. In addition to combining variegated instruments, policies must be better in tune with the stages of the transition.

9. However, by and large, most innovation policies aim to foster incremental change; fostering wider system change is a new challenge for innovation policy makers, especially as many of the actions will fall in areas outside the direct remit of research ministries or innovation agencies but where their input, co-ordination, and implementation actions will remain critical. One such example is the introduction of e-mobility systems in urban areas, which requires combining a range of innovations such as process, organisational, product, with infrastructure management, public procurement and consumer policies. Additional challenges for e-mobility are the need for international technology standards and the need to take account of consumer preferences. It is generally recognised that the transition to e-mobility will not simply be the replacement of one technology by another.

### The role of technology

10. Technologies are central for facilitating transitions in socio-economic systems. Technologies can improve productive efficiency and reduce inputs such as natural resources but also labour and capital. But technology follows its own logic from invention to diffusion, progressing through technology cycles and waves. In recent years, the convergence of biotechnology, nanotechnology and ICTs – so-called enabling or general purpose technologies - have raised expectations of rapid future technological change in the coming decades. Discussion on the new industrial or production revolution epitomises the expectations that new materials combined with lower energy inputs and the 'internet of things' will allow new forms of production that remove the need for scale economies and enhance efficiency as well as consumer utility and public service delivery. But technology in isolation is rarely the driver of system-wide change. Technology is an element in a system and exchangeability of elements of system innovation is often difficult, e.g. solutions once integrated are likely to remain in place. The human factor is also important – once users adopt a change, they are unlikely to change again radically at short notice. Often times, realising the full potential of technological change is dependent on organisational and social changes (values, consumer behaviour) as well as human-machine interfaces.

11. System innovation poses a challenge for policy makers as changes brought about by technology and innovation are largely endogenous processes and mainly driven by entrepreneurial and market forces. Large-scale change requires innovation not just in technology but also in social systems and in the relationship between the social and technical systems. As illustrated in the case studies (Chapter 4) the role of enabling technologies is secondary to achieving transitions. A lot of relevant technology for building solutions or smart cities is available, but institutional rules, political choices and socio-cultural attitudes prevent implementation. A further question is to what extent do IPRs, in particular patents, act as a source of resistance to system innovation. Wide acceptance of technology is only one component of system innovation, but the main issue remains the relationship between the different actors in the system.

**The dynamics of system innovation provide a new rationale for policy interventions based not only on single market failures but also on solving interconnected problems through a combination of market mechanisms and policy tools**

12. System innovation as a concept also sheds new light on the rationale for government action, which is often based on market and system failure arguments. From a system innovation perspective many market and system failures are interconnected and they can jointly augment barriers or spill-over as barriers to change in other domains. At the same time, many of the features of a given system that can be characterised as market or system failures from a research and innovation policy perspective may be important means to other social objectives. Furthermore, while co-ordination and demand articulation failures may lend themselves easily to government action, other failures may not be of the sole remit of government and could be resolved in conjunction with market mechanisms.

13. Change in large socio-technical systems takes time, sometimes twenty to thirty years. There are many dynamic factors within and outside large technological systems. Culture and social acceptance of change also require time; social movements, however, are not always predictable and might constitute tipping points in transitions. The temporal dimension of system innovation is also evident depending on the success or failure of policy actions; one does not move from on an inefficient system to an ideal model overnight. In the real world, rationales are contextualised and subject to political processes. Some systems may reach tipping points that accelerate transitions. Other systems may experience resistance to change – due to technology lock-in, market failures (asymmetric information) or system failures (e.g. co-ordination failures) - at critical junctures, aborting or frustrating certain transition paths. Low energy prices, the hidden costs of transition programmes, lack of market opportunities and weak consensus building with local communities create difficulties for the transition to sustainability. Other failures include the culture of the system and the acceptability or rejection of novel technology. Uncertainty with regard to demand is also a factor limiting the uptake of new technologies such as smart grids, smart meters that could limit or slow the transition between systems. Without change in consumer behaviour, many 'socially' useful technologies may not be taken up. Power relations and conflict management are also defining characteristics of system innovation.

**Business is central to innovation but innovation policies tend to favour incremental innovations that enhance efficiency rather than disruptive 'Schumpeterian' innovations.**

14. Business is a central driver behind innovation, especially incremental innovations that increase economic efficiency and productivity. Start-ups and small firms will respond to market entry and growth opportunities so policies that affect market formation and growth, such as competition policy and regulation, are hugely important. Business also has an important role in the critical (hard and soft) infrastructure that facilitates systems change. But companies can either block or facilitate transitions and system innovation. Large incumbents that are protected by their scale and driven by profit maximisation can be hesitant to invest in innovation to explore transition paths if present or future rents are threatened, which may block the transition of large technological systems to more sustainable paths.

15. Another issue is that much policy support to business innovation in OECD countries is often tailored to large firms, and not to small companies that have different needs and face different barriers to innovation. Tax credits for small R&D performing firms that have yet to turn a profit is one example (OECD, 2014). Yet policy makers have little understanding of the connections between small and large firms and their respective roles in a system innovation framework.

16. Policies can be used to operationalise a systems-based approach if rationales for interventions are broadened and policy objectives are complementary to objectives in areas such as health, the environment and competition policy. For example, business innovation policies that are attuned to competition policies

in network industries, or business support to innovation that is linked to specific goals such as assisted living for the elderly (e.g. as in the UK case study) or sustainable buildings. This is not to say the generic and sector neutral business innovation policies should be abandoned. Rather, given the systemic nature of societal problems, R&D and innovation support measures for collaborations (such as public-private partnerships) that encourage the combination of product, process and organisational innovations and their diffusion system-wide should be encouraged.

**The role of government in supporting transitions extends beyond orchestrating and co-ordinating policies and requires an active engagement in transition management**

17. A key element of system innovation is that there are transition paths towards more sustainable socio-technical systems and the government has a role in enabling, facilitating and managing such crucial transitions. System innovation, however, must be viewed through the prism of sectors and specific technologies. National strategies can articulate the government's role in system innovation. As many transitions have an explicit sectoral dimension, national policies may manage more than one transition at a time. For example, many OECD countries have explicit strategies to support transition and system innovation through a dedicated green economy agenda or as part of energy and new industrial strategy policies.

18. Governments play an important and complementary role to markets. Through funding, regulations and they can incentivise the behaviour of innovation actors. They can, through regulatory reform, public procurement and demand-side policies, also remove obstacles to transitions. Indeed, system innovation is a typical local and / or regional solution, e.g. applied in such fields but with strong interconnectedness at global level. To illustrate, the emergence of cities as actors in the transition to sustainability has given rise to a range of smart cities initiatives whose overall goals are to enable cities to become laboratories for solutions for socio-economic problems. But here, national context and the different styles of capitalism can exert significant influence on transitions. In countries with more corporatist structures, government may have a more direct influence on outcomes, while in more laissez-faire systems where prices play a stronger role in the reconfiguration of systems; government action may be more indirect. Bottom-up processes in entrepreneurial economies might be favoured in some countries whereas more government-led co-ordination may be favoured in other systems. In addition, the amount of social capital and engagement of institutions and citizens[1] as stakeholders matter. These groups can be important conduits for facilitating or impeding system change. But there must be mechanisms for public consultation that allows the mobilisation of these stakeholders.

19. There is also an element of risk of government failure. Policy intelligence can be useful to mitigate some of the risks of government intervention. Intelligence can help policy makers anticipate alternative possibilities, for example through foresight, business strategy, portfolio management or technology road-mapping. Strategic foresight can be useful in detecting impulses for change when their signals are only weak and providing a forum for reflection and debate on their relationship and likely impact on the system. Given the importance of a first mover's advantage in transitions, the utility of foresight activities seems very high, even if all it achieves is to provide a marginally advanced warning of likely general purpose technologies or dominant designs. When it comes to threats too, strategic foresight is an essential tool. It can help detect vulnerabilities, monitor changing risk impulses, and where necessary, facilitate decisions on changes in system design or investments in measures that improve resilience.

[1] In the 19th century, citizens and civic groups were precursors to environmental NGOs by acting to preserve large parts of national territories in the US and in Europe.

**System innovation is not just an innovation challenge, but also a deeply political project, which may affect vested interests from powerful incumbents**.

20. Because some transition-minded policies will negatively influence vested interests, political conflict and power struggles are likely and will need to be managed. First of all, system innovation entails not just winners, but also losers, especially when old systems are replaced by new systems. Organisations with interests linked to old systems may resist and oppose the changes. Many workers have skills that are firm- or even job-specific, and many firms are invested in capital and equipment that may be of value only for pursuing certain activities in particular locations. Such human or technological capital may be difficult to redeploy in response to a changing environment. Secondly, system innovation may require adjustments in policies, institutional frameworks, incentive structures and investment patterns. Advocates of transitions to a green economy, for instance, call not just for more investment in green innovations, but also for major policy change.

**Indicators and Evaluation**

21. Complex and systemic problems require a re-think of indicators and measurement that underline policy processes. In all of the case studies the lack of indicators makes the measurement of system innovation very difficult. It is also far from clear to assess what would have happened in the absence of policy actions. The complexity of social problems such as sustainability means that policies require rethinking the evidence base for policy making. A strict focus on economic indicators could limit the impact measurement and neglect societal impacts. System innovation means that policy relevant indicators should go beyond traditional input and output measures and consider other measures of transition such as quality of life indicators. System innovation also challenges thinking on the evaluation of impacts as well as behavioural additionality, since many of the relationships are non-linear. Evaluation of policy experiments in the area of system innovation is also important. In this vein, cluster evaluations are important learning tools given the focus on the evaluation of complex systems with different actors.

**Concluding remarks and future work**

22. A number of key policy implications can be drawn from the conceptual work and the case studies on system innovation undertaken for this project. Among these are:

1. Policy makers should have a clear understanding of the systemic nature of problem and their role for instituting changes to the design of the system. They include architectural changes that affect the ability of the system to respond autonomously as well as its ability to be steered and coordinated, such as improvements in its internal cohesiveness and reductions in concentration.
2. As illustrated in several of the case studies, this also requires clear focus from the political leadership and the administration to effect change.
3. Transition management and participatory approaches can create shared visions and co-operation among actors but these processes takes time and require consistency or stability in policy direction.
4. Resistance to change can be conscious, purposeful and therefore adaptive. It can be adaptive both with respect to the strength of the impulse and to policy efforts to facilitate the transition. Understanding, and where appropriate, managing resistance, is a key role of policy.
5. There is a need for new administrative capabilities and new needs for co-ordination across government. Innovation policy making bodies need to become agents for change, leaders in conceptualising a vision and in steering, and facilitating learning across the system. Clashing

with the interests of incumbents and their sometimes powerful lobbies requires quite a different mind-set and capabilities from those usually encountered in an innovation agency.

6. System innovation policy is predicated on accurate information about emerging opportunities and threats, the boundaries, structure, functions and performance of the system, and the monitoring of the impact of policy interventions. These are very resource intensive and imply a considerable upscaling of current intelligence gathering capacities in governments. This requires that transition programme managers are given adequate tools and incentives.

7. Policy interventions should be appropriately timed and sequenced. The very objectives of policy will vary. At an early stage the objective may be to identify and help co-establish a dominant design, whereas later on the objective may be to enable learning, and the accumulation of capabilities and of transition-specific social capital.

23. This report has shown that effective system innovation raises formidable policy and management challenges. While the case studies have provided insights on some of the key factors for success such as the role the importance of political focus and co-operation among various actors, there remain many unsettled questions regarding the process of scaling system innovations at local level to a national level or for establishing longer-term planning in policy making. There are also many trade-offs and compensation mechanisms involved in system innovation approaches. Further work on system innovation could extend our understanding of system innovation approaches by examining policies to support emerging technologies and industries in OECD member countries (e.g. Industry 4.0 initiatives) and green innovation initiatives.

# CHAPTER 1. DEFINITIONS AND BASIC CONCEPTS

## 1.1 Background

24. System innovation increasingly features prominently on the innovation policy agendas of OECD governments. For example, the UK's National Endowment for Science, Technology and the Arts (NESTA), an innovation charity, is exploring how to use the concept of system innovation in order to design policies to tackle the challenges of unemployment or ageing. The OECD's Green Growth and Sustainable Development Forum has selected the topic of "Enabling the Next industrial Revolution: Systems Innovation for Green Growth" for its meeting on 14-15 December 2015.

25. System innovation represents a broad concept that helps us frame our thinking, and sharpen our understanding of socio-economic and technological transitions and the role of policies. It is mission-oriented and can have important, and even radical, implications for the way we think about policies today. The goals of the TIP project it to deliver policy advice to governments, especially departments and agencies responsible for innovation policy. Readjusting governance structures will be a key issue in this regard.

### Motivation

26. System innovation offers a new way to deal with the direction of technological change. It also offers opportunities to reduce inequalities and inefficiencies (incl. rent-seeking behaviour) by enabling transitions that either would not happen at all or with extremely costly delay. Transitions seem urgent in light of pressure on policy to respond to the challenges of unmet growth potential, inequality and climate change. Policy leadership and intervention are needed to stem some very bleak scenarios. There is a central role for policy to shape a vision for a desirable future, to widen scope of co-ordination and extend planning horizons. Powerful arguments can be made for interventions that bring about the cost reductions and efficiency improvements necessary to guide production systems into more sustainable paths. In that respect there is invariably a critical role for public investment in infrastructure, education and innovation as well as a need for institutional changes to overcome lock-in, including in system architecture.

### Definitions

27. System innovation (SI) is a conceptual framework for understanding and managing transitions in response to radical technological and social change. In its *simplest* form the concept comprises of two core elements:

- An *impulse* for change in the form of the global emergence of a radical innovation (e.g. a major scientific discovery, a game-changing invention, a new way of organising production), a major socio-political or economic development (e.g. membership to a free trade area, a financial crisis, a war) or a great social challenge (e.g. climate change, energy, demographic shifts). Alternatively, the impulse may emerge from within (and be perhaps specific to) the system, reflecting context-specific innovations or radical shifts in tastes and preferences. Though the balance of probability is that the impulse originates outside the system, it nevertheless implies extensive technical, economic, social and political change (not necessarily in this order) within the system.

- The system's *response* to the impulse, in the form of new production and consumption arrangements, new skills, new infrastructure, subsequent innovations (many of them specific to the system's context), new social arrangements (e.g. professional associations), new rules and new forms of governance, to name but a few. The response's *duration* and *precise outcome* depend on the system's capacity to transform, itself a complex function of, among others, the system's structure and prevalent institutions.

28. Actual transitions are not tidy or seamless. The impulse may not be a single independent event or trend but a complex of interrelated ones. It may be difficult to link the stimulus to a particular place, particularly as science is a global endeavour. Inertia and resistance to change can unduly delay beneficial transitions while increasing global connectedness may increase susceptibility to some negative scenarios. Profiting from the transition thus requires a complex constellation of conditions to be "just right", an alignment which is difficult to achieve even with careful preparation. Policy has often limited or only indirect control over many of the crucial conditions, but can nevertheless be instrumental in steering the system, altering its design and modifying incentives.

29. In general terms, system innovation can be defined as *a radical innovation in socio-technical systems which fulfil societal functions, entailing changes in both the components and the architecture of system*. Some of the defining characteristics of system innovation include:

- Fundamentally *different knowledge base* and *technical capabilities* that either *disrupt* existing competencies and technologies or *complement* them, resulting in new combinations. An example could be the case of synthetic biology and its potential to revolutionise industrial and biological processes but which is limited due to regulatory barriers or incoherence between research funding policies and product and safety regulations and technical and market risks (e.g. scale, financing).

- Changes in *consumer practices* and *markets*. Digitisation and "the internet of things" are examples of change brought upon by changing consumer behaviour and technology that results in potential loss of control over consumers for companies, increased competition, and the need to engage digitally with suppliers, partners and employees and consumers/citizens.

- Changes in *infrastructure, skills* and other elements, including policy and culture. An example could be the case of modern mobility systems for people (i.e. e-mobility) that are evolving due to underlying changes in technology, ownership structure, consumer preferences and related changes in energy systems and their linkages to other systems.

30. System innovation offers a new perspective to study transitions and the role of policy in enabling or impeding them. A common tendency to approach the study of innovation from the perspective of science and technology often stands in the way of an understanding of the wider demands innovation places upon social and economic systems. This has been a central argument in support of systemic approaches to the study of technological change and innovation such as the extensive literatures on national, regional and sectoral innovation systems (Lundvall, 1992; OECD, 1997; Cooke, 2001; Malerba, 2002). Much knowledge about transitions has been gathered by studies of global paradigm shifts (e.g. techno-economic paradigms, scientific revolutions) (Dosi, 1988; Perez, 2002) as in the case of ICTs, biotechnology and nanotechnology. System innovation builds and extends upon these approaches, by applying their key insights to the study of the direction of technological change. Moreover, systems innovation acknowledges the multiple levels within which transitions occur and places an emphasis on changes in the demand-side, to a greater extent that was the case previously.

### 1.2 Kinds of change and types of systems

31. The definition of SI leaves much room for interpretation on the types of systems and the kinds of change concerned. What exactly constitutes a system? What change qualifies as radical? This section

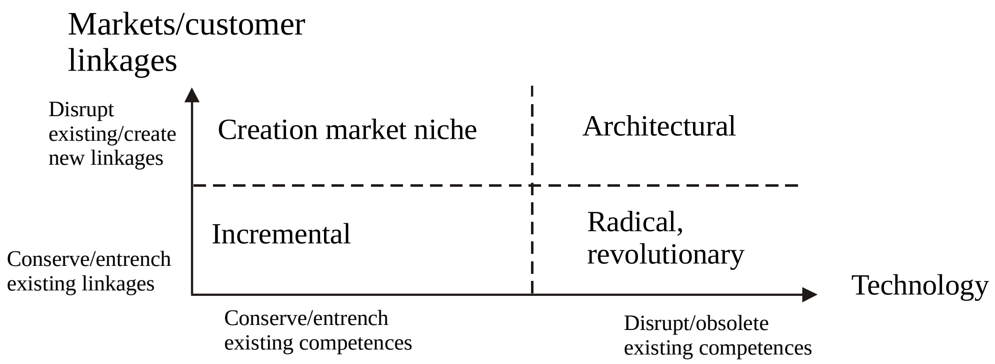
offers some initial answers to these questions, drawing from literature and some of the insights garnered from the case studies.

## Kinds of change

32. Because technological and economic changes are closely connected, they are sometimes jointly studied. Various strands of economic literature attempt to shed light on their long-term relationships, including research on “technoeconomic” paradigms (Dosi, 1988; Perez, 2002), General Purpose Technologies (GPTs) (Bresnahan and Trajtenberg, 1995; Helpman and Trajtenberg, 1996), Large Technical Systems (LTS) theory (Hughes, 1987) and, more recently, literature on socio-technical systems (Rohracher, 2001; Weber, 2003; Geels, 2004; 2005). New technoeconomic paradigms or GPTs are among the most important drivers of transitions. Their emergence acts as a powerful impulse for wider change in the system (see section 2.1). But system innovation may be about changes in specific sub-systems (e.g. sectoral) and be therefore more evolutionary than revolutionary. Impulses may also be non-technological in nature, and include socio-economic challenges (see section 2.1).

33. For SI an important dimension of change is related to the configuration of socio-technical systems, which entails both a production ‘environment’ (which generates technical innovations) and a user ‘environment’ (where consumers use technologies to achieve functionalities and enjoy services). System innovation can therefore be seen as a particular kind of innovation which entails substantial changes in both production and consumption. In terms of the innovation typology by Abernathy and Clark (1985) that focuses on competencies of firms and their linkages with customers (e.g. markets, distribution channels), system innovation entails architectural innovation (Figure 1.1) which disrupts existing technical competencies and linkages with customers. Architectural innovation also often entails new business models, new regulations, new infrastructures, and new cultural meanings.

**Figure 1.1 Typology of innovations**




*Source*: Abernathy and Clark, 1985: 8.

**Box 1.1 Case Study - E-mobility in Austria requires production and consumption changes**

E-mobility or the development and diffusion of electric vehicles will require changes on both production and use. As illustrated in the Austrian case study (see Annex), there are different obstacles in the system of personal mobility can hinder the transition towards e-mobility:

- On the producer and provider: uncertainty about future business models and a lack of standards.

- On the user side:  range anxiety and the reluctance to give up ownership. Indeed, for consumers, e-mobility is a direct substitute for conventional motorised individual transport current which implies a reduction of cultural values as freedom and choice. More, investments in e-cars are relatively expensive.

It is important to give potential users the opportunity to find out how e-mobility works – and that it works without problems.

Austria introduced in 2008 a key measure, called "Model regions electric mobility" (seven regions founded to date): it demonstrates e-mobility in practice and shows the functionality and attractiveness of electric mobility. Users were able to experience e-mobility and feedback of these early adopters was positive.

The 'model regions' It is an example of policy measure that can effect changes in perception and behavior on the user side.

**Box 1.2 Green Innovation and Systemic Changes in Korea – innovation policies in the supply side and in the demand side**

Korea's Green Growth Strategy combines supply and demand-side innovation policies to promote green innovations:

- **On the supply side:** Increase of government R&D expenditure for green technologies, twice increase for 5 years (2008-2012); Selection of 5 target areas and 27 strategic technologies in the green technology field to improve the efficiency and concentration of technical development; Government certification for green technologies, green products, and green SMEs; For companies having green tech certification have advantages to get general loan of green growth, policy loan based on green credit and governmental guarantee for green high tech companies; Encouraging nationwide regional systems of innovation and innovation clusters to set green innovation as their vision.

- **On the demand side:** Eliminating FIT (feed in tariff, ~2011) regulations and introducing the RPS (renewable portfolio standard, 2012~); Green labeling for green products and high energy efficiency products; Photo-voltaic, wind power, fuel cell and smart grid test-beds for technical transfers and applications; Support of private demand: tax incentives and infra supports for green car, direct subsidy and after service for green home, and energy efficiency (energy saving) labelling for green electronics; Green construction projects through PPPs: green town, green home, green building.

32. Without changes on the user side, technological discontinuities do not change functionalities and aim for existing markets. Examples are hybrid-electric vehicles, biofuel and flex-fuel vehicles, light emitting diodes, and electricity generation with nuclear power stations (Box 1.1). Less clear-cut examples are fuel-cell cars (which offer similar driving experience as petrol cars, but require a new hydrogen infrastructure), battery-electric vehicles (which have shorter range and thus require new trip planning routines; they also require new charging infrastructures and upgrades in the electricity system); wind-farms (which require upgrades in the electricity grid and new grid management procedures when they generate more than 20% of electricity to deal with the intermittency problem).

33. Another dimension of change refers to the meaning of 'radical innovation' in system innovation. This term is often interpreted as 'disruptive' innovation (Christensen, 1997), meaning that new technologies or systems *replace* or *substitute* existing technologies or systems. Geels and Schot (2007), however, suggest that systems can also undergo major transformation through *reconfiguration* processes,

in which new innovations and competencies are *added* to and *incorporated* within existing systems, where they trigger subsequent adjustment processes. Smart grids (or smart homes and smart cities), for example, are not about substitution of the existing grid, but about addition of new ICT devices to the grid, which enable new functionalities (e.g. two-directional communication, real-time information, demand management with grid operators switching devices on and off to manage peak loads).

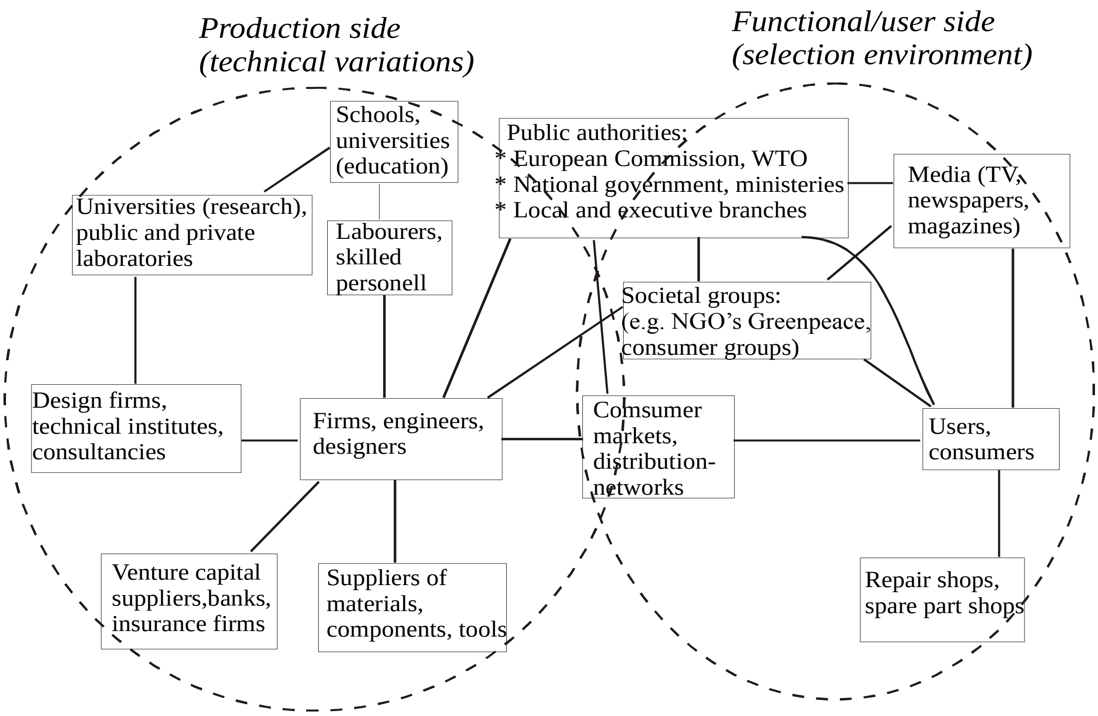
34. Changes occurring as part of system innovation can therefore include fundamentally different knowledge base and technical capabilities that either disrupt existing competencies and technologies or complement them leading to 'new combinations'; changes in consumer practices and markets; and changes in infrastructure and other elements (*e.g.* policy, cultural meaning).

**Types of systems**

35. Systems can be variously defined in terms of geographic proximity (local, regional, national and international) or in terms of production, market (e.g. a sectoral system including all upstream and downstream producers and the characteristics of the markets which they serve) or technological affinity (technological systems).

36. A general and operationally useful way to describe the system concerned is as the *set of stakeholders who have to interact so that the system as a whole fulfils a specific function (or purpose).* For example, a system that produces technological solutions in the field of biotechnology, would include a diverse range stakeholders such as small local businesses and large multinationals in sectors as diverse as food, chemicals, pharmaceuticals, manufacturing and services, government regulators and funding agencies, universities and public laboratories, professional organisations. The relationships between the various stakeholders can be quite complex and range from market transactions, to socio-political hierarchies, and knowledge networks, among others. By implication, system innovations are multi-actor processes that entail interactions between aggregate social actors (see Figure 1.2). The precise configuration of system elements and associated actors will vary between systems and over time.

**Figure 1.2 Societal groups involved in system innovation**



*Source*: Geels, 2004: 901.

37. In demarcating the system that is subject to change it is important to identify the focal function the system would be expected to fulfil. The task comprises of mapping the current system (what is inside the system, what lies outside it, how it is structured) and assessing how its internal organisation and external boundaries might be reorganised to respond to the new demands. For example, the debates on grand challenges are about societal functions such as mobility, food, housing, health care, personal care, and energy (and services such as light, heat, power). Technology (artefacts, infrastructure) is obviously important to fulfil these societal functions (e.g. cars, roads, light bulbs, grids). But the functioning of technologies requires linkages to other elements such as organisations, regulations, consumer practices, cultural ideas, scientific knowledge, and maintenance and repair facilities. Attempts to define the boundaries of complex and continuously emergent socio-technical systems will inevitably be partial, context-specific and temporary (Smith et al., 2010; Scoones et al., 2007).

38. The boundaries of the system may of course self-organise to precisely the optimal extent required to meet a given purpose. But information and co-ordination failures mean that there is, almost invariably, a role for policy in bringing about more effective configurations and in making them happen sooner. Re-configuration is gradual and can only be partly influenced by policy. As the transition progresses, the boundaries may extend, especially when apparent feasibility and ambition increase in a mutually reinforcing fashion.

39. From a policy perspective, the question of the types of systems concerned and their boundaries is often a given, determined by established governance structures, e.g. along national, regional or sectoral/thematic lines. It takes forward-looking, ambitious and capable policy to re-define these governance structures, to propose powerful visions about the desired scope and magnitude of change and to usefully position short-term interventions within this long-term framework. From a positive perspective, accurately defining the scope and magnitude of change and the boundaries of the system in question are empirical questions, the answers to which are bound to differ for each transition, and are answerable *ex post* or are, at best, continuously ‘discovered’. For this reason, timely policy intelligence is even more important in SI than in conventional innovation policy.

40. It is this tension between the politically feasible and the pragmatically necessary that has been an enduring source of resistance to the adoption of SI-minded policies (some of the implications of which [e.g. that the sequence of SI adoption by policy makers has to necessarily start from the orientation function of the system] are discussed under 3.2.1).

**Types of innovation**

41. The difference between SI and innovation as conventionally considered is both one of degree and of characteristics. In SI change is profound and far reaching; it leads to the evolution or emergence of new actors, redefines old relationships and may create new markets. Because of this it needs to be conceptualised in macro-chronological terms, with a horizon of one or more decades. While individual discoveries, inventions and other innovations are important, the appropriate framework of study in system innovation is demarcated by the sum of all innovations, radical and incremental, social and technological that is combined to bring about the transition. While this of course means that policy making in this area is difficult, the potential benefits from an early or improved transition are too many and important to ignore.

42. In the OECD Oslo Manual (OECD and Eurostat, 2005) categories of innovation such as *new-to-the-firm*, *new-to-the-market* and *new-to-the-world*, signify the introduction of novelty (e.g. technological, organisational) occurring within fixed, pre-defined boundaries, usually corresponding to firms or markets.

These categories are of course relevant in characterising the myriads of innovations necessary to bring about a transition, but are clearly inadequate to characterise the scope and magnitude of system innovation.

43. Table 1 attempts to characterise the additional categories of novelty implied by SI (the shaded area) and position them vis-à-vis established innovation categories in the OECD Oslo Manual. The first obvious extension would be an additional category (and its attendant sub-categories) which includes the "system", however defined (whether regional, national, technological, etc.) as the pre-defined boundary under study. Considering the broad category of *new-to-the-system* innovation would arguably offer a more comprehensive view, not necessarily corresponding only to but of course potentially including markets. If the boundaries of the system can be defined unambiguously, the introduction of system-centred definitions could be useful within specific settings, allowing the broad range of Oslo-compliant data collection tools, analytical and explanatory frameworks to be applied.

44. Such extensions of scope however would still fail to capture a key dimension of system innovation, namely that each transition implies profound reorganisation within the system itself. In addition, SI also implies an extension of the system's scope as it progresses such as linking up or even including other systems, the inclusion of new actors and the disengagement of old ones. Therefore system innovation is about *new system organisation* and *new boundaries* (Table 1.1). The fact that the new internal organisations or new boundaries are not defined to begin with, does not mean that they are undefinable or that there is no value in knowing what they are. Discovering the system's internal organisation and precisely mapping its boundaries is a policy intelligence task that will have to be accentuated to a much greater extent than has been hitherto the case in many policy settings.

**Table 1.1 Mapping the scope of system innovation**

| | **NEW TO THE SYSTEM** | **NEW SYSTEM ORGANIZATION AND BOUNDARIES** |
|---|---|---|
| *Novelty categories* | New to the **–firm/-market** | • Firm re-structuring, mergers, acquisitions<br>• Market extensions to new places/segments (industrial diversification)<br>• New incentive structures |
| | New to the **world** | • Changes in political hierarchies, administrative competences<br>• Changes in social and market relations<br>• Incorporation of new actors to the system, alignment with hitherto 'external' systems.<br>• New laws, standards and regulations |
| | New to other **fixed definitions of systems,** Defined e.g. in terms of geographic, technological, functional or relational proximity; including *public sector innovation* and *social innovation*. | |
| *Rate of change* | Rapid, e.g. years (micro-chronological) | Slow, e.g. decades (macro-chronological) |
| *Impact of change* | Typically small | Typically large |
| *Science & Technology* | Changing | Fixed or Changing |
| *Relations, structures, boundaries* | Fixed | Changing |

*Note*: Additional categories of novelty implied by SI in shaded area.

Source: OECD Secretariat.

## 1.3 Stylised features of system innovations

### *1.3.1 Contextual alignments*

45. While the impulse-response conceptualisation of system innovation elaborated earlier is a useful first-order approximation of transitions in individual (e.g. national) systems, the global picture is considerably more complex. Literature on the multi-level perspective (MLP) (Rip and Kemp, 1998; Geels, 2002; 2005; 2012) recognises both an S-shaped diffusion curve for radical innovations and on-going dynamics in existing socio-technical regimes (linked to existing systems) and broader socio-technical landscapes (which refer to broader secular trends). The MLP highlights the importance of broader contexts for system innovation and distinguishes between three main levels of change[2]:

a) Technological niches. This is the level characterised by high rates of change. The majority of individual niche innovations are of small overall impact though this ultimately depends on the scope of the niche itself.

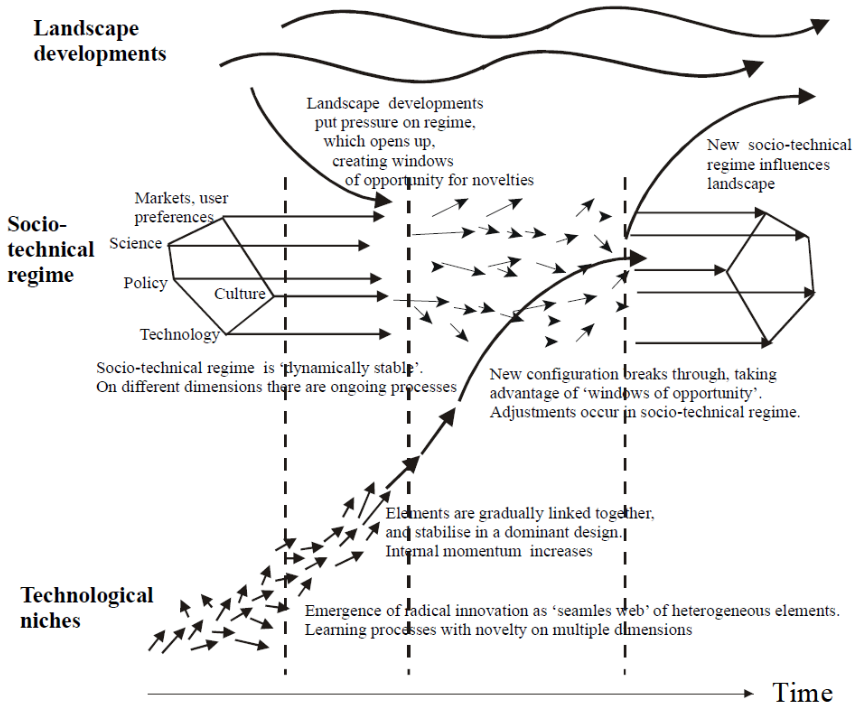
b) Landscape developments. This is the "macro" or overall social, political and economic setting within which the system is situated or exposed to. The rate of change at this level is slow. However, events and trends at this level are of pervasive significance.

c) Socio-technical regime. This level corresponds to the collection of actors that comprise the immediate functional system. The rate of change at this level is variable. It can be relatively stable for long-periods of time, until the needs of a transition imply a rapid reconfiguration of actors and their relationships.

[2] The distinction is a conceptual one that can be difficult to operationalise. As emphasised by Smith et al. (2010), distinguishing between the niche and the regime levels in particular is less clear empirically.

46. Figure 1.3 presents a stylised pattern of a system innovation process. Although each transition is unique, the general pattern is that technological niches accumulate, interconnect, gather momentum and a dominant design emerges; the emergent dominant design interacts with the prevalent socio-technical regime, eventually breaking through and having widespread impact. Pressures exerted by landscape developments may present opportunities to upset the current regime sooner; contrarily the absence of such pressures may thwart the transition. Unlike mechanistic diffusion processes, the path and outcome of the transition depend on interactions and are very much conditional on suitable alignment between the various levels. Breakthrough is not guaranteed and in practice, there is a variety of possible outcomes, as the impulses interact with existing technologies and actors in the system (e.g. the case of the fuel cell powered vehicles technology versus hybrid vehicles).

**Figure 1.3 A dynamic multi-level perspective on system innovations**



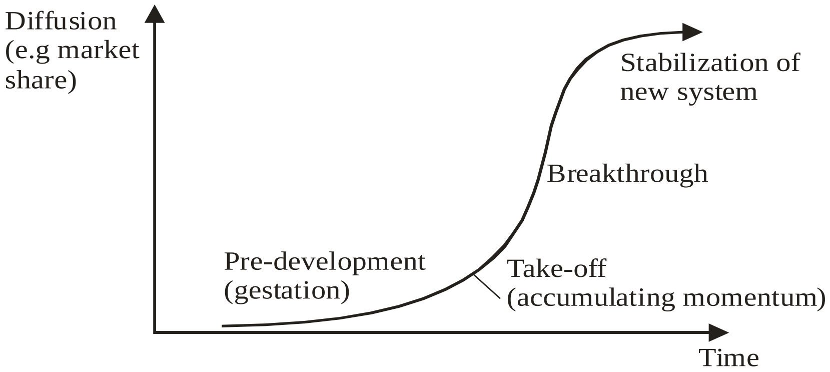

*Source*: OECD (2013), adapted from Geels, 2002: 1263.

47. Both the path of the transition and its eventual endpoint are dynamically determined by successive interactions, each step generating subtle variance in direction which may be further amplified in subsequent iterations. However, impulses for change may encounter resistance. Therefore the outcome of the transition is open-ended.

### *1.3.2 Stages of transition*

48. System innovations and transitions are complex and long-term processes (Geels, 2005; Fouquet, 2010; Smith et al., 2010), which may last decades. To understand core dynamics and general patterns, it is useful to distinguish different phases. Rotmans et al. (2001), for instance, distinguish four phases, which implicitly assume a substitution pathway: pre-development, take-off, breakthrough, and stabilization of a new system (Figure 1.4).

**Figure 1.4 Stylized phases in system innovation and transitions (Rotmans et al., 2001)**




Early stage: Fostering awareness, debate and consensus; Prototyping and scaling up system innovations.

**Box 1.3 Example of transition profile - Long-term care in United Kingdom**

Because of an ageing population, the elderly care system in United Kingdom is shifting from residential care, based on nursing homes, to a new model which emphasizes the care of the elderly in their own homes.

Here are the phases in the technological transition to assisted living – and the diffusion of the technologies:

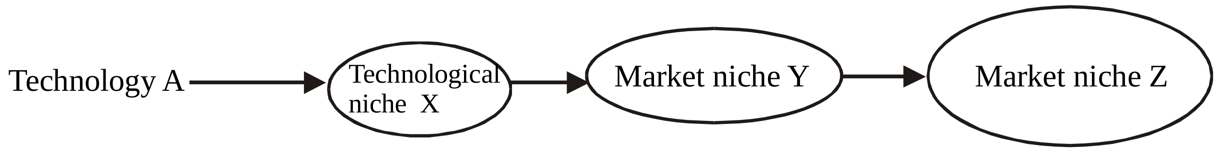
- **Pre-development (gestation)**: Technologies of assisted living are not commercially viable due to poor performance and high cost. Products are unappealing to customers.
- **Take-Off:** Firms begin to successfully sell assisted living solutions to certain public sector partners at significant scales.
- **Breakthrough:** Assisted living technologies have demonstrated to deliver cost-efficient, large-scale, and user-friendly services to certain NHS bodies and local authorities. It will raise awareness of assisted living technologies among users and greater user demand.
- **Stabilisation:** Assisted living technologies have become the new norm.

49. Radical innovations emerge as ‘hopeful monstrosities’ (Mokyr, 1990: 291-292): they are initially ‘monstrous’ because they have relatively low technical performance, are often cumbersome and expensive; they are ‘hopeful’ in the sense that proponents advance positive future visions for the technologies. Because radical innovations cannot readily compete with the established technology, they are initially shielded from mainstream market selection. Radical innovations therefore emerge in ‘technological niches’, which are “protected spaces in which inventions can be tried out and further developed".(Schot and Geels, 2007: 615).

50. For radical innovations there is much uncertainty about technological characteristics, user preferences, policy, infrastructure requirements and cultural meaning. System innovations are therefore open-ended processes, characterised by experimentation and learning (Wilkinson *et al*., 2012; Wilson and Grübler, 2011). Radical innovations are uncertain, risky, and may fail. From a practical perspective, an experimental approach can be justified in terms of reducing risk and as such can be seen a necessary prelude to wide-spread diffusion (NESTA, 2013). The diffusion process is best seen as a pattern of ‘niche-

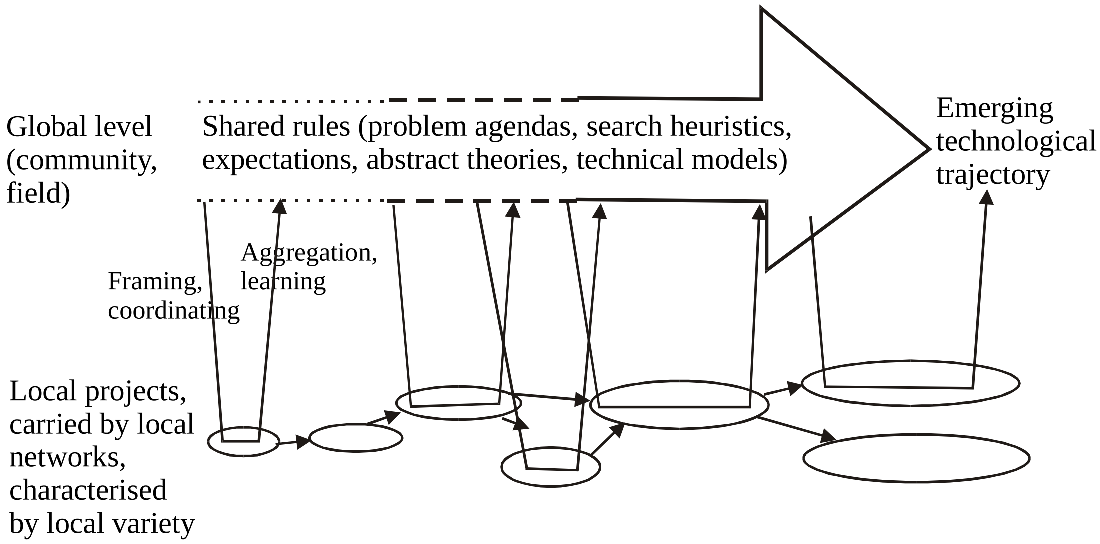
accumulation' (Geels, 2005), with a new technology emerging in a technological niche (protected space), then moving to a small market niche, and subsequently into larger mainstream markets (Figure 1.5).

**Figure 1.5 Diffusion as a process of niche-accumulation**




51. In this phase, innovations break out of protected technological niches, and establish a foothold in one or more market niches. This provides a more reliable flow of resources, which stabilizes the innovation, making it more attractive for new entrants. Learning processes stabilise into a dominant design (Figure 1.6) of the new system, which becomes institutionalized in design guidelines, product specifications, and best practice formulations.

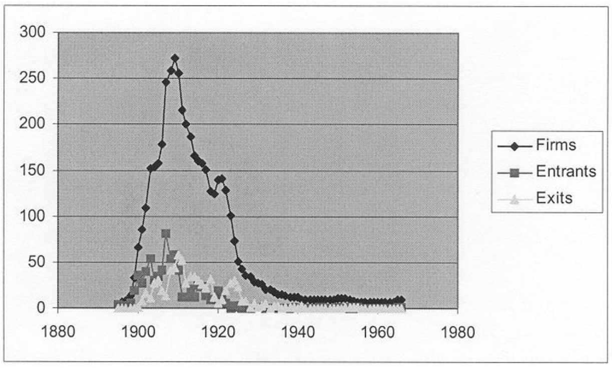
**Figure 1.6 Innovation trajectory emerging from sequences of local projects**




*Source*: Geels and Raven, 2006: 379.

52. Technical and economic opportunities attract new entrants, which gives rise to the emergence of a new industry. The early days of new industries are characterized by high turbulence with many new entrants and exits. The emergence of a dominant design often triggers a shake-out process, leading to a gradual consolidation in the new industry. In the American automobile industry, for instance, the shake-out began in 1909, when Ford's Model T established a dominant design (Figure 1.7). The industry shake-out eventually resulted in a tight oligopoly dominated by Ford, General Motors and Chrysler.

**Figure 1.7 Evolution of the automobile industry structure**

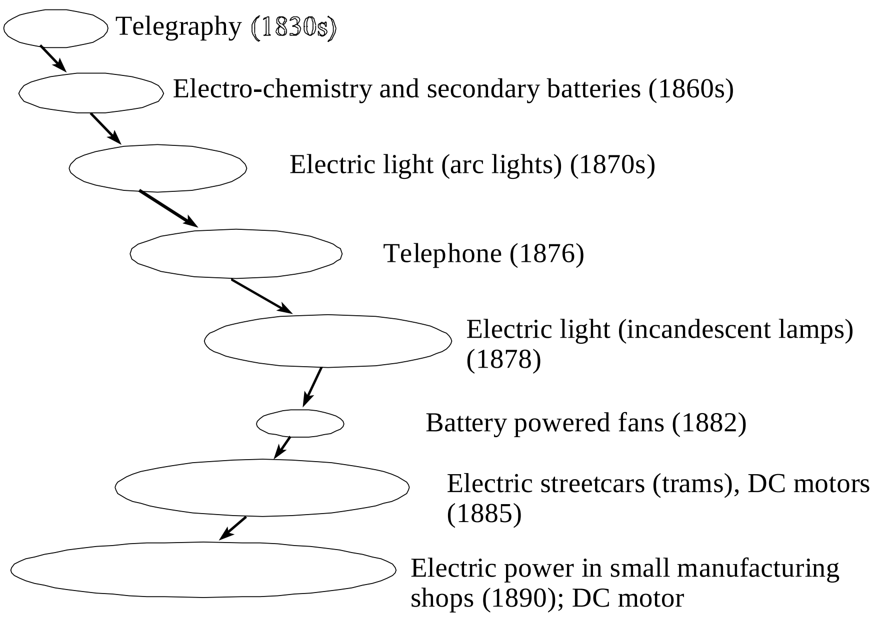



*Source*: Klepper, 2001:41.

53. Early learning processes tend to focus on functionality and performance rather than cost (Wilson and Grübler, 2011). Cost-benefit calculation is always important, but provides insufficient support for decision-making in early phases (because of pervasive uncertainties about technical performance, consumer demand, prices etc.).

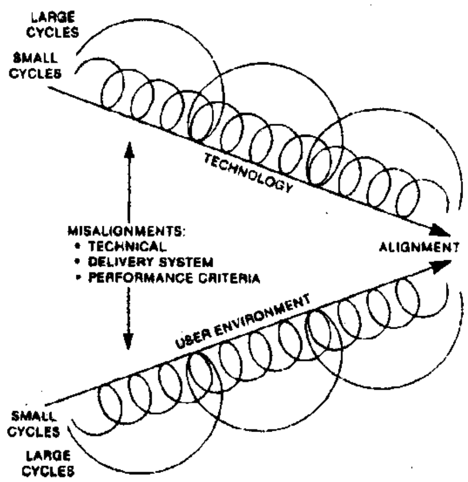
54. Markets do not readily exist for radical innovations. In fact, there may be much uncertainty about who the consumers are, what their preferences are, and what the crucial functionality of the new technology will be. How a given invention will fit into the social system, the uses to which it will be put, and the alterations it will generate, are all extraordinarily difficult to predict (Rosenberg, 1972). Electricity, for instance, was a radical innovation in the 19th century, which evolved through a range of applications (Figure 1.8). It was impossible in the 1830s to predict how electricity would be used in the 1890s, and how this would transform the economy and society. The same applies to jet engines in the 1930s, computers in the 1960s, or the Internet in the 1970s.

**Figure 1.8 Innovation journey of electricity**



55. Radical innovation and system innovation are therefore best seen as a co-construction process in which new technological systems and user environment(s) are created simultaneously (Figure 1.9). One the one hand, the technology system is adjusted (in smaller and larger steps, represented with circles of different size) to fit better with the user environment. On the other hand, the user environment (user practices, behavioural routines, infrastructures, policies, etc.) is adjusted to accommodate the new technology system.

**Figure 1.9 Co-construction of technology and user environment**




*Source*: Leonard-Barton, 1988: 251.

56. The pre-development phase may take a long time: "There may be long periods when only a few pioneers advocate change without much attention, before a tipping point comes which leads to a swarm of competing alternatives, that is then followed by a period of winnowing out, and then the consolidation of a much smaller number of models that turn out to be viable" (NESTA, 2013: 18). As the transition approaches maturity, a dominant design emerges and propagates widely, with myriad adaptations to niches At this point, public support may be gradually phased out. Markets are best-placed to maximise efficiency and the principal policy preoccupation would be with providing a level playing field and avoiding lock-in.

57. New professions emerge in this period, which codify the new body of knowledge and transfer it to students through new curricula at teaching institutions. Dedicated professional groups will work to advance the new technology, either in a technical sense (developing and codifying knowledge) or in a political sense (through lobbying). Geels (2005) described how the emergence of the new profession of American highway engineers in the 1910s was instrumental in the building of new roads and highways in the 1920s and 1930s. The rise of 'data scientists' who can create and manage information systems to analyse and process large amounts of big data in real time is a contemporary example.

### *1.3.3 A constellation of linked barriers to transition*

58. Barriers to transition are interlinked and typically only a (small) part lies within the remit of (national) public policy. The absence of complementary systems can be considered a "hard" barrier that cannot be lifted at short notice. Socio-political barriers to transition, particularly when associated with vested interests, may not recede with the passage of time. Strong versus weak links: "hard" (and external) barriers versus internal and policy variables. Resistance can be strong enough to cancel out the impulses for change and even the policy efforts (Harich, 2010)[1]. The dense web of barriers that needs to be overcome underscores the need for a *systemic* (or comprehensive), approach to management of transitions.

### *1.3.4 Open-ended endpoints*

59. The open-endedness of the endpoint of actual transitions, combined with a diverse range of possible desirable transitions, pose a challenge for monitoring and managing transitions. The desired endpoint may vary due to changes in the strength of impulses over time due to (a) A slowdown or hiatus forced by absence of complementary systems. This absence is a significant and commonly observed limitation in the history of large-scale technoeconomic transitions (Mokyr, 1992; Landes, 1969). Arthur (2010: 148) invokes the term "*reverse salients*[3]" to refer to "stuck places" (e.g. in critical aspects of science, technology or other relevant knowledge) which have been held back despite progress in proximate territory. (b) due to a new transition that overlaps with and either diverts resources and attention or directly undermines the need for the original transition (c) changes in social priorities over time. For example, in former socialist countries, their transition to a market economy was linked with, or arguably driven by, intense social pressure for greater consumption possibilities. Another more speculative example is increased social awareness of and pressure for tackling environmental challenges which could conceivably rebalance the dominant preoccupation of public policy with economic efficiency towards environmental sustainability.

**Box 1.4 DuWoBo and the Round Table Construction: two Flanders initiatives for sustainable housing and building, with a different interpretation of "system innovation"**

The two initiatives that were studied in this case, DuWoBo and the Round Table Construction, show that their interpretations of "system innovation" are not unequivocal. While a sense of necessity for change is shared in both processes and between actors, the exact meaning and nature of the change is interpreted differently and can thus become a point for divergence and contestation.

DuWoBo takes sustainable development as a normative orientation and uses the transition management approach to formulate a long-term vision, set up transition experiments and create a mixed network of frontrunners and regime actors.

Whereas the Round Table Construction is part of a search for a new industrial policy and focuses on a restructuring of the building sector towards a building-energy-environment cluster, with a group of representative sector organisations.

Although both initiatives are developed in the same system and related policy domains, different factors hinder integration and even cooperation: diverging goals and interpretations of system innovation or strategic positioning of involved actors.

62. Another example is the transition from slow moving electric trams to other forms of mass transport, made under pressure (due to congestion) to improve transport time and cost efficiency. In some cases barriers to transition (such as the high cost of large scale infrastructure) delayed the transition long enough for shifts in urban policy priorities to occur. Today, society attributes an increased importance to considerations of air quality and noise pollution as well as passenger comfort, all of which can be considered advantages of electric trams. It is arguably these changes, rather than any radical technological innovation, that have allowed the technology to regain some of its appeal and even to be re-introduced in many cities, where it co-exists with other forms of urban mass transport.

60. At each part of the transition the boundaries of the system change; the scope of the system progressively broadens to encompass a greater set of actors and also the configurations change to better

[3] A term which Arthur (2010) attributes to historian Thomas Hughes.

serve its changing functions. Boundaries of the system can be positive ("what they are", which is an empirical question) or normative ("what they ought to be", as decided by policy ambitions, market expectations, social aspirations); the transition can be considered to have completed when the two coincide.

61. Early on in the transition, boundaries may be extended by awareness raising and linkages (e.g. joint R&D projects). Setting technical standards and government regulation can act as a common language and facilitate the transition. The expansion of boundaries can be gradual or occasionally, rapid. When markets see investment in the new techno-economic paradigm as profitable, the process develops its own dynamic. Provided enough progress can be made to maintain the credibility of the vision, additional funding will be secured. The process continues either until the transition completes or some hard constraint is encountered, which could likely be a reverse salient (or external dependency, e.g. in a proximate area of science or technology which grows more slowly), lack of large-scale funding for infrastructure of the public good type or lack of dedicated skills.

# CHAPTER 2. DYNAMICS OF SYSTEM INNOVATION

## 2.1 Impulses and drivers of transition

### *2.1.1 Characterising impulses: source, magnitude, rate of change*

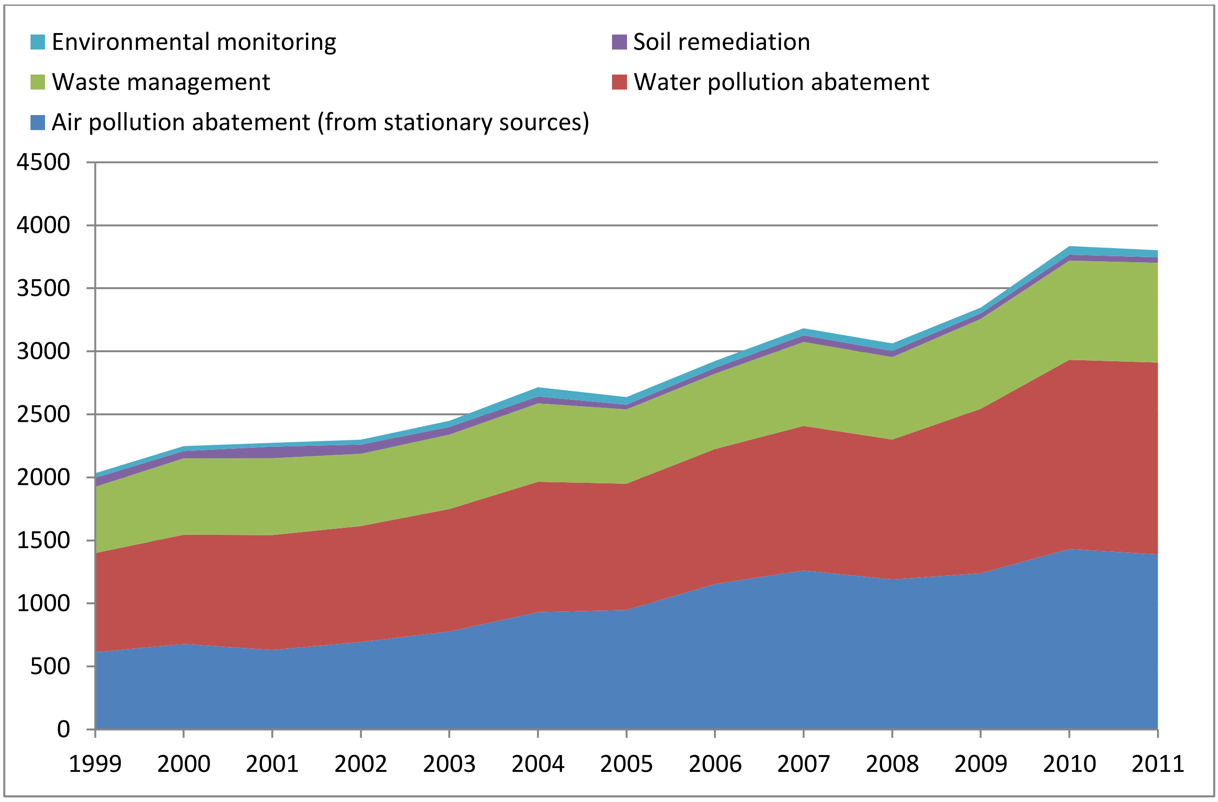
65. Impulses can be distinguished in terms of their source, magnitude and rate of change. They can represent developments in technological niches internal to the system, relating e.g. to changes in demographic composition, political ideology, cultural discourses, and environmental problems. Alternatively impulses may include, emerging general purpose technologies and rapid external shocks, such as wars, economic recessions, or oil price fluctuations. (Van Driel and Schot, 2005).

### *2.1.2 Social challenges*

66. To facilitate policy efforts to deal with environmental challenges the OECD has put forward a *Green Growth Strategy* (OECD, 2011) aiming to catalyse relevant investment and innovation. The strategy promotes a concerted policy focus on stimulating green growth as a way to boost productivity and open up new opportunities for innovation. It can also reduce the risks to negative shocks to growth by helping avert resource bottlenecks and imbalances in natural systems. Perez (2013) argues that the post-financial crisis landscape presents ripe conditions for a new economic 'golden age' fuelled by innovation in the green economy. The flurry of technological development in this direction (Figures 2.1, 2.2 and 2.3) suggests that these are sizeable and growing impulses.

**Figure 2.1 Patenting in environmental technologies, 1999-2011**

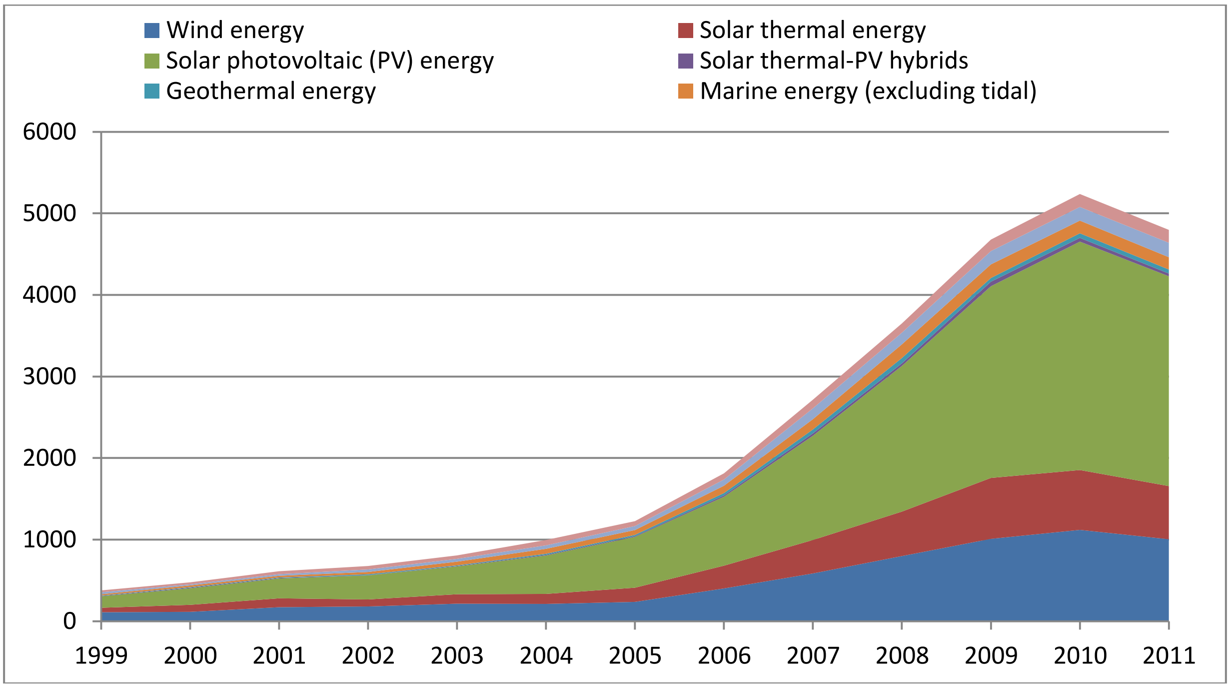
(patent applications, thousand)




*Source*: OECD Patents Statistics, Patents by Technology.

**Figure 2.2 Patenting in renewable energy technologies, 1999-2011 (**

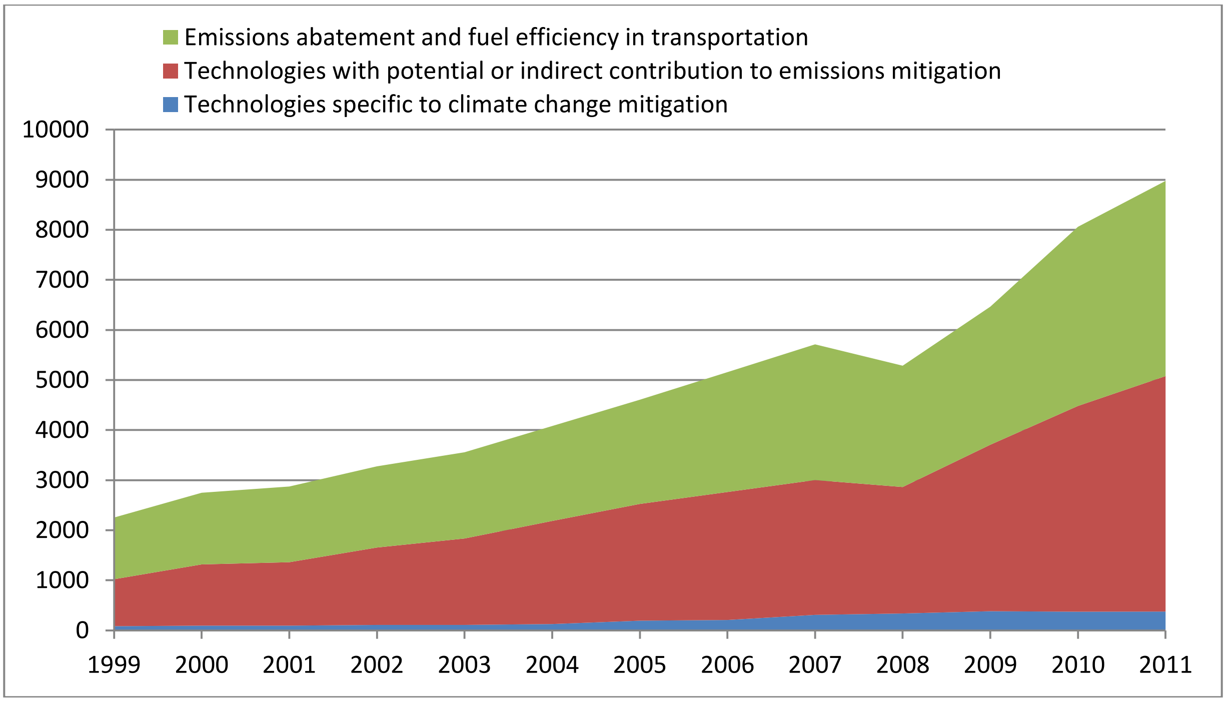
(patent applications, thousands)




*Source*: OECD Patents Statistics, Patents by Technology.

**Figure 2.3 Patents for CO2 reduction technologies, 1999-2011**

(patent applications, thousand)




*Source*: OECD Patents Statistics, Patents by Technology.

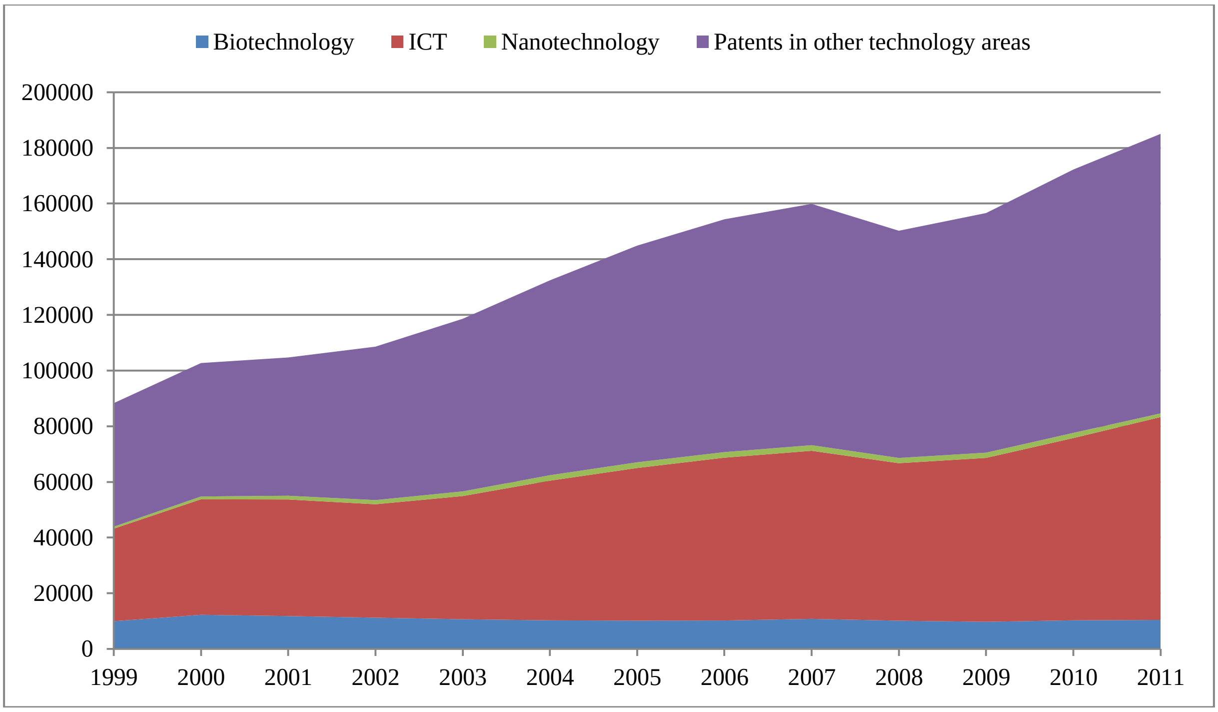
### *2.1.3 Enabling technologies*

67. Enabling or general purpose technologies are characterised by rapid internal growth dynamics and wide-ranging applications. The last quarter of the twentieth century was marked by an Information and Communications Technologies (ICT) "revolution", where the rapid pace of technological change in ICT resulted in dramatic industrial transformation (Castells, 1996). In recent years expectations have been raised, on the scientific understanding of biological processes, the ability to engineer them, and an ensuing rise in the economic importance of the field of knowledge widely known as biotechnology. Biotechnology and Nanotechnology, in addition of course to ICT, are some of the more recognisable techno-economic trajectories (Castells, 1996; Perez, 2002), and educated guesses suggest that they also hold great promise for rapid future technological change in the coming decades (Brockman, 2002). Trends in patenting (Figure 2.4) indicate that ICT remains on a growth trajectory, whereas biotechnology and nanotechnology are stable.

**Box 2.1 Green Innovation and Systemic changes in Korea – key enabling technologies**

Korean's green growth strategy includes a variety of strategies to invest in internationally recognized CO2 reduction technologies. It echoes the International Energy Agency (IEA) Blue map which suggested core technologies for carbon dioxide reduction. The Korean government selected 27 core green technologies from five sectors as climate change, energy source, energy efficiency, end-of pipe and virtual reality technologies. In accordance with the trend of ICT growth trajectory, Korea's green technology list includes many IT-related items. Korea expects that many IT-based "Smart" technologies will contribute to resource efficiency and energy savings.

**Figure 2.4 Global PCT Patents in Biotechnology, ICT, Nanotechnology and other areas, 1999-2011**




*Source*: OECD Patents Statistics, Patents by Technology.

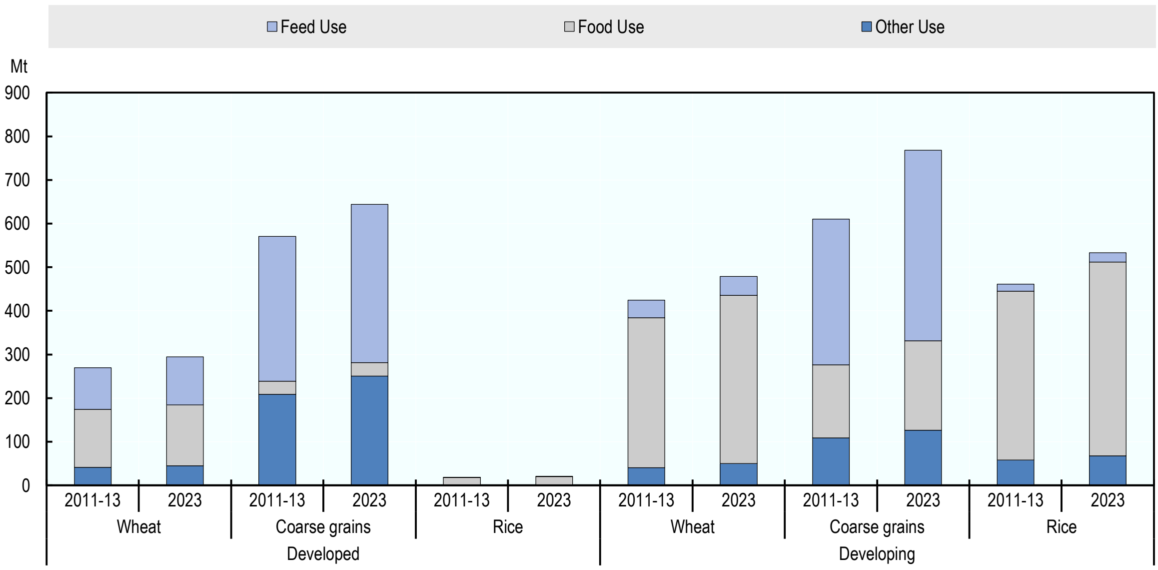
### *2.1.4 Changing demand patterns*

Changing demand patterns can have profound implications for the configuration of production and innovation systems. These include, on the one hand, changes in the characteristics of the consumer population, including increases in disposable income, greater inclusiveness and income convergence of emerging economies and on the other hand, changes in consumer tastes, fashions. A concrete example comes from the profound demographic changes under way in Europe and consequent changes in demand for social services [e.g. education, lifelong learning, long-term care (see Box 2.2)] and medical solutions for individuals with limited or impaired mobility (urban transport, access to buildings). Another example comes from the impact of shifting diet preferences on crop use (Figure 2.5). Income convergence between developed and developing countries, fuels demand for meat products, propelling animal feed as the fastest growing crop (OECD-FAO, 2014).

**Box 2.2 Long-term care system in United Kingdom driven by changing demand patterns**

The main driver of the long-term care transition in United Kingdom is demographic change. As the population ages, the demand for support for those with long-term conditions will rise. The long-term care system provides support for those people. It is undergoing a transition as the policy focus shifts from residential care in hospitals, nursing homes and care homes to treating and supporting people in their own homes. This is being driven, amongst other things, by older people who ask for greater independence and choice in later life.

**Figure 2.5 Changing patterns of crop use**
Cereal consumption in developed and developing countries




*Source*: OECD and FAO (2014).

### *2.1.5 Disruptive shocks*

68. OECD countries have been and appear to be increasingly exposed to disruptive shocks that have had significant adverse impacts not only on directly affected areas and people, but have also had substantial spill over effects at national and international level. Over the past 30 years, the damages from

major disruptive shocks (in absolute terms) have increased across OECD countries. This has led to hundreds of billions of dollars in economic losses. Single shocks have caused losses worth as much as 20 % of annual GDP, such as the earthquakes in New Zealand and Chile in 2011 and 2010 respectively. From a national perspective, storms like Katrina may have led to only 0.1 % of GDP in losses, but the local social and economic disturbances were substantial. The continuously increasing concentration of people and physical assets in risk prone areas, as well as rapid urbanisation and growing economic and social inter-dependencies are expected to drive future expected damage. The real challenge for policy makers has been that shocks are no longer confined to directly affected local areas, but rather lead to disruptions across a whole country, and sometimes cascade even globally. Failure of one country to identify and manage a major risk can have tremendous impacts on others (OECD, 2014).

## 2.2 Initial conditions and resistance to change

### *2.2.1 Proximity to transition endpoint*

69. Existing knowledge competencies and skills are key determinants of the swiftness of the response. The willingness of researchers and the organisations that employ them to shift their thematic focus and their ability to do so successfully will partly depend on their experience with proximate areas of research and the historical accumulation of a set of resources (skills, research infrastructures, sources of funding) and social capital (including inter-personal, -organisational, -institutional and financial networks) that accompany such experience.

70. Existing infrastructure can be both a facilitator and an obstacle to the transition. If it has complementary characteristics to that of the dominant design, then it can speed up the transition. For example, the existence of cable TV network infrastructure facilitated the spread of broadband internet in some countries, whereas the absence of even a widespread telephone infrastructure meant that in other countries broadband internet had to rely on wireless alternatives, which are inferior in some respects. But the presence of existing infrastructure may weaken the case for transition to technologically superior alternatives, as the relative advantage of the new technology is perceived to be low. Existing infrastructure, especially in the presence of other obstacles, such as finance, may delay such transitions for a long time (e.g. as in the case of high-speed rail connections). Regulation here can play an important role. In the case of telecommunications, regulations in the EU that forced incumbent telecom operators to provide competitors access to infrastructure resulted in lower prices to consumers and avoided the duplication of infrastructure which occurred in the US when cable companies were forced to lay down new fibre optic lines infrastructure to compete with telecom operators.

### *2.2.2 Distribution of resources and market/systemic power*

71. The regime's existing distribution of resources, knowledge and ability to make and project decisions are central predictors of the success of transitions. In sectors where the technologically efficient scale is large, the tendency may be to concentrate resources on few incumbents, which weakens the position of challengers. Concentration may reduce cognitive diversity too. To begin with, the less the concentration, the closer is a system is likely to be to the endpoint. A relatively even distribution increases the likelihood that certain actors will have developed at least *some* activities and accumulated knowledge relevant to the transition, even before it begins. Excessive concentration may also affect a system's resilience to external shocks. According to Helbing (2010), "a reasonable degree of heterogeneity (variety) among the nodes and/or links of a network (in terms of design principles and operation strategies) will normally increase its robustness."

72. Existing market structures (and their infrastructures) may favour lock-in. Radical innovations are often pioneered by relative outsiders (Van de Poel, 2000), such as start-ups, new entrants, engineers,

entrepreneurs. Although outsiders are important to generate novelties, many of them ultimately fail, because of a lack of financial and organisational means (Olleros, 1986) or opposition from vested interests. A successful system innovation may be accompanied by adjustments in framework conditions (such as laws, regulations, incentives), (NESTA, 2013: 18) which are sometimes conditional on changes in power relationships between incumbents and challengers. The breakthrough phase is characterised by conflict and struggle between the new innovation (and associated actors) and the existing technology (and incumbent actors). The struggle may give rise to three kinds of dynamics: a) The rise of new technologies may lead to the *downfall of existing firms* (Christensen, 1997). The business literature offers many examples: the rise of digital cameras creates major problems for film-based photo camera firms; the rise of desk-top computers caused problems for mainframe manufacturers; the Internet is causing problems for newspaper and other print-based companies. b) *Existing firms may defend themselves* by buying up the new firms, by hindering the new innovations (*e.g.* through pricing strategies) or by improving their own technology. The latter option is often referred to as the 'sailing ship effect'.[4] NESTA (2013: 18) warns that opposition from incumbent actors may hinder radical innovations: "But for precisely that reason many of these innovations remain small scale and don't get taken up: they threaten too many vested interests and jar with the siloed structures which still predominate in the public sector". c) *Existing firms may diversify and reorient themselves* towards the new technology. Car manufacturers, for instance, are currently diversifying towards hybrid and battery-electric vehicles. This means that incumbent actors can play a constructive role in transitions (Wilkinson *et al*., 2012: 17). Because incumbent actors have vested interests in the old technology, they are initially likely to resist reorientation. Reorientation therefore often entails accumulating external pressures: "Adapting and reforming existing systems is difficult for all sorts of reasons, but one of the most important is that it usually involves conflict" (NESTA, 2013: 40).

### *2.2.3 Systemic connectedness and functional integration*

73. Responsiveness or resistance to change depend also on how isolated different parts of the system are. Links between parts of the system can be seen as transmission mechanisms of knowledge, of ideas for further innovation, of leverage over the long-term evolution of the system's various components. On the downside, links also provide channels for the spread of negative outcomes. Again, an important conceptual distinction should be underlined between connections that exist (positive) and those that ought to be in place (normative) for the functions demanded by the desired transition endpoint to be fulfilled.

74. Connections between the technological and the scientific systems of knowledge production are obviously important. Whereas much attention is paid to science-inspired technology, the opposite direction tends to be underappreciated. Nevertheless, the branching of science is sometimes triggered by technological developments. The history of technology is replete with examples of technological inventions that were poorly understood by the science of their time. In some cases, breakthroughs were only possible after science had 'caught up' and adequately explained the behaviour first observed in new technology. Despite progress in linking science and technology, most scientific research is governed and driven by its internal dynamics and some incentive structures may discourage technology-inspired science.

### *2.2.4 Institutional determinants of shifting capacity*

75. It is clear that different systems exhibit a very different capacity to shift to resources from old to new uses (Ergas, 1987). There is much uncertainty about determinants in the absence of comprehensive study. There is the normal problem of reluctance to change, related to institutional inertia and institutional

[4] When they were challenged by steamships in the 1860s and 1870s, sailing ships were substantially improved: a) to increase their speed, more masts and sail were added to sailing ships, and the hulls were redesigned, b) to reduce labour costs, labour-saving machines were introduced, *e.g.* to rig the sails (Geels, 2005).

path dependence (Pierson, 2000; Barbier, 2011). Examples of institutional arrangements that may affect the elasticity of the system include organizational autonomy, labour regulations and labour market practices, the conditions that govern change in education curricula or the extent to which the education systems places emphasis on transferable skills.

76. Pierson (2000) identifies path dependence as a major factor in understanding political and broader institutional inertia. He traces the source of path dependence to political (and other social) processes that are subject to increasing returns, that is where the costs of change and benefits of conservation differ significantly over time. Pierson (2000) argues that this view of path dependence brings to the fore issues of timing and sequence, "distinguishing formative moments or conjunctures from the periods that reinforce divergent paths" (p. 251).

77. Markets have corrective mechanisms for the effects of path dependence. Competition (e.g. from more efficient firms) and learning (e.g. within firms and from the practices of other firms) are two powerful mechanisms through which markets can exit problematic paths. These mechanisms however function less well, if at all, when the development of institutions is concerned: there is no single goal, observing and evaluating performance is difficult and learning is very difficult (Pierson, 2000). New institutions - whether individual organisations or broader configurations of rules and routines - require high start-up costs, including considerable learning, co-ordination and adaptation of expectations (North, 1990; Pierson, 2000). Once established, institutions can produce strong inducements that promote their own stability. Because institutions do not operate in a vacuum but as part of a web of complex social inter-dependence, established institutional arrangements are inter-complementary, an arrangement that tends to promote their conservation.

78. Some institutions appear to operate as systemic delays: If they also happen to be systematically important buffers or safeguards against rare but severely negative outcomes is a question that merits careful consideration and cannot be answered within the confines of the present report.

### *2.2.5 Political economy*

79. System innovation is not just an innovation challenge, but also a deeply political project, which may affect vested interests from powerful incumbents. Because some transition-minded policies will negatively influence vested interests, political conflict and power struggles are likely.

80. First of all, system innovation entails not just winners, but also losers, especially when old systems are replaced by new systems. Organisations with interests linked to old systems may resist and oppose the changes. Many workers have skills that are firm- or even job-specific, and many firms are invested in capital and equipment that may be of value only for pursuing certain activities in particular locations. Such human or technological capital may be difficult to redeploy in response to a changing environment. Secondly, system innovation may require adjustments in policies, institutional frameworks, incentive structures and investment patterns. Advocates of transitions to a green economy, for instance, call not just for more investment in green innovations, but also for major policy change. UNEP (2011, p. 2), for example, claims that: "there is a need for better public policies, including pricing and regulatory measures, to change the perverse market incentives that drive this capital mis-allocation. (…) To make the transition to a green economy, specific enabling conditions will be required. (…) At a national level, examples of such enabling conditions are: changes in fiscal policy; reform and reduction of environmentally harmful subsidies; employing new market-based instruments; targeting public investments to 'green' key sectors; greening public procurement; and improving environmental rules and regulations as well as their enforcement." The OECD (2011, p. 8) also argues for changes in fiscal and regulatory settings (such as tax and competition policy), innovation policy, environmental policies, which "include a mix of price-based

instruments (for instance environmentally-related taxes) and non-market instruments such as regulations, technology support policies and voluntary approaches".

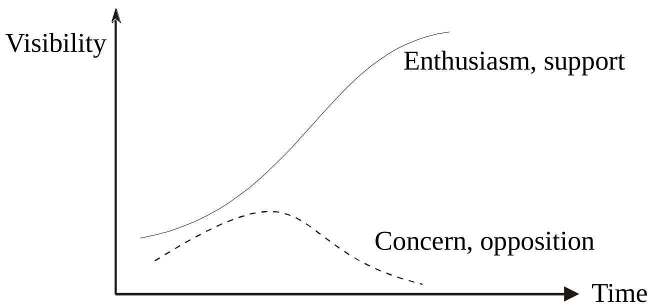
### *2.2.6 Civil society: cultural visions, social networks and public debate*

81. Positive cultural visions and media reports stimulate interest in and support for new technologies. "Transitions are more likely to be considered successful when they contribute to a different vision of the 'good life'" (Wilkinson *et al*. 2012: 17). "When new technologies link up with wide cultural visions and values, this creates a legitimisation and protected (cultural) space to work on new technologies. Aircraft in the 1920s and 1930s enjoyed great popular support, because they were seen as means to a better world, the winged gospel. The gasoline car linked up with cultural values such as excitement, danger, and adventure" (Geels, 2005: 269).

82. Civil society and public discourse are instrumentally important, insofar as the effectiveness of public policy depends upon generating widespread support from citizens (Giddens, 2009). Urgent demands from public opinion can offer politicians incentives to jockey for certain goal-oriented agendas (Burnstein, 2003). Major policy shifts are therefore often accompanied by shifts in public opinion and cultural discourse (Hay, 2004). But societal debates are also important to create public spaces where citizens and stakeholders can express disagreements and opinions about the specific goals and directions that should be pursued in system innovations. Such public participation may create legitimacy and buy-in, which is probably necessary if system innovations also entail changes in lifestyles and consumer practices. The general implication is that system innovation is not just an economic, technical or managerial process, but also a political and cultural project.

83. Citizens may also oppose if they feel insufficiently included in a top-down imposition of system innovation by technocrats. Contestation by particular groups may be relatively small compared to wider social enthusiasm, and gradually wither away as the transition gathers pace (Figure 2.6). This pattern occurred in the transition towards automobiles, which was initially opposed by farmers and anti-speed organisations (because rich urbanites used cars to race on unpaved rural roads, killing livestock and causing dust problems).

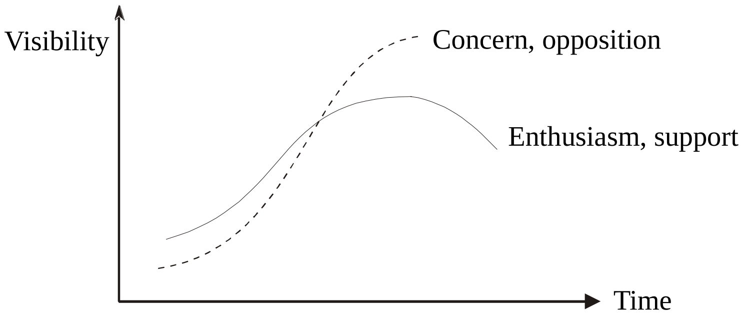
**Figure 2.6 Contested development**




*Source*: Geels et al., 2007: 151

84. But social opposition may also result in controversy and stalemate, which hinders further progression of the system innovation (Figure 2.7). Some examples are nuclear energy, genetically modified food in Europe, and cloning. With nuclear energy and genetically modified-food, proponents pushed ahead despite early concerns, assuming that 'the public' would, in time, be educated, leading to disappearance of protests. But this technology-push strategy backfired, leading to escalating protests which ultimately hindered further progress. Learning lessons from these experiences, proponents of nano-technology now engage in early stakeholder consultation.

**Figure 2.7 Controversy and stalemate**




*Source*: Geels et al, 2007: 151

## 2.3 Shifting boundaries, degrees of ambition and transition endpoints

### *2.3.1 Changes in impulses over time*

85. The diffusion process benefits from positive feedback loops, which enhance the internal momentum of the innovation. A particular mechanism is increasing returns to adoption (IRA), which improves the price/performance characteristics of an innovation. Arthur (1988: 591) identified five sources of IRA: a) learning by using: the more a technology is used, the more is learned about it, the more it is improved; b) network externalities: the more a technology is used by other users, the larger the availability and variety of (related) products that come available and are adapted to the product use; c) scale economies in production, allowing the price per unit to go down; d) informational increasing returns: the more a technology is used, the more is known among users; e) technological interrelatedness: the more a technology is used, the more complementary technologies are developed.

86. Scientific or technological breakthrough may initially show great promise, only for momentum to peter out after the first few years. This has arguably been the case in emerging technologies such as nanotechnology and synthetic biology, where it is the strength of the vision and of its economic promise that is sustaining hope, even when technological development trends (at least as captured by patents) are less encouraging.

87. Nelson (2008) argues that a primary requirement for a technological paradigm to be capable of generating rapid sustained progress is that the practices it is seeking to advance be controllable and replicable. This underlines the importance of accurate measurement and reliable experimentation, in turn depends on suitable instrumentation. If these prove difficult to develop, then the strength of the technological paradigm may be curtailed indefinitely, despite its theoretical promise.

88. Rising resource prices are one economic trend that has increased attention for system innovations and green transitions. Fischer-Kowalski and Swilling (2011) show that real resource prices for food, metals and minerals, raw materials, and energy have been rising since the year 2000, creating pressure on various sectors. The steep rise in oil prices (peaking at $145 per barrel in 2008) has been an important driver for increasing investments in renewable energy technologies, besides concerns for climate change. But, impulses may weaken before the transition completes or attention to them overshadowed by other, more urgent developments. Since 2009, the financial-economic crisis has had negative effects on investor confidence and government support for renewable technologies, because of austerity programs and weakening public attention to climate change (Geels, 2013). Also the shale gas revolution may have negative effects on renewable energy if it decreases gas prices and redirects investments towards gas turbines.

### *2.3.2 Changes in resistance over time*

89. One of the key possibilities emerging from a progressive weakening of barriers is that of raising ambition to levels that would have been previously unthinkable. A role of policy may therefore be to monitor and assess the potency of barriers with the view to sensing the right time to extend the boundaries of the 'system' and therefore of the potential impact of system innovation.

90. One would expect that gradual increases in the strength of an impulse would progressively weaken resistance and this does happen in many transitions. But the relationship is not always clear cut. Resistance to change may also increase as a function of the strength of the impulse: For instance, labour-market reforms have proven particularly hard to carry out in time of economic downturn, as the value of employment protection rises with unemployment (OECD, 2010).

91. If the impulse intensifies or at least remains at least as strong as it was at the beginning, it is fair to assume that the passage of time alone will help to erode resistance. However, this may not always be the case. Technological barriers may be irresponsive to the strength of the impulse. An underestimation of the technological development challenge and of the importance of complementary technologies (including, in the case of parallel transitions, an underestimation of the development and diffusion trajectories of complementary technologies, markets, communities) may end up leading the transition to a dead-end, at least during politically and economically feasible timeframes.

92. Importantly, conscious and organised resistance may be *adaptive* with respect to attempts to address it and may therefore pose a formidable barrier (see 3.1.3).

# CHAPTER 3. GOVERNANCE AND IMPLICATIONS FOR STI POLICIES

## 3.1 A new role for government?

### *3.1.1 Multiple rationales and mission conflicts*

93. System innovation can be motivated by either positive or negative visions of the future. Positive visions include the enormous opportunities offered by emergent enabling technologies. But managing change at the level of the system makes sense in order to prepare for negative scenarios too, including natural resource depletion, climate change and severe demographic imbalances.

94. Once these visions are recognised, the possible role of policy needs to be considered carefully. Will the functional system concerned self-organise – through the price-mechanism or by other means – to achieve a timely and effective transition? Would the transition entail risks and costs to the system that need to be managed? Are the potential risks high enough to justify slowing down the transition? These are hard questions the answers to which will depend on the context. Recent interest with system innovation is driven in part by concerns that contemporary configurations of large technology and innovation systems in areas like energy, food, transport, health may not deliver the change needed in time to avoid the bleak scenarios.

95. Justifications for many of the public policy responses required to address these challenges are sought in so-called market and system failures that are familiar to STI policy makers. These are worth restating here, if only to better demarcate some of the additional rationales relevant to system innovation.

96. Government intervention in STI has been traditionally justified on the grounds of market or other failures that are causing deviations from the conceptual ideal of competitive and economically efficient markets. Externalities are perhaps the most commonly employed rationale. In simple terms, externalities arise when costs or benefits accrue to actors, places (and, arguably, over time-frames) that are external to the firm's (or other market participants') decision making framework and horizons. In the case of the decision to dedicate resources to innovation, because knowledge and its benefits spill over to society at large there is an external benefit. This means that, if left to the market (and particularly in the absence of intellectual property rights, but to some extent even in their presence), private investors are unable to fully appropriate the returns of their investment in innovation.

97. In other words, in the presence of such external benefit in their decision to innovate, they are not inclined to dedicate resources to innovation up to the level that welfare theory expects would maximise economic efficiency. At the same time, there is a large spectrum of socially useful knowledge of the public good type (an extreme form of positive externality), ranging from basic research of the (Niels) Bohr-type for which markets simply do not exist, to curiosity-driven but application oriented research of the (Louis) Pasteur-type for which only partial markets exist. These cases make for compelling justifications in favour of government intervention and indeed motivate the majority of traditional STI policy instruments including intellectual property rights, and the various types of R&D and innovation grants/subsidies.

98. Negative externalities – arising when private decisions lead to external *costs* rather than benefits - is a commonly employed rationale for intervention in environmental policy, for instance when the price of goods does not capture production costs that are external to the firm, such as pollution. It is much less frequently invoked as a rationale for STI policy, in the particular case when R&D and innovation is one of the ways of correcting an environmental externality. Negative externalities however are an important justification for engaging in system innovation, particularly in transitions related to social challenges.

99. Imperfect competition is another rationale for policy intervention, although not one that is commonly employed in STI policy[2]. In fact, STI policy not only tolerates but *encourages* deviations from a level playing field, in the form of intellectual property rights such as patents and of the resulting oligopolies that are common in technology markets. The readiness to do so may be attributed to an implicit assessment that the severity of the efficiency penalties from unrealised scale economies (due to positive externalities) is greater than those stemming from imperfect competition. A less charitable interpretation is that it can also be a reflection of the systemic power of incumbents in shaping STI policy.

100. Dealing with negative externalities and imperfect competition has traditionally been outside the remit of innovation policy. Part of the challenge is to make innovation policy making more "inclusive" by broadening its rationale and seeing its interventions as complementary to policy objectives in areas such as health, the environment and competition policy. Another part of the challenge is to change innovation policy making bodies themselves. Addressing negative externalities and imperfect competition imply a policy approach and a set of instruments which may be unfamiliar to STI policy makers. Critically, they involve policy interventions (such as higher taxes and regulation) which have the effect of increasing production costs for firms. Clashing with the interests of (at least some) firms and their sometimes powerful lobbies requires quite a different mind-set and capabilities from those usually encountered in an innovation agency.

101. System-failure is an increasingly mentioned rationale for government intervention in innovation. Although the underpinning evolutionary reasoning is in fundamental respects incompatible with the welfare economics framework of market failure, STI policy makers frequently employ the market and system failures rationales alongside one another. System failures rationales for government action have their roots in the intellectual tradition of evolutionary economics, and emphasize dynamic processes and fitness for purpose. They observe that systems designed for a social purpose, such as national innovation systems, may fail to deliver because of binding constraints not only in short-term resource distribution and coordination, but also over long time periods in orientation and capability accumulation. The key point is that parts of the system other than the market (and even the market itself) cannot be assumed to be *effective* in delivering their prescribed functions. As opposed to market failure the key criterion is whether the function is delivered *at all*, rather than how efficiently it is delivered (Bleda and del Rio, 2013). The root of the failure is usually assumed to be the inability or unwillingness to coordinate. Responsibility or agency for this failure is distributed throughout the system rather than resting with a particular set of stakeholders. It implies that if problems are systemic, solutions must operate at the system-level, rather than at some part of it.

102. The dominant economic rationales for innovation (whether market or system) are commonly employed to justify *the scale* of support for innovation. SI is different in that, in addition to a concern with the scale of resources required in many of its component policy areas, is explicitly concerned with the *direction* of innovation. Moreover, in contrast with the predominant concern of market failure approaches with the supply of ideas, SI is concerned with the *demand* for system-wide change. Therefore, in addition to the traditional rationales of innovation policy, Weber and Rohracher (2012) propose rationales that relate to some of the specificities of system innovation:

- *Directionality*. System innovation is about purposeful transitions, oriented at solving social problems and meeting political goals. It is important to develop visions, perhaps through foresight tools or expert committees.

- *Demand articulation*. System innovation includes changes on the demand side; demand for new innovations is not waiting 'out there', but needs to be articulated; markets needs to be actively created (Sarasvathy and Dew, 2005), often in co-evolution with new technologies through a 'probe and learn' process (Lynn et al., 1996).

- *Policy coordination*: because system innovation takes place in concrete sectors or domains, (system) innovation policy needs be (horizontally) coordinated with and sectoral policies (transport, energy, agriculture). Because system innovations entail large consequential changes, support from high political levels may be needed to enhance the legitimacy and visibility of transition initiatives (e.g. embedding within and reinforcement by broader national environmental policy strategies).

- *Reflexivity:* System innovations are open-ended and uncertain processes. Evaluation and regular monitoring of public policies serve to ensure experiences feed back into policy design.

**Box 3.1 Key features of the first phase of the national cluster programme in Russia**

To address this need of policy coordination which is a specificity of system innovation, the Russian government adopted a cluster policy. The integration of the cluster approach into innovation policy requires consistency between various measures by coordinating the various efforts of multiple – authorities, namely federal and regional – and targeting support to the most promising industries and geographical area. The recognition of the cluster by the national authorities incentivizes clusters participants to collaborate further.

This case study highlights the fact that effective innovation policy requires the co-ordination of innovation policy measures for support different actors as universities, research organisations, large businesses, SMEs, venture capitalists. More, it is important to improve the efficiency of interaction between actors of the regional innovation systems including trust building.

103. Weber and Rohracher (2012) distinguish three different rationales related to a neo-classical view (market failures), an innovation system view (structural system failures), and a system innovation view (transformational system failures). The third column in Table 3.1 contains the specific challenges related to system innovation. However, generic policy challenges related to other failures (first and second column) also hold relevance for system innovation. So, the third column is *additional* to the other columns, not a replacement.

**Table 3.1 Different kinds of failures and policy rationales in different analytical approaches: neo-classical, innovation systems, and system innovation**

| Market failures (neo-classical) | Structural system failure (innovation systems) | Transformational system failures (system innovation) |
|---|---|---|
| 1) Too little investment in R&D, because of the public good character of knowledge (and leakage) and uncertainty about outcomes (which hinders cost-benefit calculation) | 1) Infrastructural failure: limited investment in physical infrastructure because of risks (large-scale investments and long-time horizons) and low return on investment. | 1) Directionality failure: Transformation process will be hindered by: a) lack of shared vision regarding goal and direction, b) inability of collective coordination of distributed agents involved in shaping systemic change. |
| 2) Negative externalities: private actors do not take negative consequences into account if they can externalize costs | 2) Institutional failures: Problems in formal institutions (laws, property rights, regulations) creates uncertainty that hinders investment and innovation. Informal institutions (norms, values, attitudes, trust, and risk-taking) may also hinder innovation. | 2) Demand articulation failure: The exploration of new user patterns and opening up of new markets will be hindered by: a) insufficient spaces and opportunities to learn about user needs, b) absence of orienting signals from public demand (*e.g.* public procurement), c) lack of demand-articulation capabilities |
| 3) Over-exploitation of commons, leading to over-use of public resources in the absence of regulations | 3) Interaction or network failure. Very strong cooperation may lead to lock-in and inward-looking behaviour. Too limited interaction hinders knowledge | 3) Policy coordination failure: Transformation will be hindered by: a) lack of multi-level policy coordination (regional, national, European), b) lack of |

| | | |
|---|---|---|
| | exchange and interactive learning. | horizontal coordination between innovation policies and sectoral policies (transport, energy, agriculture), c) lack of vertical coordination (between Ministries and implementation agencies) |
| | 4) Capabilities failure: Lack of appropriate competencies prevents access to new knowledge and inability to adapt and compete. | 4) Reflexivity failure: Transformation will be hindered by a lack of monitoring, learning, open debate, adjustment, and reflection about direction and speed. |

*Source*: Adapted from Weber and Rochracher, 2012: 1045.

### *3.1.2 System innovation versus conventional STI policy*

104. Despite the recognition that the systemic understanding of innovation receives in academic and policy analysis cycles, actual STI policy does not always heed its lessons. Much, if not most, contemporary STI policy emphasises *endogenous* radical innovation, especially by domestic firms, universities and public research organisations, under the assumption that intellectual property rights will ensure that economic returns ensue locally. STI policy tends to be disproportionately preoccupied with possible sources of endogenous radical novelty, including start-ups, the commercialisation of science, venture capital for risky ventures etc. Though the importance of diffusion is acknowledged in terms of new-to-the-firm and new-to-the-market innovation, it is typically neglected in other parts of the system. External influences to the system are usually an afterthought: in this respect contemporary innovation policy instruments do not go much beyond linking up internationally and offering circumstantial support for selected emerging technologies. Even instruments that are meant to stimulate demand for innovation, such as public procurement, are too focused on technical specifications and tend to pay little attention to social and organisational aspects of demand articulation. Part of the problem is that the required mandate rests outside the remit of innovation policy. The heart of the problem though is with the orientation of much contemporary STI policy: despite its obvious importance, the generation of endogenous *radical* novelty is too unlikely and too unsystematic (and its local appropriation even more so) to justify the nearly singular attention it so often receives.

105. Policy for system innovation, by contrast, implies harnessing not only local but also global impulses and focuses on *identifying the missing complementarities* for profiting from or adapting to them; it involves a recognition that the bulk[5] of local economic returns to innovation can be traced back to ideas that first emerged elsewhere; this in turn involves reconfiguring and repositioning the system so it benefits from developments at both the landscape and niche levels, or so that its exposure to the negative consequences is minimised. It involves profiting from aspects of intellectual novelty that cannot be secured by property rights, and go beyond market settings and are to be found in complementarities between scientific, technological, organisational and system-level innovation. This implies a change of perspective from introspection towards attention to the responsiveness of the system to various impulses. In this context, the composition of the actors, their relations not only within but also *outside* the system, and the timing and sequence of interventions are of paramount importance.

106. Another key difference is on the focus contemporary innovation policy places on the relationship between inputs and pre-defined outputs. There is of course a justified policy emphasis on performance measurement and evaluation, with a particular focus on 'impact' or 'productivity', also promoted by ‘new

[5] Empirical estimates from literature on international technology spillovers (Coe and Helpman) suggest that even in systems as large and technologically advanced as the United States, about half of the returns to innovation are due to innovations from abroad.

public management' approaches to governance. This emphasis has yielded undoubted efficiency improvements, particularly in the public sector. Nevertheless, due to the short length of policy horizons, and in some cases inherent limitations in current measurement tools, the focus can be on the short-term. The effect is a strong tilt in policy direction towards the theoretical economic construal of *static efficiency*. Concentration of productive resources (and the resulting scale economies) is a key determinant of static efficiency, which explains why policy interventions in many areas (including innovation) can be scale-biased and promote larger firms/organisations, mergers and the elimination of perceived duplication. There are obviously important, and sometimes underappreciated trade-offs from this bias as increases in concentration are not costless (Geroski, 1989a). They imply reductions in technological, scientific, occupational and cognitive diversity, which form the fertile pool of combinatorial possibilities needed to "seed" new growth areas and imply reductions in competition and in redundancy, which are needed to cushion systems from the effects of abrupt change (Stirling, 1998; Stirling, 2007; Page, 2007; Arthur, 2010). In other words they imply a reduction in the system's *dynamic efficiency*, as manifested in its responsiveness and resilience. By contrast, the overall goal of policy concerned with SI is to bring about conditions that facilitate *dynamic efficiency*. There are strong indications that policy or government failures are pervasive on that account. More sustainable and resilient systems would require a shift in policy paradigm too.

### *3.1.3 Broad policy approaches*

107. Managing the transition process so that it occurs in a timely fashion and minimises any risks are worthy policy goals. Policy on system innovation needs to be situated within the domain of what is manageable and what should be managed. In practice, the complexity of the "universe of systems" (and sub-systems) is such that being at the right place, at the right time is extraordinarily hard. There are obvious limits in the planner's ability to know enough and to know it early enough to act. Even if complete and timely information were available, identifying policies for proper alignment is a non-trivial task, as by definition no best practices exist. There can be well-founded disagreement about the nature, sequence and implications of change among different parts of society. And of course effectuating the requisite change takes time and overcoming either inertia or active resistance cannot be guaranteed. In sum, the policy task is daunting, and one should not overestimate the extent to which transition processes are manageable or should be managed. Charting the policy space for system innovation is therefore an exercise in *relative improvements* in current policy practices, rather than panacea.

***Changes in System Design***

The role of policy concerned with the design of the architecture of the system is especially important. Insofar as comprehensive changes in a system's design are feasible they are likely to have a stronger impact than interventions in response to *ad hoc* diagnoses of failures (Box 3.2). Insights from literature on SI as well as broader literature on innovation systems has underscored the importance of system designs that maximise the flow of information, exemplified in the study of linkages between various types of knowledge producers, including firms, universities and public research organisations. They include architectural changes that affect the ability of the system to respond autonomously as well as its ability to be steered and coordinated, such as improvements in its internal cohesiveness and reductions in concentration. The latter may include not only resource concentration but also concentration of decision-making power, which could be curtailed e.g. by increased delegation of authority to specialised agencies or by university autonomy. Other types of general architectural changes that may be useful irrespective of the specific instance of transition include changes that affect the availability and distribution of information. These may include flatter hierarchies, inter-agency coordination and more distributed decision-making mechanisms, including via the establishment of high-level councils, parliamentary validation and public consultation.

**Box 3.2 A new design for the system a bio-based economy in the Netherlands**

Netherlands changed the design of the system to support and accelerate the transition to a bio-based economy (the transition from an economy that runs on fossil oil to an economy based on biomass as a raw material). To achieve this transition, the Netherlands tries to take advantage of its economic strengths and markets, such as strong chemical and agricultural sectors, while addressing desirable societal benefits. With that goal, a policy agenda and measures were set up.

To support this agenda, a model of 'networked governance' was implemented. In this model the parties "outside" must contribute to the collective effort for transition. Indeed, past experiences have shown that government cannot act alone to accompany the transition, it relies on these external parties (which also depends on the government). In this regard, networks and platforms were set-up in order to support the transition processes in the society. These networks create connections between companies from different sectors (like chemical and agricultural) and between companies and research institutes. It also stimulates co-operation with SMEs. The results have been positive: the government and stakeholders meet twice a year to discuss advances in bio-based economy and meet new stakeholders.

108. Critical aspects of a system's design go beyond the architecture or configuration of its elements. Resistance may be due to inertia and features of the system that affect the speed with which it can shift to novel configurations. These may be due to institutional constraints (the incentives to link up different parts of the system and to engage in innovation) and regulatory and administrative barriers to change. Inertia can be reduced with the removal of buffers (Helbing, 2010), such as the delays put in place by co-decision and coordination between various parts of layers of administrative authorities. The long-term implications of reducing inertia may of course be adverse, as demonstrated by the recent financial crisis. Careful evaluation of repercussions would be needed to ensure that short-term gains are not simply exchanged for long-term costs.

109. In specific instances of transitions or in other cases when policy needs to be reactive, changes in the system design need to take account of the specific coordination tasks required. Broadly defined, the task of policy is to, over the short-term, identify potential complementarities between parts of the system and make the needed connections, while over the long-term to raise ambition and push the boundaries of the system so as to facilitate an efficient and effective transition. Coupling (or linking) disparate (parts of) systems, is a way to reduce information and coordination failures and bring about large-scale change. From this perspective, the environmental sustainability problem can be seen as one of insufficient or improper coupling between two systems – the economy and the natural environment. Indeed, the dominant policy approach practiced by policy aimed at a transition towards environmental sustainability has been that of establishing "missing" links between ultimately inter-dependent systems (Harich, 2010). This has chiefly been done by policy seeking to influence prices in the economic system, by linking them (via taxes, quasi-markets, or regulation and standards) with the natural environment within which economic activity takes place. But the price mechanism is not the only way to link potentially complementary or inter-dependent systems.

110. To a certain extent democratic institutions and modes of governance allow for such coupling to materialise, insofar as policy making is predicated on social legitimacy and accountability. In principle, democratic institutions encourage alignment between the development of transition visions and social needs. Yet, there are indications that in practice epistemic matters take precedence over democratic considerations (Hendriks, 2009). Moreover, given prevalent social values, there are good reasons to expect that even more democratic arrangements may not ascribe sufficient importance to the interests of future generations. Public policy and governance needs to be reflexive in this context and to also shape social visions and earn social legitimacy. Even when society begins to pay increasing attention to future generations (e.g. the rise of environmental concerns linked with climate change), the logic of electoral politics would strongly favour short-term horizons. Pierson (2000) argues that politicians tend to pay

attention to long-term impacts only when these become electorally relevant or when they cannot anticipate short-term electoral costs. The problem is that switching costs associated with the transition occur mostly in the short-run, whereas the benefits from the transition accrue in the long run. System redesign must seek to lengthen planning horizons, for instance by way of systematic measurement of costs and benefits over long periods. Increased transparency, further steps towards evidence-based policy (including by way of *ex post* evaluation that feeds back into policy planning) and other mechanisms that improve the credibility of policy making and foster policy learning can help extend planning horizons beyond the policy cycle. In the past, institutional designs that aim to extent planning horizons beyond the electoral cycle have focused on areas where the measurement of performance is relatively easy, such as monetary policy (e.g. central bank independence). Systematically evaluating performance in aspects that relate to the transition can be crucial to lengthening policy-making horizons.

***Understanding and managing resistance***

117. Design changes, such as coupling between systems and between the present and the future may not be sufficient on their own. Resistance to change can be conscious, purposeful and therefore *adaptive*. It can be adaptive both with respect to the strength of the impulse and to policy efforts to facilitate the transition. Therefore understanding, and where appropriate, managing resistance, is a key role of policy.

118. Of course not all resistance is harmful. Resistance may be based upon legitimate concerns about society as a whole, and may reflect perspectives that had been overlooked by the vision and not adequately prepared for. In this case it would be important to perform a revised assessment of the social welfare implications of the transition. In some cases, the preponderance of popular opinion may resist a transition, as e.g. in the case of genetically modified crops in Europe. This raises the issue of democratic accountability – if majority opposition is based on a full appreciation of available information it reflects social values and preferences.

119. Opposition may be the result of lack of information. When the transition would imply serious threats to vital parts of the system (e.g. the economy, or the environment) but the probability of these threats is uncertain, it may be prudent to slow down the transition. These may be cases where contemporary scientific evidence is unclear and time is needed to obtain a solid assessment of risks and costs (e.g. as genetically modified crops, climate change), or cases where there is a serious discrepancy between the realisation time span of the benefits versus the costs of the transition[6]. There are cases where achieving some of the transition's goals quickly implies dismantling long-standing safeguards against negative outcomes. Delaying the transition may make sense in such cases too.

**Box 3.3 Long-term care study in UK: lack of information as barrier to demand**

A lack of awareness of assisted living options represents an information failure that severely restricts demand. Among patients, a recent survey found that 85% of those individuals surveyed over 65 years of age were not sure what tele-care is and only 7% said they would use it. However, once the concept was explained to them, the share of respondents who said they would use the service rose to 85%. This shows clearly that assisted living technology is attractive to users but that there is a distinct lack of awareness.

[6] An example of the latter is the continuing temptation efficiency-seeking policy makers are faced with to sacrifice cognitive diversity in a knowledge production system in order to obtain economies of scale. This can be done by merging organisations, setting few priorities, or focusing resources in specific actors and regions. The benefits may be reaped at relatively short notice, whereas the costs accrue over long periods of time.

120. Resistance may of course be due to a reaction from those who stand to lose from the transition. The short-term costs of the transition may be borne by few actors, whereas the benefits accrue to a larger part of the system. When the few happen to be well organised, well-resourced and vehemently opposed to change then their resistance cannot be ignored. For example, there are some indications that in the case of environmental sustainability transition, organised and adaptive resistance may have had the effect of cancelling out policy efforts (Harich, 2010; Turner, 2014). A typical reaction of groups threatened by a transition is to attempt to saw doubt on the benefits of the transition and exaggerate its costs. For instance, opposition lobbies may be compelled to support specific strands of scientific research that would tip the balance of available evidence in their favour (e.g. climate change, tobacco). Accurate evidence on the costs and benefits is crucial in this context too. Strengthening the production of comprehensive, impartial evidence is a critical contribution of policy in this context, including by funding more and more diverse scientific research and ensuring its independence.

121. Co-opting these groups (achieving appropriate coupling) and perhaps even adequately compensating them for parts of their losses are possible solutions. While some form of compensation or transitional assistance could help expedite the transition, it runs the risk of moral hazard. Transitional assistance meant to enable them to develop the capabilities necessary to thrive under the new regime is a more attractive option; in addition to facilitating the transition, it ensures that these groups add to the momentum of the transition and to the overall productive capacity of the system.

**Box 3.4 Leverage points: Places to intervene in a System**

**(in increasing order of effectiveness)**

Donella Meadows (1941-2001), was a prominent environmental scientist widely known for her role as lead author of the influential *Limits to Growth*, report produced in 1972 for the Club of Rome. The report used a computer simulation to forecast the consequences of economic and population growth against a background of finite resources. A revisit of the baseline forecast by Turner (2014) shows a very strong ex post fit to actual data over the four intervening decades. Building on her experience as a modeller of complex systems, Meadows (1999) produced a list of informal suggestions to anyone concerned with their design and management. Despite its provisional form, the list is often cited in, among others, literature on systems design, environmental sustainability, and software design as well as innovation studies. A shortened version is reproduced here with relevant adaptations, additional examples and explanations.

**Constants, parameters, and numbers (such as subsidies, taxes, standards):** In simple terms parameters affect the rate of flow between different parts of the system. Parameters can be important in the short term and can be important to the individuals (or parts of the system) that stand in the flow. Because of their importance to (sometimes vocal) individuals and because political systems tend to have short-term horizons, parameters typically command most of policy makers' attention. However, parameters rarely have lasting changes in behaviour. If the system is stagnant, parameter changes rarely kick-start it and if it is wildly variable or spiralling out of control, parameter changes do not stabilise it.

**The sizes of buffers and other stabilizing stocks, relative to their flows:** A buffer is a stock that has a stabilising influence in a system. It can help mediate between parts of the system that change at very different rates. Examples of stocks include shop inventories, bank savings and water reservoirs. Often one can stabilise a system by increasing the capacity of a buffer. But if a buffer is too big the system becomes inflexible. While changes in buffers can therefore have important impacts in the system's resilience, buffers can also be quite hard to change.

**The structure of material stocks and flows and nodes of intersection:** Structure in this context refers to the physical design of e.g. road networks, the physical location of capital and labour or the processing capacity of production systems which cannot change at short notice. Physical structure is crucial in a system, but rarely a leverage point, because changing it is not often simple. The leverage point is in proper design in the first place. After the structure is built, the leverage is in understanding its limitations and bottlenecks and refraining from fluctuations or expansions that strain its capacity.

**The lengths of delays, relative to the rate of system changes:** Delays arise in many parts of systems. Examples include the time it takes for a price to adjust to a supply-demand imbalance, the delay between the birth of a child and the time when that child is ready to have a child. The timeliness of information about the state of a system and the timeliness of a planner's reaction to this information can be crucial to achieving a stated objective. A system cannot respond to short-term changes when it has long delays. Reducing delays is not always beneficial, however. From a different perspective some delays may be seen as safety buffers (e.g. money transfer delays in financial markets). Despite the important effects of potential changes in delays, these are often not changeable (consider e.g. the construction time of infrastructure, the maturation time of a child, or the growth rate of a forest). It is usually easier to slow down growth rates in other parts of the system, so the inevitable delays will not cause as much trouble.

**The strength of negative feedback loops, relative to the impacts they are trying to correct against:** A negative feedback loop, is a mechanism built into a system that maintains some appointed stock within safe bounds. A simple example is that of a thermostat. Another example is inflation targeting. The ability of a negative loop to keep its appointed stock at or near its goal depends on the accuracy and swiftness of monitoring, the quickness of response, the focusing and magnitude of corrective flows. Effective negative feedback loops need to be adaptive: if the impact increases in strength, the feedback has to be strengthened too.

**The gain around driving positive feedback loops:** A positive feedback loop is a self-reinforcing, cumulative causation process. They are sources of growth and explosion. Wealth accumulation is one such example, where success breeds further success. At the individual level this happens through mechanisms such as interest on financial capital, good education and inheritance. At the level of entire economies, working versus malfunctioning positive feedback loops distinguish developed from developing economies. Economic development is largely about kick-starting a positive cumulative causation process in productive capabilities. Seen from a global perspective however positive feedback loops cannot carry on indefinitely as closed systems have limits. Erosion and collapse is their final conclusion. Whereas strengthening some positive feedback loops may make sense as a transient measure (e.g. in poverty alleviation or in cross-regional /-country income convergence), in seeking to achieve balance and long-term sustainability it may be more effective to seek to weaken the positive feedback loops (e.g. in alleviating poverty among individuals with progressive taxes and universal high-quality education).

**The structure of information flows.** Missing information feedback and the absence of learning is one of the most important causes of system malfunction. Distributing information can improve accountability and discourage socially damaging behaviour. Improving the structure of information flows can be difficult, as it is often built into physical and social arrangements, but technological and social changes often make them possible. Even small changes in information flows can have profound impact.

**The rules of the system.** The rules of the system define its scope, its boundaries, and its degrees of freedom. Physical laws such as the second law of thermodynamics are absolute rules; constitutions are strong social rules, whereas laws, punishments, incentives and informal social arrangements are progressively weaker rules. Rules can have an enormous influence on human behaviour and changes in many of these are within the reach of policy planners.

**The powers to add, change, evolve or self-organise system structure.** Technical advance and social revolution can transform social systems by creating new structures and behaviours or in systems terminology permit them to "self-organise". The ability to self-organise is the strongest form of system resilience. In resilient, long-lived systems self-organisation is not an accident but down to successful rules for self-organisation, the most obvious of which are the rules governing evolution through (natural or artificial) selection. The enormous genetic diversity encountered in nature, has been the cumulative product of evolution spanning countless centuries and is the source of evolutionary potential, just as the diverse knowledge found in science libraries and labs and universities where scientists are trained are the source of technological potential. Allowing a living species to become extinct is damaging to a system, just like eradicating knowledge of a particular type of science or particular kinds of scientists.

**The goals of the system**. Changing a system's orientation can have profound influence in its long term direction and can determine outcomes such as its growth, survival, resilience, differentiation and evolution. Whole-system goals do not always correspond to proclamations and are only deducible from observing the actual behaviour of the system. Only planners at the very top of a system's decision making hierarchy have the power to alter the system's goals, even if partially.

**The mind-set or paradigm out of which the system arises.** A society's paradigm is a deep set of beliefs about how the world works. These beliefs are so well-known to members of a social system that are often not deemed worthy of stating and have therefore to be independently discovered by outsider observers. Understanding what the paradigm is and designing interventions that are cognisant of its logic, its dynamics and limitations is a strong leverage point.

Paradigm changes at the level of entire societies are difficult, but not impossible, to bring about.

**The power to transcend paradigms:** The ability to understand that there are paradigms, and that just because, from one's own vantage point, only one paradigm appears dominant, does not mean that it is also superior to the limitless possibilities that exist. Promoting this understanding can help systems stay unattached in the arena of paradigms and thus derive enormous benefits by commencing an early transition to a superior paradigm once it emerges.

*Source: Adapted from Meadows (1999)*

## 3.2 Policies for System Innovation

### *3.2.1 Policy actors: their roles and relationships*

*Roles of actors according to their function in the system*

122. **Orientation**. Providing system-wide orientation is very important to SI, particularly at the early stages. It helps conceptualise boundaries and provide a common frame of reference for coordinated action. For system innovation, orientation is the key function. The likelihood of the success of SI increases when the policy makers at the top of decision-making hierarchies (in government, in firms as well as intellectual and opinion leaders in civil society) adopt it *first*. Adoption of the new paradigm may run counter to the logic of established administrative divisions, requiring principals at all levels of governance to at least yield or share some of their authority, and at most to see the boundaries of their authority completely redefined. This makes it unlikely that general adoption of the paradigm will emerge spontaneously in a bottom-up fashion from lower layers of the hierarchy.

**123. Programming and Co-ordination.** SI implies a shift of emphasis on the articulation and stimulation of demand and on coordination instruments such as information platforms that map out the system, and instruments such as PPPs and technology platforms that help dynamically extend the system's boundaries to new areas. SI is much more demanding in terms of coordination than conventional innovation policy. One of the key messages from the TIP project is that system innovation requires orchestration of policies in a range of areas, from basic research, regulation, knowledge management, human capital and skills and in the target areas (housing, urban, manufacturing, energy etc.). It also requires openness and new modes of co-production and value creation between public and private actors. Policy programming needs to identify possible complementarities and make the required links (within government and among a wide range of stakeholders).

**Box 3.5 Sustainable housing (Flanders, Belgium) : the challenge of policy co-ordination**

The challenge for system innovation policy, as illustrated by the Flemish case study, is the problem of policy coordination. System innovation implies an approach that integrates different policy domains (horizontal co-ordination), between different policy levels (multi-level coordination) and with different societal actors (multi-actor co-ordination). This proves to be particularly challenging.

For example, the long tradition of compartmentalisation of policy in Belgian and Flemish policies hinders horizontal policy co-ordination, as shown by the fact that DuWoBo programme and The Round Table Construction processes did not succeed in involving the central policy departments of housing and spatial planning. Initially, the Round Table Construction initiative was framed as a pilot process for a new style of collaboration between the government and stakeholders, but did not succeed in connecting the goals of the government and the building sector.

124. **Evaluation and reflexivity**. SI requires new monitoring and measurement tools to understand the extent of the transition; the importance of specific structural bottlenecks and of other forces of resistance; information polling mechanisms that feed weak signals back to the orientation function, including stakeholder consultation, surveys, etc. SI brings to the fore the need for policy makers to be themselves engaged in 'social' innovation. (Nelson and Sampat, 2001). Among other things, this involves continuously mapping the system's changing boundaries, formulating hypotheses about binding constraints, and experimenting with various approaches to lifting them, considering possibilities for alternative configurations.

*Division of policy functions between portfolios and between levels of governance*

125. SI has important implications for division of policy functions across different parts of government. Innovation policy making bodies need to become agents for change, leaders in conceptualising a vision and in steering, and facilitating learning across the system. Innovation policy makers possess unique knowledge of the system and its bottlenecks and are best positioned to take the lead in instrument design. They can become long-term guardians of the vision and help extend the planning horizon beyond the policy cycle of the system. Innovation policy makers also have new roles as intelligence gatherers. They need to map, understand the workings of and progressively extend its boundaries.

126. Moreover, SI highlights the important of role of central coordinators (e.g. Prime Minister's office, central planning office etc.). The logic of administrative hierarchies dictates that the likelihood of widespread adoption increases when central coordinators adopt a vision and facilitate the positioning interventions within a long-term framework, whilst ensuring that the framework (boundaries/endpoint) is adjustable and adjusted. SI ascribes important roles to the various thematic ministries (e.g. health, energy, environment), in terms of mobilising funding and helping to set standards whilst linking up with innovation policy makers and with the central coordinating ministry.

127. Furthermore, SI requires vertical coordination and addressing any gaps within a multi-level governance setting. The relevant levels include the international/supra-national, federal/national, regional/sub-national down to the urban level and local communities. Existing divisions of policy portfolios emphasise the role of national and increasingly regional levels of governance for innovation, while the city level has traditionally received little attention. However, innovation needs and complementary investments during transitions can be highly localised requiring the mobilisation of policy makers from the national, regional and, especially, the city level of governance. Lack of mandate or of clarity about mandate has been shown to be a barrier to the effective governance of transitions during the on-going system innovation case studies on smart mobility. Table 3.2 presents some of the common gaps emerging in the multi-level governance of transitions and some common tools for tackling them.

**Table 3.2. Tools and strategies for addressing multi-level governance gaps**

| Gap | Conditions | Tools and Strategies |
|---|---|---|
| Accountability gap | Principal-agent problems stemming from asymmetric information or conflict of interest | • Institutional autonomy<br>• Performance contracts |
| Administrative gap | Mismatch between administrative boundaries and the boundaries of the functional system concerned. Lack of clarity about division of competences between levels of governance. | • Co-ordination between levels<br>• National strategies |

| | | |
|---|---|---|
| Capacity gap | Lower level governance actors have insufficient expertise, knowledge and infrastructure to effectively design/customise and implement policy | • Consolidation of programming and delivery functions<br>• Inter-agency coordination |
| Funding gap | Insufficient or unstable funding | • Traditional financial transfers between levels of government<br>• Attraction of private (e.g. PPPs) and international funding (e.g. EU). |
| Information gap | Lack of statistics, and other policy intelligence depriving policy makers of a common frame of reference | • Collaboration with statistics gathering and policy-relevant intelligence gathering agencies<br>• Establishment of benchmarks<br>• Information provision requirements for public organisation |
| Objective gap | Disconnect or misalignment of policy objectives between and within levels of governance | • Multi-stakeholder partnerships (e.g. PPPs)<br>• National strategies<br>• Joint lobbying to legislative authorities |

*Source*: Adapted from OECD (2013).

### *3.2.2 Possible policy instruments for system innovation*

128. The government can play a critical role in the transition by providing information, infrastructure, skills and support for types of innovation that are otherwise likely to attract little attention and resources.

**Box 3.6 China – the case of electric vehicles: a development mainly driven by central government**

The development of electric vehicles (EV) industry in China is characterised by a top-down model. Governmental interventions have played a significant role in this transition. Government is the initiator, driver and facilitator of the transition. Due to the high risk, complexity and long-term timeframe of EV development, without government the transition will not be started and have little chance of success. Government's interventions are: R&D support, promoting pilots, tax credit for EV enterprises, and subsidies for consumer purchases of EVs. It has established a policy framework covering both supply-side and demand-side policies.

But even if government's interventions are crucial, a lesson to be learned from China's experience thus far is the market mechanism should play its role. The long run, Chinese auto enterprises cannot rely on subsidies. Policy makers can encourage auto enterprise to produce EVs, but at the same time, policy should let market competition play its role in the development of the EV market.

#### Types of instruments

*Transfer of authority and organisational redesign*

129. The transfer of authority for decision making to other parts of government or outside it has considerable potential to affect the efficiency and effectiveness of policy. Importantly, transfers of authority represent opportunities to enhance the innovation system without necessarily implying a budget burden. Decisions on transfers of authority take a wide variety of forms and intensities, ranging from the complete transfer of executive powers to different organisations to arm's-length co-ordination on a voluntary and *ad hoc* basis. This may also involve the setting up of distinct organisations or their integration (e.g. as in a merger) and the transfer of ownership (e.g. privatisation or nationalisation). Among other considerations, decisions on transfers of authority have to take into account the relevant parties and the nature of the co-ordination, as well as its frequency and intensity.

**Box 3.7 Sustainable renovation of housing in Sweden to meet current challenges**

Swedish housing policy has over the past years been characterized by a growing awareness of the significant role housing and especially cities have, in meeting the challenges of climate change and sustainable development. To complete the government's interventions – in particular through laws and regulations – municipalities are key actors to address these challenges. They were given the authority to identify and prioritize local environmental problems and to apply for funding for the solutions that the municipalities considered effective. This served as strong stimulus to municipalities and regions to intensify their efforts and to build competence and knowledge to increase ecological sustainability.

130. International experience shows that specific configurations within the government – such as delegation of executive funding decisions or an advisory role to an intermediate level – can improve the efficiency and effectiveness of policy. Transfer of authority of this kind can be useful for system innovation in at least three ways:

- It breaks down concentration of systemic power by distributing decision-making ability to a greater number of actors. In doing so it may weaken resistance, at the likely cost of complicating coordination and hampering steering.
- Insofar as objective monitoring is possible, transfer of authority can help locate responsibility and improve accountability about outcomes.
- Specialised organisations can provide checks and balances (e.g. in the provision of policy intelligence) and act as buffers that cushion systems from sudden external changes.

131. Drastic or wide-ranging changes in the architecture of the system are typically not possible within conventional policy horizons. However, the opportunities may be greater for developing systems. Even if changes in the design of a system are not possible at short notice, an understanding of its limitations can be nevertheless useful in preparing better policies for transitions (e.g. in terms of managing expectations and gaining long-term credibility).

*Policy intelligence*

132. System innovation policy is predicated on accurate information about emerging opportunities and threats, the boundaries, structure, functions and performance of the system, and the monitoring of the impact of policy interventions. These are very resource intensive and imply a considerable upscaling of current intelligence gathering capacities. Though typically associated with quantitative measurement and statistics, policy intelligence can take various forms. At its simplest it can be seen as the outcome of continuous interaction between policy makers and actors in the system. For system innovation, qualitative insights about desirable futures, regulatory barriers, inter-dependencies, and perverse incentives are of central importance. These can be codified in detailed case studies and statistics, or they can take a more tacit form, resulting from stakeholder consultation and network building activities. A policy intelligence task that is generally underappreciated but seems distinctly necessary for system innovation is that of mapping the system, in a more or less continuous fashion. Discovering the system's internal organisation and precisely mapping it can be important in understanding the system's boundaries and identifying potentially profitable missing links. Doing so may bring into view the bottlenecks that stand in the way of extending the system's boundaries and facilitating the transition.

133. Statistics are important in at least two broad ways. One is in establishing the stage of progression of the transition, given the importance of timing and sequencing interventions, as discussed previously. Of

particular relevance to innovation policy makers here is the identification of reverse salients in science and technology (corresponding to slowly moving or stuck areas of inquiry) that are holding back the transition. Another one is in presenting initial monetary estimates of the costs of and benefits from the transition. To the extent that these can be costed, comprehensive social cost benefit analysis can be used to secure legitimacy for the transition and presenting a common frame of reference for public discussion and debate.

134. Policy intelligence can be useful in preparing for alternative possibilities for example through foresight, business strategy, portfolio management or technology road-mapping. Strategic foresight can be useful in detecting impulses for change when their signals are only weak and providing a forum for reflection and debate on their relationship and likely impact on the system. Given the importance of first mover's advantage in transitions, the utility of foresight activities seems very high, even if all it achieves it to provide a marginally advanced warning of likely GPTs or dominant designs. When it comes to threats too, strategic foresight is an essential tool. It can help detect vulnerabilities, monitor changing risk impulses, and where necessary, facilitate decisions on changes in system design or investments in measures that improve resilience (OECD, 2014b).

135. System innovation policy is by nature dynamic. In this respect, policy intelligence plays an important role in maintaining a reflexive and adaptive system. Systematic monitoring and evaluation of policy interventions, as well as sharing of experiences internationally, can facilitate policy learning, extend policy horizons and improve impact over time.

*Socio-economic visions and strategies*

136. In light of the central importance of the orientation function, creating visions and long-term strategies is a key instrument for SI. A vision provides a long-term framework within which individual interventions can be situated and sequenced. Recent initiatives such as the Dutch Top Sectors approach (Box 3.11) demonstrate that this does not have to be exclusively a top-down exercise. Some similar initiatives on long-term priority setting use a mixture of top-down and bottom-up inputs (using stakeholder participation or mechanisms that reward entrepreneurial experimentation). Ultimately though, the task of bringing this together into a coherent vision falls upon government and its agents.

137. There is understandable hesitation about firm political visions, stemming from the fact that they rest on (implicit or explicit) predictions. While the effectiveness of orientation clearly depends on the accuracy of such predictions, whether the visions turn out exactly as planned is of secondary importance to their impact in facilitating coordination and strategic adaptation throughout the system. An additional argument in favour of a strong orientation function is that the very identification of barriers (e.g. regulations, or reverse salients in science and technology) is conditional on the presence of a vision for the future. In other words, barriers cannot be identified unless one knows the direction of the path.

138. The ability of policy makers to put forward realistic visions varies across jurisdictions and over time. It may be within the reach of large, developed countries to turn their political visions into self-fulfilling prophecies; for smaller or less capable countries visions are little more than a source of inspiration – important as this is. The type of vision put forward will also vary according to the stage of the transition. The purpose of the vision may well be *not* to commit resources to a particular path but to test out alternative paths within a board trajectory. Strategic preparation and planning comes into the fore once an emerging technology or other impulse has taken a clear shape (e.g. a dominant design has emerged) and much of the transition path can be foreseen and prepared for. Safeguarding the independence and long-term horizon of orientation is central to its credibility and, by extension, to its effectiveness.

139. Visions should be sufficiently forward-looking and suitably contextualised. In putting forward visions, it is not sufficient to aspire to catch up with the transition leaders. Rather the vision articulated

should be suitably differentiated and ambitious. Uncertainty can be reduced by opting for thematic sectoral targeting aiming for differentiation within a global paradigm. The key question is how granular these decisions are and how much room for manoeuvre remains for adjustments after they are made – ideally the focus should be on investments of the infrastructure-type (not just physical) that have broad appeal in the new paradigm and do not, by themselves, block alternative development trajectories. Risks entailed in betting against an uncertain future can be somewhat minimised by ensuring that objectives are adaptive, and subject to co-decisions such as those in public-private partnerships (PPPs).

*Tax incentives for investment*

Tax incentives can directly affect the cost of capital for investment and are among the primary instruments used to influence the magnitude and direction of investment. Accelerated depreciation allowances for machinery and intangibles (such as patents and software) allow companies to deduct these investments from their profits and reduce their overall tax burden. As such they hold a powerful sway on corporate investment decisions, including those of multinational enterprises.

Tax may usefully contribute to the mobilisation of venture capital, for instance with generous provisions for capital gains linked to specific types of investment or investment in specific sectors. Additionally, tax incentives can be very effective in facilitating technology adoption and retooling in response to the emergence of a global trend. China, for example, exempted key electronics industries from tariffs and import-related VAT for the purchase of equipment during the 9th and 10th five-year planning periods (1996-2005) (Yusuf, Wang and Nabeshima, 2005).

Removing existing tax subsidies to the production structures that the transition is seeking to replace is equally important. Despite the increasing importance attached to renewable energy, tax subsidies to fossil fuels remain pervasive (OECD, 2015). While these often reflect resistance to change, pragmatic considerations (including some less contestable realities, such as the dependency of poor families on fossil fuels for their most basic energy needs) mean that they cannot be removed at short notice.

R&D tax incentives can be powerful instruments too. They can be an important tool as part of a balanced set of interventions, aiming to co-opt industry into joint research and PPPs. However they are difficult to target to particular technologies or sectors, and evidence of their long-term impact is mixed. Carefully designed R&D tax incentives and tax provisions for intangibles (such as "patent boxes") may nevertheless play an important role on the location decisions of multinationals provided they include local development conditions (Alstadsæter et al., 2015).

*Funding for R&D and innovation*

140. Public funding for R&D and innovation in the broad scientific, technological, sectoral and societal domain of the transition is of course necessary given the pervasive and overlapping market and systemic failures discussed earlier. It can play an important role in reducing uncertainty and acting as a catalyst for decisions to either hasten, slow down or to address issues raised by the transition. Many countries single out emerging technologies (ICTs, biotechnology, nanotechnology) and societal challenges (notably within Europe as part of the EU Horizon 2020) as eligible for preferential funding in their innovation programmes. For emerging technologies, transition-specific R&D and innovation funding would be aimed at facilitating the detection, amplification, adaptation and accelerated propagation within the system, of knowledge impulses originating outside the system.

141. The bulk of such funding would likely focus on context-specific adaptations (or new to the system innovation, including organisational and design aspects) in response to the specific impulse. There may, however, be a need for more finely targeted support aimed directly at overcoming the barriers posed

by reverse salients[7] – defined earlier as areas of science and technologies that are slowly developing or are stuck but whose development is crucial for the transition. For systems that find themselves close to the endpoint courtesy of fortuitous experience in the specific domain, or those that have an ambition to develop such capabilities, funding more ambitious types of R&D and innovation may be a possibility. Somewhat paradoxically though this type of R&D innovation is less amenable to targeting of performers (or analysis of its impact): Insights from the statistical distribution of high impact innovations suggest that failure is to be expected in the majority of cases and that there are no measurable ex ante traits that can predict the successes (Scherer and Harhoff, 2000; Silverberg and Verspagen, 2007).

142. Resources devoted to the pursuit of innovation within the public sector would be very important too. The transition may demand new forms of public service delivery or citizen engagement. Research into the social drivers (e.g. public understanding of science) and social implications of the transition (e.g. employment) would have to be funded by government too.

143. At the same time conventional, technology neutral R&D and innovation funding, can play a crucial role in the emergence of paradigm-changing, global impulse generating innovations or original solutions to global social challenges. The balance between the two may well vary as a function of the stage of the transition (Table 3.4)

**Box 3.8 Crucial role of government support for sustainable housing in the case of Sweden**

The Swedish state has earmarked funding for improving the environmental performance of Swedish housing. Between 1998-2002, the state injected SEK 6.2 billion in central government funding to Local Investment Programmes. The government also provided support for research and innovation related to urban development, buildings and construction (called ‘built environment’) has primarily been channeled through the Energy Agency, the Research Council Formas and VINNOVA.

From 2010 to 2013, Formas doubled its funding of research for ‘built environment’, partly reflecting earmarked funding for the area in the most recent government research and innovation bill. In 2013, the Energy Agency started a new programme, “research and innovation for energy efficient construction and dwelling” with an annual budget more than twice that of a similar previous program. VINNOVA’s involvement with urban development has increasingly sharply after it launched its programme “challenge-driven innovation” in 2011. Projects in area of “sustainable and attractive cities”, one of the four broad challenges addressed in the programme, in 2013 received about SEK 80 million in funding, part of which was allocated to the called Innovation Platforms in Malmö and three other cities.

*Funding for infrastructure*

144. Some transitions (e.g. in urban transport systems) have been greatly facilitated by public or public-private investments in critical infrastructures (see chapter 4) In at least one recent example (Tesla motors in the United States) the private sector has shown willingness to shoulder the burden of nationwide infrastructure provision. Nevertheless, with respect to the identification of infrastructure gaps, current practice seems to be *ad hoc*. Part of the reason may be the numerous important policy considerations, pertaining to the identification of the ‘right’ targets for investment, the timing or sequence of the interventions and their impact in terms of lock-in of the system into particular trajectories. Although these are relevant for all forms of government intervention in SI, they are particularly acute in the case of infrastructure due to the long-term nature of the commitments.

[7] Of course, reverse salients may not be possible to tackle within the current paradigm (Kuhn, 1967).

145. At this early stage of research on suitable policy responses only some broad remarks seem appropriate. The first is about the importance of probing and evaluating alternative possibilities. In delineating the role of government stakeholder and expert consultation will be needed to find out about the broadest possible range of investment possibilities that can bring about an effective transition. The business sector should have an important say, but current and potential users of the infrastructure, whether from the business sector or not, should arguably be central to this process. Analysis can then be used to evaluate the likely impact of alternative investment possibilities *ex ante*, cost, prioritise and match them with available financing options. The timing of such probing process is critical too. A single round may not produce any attractive investment targets, but later iterations, when conditions either in the technology or in other parts of the system have changed sufficiently may provide very different outcomes.

146. A second broad observation, relates to the timing of the intervention. Early interventions stand to accelerate a transition but at the possible cost of lock-in into ineffective or 'losing' trajectories. Literature suggests that early on in the process many alternative designs compete before a dominant design emerges (Nelson, 1994). Early interventions, before a dominant design emerges, may have a role but should be carefully designed to avoid tipping the balance in favour of any one alternative. It seems reasonable that, other things being equal (e.g. cost to the taxpayer), interventions that keep alternative options open, should be preferred over those that channel the transition toward narrower trajectories. Once a dominant design emerges, the transition path may be predictable and appropriable enough to attract sufficient private financing. International coordination among policy makers confronted with similar questions seems likely to play a crucial role in both the choice and the timing of interventions. It may provide early signals on the establishment of international technical standards, point to likely dominant designs, and foster learning on good policy practices.

*Skills provision*

147. Historical experience suggests that when a new industry emerges, the demand for relevant skills can only be filled quickly enough with imported labour (Stigler, 1951; Mokyr, 1992). Arguably the most important role of policy at this early stage would be to permit and even encourage such mobility. Indeed, responding to global stimuli can only be done quickly by hiring relevant human resources.

148. Much also depends on the responsiveness of education systems to industrial demand and to their receptiveness of global stimuli. The latter can be a strategic objective of internationalisation policies in education. Over the long-term, and once the dominant design has emerged, the provision of relevant skills will have to be addressed by a combination of *ad hoc* interventions in the education system and support for on-the-job training.

*Public Procurement: seeking complementarities and lifting constraints*

149. Public procurement may be an especially attractive instrument for system innovation. Its appeal stems from the fact that it can help mobilise budgets outside the narrow remit of STI policy, and thus overcome indivisibilities that may be difficult if not impossible to address otherwise.

**Box 3.9 Long-term care in the United Kingdom: a fragmented public procurement**

Long-term care in the United Kingdom faces a problem of public procurement. Indeed, the governance structure of the long-term care system is large and fragmented. Many public bodies are involved in long-term care, at different layers: international, national, regional and local. Procurement in the long-term care system is primarily delivered at the local level which includes a vast number of procurement actors. This fragmentation means there is no single procuring body that can take an overview of assisted living needs and deliver a comprehensive package.

149. The reasoning behind the use of public procurement for innovation is that the public sector can use expenditure for its procurement needs creatively to emulate a “lead market”. Lead markets normally comprise of early adopters, who tend to be technically proficient and are willing and able to pay a price premia. Therefore, in attempting to emulate lead markets governments have to have high levels of technical capability and be in a position to justify spending on goals other than cost-effectiveness, both of which can be challenging for many public administrations today.

150. Public procurement of innovation needs to be carefully planned and its use made conditional on the capabilities of procuring organisations. In a recent survey (Uyarra et al., 2014), public sector suppliers in the UK report significant barriers such as lack of interaction with procuring organisations, too much attention on tender specifications as opposed to outcome based specification, lack of competences among procurers and poor risk management. While some extent of demand homogenisation can be important at the early stages of the transition (a function also partly fulfilled by public procurement), too much demand homogenisation harbours risks[3]. The design of public procurement instruments needs to ensure that it does not result in an undue reduction of specialisation and of potential diversity, in light of its value for the system’s long-term resilience. Therefore, public procurement instrument design should place adequate attention to the generation of derivative demand and should have clear phase-out clauses and horizons.

Designing the instrument and its objectives can be demanding. The product or service to be procured may address a combination of social, technological, and other needs that remain unmet due to a misalignment between markets, technology, the public sector and society. It would require detailed policy intelligence on innovations that are complementary to the dominant design or which address binding constraints elsewhere in the system. After identification, expert analysis would be needed to assess, cost and prioritise. Sound intelligence about latent demand will be essential, possibly using techniques that are commonly used for the evaluation of environmental goods (e.g. willingness to pay surveys). It would have to involve an assessment of possibilities for leveraging additional demand, under different combinatorial scenarios and to also examine various dimensions of demand, including demand for complementary products and services (including information provision, research etc.). But it is not only about complementary innovations. Constraints of a different nature may be present, which is why public procurement should be planned in tandem with changes in regulations, standards and skills.

*Standards, regulation and legislation*

151. There are obvious reasons why standards are important for SI. Setting standards extends markets by homogenising demand and by reducing uncertainty, enables a division of labour to emerge in supply (Geroski, 1989b). Standards may also help create new markets. Often the bottleneck in system innovation is that markets are not yet present and that they are difficult to open by firms (Hekkert, 2013). From a broader perspective, standards can act as a common language, thus integrating previously disparate systems, in effect extending the boundaries of the system (Table 3.3).

**Box 3.10 Sustainable housing in Sweden: mandatory energy standards**

The government influences the construction of buildings and the housing market through various laws and regulations. Policy measures had to meet the demands of relevant EU directives: mandatory energy standards were introduced in Sweden in January 2013 and applied only when buildings are “altered”. In principle, the same energy standards now apply to “altered” buildings as to new buildings. But there are numerous caveats, such as “if economically reasonable”, which make the standards still very unclear.

**Table 3.3 Key features of demand-side innovation policy instruments**

| Demand-side policy | Procurement | Regulation | Standards |
|---|---|---|---|
| **Objective** | New product or service; complementary-to-dominant-design product or service | Market uptake, increased competition and social goals | Market uptake, interoperability, transparency |
| **Input** | Finance, performance requirements, skills | Legal process, need to co-ordinate | Participation of standards agencies, co-ordination of participants in the standards development process |
| **Participatory incentive** | Sales, risk reduction, preferential treatment (e.g. SMEs), attraction of additional private-sector finance | Mandatory | Voluntary |
| **Effects of success** | Improved and less costly public services, stimulation of innovation | Reduced market risk, transparency, stimulation of innovation | Reduced market risk, transparency, increased interoperability, increased trade |
| **Possible risks** | Insufficient skills in the public sector, lack of co-ordination across government, idiosyncratic demand | Conflicting goals, length of the process | Technology lock-in, inadequate attention to consumer needs (with industry-driven standards) |

*Source*: OECD, based on Aschoff and Sofka (2008).

152. When market and other coordination failures cannot be addressed via the price mechanism, legislative changes can be used to either regulate or prohibit certain types of activities. Changes in legislation may be needed to encourage the transition too. For instance, changes in traffic regulations have been used to allow electric cars to use bus lanes, improving their attractiveness as a mode of city transport. Legislation may provide clarity about the apportionment of liability and the distribution of risks in areas where no precedent exists.

153. Changes in institutional ‘rules of the game’ may also be necessary. For instance, one area requiring attention is the ‘branching’ of scientific disciplines that is sometimes necessary to facilitate transitions. Funding opportunities for communities of researchers interested in emerging topics may be hard to come by. Social processes, such as reputation dynamics (e.g. older scientific journals have higher citation ranks but may be conservative) may act as barriers to branching. For the branching of technology too, the formation of viable voluntary associations can be crucial to standardisation. Institutional changes to encourage branching of sciences and of industries may include university autonomy, seed funding for the creation of new communities of researchers in new areas (c.f. EU FP6’s positively received “Networks of Excellence” instrument) and policies promoting internationalisation and inter-disciplinarily.

154. Great care needs to be placed in the design of such interventions. While regulation can play an important role in stimulating incremental innovation once a clear path has emerged, it can also lock development trajectories into particular paths. Some studies of the effects of regulation on the automobile industries (reported in Blind, 2011, p. 14) have shown that it can be a barrier to more radical forms of innovation. However, on the whole the empirical record is rather ambivalent about the relationship

between regulation and innovation (Blind, 2011), which is likely highly conditional on qualitative characteristics of regulation (e.g. its stringency) and context (e.g. timing, sector).

155. The community of public administrators is an important part of the system and the rules that govern their actions can have important implications for SI. Changes in the way public administrations work may be inevitable if the policy system is to be aligned with the needs of the transition. A key problem is that policy design will have to ignore the vested interests of the designers themselves, a behaviour that may not be guaranteed; even if policy designers are unusually altruistic, public sector reform typically takes long periods of time to bear fruit, so leadership will have to be sustained (OECD, 2010).

*Support for networks and PPPs*

156. Policy may have to engage in continuing discussion and facilitate community-building with or by the stakeholders in question. The incentive of individuals to participate in transitions early on is low, as the benefits from participation are partly a function of the number of actors participating. Policy has a role in seeding and building these networks until such time as they develop their own internal momentum (Box 3.11).

**Box 3.11 The Netherland's top sectors approach for innovation in the business sector**

Motivated by concerns over international competitiveness and emerging social challenges the Dutch government announced the top sectors approach in February 2011. This new form of industrial policy focuses public resources on specific sectors and promotes co-ordination of activities in these areas by businesses, government and knowledge institutes. The nine area chosen (which do not correspond exactly to industrial sectors in established classifications) represented strong economic sectors: agro-food, horticulture and propagation materials, high-tech systems and materials, energy, logistics, creative industry, life sciences, chemicals, and water. In 2011 these sectors accounted for over 80% of business R&D and for just fewer than 30% of value added and of employment.

Whereas traditional approaches to industrial policy are government-centred, industry representatives are at the centre of the co-ordination process in the top sectors. For its part government undertakes to develop sector-specific policies across ministerial portfolios, including education, innovation and foreign policy, as well as regulatory burdens. The relevant policy also envisages reducing the administrative burden for businesses, uniting the henceforth disparate channels of public support to businesses with a one-stop shop for service delivery (the so-called Ondernemersplein).

The approach involves new forms of governance. So-called "top teams" composed of high-level representatives from industry, public research and government draft knowledge and innovation agendas which they submit to the government for consideration. The government then evaluates each top team's proposed agenda, which includes a strategic plan and suggested instruments relevant to the top sector. The government's evaluation takes into account the level of ambition, the degree of commitment of stakeholders, the degree of openness, the balance between social and economic agendas and the extent to which the objectives can be monitored and evaluated. The relationships and sectoral plans are then formalised in the top consortia for knowledge and innovation (TKIs) of which some top sectors have more than one. For the case bio-based economy, the Dutch government organises a cross sectoral TKI Biobased economy, which is linked to different top sectors. This TKI is responsible for the innovation and research agenda for the use of biomass in the energy, agricultural and chemical sector.

The Dutch government estimates that (excluding regional and EU funding) between EUR 1 billion and EUR 1.1 billion will be made available to the top sectors every year over the 2013-16 period. Of this only the TKI funding allowance (between EUR 50 million and EUR 130 million a year) can be clearly identified as additional funding. Between EUR 50 million and EUR 30 million a year are foreseen for specific education and labour market interventions, while EUR 700-900 million a year are foreseen for research and innovation.

*Source*: OECD (2014), OECD Reviews of Innovation Policy: Netherlands 2014, OECD Publishing. http://dx.doi.org/10.1787/9789264213159-en.

*Public consultation*

157. The importance of public consultation for SI cannot be overstated, given the key role of stakeholder engagement for establishing the desirability of the transition and reducing resistance to change. Public consultation, in addition to being a component in the design of many other instruments, is one of the key regulatory tools in and of itself (OECD, 2010). In the case of SI, it can aim to seek input on social demands and policy expectations, to provide a public space for discussion and debate, and legitimise the transition. Public consultation procedures when developing new primary laws and regulations is widely employed in all OECD countries as well as in the European Union. Given the long-term perspective required by SI the use of public consultation exercises in policy design can be challenging. Once a long-term vision with broad social legitimacy has been agreed, SI policy design needs to situate public inputs into a long-term framework, which may imply weaker sensitivity to occasional demands for course changes.

*Innovation programs*

158. Innovation programs may aim to seek to develop prototypes that are in tune with the needs of the system, perhaps by focusing on smaller parts of the systems (for example a city or a specific sector). Such programs can play an important role in validating the feasibility of application and help establish a cost-benefit structure. In addition, they may reveal opportunities for innovation that are specific to the (e.g. national) context. The task of such programs can be to probe and chart entry points for future development and produce an inventory of possible options and likely trajectories, as they become apparent in the course of the project. Projects play a pivotal role in niche accumulation at the global level (see Chapter 1). Innovation programs for system innovation are therefore best organised as portfolios and sequences of projects, focused on learning and exploration. Attention should be given to knowledge flows between projects, so that lessons from one project form inputs into subsequent projects (Box 3.12).

159. A key point about SI is that long-term success is conditional on social change. The social technologies required for effective transition though may be very sensitive to context. Social technologies are technologies the functions of which are sensitive to the behaviour of people and are thus much more difficult to control and replicate than ways of doing and thinking that are largely dominated by physical artefacts (Nelson and Sampat, 2001; Nelson, 2008). As an example of this, Nelson points to our still very limited ability to understand better the process of education, despite the formidable resources devoted to this purpose. This insight may serve to temper one’s expectations about the generalizability potential of lessons to be drawn from specific instances of system innovation and the feasibility of the transfer of ‘best practices’, in a field that is predominantly social, and at an early stage of development with regard to definitions and measurement.

**Box 3.12 Lessons from Innovation Projects**

Based on an evaluation of eight projects with radical transport innovations (battery-electric vehicles, bike-sharing schemes, gas and electric buses, car-sharing, individualised public transport) in European cities in the late 1990s, Hoogma et al. (2002, pp. 191-194) report several recurring design problems:

- Insufficient user involvement. Users generally played a rather passive role in the experiments. They were hardly listened to, let alone involved in the set-up of the experiments. Users were mainly perceived as consumers with given needs and preferences. Hence, the aim of many demonstration projects was to discover (mis)matches between technology features and these (assumed) needs. Standardised surveys and usability trials and panels were used to investigate these (mis)matches. Projects rarely investigated possible changes in people's mobility patterns.

- Pre-dominance of technology-oriented first-order learning. Many demonstration projects followed a technology push approach, in which learning was mainly about the technology (vehicles) rather than about mobility, and ways to achieve sustainable mobility. Users were not challenged to question their mobility needs and practices (second-order learning). The projects did not create enough space for processes of co-evolution of new technology and user practices (see Figure 7).

- Minimal involvement of outsiders. The projects were dominated by regime insiders (e.g. car manufacturers), who has an interest in the status quo, and therefore were less inclined to investigate alternative mobility options and practices.

- Projects were overly self-contained and not oriented towards wider sustainability visions. In many projects the social networks were rather narrow, which shaped the design and orientation of the projects. Networks that were broad and contained outsiders provoked more second-order learning.

These kinds of lessons have been replicated in other studies of transition experiments, which have been reported in an overview of 10 years of research in strategic niche management (Schot and Geels, 2008). The overarching message is that it is not easy to design and manage system innovation projects, which truly address various socio-technical dimensions. Many projects that start out with this ambition appear to become reframed and organised as 'normal' innovation projects (focused on technology and business dimensions), as the experience with the Dutch energy transition program also indicated (section 4.3.).

Another lesson is that system innovations are not brought about by single experiments or projects. Hoogma et al. (2002: 195) conclude that "The experiments were relatively isolated events. It seems difficult for the actors to build bridges. Although more could perhaps have been done and achieved, there are limits to the power of experiments. Only occasionally will an experiment be such a big success that it will influence strategic decisions. Experiments may tip the balance of decision-making, but they will not change the world in a direct, visible way. One should therefore not evaluate an experiment on the basis of its immediate economic success, but on the basis of what has been learned and its contribution to processes of social embedding." The implication of this lesson is not that projects are not important, but that one should look at portfolios and sequences of projects, which can constitute innovation trajectories. On the one hand, local projects (in cities or other localities) are informed by search heuristics, theories and models at a more general 'global' or community-level. On the other hand, outcomes of a local project can contribute to the further articulation of technical specifications and problem agendas. The transformation of local outcomes into generic 'rules' does not occur automatically, but requires dedicated 'aggregation activities' such as codification, formulation of best practices, model building, and standardization. While 'rules' (technical models, heuristics, agendas) are initially diffuse, broad and unstable, they become more articulated and specific through sequences of projects and associated learning and aggregation processes.

### *3.2.3 Policy design according to transition stages and prevalent governance styles*

160. Effective governance of transitions requires both the mobilisation existing policy frameworks and instruments and the creation of new ones. The choice of instrument will depend on context. Major factors affecting choice include the stage of the transition and the prevalent policy style and room for manoeuvre.

*(a) Stage of transition*

161. Policy interventions should be appropriately timed and sequenced. The very objectives of SI-minded policy will vary (Table 3.4). At an early stage the objective may be to identify and help co-establish a dominant design, whereas later on the objective may be to enable learning, the accumulation of specific capabilities and of transition-specific social capital. Different objectives imply different policy gaps and instruments. For example, financing needs differ at various stages of transitions. Effective transition invariably requires additional research and innovation – much of it public and context-specific. The availability of technology-neutral funding may be central to the initial emergence of niche areas. However, their further development and embedment in existing systems may require lumpier, technology-specific funding (notably for infrastructure) that is difficult to mobilise at short notice. Appropriate timing and sequencing of interventions relies on very strong policy intelligence and an agile policy apparatus. Whether policy interventions are ultimately worthwhile in light of prevalent constraints (e.g. administrative and coordination capacities) is an open question. It appears however that the answer to this question is more likely to be affirmative early on in the transition.

**Table 3.4 Main policy contributions according to transition stages**

| | Early stage | Take-off | Maturity |
|---|---|---|---|
| **Objective** | To identify and co-establish a dominant design | To enable learning and the accumulation of capabilities and directional social capital | To enhance efficiency while not compromising reflexivity |
| **Infrastructure gap** | High | Medium | Low |
| **Coordination gap** | High | Medium | Low |
| **R&D gap** | Basic research &<br>Technology-inspired science | Technology-<br>and/or sector-specific applied research | Basic research |
| **Distribution of support** | Technology-neutral innovation funding &<br>Technology-specific innovation funding | Technology-specific innovation funding | Technology-neutral innovation funding |
| **Instruments** | Social cost-benefit analyses<br>Foresight exercises<br>Support networks / PPPs<br>communities of practice | Subsidies/taxes/regulations<br>Networks<br>Standards<br>Technology Platforms | Performance based contracts<br>Quasi-markets (e.g. vouchers) |
| **Competition regulation** | Reduce market/systemic power and barriers to entry | Reward early movers<br>Tolerate concentration temporarily | Reduce market/systemic power and barriers to entry |

*Source*: OECD Secretariat.

*(b) Prevalent governance style and room for policy manoeuvre*

162. Governments in different countries practice different policy styles. They are therefore likely to manage specific system innovation challenges in different ways. To govern system innovation different governments are likely to use different policy mixes and instruments.

163. System innovation is difficult to manage and steer, because it is an open, uncertain and complex process, involving multiple social groups and co-evolution between various system elements, many of which are outside the immediate control of policymakers. The state is not an all-powerful and all-knowing actor, which can steer system innovation by pulling levers from an outside 'cockpit' point of view. Rather, policymakers are one social group amongst others, dependent on firms (for knowledge, resources, innovation, jobs, and taxes), and wider publics (for legitimacy and consent). Furthermore, the state is not

one actor, but fragmented across different domains (e.g. sectoral ministries) and levels (e.g. international, national, local). In political science, this awareness has led to a shift in focus from 'government' to 'governance' (e.g. Rhodes, 1997; Van Heffen et al., 2000). Governance means that there is directionality and coordination at the systems level, but that it has an emergent character, arising from the interaction between multiple societal groups. Public authorities have special responsibilities and resources to shape this emergent directionality, but cannot steer it entirely at will.

164. The political science literature further usefully distinguishes three policy paradigms, which differ in their view on social relationships and roles of policymakers, coordination, underpinning scientific disciplines and preferred policy instruments (Table 3.5). It is unlikely that system innovation can be brought about by a single policy instrument from one paradigm. Instead, shaping system innovation will entail a mix of policy instruments, which may differ between countries (see below).

**Table 3.5 Different policy paradigms**

| | Classic steering (top-down) | Market model (bottom-up) | Interactive network governance |
|---|---|---|---|
| **Characterization of relationships** | Hierarchical, command-and-control (government sets goals or tells actors what to do) | Autonomous (government creates incentives and 'rules of the game', which create context for autonomous actors). | Mutually dependent interactions |
| **Characterization of coordination processes** | Government coordinates through regulations, goals, targets | Incentives and price signals coordinate self-organizing actors | Coordination through social interactions and exchange of information and resources |
| **Foundation scientific disciplines** | Classic political science | Neo-classical economy | Sociology, innovation studies, neo-institutional political science |
| **Governance instruments** | Formal rules, regulations and laws | Financial incentives (subsidies, taxes) | Learning processes, demonstration projects and experiments, network management, vision building through scenario workshops, strategic conferences, and public debates |

*Source*: Based on De Bruijn et al. 1993: 22.

165. Instruments from the third paradigm (Interactive network governance) may be most prevalent in the early phases of system innovation, which are characterized by uncertainty, open-ended learning about new technologies and consumer preferences, opening up new markets, building of new networks around innovations. Policymakers cannot bring about these processes on their own, but need to work with other actors through public-private partnerships, demonstration projects, scenario workshops, vision building, public debates, and network management. So, in early phases of system innovation, policymakers tend to act as facilitator, stimulator, and chain manager. In later phases, when there is more clarity about the best technology, market demand, and infrastructure requirements, other policy instruments (*e.g.* regulations, standards, taxes, subsidies, financial incentives) tend to become more important, aimed at widespread deployment and uptake.

**Box 3.13 The transition management approach**

The transition management (TM) approach has received quite some attention in countries with a corporatist policy style (particularly the Netherlands). This approach offers a particular way of addressing the specific policy challenges, discussed above. The TM-approach was developed by academics (Rotmans et al., 2001; Kemp et al., 2007; Loorbach, 2010), and tried from 2002 onwards as a policy program in the Dutch energy transition by the Ministry of Economic Affairs (Kemp, 2010). In 2010, the new coalition government abandoned the energy transition program, and the associated TM-approach.

The TM-approach is organised around the following principles (Rotmans et al. 2001):

- Long-term thinking as a framework for short-term policy (at least 25 years).
- Thinking in terms of more than one domain (multi-domain) and different actors (multi-actor) at different scale levels (multi-level).
- A focus on learning-by-doing and doing-by-learning.
- Keeping open a large number of options (wide playing field).

The basic steering philosophy is not planning-and-control, but goal-oriented modulation. This means that long-term visions provide goals and directionality for system innovations, but that the pathways towards those visions arise from adjustments in ongoing dynamics (aligning bottom-up initiatives with regime and landscape processes) rather than top-down steering. Sustainability visions and transition pathways are explored through projects, and may be adjusted as a result of the learning processes and network negotiations. Transition management is therefore forward-looking, yet adaptive.

Concretely, transition management includes four types of activities with different orientations and actor constellations (Loorbach, 2010):

Strategic activities include vision development, strategic discussions, and long-term goal formulation. The TM-approach suggests that these strategic activities take place in a 'transition arena', which includes not only regime players (e.g. incumbent firms, high-level policymakers), but also 'frontrunners' (e.g. opinion leaders, entrepreneurs, NGOs, knowledge institutes) who can think 'out-of-the-box'. Actors are supposed to make comprehensive in-depth analysis of structural problems and propose innovative visions and directions for solutions.

Tactical activities include more concrete processes such as agenda-building, negotiating, networking, coalition building. Actors from existing structures (e.g. specialists from Ministries, advisory and professional bodies, sector representatives) are involved in the TM-process to develop more specific plans and proposals for concrete routes, preferably accompanied by negotiations about investments.

Operational activities include specific processes such as innovation experiments, demonstration projects and implementation activities with a short-term horizon (1-3 years). These on-the-ground activities are enacted by innovation agencies (e.g. Senter-Novem, Vinnova, and Tekes), cities, firms, entrepreneurs, and citizens, and aimed at learning-by-doing and doing-by-learning. Transition paths are explored by 'walking the talk'.

Reflexive activities relate to operational, tactical, and strategic activities: evaluation of concrete projects, assessments of agendas and coalitions, monitoring of progress and directionality of the overall transition. The evaluation activities may lead to suggestions for adjustments in overall visions, specific policies and structures, or the articulation and dissemination of best-practices

Transition management has attracted considerable attention in academic literature, but has also been criticized. Despite the participatory and interactive language of TM, Hendriks (2009), for instance, criticized the approach for lacking democratic accountability: the small group of actors in 'transition arenas' seems to articulate long-term strategic directions without much wider involvement. Shove and Walker (2007) also raised several problems, including the lack of attention for politics in TM, the downplaying of conflict through technocratic and consensual language, and the lack of attention for normal policy instruments such as taxes, regulations, and incentives.

**Box 3.14 Russian Federation case study – Technology platform Medicine of the Future**

This case study dealt with the importance of technology platforms in Russia, which is a new institutional form of co-operation between different actors in the framework of the STI policy on the Federal level. These platform initiatives are supposed to be a stimulus for high-tech sectors development, and thus enhance new business demand for innovation. There is also the expectation that new actors would be involved in innovation processes. The platform selected for the case study is “Technology Platform Medicine of the Future” (TPMF). Its governance structure is coordinated by a general assembly, a steering committee and 9 Science and Technology Councils. The TPMF members have elaborated a “Strategic Research Program till the year 2020” and a new technology platform development instrument “Full cycle complex project”. These strategic programs (including coherent policy measure and governance instruments) and mobilization demonstrate a real management of the TPMF transition in Russia.

However, two main bottlenecks were identified in the process of the TPMF transitions, which do not always depend on TPMF management: a lack of development supporting infrastructure and lack of funding.

### *3.2.4 Indicators for system innovation policy monitoring and analysis*

166. Given the complexity and context-specificity of transition experiences the development of systematic indicators that allow comparisons of *transition experiences across systems* is still at the conceptual stage of development – though some interesting examples are emerging from the case studies in specific contexts (see appendix).

167. Much less progress has been made in the development of universal transition indicators that compare *different transition experiences* in the same system or across systems. Assuming a start- and end-point can be identified for transitions, then measurement seems feasible and various indicators can be envisaged denoting speed, duration or responsiveness to a stimulus/impulse. Follow-on work can develop an indicator framework and test its feasibility for the systematic monitoring and comparison of transition experiences, with a view to eventual standardisation of measurement practice.

168. Table 3.5 offers some tentative proposals. One possibility for generalising impulse-response indicators may be to treat them as elasticities, i.e. the degree of change in one variable with respect to a change in another. Elasticities are effectively ratios of growth rates and as such provide for a unit less measure that can permit comparisons. For instance, when the objective is to evaluate a transition experience at the national level, a suitable indicator can be the elasticity of any of the progress indicators of interest at the national level (response) with respect to its level at the global level (impulse).

In the absence of generally agreed definitions, it can be difficult to establish even start-points, which complicates measurement and comparisons. To begin with, the start of a transition may be decided an *ad hoc* manner – despite the potential importance of the choice of starting point for evaluation and measurement, taking such pragmatic choices means that indicators permitting at least some systematic comparisons to be made are feasible, which is arguably preferable to no indicators at all. Further development along these lines can bring methodological insights from business cycle analysis (particularly concerning the empirical identification of start and end points).

**Table 3.5 Indicators of responsiveness**

| System component | Possible dimension(s) of novelty | Suggested indicators<br><br>(responsiveness calculated as the ratio of annual change at national level to annual change of world level) |
|---|---|---|

| | | |
|---|---|---|
| *Science* | • New research theme (e.g. cluster of keywords in bibliometrics)<br>• Shift in relative importance between fields of science<br>• New discipline (addition to fields of science) | • Bibliometric counts<br>• R&D expenditure by field of science |
| *Technology* | • New group of IPC patent classes (defined either ad hoc or empirically e.g. through cluster analysis)<br>• New IPC patent classes. | • PCT patent counts<br>• R&D expenditure by NABS socio-economic objective (e.g. Environment, Energy) |
| *Industrial production* | • New areas of economic activity (e.g. identified through cluster analysis)<br>• Shift in the relative importance of industries (e.g. in the ratio of output from high-technology industries, or in industries corresponding to social challenges, incl. services) | • Industrial output, employment value added by sector (OECD STAN Database)<br>• Employment and value added in sectors producing environmental goods and services (OECD, 2014) |
| *Education* | • Emergence of new types of skills (ISCED fields of education, [UNESCO, 2014]) and/or professions (occupations in the ISCO classification [ILO, 2008]).<br>• Shift in skill generation by discipline | • Headcounts of enrolments, graduates by field of education<br>• Education expenditure by field of education |
| *Infrastructure* | • Emergence of technological artefacts which are representative of the dominant design (e.g. for internet includes top level domain servers, broadband connections)<br>• Shifts in infrastructure spending priorities (e.g. in the share of expenditure between alternative types of infrastructure) | • Adoption rates of representative technological artefacts<br>• Infrastructure expenditures (e.g. on health or new forms of transport) |
| *Public interest* | • Emergence of new vocabulary<br>• Membership of voluntary organisations<br>• Shifts in donations and user-innovation trends | • Indicators of interest or concern from surveys (e.g. Eurobarometer)<br>• Adoption / usage trends established via webometrics, content analysis<br>• Crowdfunding (e.g. kickstarter campaigns) |
| *Policy* | • Shift in relative priorities of interventions aimed at any one of the system components<br>• Public sector innovation | • Government budget appropriations or outlays for R&D (GBAORD) by NABS socio-economic objective (e.g. Environment, Energy)<br>• Support estimates for fossil fuels (OECD, 2014)<br>• Environmentally related tax revenue (OECD, 2014)<br>• Government reform indicators (OECD, 2010)<br>• Indicators from surveys of policy makers |

*Source*: OECD Secretariat.

**Box 3.15 Transition Management in Flanders (Belgium)**

The transition approach has been adopted by the Flemish government in 2011 as a general methodology for the organisation of its future strategy 'Flanders in Action'.

The Flanders in Action (ViA) program was launched in 2006 by the Flemish government in order to tackle several grand societal challenges. An intensive and participative societal trajectory led to the formulation of a set of joint objectives, accompanied by indicators for monitoring those objectives (Pact 2020). The pact was signed at the start of a new government cycle in 2009 by over one hundred partner organisations and the implementation was concretised by 337 key projects. The progress of those key projects and the evolution of the indicators were monitored on a yearly basis.

At the start of 2011, the monitoring results clearly showed that insufficient progress was being made. The limitations of the traditional program approach became apparent in the confrontation with the consequences of several systemic crises. In addition, this traditional program management lost connection with the power of partnerships. On the basis of running experiments with system innovation using the transition approach, in particular 'Sustainable Building and Living' and 'Sustainable Materials Management' (see Annex), the Flemish government decided to scale up the transition approach and to put transition thinking at the core of the Flemish policy. This transition management approach should enable system innovation with closer involvement of partners in co-creation of solutions to tackle systemic problems.

During the summer of 2011, 13 'transitions' were identified and a process manager for Flanders in Action was appointed to coordinate the progress of the ViA-program. The manager was the central point of contact for ViA and the link between the administration and the political level. The ambition was to engage all government sectors, but the maturity of these 13 projects regarding transition vision and stakeholder involvement was uneven. As a consequence results are uneven too. Probably too many 'transitions' were put in motion. As another consequence, lots of experiments were new partnerships and progress was made for the further development of the transition approach in Flanders. E.g. working with the circular economy roadmap, an integrated approach of the care system, new thinking about spatial planning… .

In May 2014 elections took place and a new political coalition came to power. A certain continuity is expected, but this government wants to evaluate the work that is done in ViA. This political change is a very important turning point. In the last three years Flanders has had a transversal governance coordinating framework, which is a quite unique approach for system innovation policy, specifically in terms of scale and complexity. A number of important lessons can be drawn from this experiment:

**Walk the talk.** One should already apply system innovation within the government administration when developing a system innovation policy approach. Clearly, a participatory trajectory at the start was a necessary precondition to bring the transition approach central to Flemish policy. This also involves a new way of working together, a subtle, concerted action of many players, participation and co-creation. A transition process creates new insights and ideas by sharing different types of knowledge and experiences. In a transition process, one looks across the existing ways of thinking in order to change systems. This process takes time and a common idea of the future and a long-term vision are essential. Based on this shared vision and cooperation between all actors, innovative experiments are set up.

**Invest in getting and keeping the political engagement.** A central coordination made sure that system innovation remained a priority on the political agenda. The engagement of the Minister-President was crucial. Nonetheless, the objectives to broaden the commitment, to create ownership for the transition approach within all departments and to have it fully supported by the Flemish Government as a whole was insufficiently reached, partly because the political ownership was too much concentrated.

**Focus, focus, and focus**. Policy makers should focus on those domains where they or their partners can make the difference. Domains for which they and their partners have the necessary leverage to change the system. In some of the transitions (e.g. energy) important policy instruments were not available at the regional (Flemish) level, as the domain is mainly a federal competence. While a multi-level and international dimension in the approach is needed for consistency, the capacity to impact might determine a government's priorities in the transition agenda.

**Make the bigger picture.** One should not lose sight of the importance of a connecting story line between the different transitions. A more clearly identified framework on what the 13 transitions are about, might have avoided a number of discussions between the transition managers and those who are responsible at the policy level.

**There is no such thing as a free lunch.** Give transition managers the proper mandate, supporting team, tools and budget to establish the needed transition. Establish a learning network for the transition managers. Strong support creates safety. Transition managers are pioneers and have to be very motivated, hard-working people. In case they lack the necessary means and support, there is a high risk of disappointment and personnel turnover, which is very harmful for the transitions.

## 3.3 The role of businesses and civil society

### *3.3.1 The role of the financial service industry*

171. Finance in one form or another accompanies most innovations, be they incremental or systemic. But system innovation is especially demanding in terms of finance. The magnitude of the cost, time and risk burden to firms in developing an innovation are inversely related to progress made in building the innovation system within which it will be embedded; More novel innovations require greater change in all system functions and therefore greater development time, greater cost and carry an increased risk of failure (Van de Ven, cited in Hekkert, 2013).

172. Successful innovations often require the invention of new financial arrangements. Evidence shows that system innovations and finance have evolved together, often in a synergistic manner, over several centuries (Allen and Gale, 1994; Frame and White, 2004; Goetzmann, 2009; Tufano, 2003). For example, to finance the construction of vast railroads in the 19th and 20th centuries, financial actors developed specialised investment banks and accounting systems to facilitate screening and monitoring by distant investors (Chandler, 1965, 1977; Baskin and Miranti, 1997; and Neal, 1990). Also, innovative

financial products prompted the development of the steam engine as a key component of the industrial revolution (Pathania and Bose, 2014). More recently, financial actors developed modern venture capital firms to help fund risky ventures. These examples indicate that the financial service industry has fostered a long series of useful innovations; delivering benefits widely felt across the broader economy (see Box 3.16 for the definition of financial innovations). Over the past centuries it has made financial markets more complete so that households, firms and governments can obtain finance, find the most suitable investments, and share risks in a mutually rewarding manner. However, as today´s financial system and its actors are highly interconnected, financial innovations are likely to generate a complex web of externalities, both positive and negative. The result of unsuccessful financial innovations has been felt around the globe during the financial crisis, where they mutated from their original purpose. Over time, however, most have been accepted as beneficial, even though quantifying those remain speculative (World Economic Forum [WEC], 2012).

**Box 3.16 Defining financial innovation**

Lerner and Tufano (2011) define financial innovation as "the act of creating and then popularising new financial instruments, as well as new financial technologies, institutions and markets. The innovations are sometimes divided into product or process variants, with product innovations exemplified by new derivative contracts, new corporate securities or new forms of pooled investment products, and process improvements typified by new means of distributing securities, processing transactions or pricing transactions." Tufano (2003), Frank and White (2004, 2009) as well as Lerner and Tufano (2011) provide overviews on innovations in the financial market.

173. Financial innovations can be seen as playing a role akin to that of the "general purpose technologies" delineated by Bresnahan and Trajtenberg (1995) and Helpman (1998): not only do these breakthroughs generate returns for the innovators, but they have the potential to affect the entire economic system and can lead to far-reaching changes. For example, financial innovations may have broad implications for households, enabling new choices for investment and consumption, and reducing the costs of raising and deploying funds. Similarly, financial innovations enable firms to raise capital in larger amounts and at a lower cost than they could otherwise and in some cases (for example, start-ups) to obtain financing that they would otherwise simply be unable to raise (WEC, 2012).

***The need of financial innovation for fostering system innovation***

174. For system innovation, access to and cost of capital is a central determinant for the initiation of transformation processes. The cost of capital is influenced by perceptions of the risk involved (i.e. investor's perception of "radicalness") in the particular pathway as outcomes may be highly uncertain. Furthermore, as economic theory stresses, there is often a high degree of information asymmetry and moral hazard between the financier and the innovator which may lead to opportunistic action (e.g. Hall, 2010). As mentioned above, financial innovations may help to cut the cost of funds raised for investment and to raise funds more securely and quickly. In the area of business finance, the venture capital industry, a radical financial service innovation, helped to launch many of today´s most innovative companies (Allen, 2012).

175. Other more recent financial innovations that help to direct its capital more efficiently include the Internet marketplaces that have sprung up to provide a new route to liquidity for (micro-)investors in start-ups. There is an active debate surrounding the potential of crowdfunding to alleviate the financing gap faced by ventures. Currently, equity-based crowdfunding is not allowed in most OECD countries, largely due to the lack of institutionalisation, but legislative and regulatory changes are under way (OECD, 2013).

176. Not only financial resources must be expended to initiate, but also to direct and sustain system innovations. Whereas publicly-funded R&D, complemented with private equity and venture capital, tend to

dominate early phases, up-scaling and deployment in the take-off phase, usually of capital intensive nature, tend to draw on other types of financial innovations. Some current financial arrangements, such as securitization of assets and use of credit default derivatives, can be used to market securities based on non-fossil fuels, for example. Pension funds along with other institutional - and alternative - investors, such as infrastructure funds potentially have an important role to play in financing emerging system innovations (OECD, 2011).

177. In those later phases, increasing technical clarity and economic opportunities generally increases the willingness of actors to invest, resulting in greater availability of financial investments (from government, firms, and investors). Thus, financial innovation is needed to redirect private capital and investments by re-evaluating and -balancing risks across sectors of the economy, to provide mechanisms for the pooling of resources (e.g. mutual funds) and to manage risks. For example, new business models are likely to emerge, new ways of managing risk will be developed and new products will be required to shift financial resources into innovative sectors and industries. Optimally, financial capital may break loose from the mature sectors of the economy and reallocate funds to any emerging innovations outside the well-known paths (Perez, 2010). But surprisingly, to date little or no attention has been given to the analysis of financial innovation as concerns the adoption and installation of system innovations.

178. As shown, financial innovation played a fundamental role in the articulation and propagation of system innovations. Finding new ways to identify "financial entrepreneurs" and fund their inventions might be almost as important as innovations themselves (Michalopoulos, et al., 2009). This may highlight that an overly restrictive approach towards financial innovation would be counter-productive by potentially decreasing the amount of financial innovation needed in providing new solutions to systemic challenges (WEC, 2012).

### *3.3.2 The role of the wider business sector*

179. The innovative firm is the central institution for the effectuation of system innovation. It possesses the relevant capabilities and resources (finance, people, supply and distribution chains), and manages and operates most large technical systems (e.g. railways, aviation, Internet, electricity) (OECD, 2013). As such, the business sector plays a large role in determining the rate, direction, and nature of systemic changes.

180. However, it is to highlight that firms exist and innovate neither in isolation nor in some "flat" world. One must first understand the external factors that affect firms to innovate. The firm's ecosystem, including supporting institutions and legal structures - sometimes favourable, sometimes unfavourable - remain of great importance. A less important context for innovation, which has received particular attention from academic scholars, is market structure, particularly the degree of market concentration. The consensus is that market concentration and innovation activity most probably either co-evolves or is simultaneously determined (Metcaffe and Gibbons, 1988). The technological environment in which a firm innovates is yet a third cluster of factors which shape and are shaped by innovation. One prominent feature of the environment is the abundance (or scarcity) of technological opportunities. For example, in an industry with lots of technological opportunities (for example nowadays in the ICT sector) innovation is expected to be relatively easy due to a lower expected development cost and/or a plentiful supply of relevant and available knowledge.

181. When it comes to displaying and understanding the processes which result in the creation of new system innovation initiated inside the firm, the innovative firm is still a "black box". But often scholars and policy-makers alike neglect considerations of capability augmentation (i.e. capabilities to renew and enlarge existing competencies) and management, despite their importance in today´s economic and industrial landscape. For example, how and why some firms tap into technological opportunities remains

somewhat enigmatic. The microanalytics of these decisions are not well explained by economic theory, or by any other theory for that matter. In addition, the various theories of innovation pay very little attention to factors inside the firm.

182. Therefore it is not of paramount importance to policy-makers in innovation, for example, whether new ventures or large, incumbent firms are responsible for system innovation as it does not help operationalise decision-making (Box 3.17 outlines the need for both incumbents and new ventures). Here, the challenge is rather to shape business behaviour and strategies by linking their objectives and management tasks with the goals of system innovation.

**Box 3.17 What is the division of labour in the production of radical innovations?**

This fundamental question has attracted the interest of scholars and policy-makers alike, and has spawned a broad literature going back to Schumpeter (1912) and as far as Say (1827). Scholars have examined the relationship between firm size relationship and the types of innovation pursued, focusing on the generation of incremental versus more systemic or radical innovations. The key findings are that larger, incumbent firms tend to pursue relatively more incremental innovation (e.g. Henderson, 1993; Mansfield, 1981; Wilson et al., 1980; Scherer and Ross, 1990 and Van Praag and Versloot, 2007) than smaller firms. Additional literature on disruptive innovation (Christensen, 1997; Utterback and Acee, 2005) and technological discontinuities (Anderson and Tushman, 1990) found related results.

However, whether new ventures and entrants (as opposed to small firms more generally) are responsible for radical innovation—though often talked about—suffers from a dearth of rigorous empirical study (Cohen, 2010). The literature therefore provides less guidance about whether large or small firms are more capable at generating radical innovations, despite studies suggesting that small firms or entrants may be (Cohen, 2010). In addition, one can easily obtain examples of the magnitude of the innovative contributions of large companies, whose incremental contributions can add up and compound to results of enormous magnitude. One such illustration is the progress in computer chip manufacture by the Intel Corporation, which is the leading manufacturer of these devices and has brought to market successive generations of chips and transistors. Though each such small improvement may be relatively unspectacular, added together they can become very significant (Baumol, 2010).

In general, when a radically new innovation has replaced an older mature one, incumbent firms often have difficulty in making the adjustments. In such circumstances, change has been what Tushman and Anderson (1986) has called "competence destroying." The industry may experience a renewal, but often under the drive of a new set of firms (Dosi and Nelson 2010). However, in reconfiguration processes incumbent large firms and new entrants (often firms diversifying from other sectors) tend to collaborate rather than compete. Smart grids, for instance, require new collaborations between utilities and grid managers and firms from the ICT sector (which may lead to frictions when innovation routines and cultures vary). Baumol (2010) explains this as the result of a process where "[T]he giant companies may account for the major share of the economy's R&D financing, but these better established firms tend to minimize risk by specialising in incrementally improving the most promising of the radical innovations they purchase, license or adapt from the smaller firms that created them".

### *Firm strategies*

183. Diversity between firms is a fundamental and permanent characteristic of environments undergoing technical and systemic changes. Firms differ because of different capabilities with respect to innovation, differing degrees of success in adapting technologies, possibly developed externally, and different cost structures. They may also differ because of differing search/sensory procedures and capabilities, and differing strategies.

184. Accordingly, firms are not constrained by nature, but by their own capabilities. In order to identify radical opportunities, firms must constantly engage in scanning, searching, and exploration across technologies and markets, both "local" and "distant". This activity not only involves investment in R&D and the probing of customer needs and technological possibilities; it also involves understanding latent demand, the structural evolution of industries and markets, and likely supplier and competitive responses.

185. For a firm, there is a requirement to first identify new opportunities and threats and then to shape (or reshape) the organisation. The capacity to reengineer its innovative capabilities towards radical innovation depends on its internal activities as well as its external relationships.

**Box 3.18 Korean case study – leveraging new growth opportunities from existing industries**

Developed primarily in the Busan and Gyeongnam region, and subsequently wind turbines proliferated throughout the nation. Located in the southeastern part of Korea, the Busan and Gyeongnam region serves as home to large enterprises specialising in shipbuilding and machinery and SMEs supplying parts and materials to the large businesses. Propelled by the green growth strategy, traditional shipbuilders such as Hyundai Heavy Industries, Samsung Heavy industries, Daewoo Shipbuilding and Marine Engineering, Doosan Heavy Industries & Construction, HYOSUNG Power and Industrial Systems Performance Group pursued to develop wind turbines. They swiftly strengthened their technical capabilities by developing original technologies, acquiring foreign winder power companies, and making industry-academy technical co-operative partnerships and pioneered markets at home and abroad. The case shows how government action helped firms incorporate a green agenda in their visions and strategies.

### *Firm-internal activities*

186. To respond to systemic challenges through innovation, firms need to develop and deploy adequate capabilities. It will be necessary to completely revamp the organisation (or parts of it) and create an entirely new "break out" structure within which an entirely different set of structures and procedures are established (Teece, 2000). Management can make big differences through investment choices and other decisions, including how the firm actually performs the tasks of storing the knowledge that underlies productive competence, transferring it internally (or externally), enlarging it in value-enhancing ways, and identifying and exploiting complementarities, amongst others.

187. At the same time, they must direct the reinvestment of cash flow, and must configure asset portfolios, including allocating resources between exploitation and exploration (March, 1991, 1994). They must also stand ready to reconfigure asset portfolios and organisational systems as circumstances change. Another fundamental function of management involves how to manage and integrate the output of highly skilled experts across countries, time zones, and organisational boundaries. There is also a strategic component for management on what tasks to assign, what priorities to set, what resources to use, and where to get them from.

188. This strategic reorientation process is difficult, however, because firms, for example, do not need continuously reinvent themselves. The need to reinvent depends on events, anticipated or otherwise that impacts business behaviour at the management and operational level. Selecting suitable business models, making the right strategic investment decisions, and pursuing incremental innovation can keep an enterprise highly competitive if the environment is stable. If a large incumbent controls standards, or can somehow help stabilise its own environment, for example thorough strategies to influence policy-making (see Box 3.19), then it may not need to engage in the continuous and costly exploration of radical alternatives.

**Box 3.19 Common corporate strategies to shape policy-making**

The literature on corporate political strategy (Yoffie, 1988; Hillman and Hitt, 1999; Scherer et al., 2009) suggests that firms can act as political entities and use various strategies to shape policy-making processes:

- Information and framing strategy. Industries can: a) set up research institutes or sponsor favourable research, b) use this expertise to contest scientific findings and draw attention to uncertainties, c) report research results to influence policy debates or demonstrate the (in)feasibility of certain solutions, or d) testify as expert witnesses in policy hearings.

- Financial incentives strategy. To influence policy makers, industries can: a) make contributions to politicians or political parties, b) pay fees for speaking at conferences, c) offer politicians lucrative jobs at the end of their career.

- Organised pressure strategy. Industries can mobilize networks to create pressure through: a) mobilization of employees, suppliers, customers, etc. who send letters and pressure their representatives, b) creating fake grassroots organisations ('AstroTurf') that claim to speak on behalf of public interests, but are funded and managed by industries, or c) create industry associations that speak for the industry.

- Direct lobbying strategy. Industries can: a) hire lobbyists or b) directly mobilise company executives to engage governments.

- Confrontational strategies. Industries can: a) oppose laws through litigation; b) threaten policy makers with plant closures, layoffs, or relocation; c) refuse to implement policies; or d) comply only partially with policies.

***Firm-external relationships***

189. The systemic nature of many innovations compounds the need for external search. The potential to generate radical, disruptive innovative output should be higher when very diverse sectoral knowledge bases are combined, while incremental innovation should demand specialised knowledge, which is necessary to improve existing technologies (Schumpeter, 1942). In that sense, collective learning and collaboration is essential for system innovation as it helps to develop knowledge about root causes, linkages and patterns, to construct shared meanings and to clarify common ground and differences in perspectives, interest and needs (Svendsen and Laberge, 2005).

190. Firms need to have an appropriate culture for this, with collaborative capabilities and values such as being open and responsive to multiple perspectives, building networks and developing mutual understanding (Boons and Roome, 2005; Clarke and Roome, 1999; Wheeler et al., 2003). Other conditions for multi-stakeholder processes include defining the goals of the network, clarifying roles and responsibilities, agreeing on shared rules and norms and collective learning (Gray, 1989).For instance, Loorbach (2007) points to the importance of bringing together stakeholders to understand root causes of persistent complex problems. He argues to compose small groups of frontrunners that are able to reframe problems into attractive sustainability visions, instead of representatives of all organisations involved in an issue.

191. To direct transitions toward system innovation, new modes of governance are needed that take into account the long time-horizon, the uncertainties and complexities and the multitude of actors and interests involved.

192. The rate and direction of system innovation at the level of the firm does not only depend on the ecosystem or framework conditions but also on the competences of the firm, the internal and external knowledge the firm can draw on , and its complementary assets . Learning and innovation will also shape the boundaries of the firm to innovate in a radical manner.

### *3.3.3 Civil society organisations*

193. Radical innovation is a pervasive phenomenon and involves a wider range of actors. There is a growing recognition that there is a deep and implicit link between radical innovation and the actions of

civil society organisations (CSOs). Similar to innovators in the financial service industry, they are considered as a necessary and potentially powerful aspect of systematic change. In the environmental and energy area, for example, civil society initiatives may include green lifestyle-based activities to reduce energy consumption (e.g. Transition Towns, and Carbon Reduction Action Groups), more traditional behaviour change initiatives such as neighbourhood insulation projects and energy-saving campaigns well as renewable energy generation projects such as community-owned windfarms and biofuel projects.

194. However, it is not straightforward to grasp the nature of CSOs as they embrace a wide spectrum of activities, actors, institutional forms and intentions. They vary in their degree of formality, autonomy and power, and populate organisations as diverse as registered charities, non-governmental organisations, community groups, professional associations, trades unions, self-help groups, social movements, business associations, and advocacy group (LSE, 2004).

195. Clusters of activities relevant for system innovation can be conceived as contributing towards unsettling and delegitimising technology regimes (and thereby opening windows of opportunity for alternatives), nurturing alternatives in niche settings, and helping solutions translate from marginal to mainstream settings (Smith, 2012). At the one end, CSOs can act as early adopters and users of innovative niche ideas and practices. Just like private companies and public institutions, CSOs are increasingly adopting innovations to help them achieve their original goals. For example, CSOs have often been proactive early adopters of a variety of sustainability innovations like solar power (Truffer, 2003; Smith, 2007). However, given that most projects appear to be small, vulnerable to withdrawal of grants and difficult to replicate on a broader scale, the momentum does not necessarily lie in the validation of the technology or invention.

196. It may be rather be the case to convince the mainstream consumers that “the rules of the game” may need to be changed. In fact, for the successful introduction of a radical innovation into the market, it must be commercially viable but also socially accepted (e.g. public resistance in some countries to the introduction of genetically modified organisms in food crops). Despite the considerable attention paid to academic research into the adoption of innovations by public and private sectors, little attention has been paid to CSOs.

197. At the other end, social pressure from CSOs through lobbying and protests may impact the momentum of technology trajectories, both supportive and against change. Even though indirectly, the extent to which new car consumers, for example, are receptive to social pressure from business associations may constitute an important barrier to the development of propulsion systems for electric vehicles. As such, CSOs will therefore be crucial drivers for system innovation. Their actions will shape framework conditions and/or consumer practices, which ultimately will lead to changes in business innovation practices.

#### *3.3.4 Social trends*

198. Innovation also happens on the user side, as consumers develop new kinds of behaviour. Technology adoption to specific settings frequently entails elements of innovation (Rip and Kemp, 1998). Sociologists of innovation emphasize that users have to ‘domesticate’ new technologies (Lie and Sørensen, 1996). Consumers do not just buy new technologies, but also need to embed them in user contexts. New technologies have to be transformed from unfamiliar things to familiar objects embedded in the routines and practices of everyday life. This involves three kinds of processes: 1) cognitive work which includes learning about the artefact and the development of new competencies;, 2) symbolic work, which refers to the articulation of new symbols, beliefs and preferences; 3) practical work, in which households adjust routines and user practices to fit the new technology; routines associated with family meals, for instance, have changed in relation to the diffusion of micro-waves, ready-meals, and television.

199. Enthusiasm about the new technology and visions about how it may solve social problems may lead to the emergence of social movements or wider coalitions for change that support the system innovation (by lobbying policymakers and elaborating supportive public discourses).

# CHAPTER 4. SYNTHESIS OF THE TIP CASE STUDIES

## 4.1 Introduction

200. This chapter presents some of the salient findings from the case studies undertaken for the project while Annex 1 contains brief profiles of the studies.

**Drivers and barriers to system change**

201. The drivers of sustainability and system change are many; from the economic (preservation of limited natural resources) to the environmental and the political and social. Reductions in CO2 emissions are one of these drivers. In terms of barriers one common barrier is the resistance to change from incumbents or consumers. In the Austrian case on e-mobility for example a diver of change resistance was the behaviour of consumers and the issue of technological standards. Other barriers are finance, co-ordination and lack of knowledge of technical solutions, which make it especially difficult to get stakeholders involved. To overcome change resistance, one solution is to divide the problem into smaller pieces; another solution was to engage in public-private partnerships. The case studies also highlight differences in the drivers between small and large countries; for small countries the scope of policies for transition are shaped by global players or factors (knowledge, capital, factor prices) that lie outside their borders. This may requires international co-ordination among smaller countries or regions.

**The role of enabling technologies**

202. The role of enabling technologies in most of the case studies is considered secondary to achieving transitions. A lot of relevant technological for building solutions or smart cities are available, but institutional rules, political choices and socio-cultural attitudes prevent implementation. That does not mean that technological innovation is not necessary or desirable (in energy, materials, collective systems, but a lot of innovation will have to be institutional and socio-cultural. A further question is to what extent do IPRs, in particular patents; act as a source of resistance to system innovation. Wide acceptance of technology is only one component of system innovation, but the main issue remains the relationship between the different actors in the system.

**Governance for transition and system innovation**

203. A central tenant of system innovation is that governance of the transition does not lie solely in the marketplace but in niches and regimes where institutions, regulations, consumers, and governments interact. The analytical challenge faced by the subject in the case studies was to foster 'system innovation' so as to facilitate not only greener buildings, firms, or transport but also to foster more sustainable practices from all members of a regime

204. The case studies show that there is no one size that fits all approach to governance. Instead it is necessary to bundle different measures that fit the respective national context. In the Belgian experience, it has not been that easy to engage all stakeholders. In this case, it has been paramount to be clear about the participants' interest to better understand why and how they engage in such governance processes. The real challenge for co-ordination bodies starts after the initial phase, when different expectations and subsequent frustration might arise. Keeping the process rather short may help keep stakeholders engaged

205. In the German case, stakeholder engagement was encouraged by reassuring participants that it was the committee´s task to consolidate their different inputs into final recommendations, thereby keeping the workload of stakeholders to a manageable minimum. Shared ownership and co-creation can also

present a key factor to success. However, the question remains to what extent partner in the platforms can be a true partner to governments, as they can potentially challenge their role.

**Box 4.1 The role of stakeholders in transitions: the experiences of the Fraunhofer IBP**

Pursuing systemic approaches to innovative urban planning as currently pursued in the Morgenstadt City Insights project, which is industry and city-financed. About 60 Fraunhofer institutes within different fields contribute with their expertise, as do various partners of the Fraunhofer international network. The aim is a holistic approach that also collaborates with city and industry partners. Hertzsch admitted that the mix of fields can be confusing but he insisted that these challenges need to be overcome to achieve more sustainable city planning. Similarly, the National Platform Future City attempts to build up a research and implementation agenda to innovate city planning. The committees' office coordinates the various working groups. Together with public, research and private sector actors the platform currently builds a road map to guide further policy steps. The integration and cooperation of competencies are key issues in the work of both projects. It remains a challenge to find common ground among the various actors in order to come to recommendations on future directions. One success factor is for the coordinators to be clear about duties and responsibilities. Most members seem to have a strong interest in working in this broad field of city development, which can serve as one explanation. For the selection of actors with the right competencies, the committee starts with neutrally drafting a list of ideal partners which are then approached. A right mix of representatives of SMEs and MNCs can also be helpful to give a balanced view on a great variety of issues. So far, the engagement of civil society is not apparent. Here, problems seem to be the selection of the right citizen groups and how to engage them.

206. In many of the cases, commitment and co-operation between different ministries was often necessary to implement system innovation. Contracts are also tool to ensure different actors deliver on shared goals. In the Finnish case, the government developed an operative governance model based on contracts. The government commits to certain financing while cities in turn commit the urban development according the agreed upon plans.

### The role of innovation policies in transitions

207. In many of the case studies, innovation policies have an important role in facilitating system innovation. In Finnish case the government supported programmes to support the development of electronic vehicles. Regional innovation policies also play an important role in fostering transitions through innovation. Experimentation in innovation policies and public-private partnerships and public procurement of innovation are also important as they can help test new services and the delivery of public infrastructure that is greener. While experimentation is important, some cases highlight the fact that too many changes in policy or inconsistency can be a barrier to engaging private investment for scaling up solutions.

### Indicators for transitions and system innovation

208. In all of the case studies the lack of indicators makes the measurement of system innovation very difficult. It is also far from clear to assess what would have happened in the absence of policy actions. The complexity of social problems such as sustainability, means that policies require rethinking the evidence base for policy making. A strict focus on economic indicators could limit the impact measurement and neglect societal impacts. Another issue is that much of innovation policy making is strongly guided by the Standard Practice for Surveys for Research and Experimental Development (OECD Frascati Manual). Besides that, the Guidelines for Collecting and Interpreting Innovation Data (OECD Oslo Manual 2005) try to widen the scope to cover innovation. Yet R&D and innovation are seen as separate processes, which is not always the case in the real world where they are more often integrated and interactive processes. System innovation means that policy relevant indicators should go beyond traditional input and output measures and consider other measures of transition such as quality of life indicators. System innovation also challenges thinking on the evaluation of impacts as well as behavioural additionality since many of the

relationships are non-linear. Evaluation of policy experiments in the area of system innovation is also important. In this vein, cluster evaluations are important learning tools given the focus on the evaluation of complex systems with different actors.

209. The historical learning approach, currently developed at Gent University, could be interesting tool to learn more about socio-technical innovations. A prerequisite for all measurement efforts must be a clear definition of the boundaries of what is being monitored. The question arises whether it is preferable to only focus on best practice or rather learn from common mistakes.

**System innovation for sustainable housing and building**

210. In case study on system innovation for sustainable housing and building in Flanders, Belgium this case, system innovation is linked to sustainability, ecological, social, economic, institutional and cultural long-term ambitions. Urban developments in Flanders have been characterized by suburbanization and urban sprawl, as well as by a highly fragmented governance system. Occurring problems have been recognized to some extent as being systemic, as is evident in research, policy analysis and public debates. Still there are divergent views on the actions that are necessary to achieve system innovation. The system is changing at a slow rate but it is prompted by experimental transition management, as well as new industrial, spatial and housing policy. The direction of this change at this current point remains vague. There is some hope that socio-technical innovation will help to achieve this transition, whereas institutional and socio-cultural innovation is seen as more important than enabling technologies. Trust and legitimacy seem to play a major role in facilitating change in Flanders. More efforts in qualitative monitoring could help facilitate this.

**Transitions to smart traffic in a city context**

211. In the Finnish case study, system innovation shall facilitate a seamless digitalized transport system. To analyse the system under study, the case study builds upon the multi-level perspective on sustainability transitions developed by Frank Geels, which structures the analysis of system innovation by separating niche, regime and megatrend developments. Important issues, among others, are integrating different modes of transport, solving congestion problems and facilitating smart regulation. Financing, new types of steering instruments, a shift in policy thinking societal values, big data analytics and enabling technologies constitute strong driving forces. Competing visions and strategies present obstacles, as do unclear divisions of labor and diverging responsibilities. It is furthermore unclear, whether councils, NGOs or business should make up the main system integrator. Experimentation of innovation policy on the niche level and PPPs are expected to be beneficial. The Finnish case shows that utilizing the perspective on niches, regimes and megatrends as a starting point for measurement and the development composite indexes at these different levels. They could help find common visions and aims for further steps.

**City of the future**

212. The German case study build on research of the German future looking project *City of the Future*, which serves as an agenda setting platform. The overall goal is to make cities CO2-neutral, energy efficient and climate adapted. Major stakeholders in this process are city administrations, research institutes, companies and central government. Among the drivers for system innovation are citizen pressures, the strong increase of transition city contests and local agendas. Nonetheless, pressures through financial problems, traditional industries and the lack of transparency of existing projects hamper the system transition noticeably. Enabling technologies are attributed as being an important force behind system innovation, but their adaption is still seen as problematic. Strategic PPPs to boost long-term investments in infrastructure and co-creation for smart devices pose potential solutions, but there is considerable skepticism towards technology. Hence key questions revolve around social versus

technological innovation. The case showed the result of governance in transition should be the focal point of analysis, but rather the process that the discussion is embedded in. With regard to measurement indicators should be dynamic and transparent to increase civil society involvement.

**Malmö Innovation Platform**

213. The Swedish case focused on the challenges of the sustainable renovating of housing in Malmö, which were constructed during the 1960s and 70s. The *Malmö Innovation Platform* uses the renovation plans of the Swedish *Million Program* as an engine for a wider process of change towards a sustainable city. The analysis was based on the multi-level perspective on sustainability transitions. Much of the building stock in Malmö exhibits urgent renovation needs, poor energy efficiency and social segregation. Currently there is a lack of policies and instruments in the housing area. Other bottlenecks are finance, coordination and knowledge of technical solutions, which make it especially difficult to get stakeholders involved. Still there is increased awareness of the importance of a systemic approach and collaboration solutions such as PPPs. In addition, Malmö has demonstrated strong political leadership with earlier transitions, e.g. to overcome economic decline and restructure the regional economy. The aim is to experiment with innovative financing models and to get politics, industry, society and academia involved. Likewise, enabling technologies such as ICT, smart grids and biotechnology are expected to play an important role. Innovation policies are currently at a very early phase, as are the development of housing data and related measurements.

**Austria case studies: sustainable building and e-mobility in Austria**

214. The Austrian case study on sustainable building linked domains of sustainable housing, energy, mobility and ambient-assisted living. Major actors were identified at the EU- and national level, cities, municipalities, architects, planners and developers. In a collaborative effort, they try to reduce CO2-emissions and minimize their dependence on international energy suppliers. Although the term system innovation is largely unknown to most stakeholders, various initiatives are congruent with the idea behind the concept. Key barriers to system change are legal challenges, supply side capacity problems, non-transparent information, social values and poor spatial planning. National innovation policy is providing a technology push with specifically targeted programs. There are, however, divergent rationales by different public institutions, which impede a coordinated effort. Measurements for system innovation could potentially target attitude changes. Indicators should reflect various rationalities, i.e. innovation, environmental and urban policy orientations.

215. The second Austrian case study on e-mobility examined the challenge of defining the boundaries of e-mobility from a policy perspective. The impacts are expected to be great, with changing car use patterns, ownership models and intermodal mobility systems. Thus, the stakeholders are manifold, ranging from local to international level and including the automotive industry and electric utility companies, among others. At the moment, range anxiety and the reluctance to give up ownership on the user side, and the uncertainty of future business models and lacking standards on the provider side represent major barriers to system change. Innovation policy should try to avoid the duplication of activities and improve policy coordination. There is general acknowledgement that the transition to e-mobility will not simply be the replacement of one technology with another. With regard to economic incentives, there should be more efforts to adjust business models to local conditions. Indicators for monitoring the transition are currently lacking, one reason being the unclear relationship between policies and indicators.

216. In comparison of both Austrian case studies, it is that policy influence is higher in building transition than e-mobility. It is the other way round, however, as regards the need for standardisation and interoperability.

**Bio based economy**

217. The goal of the Dutch bio-based economy programme is to replace fossil feedstock with biomass, with a focus on applications in chemistry and agriculture. This aims to reduce greenhouse gas emissions and to make the Dutch society less dependent on fossil feedstock. Biomass is ideally suited to replace applications where carbon is essential such as liquid fuels, materials and chemicals. The Dutch chemical sector expects to replace 15% of its feedstock by biomass in 2030.

218. The government’s main role is to initiate and stimulate new networks between universities, knowledge institutes and different business partners in chemistry, energy, agriculture and water processing industries. The government creates different platforms for strategy and vision forming, development of new business models and discussions on the sustainability and ethical aspects of the use of biomass in various applications. The role of society is essential in the debate on the sustainability and ethical aspects. Also societies role is essential in the formation of markets for bio-based products for instance in its willingness to pay a green premium for bio-based products.

219. Another role of the government is to stimulate P/PP initiatives. From the 1980s, the Dutch government has stimulated research and innovation on this topic. The successes and technological breakthroughs of in industrial biotechnology in the 1990s have made bio-chemicals and bio-fuels a viable option these days. The high energy prices of recent years are an important driving force in the up-scaling of these technologies.

220. Progress has been made in the development of indicators, which were analysed in various studies. As one example, the number of networks linkages of the bio-refinery technology has increased significantly from 2010 until 2013.

**Technology platforms**

221. The case study on Russian technology platforms focused on the example of medicine for the future. The governance structure is coordinated by a general assembly, a steering committee and S&T councils. Together with universities and research organizations, they try to find solutions to gaps in specific healthcare technologies and to fight socially important diseases. Since 2012, the number of organisations and businesses involved in the technology platform has increased greatly. The concept of system innovation is not yet practiced in Russia, but there is consensus as to its different dimensions. Key barriers to date are a lack of infrastructure, PPP initiatives and funding, as well as non-transparent public procurement in medicine. There is also a risk of rent seeking of the most active members within the TMPF. At the moment there is no evidence that innovation policies impede technology platform development. The main indicator used is R&D funding which makes the development of further quantitative and qualitative indicators desirable.

**Clusters approach**

222. The case study on the Russian cluster initiative highlights the importance of taking into account the specific innovation profiles of regions and the involvement of regions in the drafting and implementation of federal policies; supports the coordination of innovation policy measures for support different actors (universities, research organizations, large businesses, SMEs, venture capitalists and business angels, etc.) and improves the efficiency of interaction between actors of the regional innovation systems, including trust building. As many other cluster programs, the Russian one is not just national. It involves joint work between the federal and the regional levels, with the former playing the role of facilitator and the latter managing or coordinating or taking part in the clusters. The federal level program is facilitated through an inter-ministerial committee. It provides the involvement and coordinated work of

several ministries, agencies and development institutions to guarantee the pilot clusters comprehensive support. In general, the cluster program in Russia is consistent with the most successful international models.

223. There is an increasing support to small and medium enterprises in the pilot clusters. Another positive trend is the recent decision to change priorities for cluster support. Despite it was originally expected to fund mainly the development of basic infrastructure in clusters, e.g. transport, engineering, housing, power, later infrastructural imbalance was offset. The pilot 14 clusters were offered to choose two of five possible areas of spending subsidy from the federal budget: the purchase of new equipment, additional education and training, cluster management activities and external consultancy, consultancy for the preparation of investment projects in the sphere of innovation, participation in international fairs, forums, round tables, etc. These areas of support - more than the basic infrastructure development - correspond to the idea and principles of cluster policy. Thus, it can summarized that cluster policy in Russia is constantly changing and evolving.

**System innovation in long-term care**

224. In the UK, the elderly care system is shifting from residential care, based on nursing homes, to a new model which emphasizes the care of the elderly in their own homes. Both an ageing population and financial pressures force governments to re-think their approaches to elderly care. Assisted-living technology can help enable elder citizens to stay independent longer than is currently possible. The goal is to use new technology to monitor people at home and transfer the data to health and care facilities. The shift is expected to take decades, hence the project is still in an early phase. There are two main lessons learned: barriers to system change can be closely interconnected (technical, procurement, cultural values, fragmented policies), which is why policy needs to respond to this interconnectedness. Secondly, uncertainty is particularly important in this case and needs close attention to deliver successful elderly care. This makes a holistic approach necessary, as one particular political actor will not be able to overcome all challenges at once. Uncertainties, also with respect to business models, are addressed through the economic and business models of ALIP.

**Green innovation**

225. In Korea, the country’s green growth strategy aims to mitigate the degree of climate change and to create new growth engines for the future. Korea has the ambition to become a leader in the global market of green innovation. The Korean government is committed to using a holistic strategy to connect enterprises, local governments, local innovation actors and towns. Increasingly, civil society actors are also integrated. Ongoing initiatives include energy plans, green towns and a smart grit roadmap. Low energy prices, hidden costs of transition programs, few market opportunities and weak consensus building with local communities pose challenges to system transition. Enabling technologies are expected to play an increasingly important role in Korean system innovation, since many of them are in the early stage of diffusion. One problem seems to be the confusing boundaries of what is green.

226. The participation and involvement of firms, in particular MNCs, is an important issue in system change as they develop much of the technology needed for system innovation. The question arises to what extent MNCs in fact need a political initiative to get involved. Still MNCs can help create synergies, e.g. in the smart city context, and that many problems go way beyond the capabilities of one single company. Hence incentives should rather be aimed at bringing together a great variety of enterprises than just a few big players.

### 4.2 The role of technology and organizational innovations in enabling transitions

227. The role of technology differs throughout the various case studies. In the UK, one emphasis is on the conditions in which technology can thrive. In that case, user-centered design, market applicability and inter-operability were important features. Technological innovations such as new batteries or new applications can make a real difference, as can standards to scale up system innovation. It was recognized that there is great international market potential for such innovations. One example is the technology trend that can turn houses from consumers into producers, a development representing a significant game changer. Technology can be seen as having five dimensions: solutions, enabling participation, measurement of change, social innovation and product for markets. Having these dimensions in mind can help when discussing the usefulness and impact of certain technologies. Stakeholders have different rationales, which can be for example showcasing their products or finding solutions. Likewise, cultural aspects need consideration, as consumers can either be very suspicious of or readily accepting of technology developments.

228. Innovation policy should function as a stimulus, which is ideally both targeted and directional. Smart innovation instruments, such as innovation competition, can serve to nurture demand. A widespread problem faces businesses, as they have difficulties with finding viable business models to new innovations. Supportive government instruments should kick in temporarily and guide businesses at the beginning. Ideally, policies give stakeholders room to meet and experiment, e.g. with business models. With all business models, however, it is necessary to distinguish between the payback period and life-time returns on investment. Past policies have been inconsistent, swinging from one solution to the other, which has hampered investment significantly. If a new innovation is seen as beneficial but unable to compete with existing ones, policies spurring procurement, e.g. in the energy sector, have proved successful. At the same time, incentives to change existing price structures of the market can benefit some but will be a problem to others. It is hence interesting to see why current stakeholders resist price changes or technology adaptation. After all, if there is no resistance, one can hardly speak of system innovation. As has become clear, the so-called soft infrastructure, i.e. social structure, can be very hard. Here socio-technical innovation as a concept could be helpful.

229. As the example of high oil prices that spurred e-mobility demand has shown, often coincidences create windows of opportunities for certain innovations, which need to be utilised – with or without guiding policies. As an example, fiscal constraints in the aftermath of the financial crisis force people in southern Europe to become innovative in order to keep up their living standards. This can be seen as an innovation laboratory from which other countries might learn.

230. It might also be beneficial to look at broader changes, such as in the production system, and see how they influence our future. Case studies can only exhibit what is possible now, but they might not be the actual best solution.

231. Innovation policy should reflect this and be very broad about renewal as such, not necessarily about R&D or technology. One principal of innovation should be to decrease risks of stakeholders to increase involvement. Public deliberation can be one way of solving uncertainty issues. Similarly, an open question was brought up, asking how far we should go with change, if policy should spur endless renewal and whether this is socially desirable at all.

#### Indicators for system Innovation

232. Lessons from the OECD green growth indicator evaluation projects show that to evaluate and compare green growth in five very different environments, i.e. Germany, Denmark, two places in the Benelux area and Chile. There is great variation in measurement and it has proven difficult to find the right

figures. This explains why not all indicators of the OECD green growth indicator set have been used, as in most cases local data is not available. Still the analysis has facilitated some recommendations and affected the reconsideration of existing policy approaches. The capability maturity model, which represents a five-phase model to analyse the maturity of companies and their internal processes to question existing systems. The model also allows to picture future developments, which can somewhat help detach the analysis from relying on past perspectives.

**New mobility concepts - a case study for applying innovation indicators to measure system innovation**

233. With changing societal values and rising resource pressures, there is a strong need for new mobility concepts. The future direction seems to move towards a fifth mode of transportation, meaning multi-modal, integrated, seamless passenger transport. These systems will be increasingly connected, allowing passengers to access a multitude of transport modes with one contract. Prerequisites are technology, infrastructure, and new forms of organization, behavioural change and new regulation. For the analysis of innovation systems, Schade (2014) has postulated six possible dimensions with exemplary indicators, i.e. knowledge (patents), guidance of search (mobility service replacement of car sales), entrepreneurial activity and competition (number of car sharing operators), market formation (growth of car-sharing), legitimation (quotes of car-sharing and mobility in media) and resource mobilization (e-mobility funds, expected market shares). There is evidence that system transition towards new urban mobility is ongoing in Germany. The scientific community, however, is struggling to keep up with the fast pace of the business world.

234. It is clear in the case studies that there can be different levels of indicators. It is important to understand and monitor the processes as well as key drivers behind system innovation processes. A high number of indicators is desirable in theory, but very difficult to acquire and compare in practice. The combination of quantitative with qualitative data can be crucial to get a holistic picture. To develop a promising set of indicators, it is necessary to be clear firstly about the logic behind the measurement, and secondly about the aim of measurement, e.g. output, impacts or processes. Only then should it matter which data to use and how reliable they are. Measurement however, may not have to be complicated, as for example with climate change one indicator is clearly $CO_2$-emissions which have the merit of creating a common measure and a price for internalizing externalities. While the price mechanism is important however, improving measurements of the entire process is desirable from a policy learning perspective. Ultimately, the function of indicators should be to tell a story or provide a narrative to help policy makers engage stakeholders into taking action to move towards sustainable developments paths.

## ANNEX 1. PROFILES OF CASE STUDIES ON SYSTEM INNOVATION

| Austria | Electric mobility |
|---|---|

**Summary:**
The Austrian case study on e-mobility examined the challenge of defining the boundaries of e-mobility from a policy perspective. The impacts are expected to be great, with changing car use patterns, ownership models and intermodal mobility systems. Thus, the stakeholders are manifold, ranging from local to international level and including the automotive industry and electric utility companies, among others. At the moment, range anxiety and the reluctance to give up ownership on the user side, and the uncertainty of future business models and lacking standards on the provider side represent major barriers to system change. Innovation policy should try to avoid the duplication of activities and improve policy coordination. There is general acknowledgement that the transition to e-mobility will not simply be the replacement of one technology with another. With regard to economic incentives, there should be more efforts to adjust business models to local conditions. Indicators for monitoring the transition are currently lacking, one reason being the unclear relationship between policies and indicators.

**Broader transition aim/goal**
Development and diffusion of electric vehicles

**Current transition stage:** Pre-development

Electric vehicles represent only a small share of vehicles in Austria (0.1% of registered vehicles in April 2014). However, numbers are higher if one includes hybrid electric vehicles.

**Transition mechanisms and bottlenecks**

Drivers:
- Reduction in negative transport impacts, particularly transport related CO2-emissions and local air pollution
- To improve competitiveness of the Austrian industry

Obstacles:
- High market prices and range restrictions
- Lack of public charging infrastructure and intermodal transport solutions
- Uncertainties about dominant (future) business models
- Lack of industrial commitment, especially from OEMs
- Low political priority
- State aid rules by European Comission

**Describing Policy**

Key policy actor(s):
- Federal Ministry for Transport, Innovation and Technology (national)
- Federal Ministry of Agriculture, Forestry, Environment and Water Management (national)
- Austrian Climate and Energy Fund (financing)
- Austrian Research Promotion Agency (FFG) (programme administration)
- KPC Public Consult (programme administration)

Key agenda(s):
*Introduction plan e-mobility* (2010): common framework for the activities at the federal, provincial and community level regarding e-mobility with the aim to improve coordination. The plan contains six application priorities: commuters, taxis, public fleets, private fleets, model regions, (young) users of motorcycles and –bikes.

*Implementation Plan 'Electromobility in and from Austria – the common path* (2012): defines a common vision of the three key ministries regarding e-mobility; measures are clustered around five themes: namely i) Electromobility in the overall transport system", ii) 'energy system and charging infrastructure', iii) preparation of the market and incentives system, iv) raising awareness and information' and v) effects on the environment and monitoring.

Key measure(s) (programme administration varies):
- *Model regions electric mobility* (since 2008 and seven regions founded to date)
- *I2VS* and *I2VS plus– Intelligent Transport Systems and Services* (R&D programme)
- *Climate and Energy model regions*
- *Mobility of the future*
- *Innovation platform "e-connected"*
- *Technological lighthouses e-mobility*

**Policy lessons:**
- Better coordination and new governance mechanisms
- Policies and Business models have to be adjusted to the

| | |
|---|---|
| necessary (e.g. no single policy actor or ministry has the knowledge and competences to develop adequate policy interventions) | local situation (e.g. Initiatives to foster e-mobility by offering additional benefits will not work in different regions and contexts.)<br>• Maintaining and strengthening the acknowledgement that the transition to e-mobility will be more than a ‘technology fix’ |

| Austria | Sustainable buildings |
|---|---|

**Summary:**
The Austrian case study on sustainable building linked domains of sustainable housing, energy, mobility and ambient-assisted living. Major actors were identified at the EU- and national level, cities, municipalities, architects, planners and developers. In a collaborative effort, they try to reduce CO2-emissions and minimise their dependence on international energy suppliers. Although the term system innovation is largely unknown to most stakeholders, various initiatives are congruent with the idea behind the concept. Key barriers to system change are legal challenges, supply side capacity problems, non-transparent information, social values and poor spatial planning. National innovation policy is providing a technology push with specifically targeted programs. There are, however, divergent rationales by different public institutions, which impede a coordinated effort. Measurements for system innovation could potentially target attitude changes. Indicators should reflect various rationalities, i.e. innovation, environmental and urban policy orientations.

**Broader transition aim/goal**
Sustainable retrofitting of existing buildings of different categories

**Current transition stage:** difficult to classify as considerable differences exists among projects.

**Transition mechanisms and bottlenecks**

Drivers:
- Climate change and related CO2 emission reduction targets
- Local air pollution
- Urbanisation
- Changes in consumer preferences

Obstacles:
- Legal barriers (e.g. tenants not obliged to share costs)
- Economic barriers (e.g. cost savings do in most cases do not pay-off in the longer term for many buildings)
- Capacity and transparency problems on the supply side (e.g. lack of architects, planners and developers)
- Lack of necessary changes in the values, beliefs and norms of developers and private clients
- Inertia: mature phase with established routines, practices, structures and institutions

**Describing Policy**
Key policy actor(s):
- Ministry for Transport, Innovation and Technology (BMVIT) (national)
- Austrian Research Promotion Agency (programme administration)
- Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) (national)

Key measure(s):
- *House of the future*: supporting innovation activities in sustainable retrofitting
- *klima:aktiv*: diffusion oriented programme

Local niche experiment(s):
*Wißgrillgasse (Vienna);* integral modernisation of a building
The building was refurbished energetically and a high efficient attic was developed. Goal of the project was a comprehensive and sustainable system solution, which allows a broad reproduction to further Wilhelminian style buildings.

*Dieselweg (Graz);* refurbishment of a housing complex
The refurbishment result was the elimination of the harmful substances and an improved air quality.

*BIGMODERN - Subproject 8: Demonstration building Amtshaus Bruck;*
The aim of this project is to gather information/experience from pilot projects to be used in the planning and decision-making process of building owners (e.g. *Bundesimmobiliengesellschaft [BIG]*)

**Policy lessons:**

| | |
|---|---|
| • Removing legal barriers for change (e.g. aligning incentives)<br>• Reforming the complex system for residential building subsidies (e.g. removing inconsistencies across policy levels)<br>• Provision of transparent information on the supply side for developers and private clients | • Quality management and control (e.g. indicator system is missing that tracks real life performance and user satisfaction)<br>• Need for knowledge exchange and training<br>• Further Development of standards and their implementation |

## Belgium - Flanders | Sustainable housing and building

**Summary:**
In the case study on system innovation for sustainable housing and building in Flanders, Belgium, system innovation is linked to sustainability, ecological, social, economic, institutional and cultural long-term ambitions. Urban developments in Flanders have been characterized by suburbanization and urban sprawl, as well as by a highly fragmented governance system. Occurring problems have been recognized to some extent as being systemic, as is evident in research, policy analysis and public debates. Still there are divergent views on the actions that are necessary to achieve system innovation. The system is changing at a slow rate but it is prompted by experimental transition management, as well as by external pressures (such as EU climate and energy policies) and new developments in industrial, spatial and housing policy. The direction of this change at this current point remains vague, but is usually framed as "more sustainable" and "energy efficient". There is hope that socio-technical innovation will help to achieve this transition, but institutional and socio-cultural innovations are seen as equally important as enabling technologies.

**Broader transition aim**
Stimulate innovation in the housing and building sector at a system level through a focus on sustainability, networking, experimenting and improved coordination among policy actors.

**Current transition stage**
A lot of innovation is going on at niche level, but also established institutions, practices and actors are starting to change. A variety of actors is involved in policy-making: housing and spatial planning, financial and economic policy, environmental policy, mobility policy and urban policy. Coordination between policies is limited.

**Describing Policy**
Key measure(s):
*DuWoBo: stimulating system innovation through transition management* (since 2004)
Stated goal: innovate policies and practices for sustainable housing and building at Flemish level.

- DuWoBo succeeded in formulating a future, integrated vision for the housing and building system, setting up a network of regime and niche actors, and initiating innovative experiments and projects.
- The integrated, long-term view of DuWoBo did not break through in the existing segments of the policy regime (such as spatial planning and housing), but it created a small policy arrangement focused on specific projects for sustainable housing and building.

*The Round Table Construction* (2012)
Stated goal: Forward-looking roundtable to discuss how to evolve towards a construction-energy-environment cluster, in order to set in motion the transformation processes that are necessary to prepare the construction sector for the future.

- The Round Table met between February 2012 and February 2013, with representatives from the contractors, architects, engineering and consultancy, labour unions and Flemish government.
- Consultations ended in May 2013. However, the process seems to have created more openness with actors for the need of new forms of cooperation and governance within the context of national and European system-wide challenges.

**Policy lessons:**

- Approaches for system innovation exhibit important new policy features: a focus on systems, on the long term, on networking with a broad array of actors, on sustainability as a societal challenge
- It is no surprise that such an approach is not self-evident in historically deeply embedded systems. There is no fast and easy way of influencing system innovations (e.g. because of resistance from incumbents). A continuous investment in creative, active coupling of system innovation policies with the surrounding policy context is necessary.
- Influence of system innovation policies depends further on factors such as smartly utilizing pressures on the system, reframing problems and solutions, and overcoming resistance of incumbents
- Both initiatives were developed in the same system and related policy domains, but different factors hinder integration and even cooperation: diverging goals and interpretations of system innovation,
- System innovation policy needs long-term thinking, integration of policies, coordination between departments, but in general these are not common practices. Traditional innovation policy seems ill-equipped to deal with these challenges

strategic positioning of involved actors, difficult harmonisation between policy departments.
- Policy learning is important in such a situation, but actively investing in learning is hardly ever done. Still, both cases show signs of policy learning.

| **Belgium - Flanders** | **Sustainable materials use** |
|---|---|

**Summary:**
The second Belgium case study looks closely at the evolution of the waste and recycles system in Flanders since the 1970s. Using a 'learning history' trajectory-based approach, several historical systems and a desired future system have been identified. The 2050s ideal-type system should optimally go beyond "recycling", including addressing human behaviour for fulfilling needs and re-designing a linear process of take-make-use-discharge into a more networked and circular setting, amongst others. In order to establish the desirable/desired circular system, policy-makers in Flanders established policy mechanisms, including i) the '*Sustainable Materials'* strategy as a spearhead policy as well as ii) the *Flemish Materials Programme* as a unique approach that connects policy, industry, science and civil society to steer a coherent programme. Although there is no single silver bullet solution/methodology, a coherent combination of multiple strategies/attitudes/roles seems indispensable (see below).

**Broader transition aim/goal**
Transition towards a circular economy system

**Current transition stage:** Pre-development

Current system is characterised by a system which is anchored by own legislation, (infra) structures and business models; it can be regarded as a new (niche)-regime that has its typical assets of self-preservation, inertia and resistance to change (e.g. with regards to initiatives in relation to re-use).

**Describing Policy**
Key agenda(s):
*Sustainable Materials;* initiated by Flemish government; legislatively anchored by the Flemish Material Decree and in an explicit discourse of transition (management).

Key measure(s):
*Flemish Materials Programme*; Stated goal: a unique approach that connects policy, industry, science and civil society to steer a coherent programme, establish an agenda and collaborate on the necessary actions.
It consists of three pillars:
- long term vision and disruptive experiments
- policy research and
- an agenda of 45 actions

**Guiding principles:**
- Grass root initiatives should be recognised,
- establish a coherent, inspiring and positive image/narrative of future opportunities
- Redefine organisations with regard to their future roles/functions
- Connect different actors into pro-active and collaborative platforms
- Make a coherent combination of local/regional focus areas
- Deploy appreciative inquiry for 'individual' initiatives
- Inspire and support creative, new value creation models that can be translated in sustainable business models/logics
- Recognise and give visibility to business leadership in sharing systems, product service models, re-use, re-distribution
- Establish demonstrators/pilots and give them visibility;
- Don't over-regulate
- Work towards transversal policy; allow for policy entrepreneurship
- Use well informed communication to stir up the sense of urgency
- Integrate sustainable societal system configurations in
- Peer-to-peer communities and bottom up revolutions aided by e-platforms are expected to play a major role in new paradigms of de-centralised power and agency;
- Enrich operational progress and tangible results
- Identify transformative leadership
- Learn not to eliminate uncertainty and complexity
- Focus on those assets for which a strong position is already acquired

| China | Electric vehicles |
|---|---|

**Summary:**
Electric vehicles (EVs) are seen to offer China enormous potential to achieve industry leadership and address the shortage of oil-based fuel and environmental pollution. The transition of EV transport system covers a series of changes from strategies and policies in central and local governments to the behaviour of industry and consumers. It is a long-run effort which needs long-term and sustainable policy involvement and other interventions. Success could only be achieved through concerted public and private investments. Development of an EV system covers different layers - social, technological, industrial, economic, and policy. Since 2000, the Chinese government has been taking great efforts develop and commercialise EVs. Polices include supply-side measures and demand-side measures. So far China has achieved great progress in the EV development, both technologically and market. However, the transition to an ideal EV transport system is still in an early stage of take-off. It is still facing several challenges in technology, infrastructures, market and local protectionism.

**Broader transition aim/goal**
To address China's energy dependency and environmental challenges and to build a car industry that could leapfrog its global competitors in electric vehicle industry.

**Current transition stage:** early stage of take-off

Transition towards an electric vehicle transport system is in an early phase of take-off. China still lags behind its advanced competitors and lacks some core technologies and core components. Also the industrial development of electric vehicle is facing quite a few challenges and has not reached the expectations of a national strategy.

**Transition mechanisms and bottlenecks**

Drivers:
- Central government is the initiator and main driver for the EV development.
- Local governments also provide subsidies to EV production and sales.

Obstacles:
- Bottleneck in technology such as hybrid engine technology and key components such as chip and IGBT etc.
- Insufficient provision of large-scale infrastructure.
- High price of EVs compared to equivalent Internal Combustion Engines.
- Consumers' habits and demand for long-range vehicles. Local protection for local EV makers.

**Describing Policy**

Key policy actor(s):
Ministries:
- Ministry of Science and Technology
- National Development and Reform Commission
- Ministry of Industry and Information Technology
- Ministry of Finance
- Local governmental departments

Key measure(s):
- The Plan of Energy-Saving and New Energy Vehicle Industry Development (2012-2020) adapted a phased introduction of electric vehicles and set a goal for electric vehicle industrial development in various phases.
- Supply-side policies and measures
  - Electric Vehicle Special Project supported under the 863 Program and New Energy Vehicle Technology Innovation Programme.
  - Government support for commercialisation of new energy vehicles and their key components.
  - Subsidies and tax credit for automakers to produce EVs
  - Investment for infrastructure
- Demand-side policies and measures
  - Subsidies for consumers: For example, up to 57000 yuan subsidy for privately purchasing BEV with driving mileage above 250 km.
  - Tax reduction for consumers: Vehicle purchase tax exemption for EVs.
  - Public procurement: EVs should take up at least 30% in the new and updated public vehicles, official affair vehicles, and logistics and sanitation vehicles.
  - Setting standards for electric vehicles: 75 standards take effects, 77 is being revised or newly formulating.

**Policy lessons:**
- The development of EV industry in China is a top-
- Automakers rely too much on governmental subsidies, which limit the role of market mechanisms.

down model and governmental interventions have played a significant role in this transition.

- A fledged policy framework covering both supply-side polices and demand-side polices is critical at the early stage of EV system transition.

- Policies focus more on purchase of EVs and less on their use such as preferential mode of mobility.
- Co-ordination between ministries should be strengthened, especially in infrastructure construction.

| Finland | Transition to smart transport systems in a city context |
|---|---|

**Summary:**

In the Finnish case study, system innovation shall facilitate a seamless digitalised transport system. To analyse the system under study, the case study builds upon the multi-level perspective on sustainability transitions. Important issues, among others, are integrating different modes of transport, solving congestion problems and facilitating smart regulation. Financing, new types of steering instruments, a shift in policy thinking societal values, big data analytics and enabling technologies constitute strong driving forces. The City of Tampere with a focus on smart transport systems has been analysed as a transition case given their ambition to utilise the INKA programme for renewing its traditional industry base. However, competing visions and strategies represent obstacles, as do unclear divisions of labour and diverging responsibilities. It is furthermore unclear, whether councils, NGOs or business should make up the main system integrator. Experimentation of innovation policy on the niche level and PPPs are expected to be beneficial. The Finnish case shows that utilising the perspective on niches, regimes and megatrends as a starting point for measurement and the development composite indexes at these different levels. They could help find common visions and aims for further steps. The study also found that new skills and capabilities are required in order to manage transitions, in particular at the local level.

**Broader transition aim/goal**

Support system level transitions and exportable innovations in a city and regional context

**Current transition stage:** Early phases of take-off (Tampere and Finland overall)

The development towards digitalized transport systems are detectable both at regime and niche levels while the broader transition to green and sustainable growth still may take decades to unfold also in Finland.

**Transition mechanisms and bottlenecks**

*Drivers:*

- Emission and renewable energy targets
- Urbanization in combination with ageing and the prolonged economic crisis
- Global competition
- Emerging and enabling ICT technologies
- Availability of qualified persons with high ICT skills.
- National policy

Obstacles (context of the INKA program and the city of Tampere):

- While collaboration and coordination between key policy actors works well, there are still competing visions and strategies
- Vertical strategising versus horizontal implementation
- Uncertainty in the division of labour hampers niche developments and challenges the existing regime of regulations, norms and other institutional arrangements
- Lack of competencies to implement innovation policies at municipal level
- Policy instruments remains rather narrow and dominated by R&D project funding

**Describing Policy**

Key policy actor(s):

- Ministry of Employment and the Economy (national)
- Ministry of Transport and Communication (national)
- Ministry of Environment (national)
- Tekes (national)
- Municipal actors in Tampere (case specific)

Key agenda(s) (regarding Smart Cities):

- *Transport strategies and policies of the European Union*
- *Competitiveness and Well-being through Responsible Transport*
- *Environmental Strategy for Transport in 2013-2020*
- *Towards a new transport policy - Intelligence in transport and wisdom in mobility*

Key measure(s):

- *Innovative Cities (INKA)*(key transition programme)
- *Witty City*
- *Electric Vehicles and Systems (EVE) programmes*
- At regional and local levels there are some developments (in addition to *INKA, EVE, and Witty City*, where cities and regions participate).

**Policy lessons:**

- New Finnish transport policy represents a clear departure from mere transport infrastructure development
- Commitment and co-operation of three key ministries is becoming increasingly evident and important
- Full potential of the new national transport policy is yet to be realized and cannot be fully assessed yet
- In the area of innovation the transport policy includes the use of "new ways and technologies", and ICT in particular, as an important way to make the transport system more productive, safe, smooth and environment friendly
- New types of indicators and evaluation practices that monitor developments simultaneously both at the regime and niche level are needed
- It is no longer feasible to solve the transport problems in traditional ways and means (e.g. more cross-sector administrative co-operation etc.)
- The current support measures are mainly targeted at innovations to reduce vehicle and fuels emissions.
- The policy gaps relate in particular to knowledge development and diffusion, market formation and entrepreneurial experimentation.
- New types of innovation programs are important in developing shared goals
- Cross-administrative co-operation at the Government level has not yet been sufficiently active

*Further policy lessons see case study (p. 15-18) and on policy mix recommendations in the transport sector, see Temmes et. al 2014.*

## Germany | City of the Future

**Summary:**
The German case study builds on research of the German future looking project City of the Future, which serves as an agenda setting platform. The overall goal is to make cities CO2-neutral, energy efficient and climate adapted. Major stakeholders in this process are city administrations, research institutes, companies and central government. Among the drivers for system innovation are citizen pressures, the strong increase of transition city contests and local agendas. Nonetheless, pressures through financial problems, traditional industries and the lack of transparency of existing projects hamper the system transition noticeably. Enabling technologies are attributed as being an important force behind system innovation, but their adaption is still seen as problematic. Strategic PPPs to boost long-term investments in infrastructure and co-creation for smart devices pose potential solutions, but there is considerable scepticism towards technology. Hence key questions revolve around social versus technological innovation. The case showed the result of governance in transition should be the focal point of analysis, but rather the process that the discussion is embedded in. With regard to measurement indicators should be dynamic and transparent to increase civil society involvement.

**Broader transition aim/goal**
Towards CO2-neutral, energy-efficient and climate-adapted cities with the aim to increase the efficiency of energy supply and consumption

**Current transition stage:** Pre-development

Policy drafting and implementation stage

**(Transition) policy mechanisms and bottlenecks**

Drivers:

- *Federal Government´s Energy Strategy* (*Energiewende*)
- To promote sustainable and self-sufficient cities

Obstacles (implementation):

- Funding and long-term planning process

**Describing Policy**

Key policy actor(s):

- Federal Ministry for Education and Research (BMBF)
- Federal Ministry for Economic Affairs and Energy (BMWi)

Key agenda(s):
*The High-Tech Strategy 2020* (2009) and the *High-Tech Strategy Action Plan* (2012) discussed the framework including main objectives, related measures including financial resources, initial milestones, and stakeholder involvement.

Key measure(s) (to the overarching aim of the *"City of the Future"*):

- Energy-efficient city measure (Federal Ministry for Education and Research [BMBF])
- Energy-efficient city measure (Federal Ministry for Economic Affairs and Energy [BMWi])
- *ZukunftsWerkStadt* competition
- *National Platform for the City of the Future*

**Policy lessons:**

| | |
|---|---|
| • Transformation processes like the "City of the Future" project cannot be initiated by top-down government action alone but must also rely on existing dynamism for change.<br>• Broader political support from different government departments which ideally cover the entire range of relevant transformation factors.<br>• The need for stakeholders to become involved on a broad basis and for civil society to participate more strongly suggests that novel instruments such as foresight or visions and scenarios should be used.<br>• Cities functioning as labs have generated a whole range of interesting solutions. However, scaling of individual approaches and results to a broader level for the purpose of developing national solutions remains a challenge to be addressed.<br>• Another largely unsettled question is how to establish a long-term perspective in existing planning and decision-making processes. | • Efforts to "regulate" networking processes, for example by networking between networks, have rarely been successful so far. Optimum networking is difficult to achieve.<br>• The innovation system and its players still have to "learn" a broader concept of innovation<br>• The broad and close involvement of stakeholders<br>• The national level is not as relevant and important in the largely decentralized transformation processes as was originally thought.<br>• New players enter the stage in systemic transformation processes with their local focus. Cities in particular play a new role at national and even European or international level.<br>• Many local authorities also face considerable funding problems. Ideas for new funding models are being discussed on a broad basis.<br>• Civil participation is a key issue of new transformation approaches which still needs to be fully settled. |

| **Korea** | **Green Innovation** |
|---|---|

**Summary:**
In Korea, the country's green growth strategy aims to mitigate the degree of climate change and to create new growth engines for the future. Korea has the ambition to become a leader in the global market of green innovation. The Korean government is committed to using a holistic strategy to connect enterprises, local governments, local innovation actors and towns. Increasingly, civil society actors are also integrated. Ongoing initiatives include energy plans, green towns and a smart grit roadmap. Low energy prices, hidden costs of transition programs, few market opportunities and weak consensus building with local communities pose challenges to system transition. Enabling technologies are expected to play an increasingly important role in Korean system innovation, since many of them are in the early stage of diffusion. One problem seems to be the confusing boundaries of what is green.

**Broader transition aim**
Transition towards a low carbon energy system

**Transition mechanisms and bottlenecks**

Drivers:
- Competition in domestic and international markets
- Global financial crisis
- Societal awareness

Obstacles:
- Fall in oil and energy prices (e.g. shale gas developments)
- Centralised power generation and distrution systems
- Political short-terminism

**Describing Policy**

Key policy actor(s):
- Presidential Committee for Green Growth
- Ministries implemented green growth action plans

Key agenda(s):
*Green Growth Strategy*

Key measure(s)
Supply measures:
- Increase of government R&D expenditure for green technologies
- Selection of five target areas and 27 strategic technologies in the green technology fields
- Government certification for green technologies, green products, and green SMEs
- Encouraging nationwide regional systems of innovation and innovation clusters

Demand measures:
- Eliminating FIT(feed in tariff, ~2011)regulations and introducing the renewable portfolio standard (RPS)
- Green labelling for green products and high energy efficiency products.

- Support of private demand: tax incentives and infrastructural support
- Public-Private-Partnerships (PPPs): green town, green home, green building

**Policy lessons:**
- n/a

## Netherlands | Biobased economy

**Summary:**
The goal of the Netherland's biobased economy project is to largely replace fossil oil by biomass, with a focus on chemistry and agriculture. Some materials can in fact only be produced with biofuels, e.g. policy lactic acid. The government´s main function is that of a network partner between science, chemistry, energy, agro-food, horticulture and water processing industries, while the role of society is central to the success of system innovation. Open questions concern the sustainability and ethics of biomass production. Most sectors involved in biofuel are supported through PPP initiatives. Progress has been made in the development of indicators, which were analysed in various studies. As one example, the number of network linkages of the biorefinery technology has increased significantly from 2010 until 2013.

**Broader transition aim/goal**
Transition from an economy that runs on fossil oil to an economy based on biomass as a raw material

**Current transition stage:** Pre-development

**Transition mechanisms and bottlenecks**

Drivers:
- Energy saving goals of the Dutch government
- Bio-based R&D by government institutions
- Early product introductions by major corporations

Obstacles:
- Low oil price during 1990's throughout 2003
- Strong sector focus

**Describing Policy**
Key measure(s):
*Biobased Economy Innovation Contract: 'Green Growth – From Biomass to Business*
The government joined the business community and research institutions in developing a demand-driven medium-term approach to expertise and innovation by means of the Bio-based Economy Innovation Contract. Work packages include:
- Bio-based materials
- bioenergy and biochemical,
- integrated bio-refinery, crop optimisation and biomass production,
- recovery and reuse:
- water nutrients and soil,
- and economy, policy and sustainability

**Policy Lessons:**
n/a

## Russian Federation | National Cluster Programme

**Summary:**
The case study on the Russian cluster initiative highlights the importance of taking into account the specific innovation profiles of regions and the involvement of regions in the drafting and implementation of federal policies; supports the coordination of innovation policy measures for support different actors (universities, research organizations, large businesses, SMEs, venture capitalists and business angels, etc.) and improves the efficiency of interaction between actors of the regional innovation systems, including trust building. As many other cluster programs, the Russian one is not just national. It involves joint work between the federal and the regional levels, with the former playing the role of facilitator and the latter managing or coordinating or taking part in the clusters. The federal level program is facilitated through an inter-ministerial committee. It provides the involvement and coordinated work of several ministries, agencies and development institutions to guarantee the pilot clusters comprehensive support. In general, the cluster program in Russia is consistent with the most successful international models.

There is an increasing support to small and medium enterprises in the pilot clusters. Another positive trend is the recent decision to change priorities for cluster support. Despite it was originally expected to fund mainly the development of basic infrastructure in clusters, e.g. transport, engineering, housing, power, later infrastructural imbalance was offset. The pilot 14 clusters were offered to choose two of five possible areas of spending subsidy from the federal budget: the purchase of new equipment, additional education and training, cluster management activities and external consultancy, consultancy for the preparation of investment projects in the sphere of innovation, participation in international fairs, forums, round tables, etc. These areas of support - more than the basic infrastructure development - correspond to the idea and principles of cluster policy. Thus, it can be summarised that cluster policy in Russia is constantly changing and evolving.

**Broader transition aim/goal**

Increase innovation activities and capacities of Russian enterprises

**Transition mechanisms and bottlenecks**

Drivers:

- State funding for science has increased
- Considerable efforts have been made to encourage research and innovation activities in universities
- Federal development institutions were formed to create an "innovation lift" in the economy to fund innovative companies at different development stages
- Attempt at "coercion to innovate" of large state-owned enterprises (SoE)
- System of infrastructural support for innovative small and medium enterprises was established
- Inter-ministerial commission chaired by the President and Prime Minister of the Russian Federation was established

Obstacles:

- Low innovation activity of businesses
- Low efficiency of the domestic R&D sector, especially
- Weak link between innovation actors

**Describing Policy**

Key policy actor(s):

- Ministry of Economic Development

Key agenda(s) and measure(s):

Cluster competition: 25 cluster-like formations were selected and divided into two groups: The first group (14 clusters) is planned to be supported with the special subsidy from the federal budget. 1.3 billion Roubles (approximately 325 million euros) have been allocated for that purpose. The second group requires further improvement of its projects and clusters from that group won’t receive federal subsidy

**Policy lessons:**

- First national cluster programme in Russia is consistent with European experience (e.g. Germany)
- Russian Cluster Observatory will help to narrow down issues for future analysis
- Should include not only companies, but other important actors of regional innovation system (e.g. start-ups, innovative SMEs, universities, science organisations)

## Russian Federation — Technology Platform Medicine of the Future

**Summary:**

The case study on Russian technology platforms focused on the example of medicine for the future. The governance structure is coordinated by a general assembly, a steering committee and S&T councils. Together with universities and research organizations, they try to find solutions to gaps in specific healthcare technologies and to fight socially important diseases. Since 2012, the number of organisations and businesses involved in the technology platform has increased greatly. The concept of system innovation is not yet practiced in Russia, but there is consensus as to its different dimensions. Key barriers to date are a lack of infrastructure, PPP initiatives and funding, as well as non-transparent public procurement in medicine. There is also a risk of rent seeking of the most active members within the TMPF. At the moment there is no evidence that innovation policies impede technology platform development. The main indicator used is R&D funding which makes the development of further quantitative and qualitative indicators desirable.

**Broader transition aim/goal**

Foster transition processes within technology platforms

**Transition mechanisms and bottlenecks (Medicine of Future Platform)**

Drivers:
- Industry/sector development programmes
- State (federal) R&D programmes
- Societal demand
- Business demand

Obstacles:
- Lack of development supporting infrastructure
- Lack of funding

**Describing Policy**

Key policy actor(s):
- Russian Federation Government Commission on High Technology and Innovation (national)

Key agenda(s):
- *Concept of Long Term Socio-Economic Development of Russia till 2020* (national)

Key measure(s)

*Medicine of the Future (TPMF)* (one of 34 technology platforms):

Being established in 2010, by 1 January 2014 the Medicine of the Future platform had 358 member organisations, including:
- 147 business enterprises,
- 103 research institutes (including 30 of the Russian academy of sciences),
- 72 universities and,
- 36 non-commercial entities (associations, scientific unions, etc.).

The key measures of the TPMF are:
- *Strategic Research Programme* (now available for years 2012 – 2020);
- *Full Cycle Complex Projects*

Internal governance:
- Steering committee
- Nine Science and Technology Councils
- Executive administration
- Five Working groups

**Policy lessons:**
- Future successful transitions will require additional efforts (e.g. upgrading university programmes, training and new research and engineering infrastructures).
- A new approach to S&T foresight will be required
- Need of an International dimension

## Sweden | Sustainable Renovation

**Summary:**

The Swedish case focused on sustainable renovation of multi-family residential areas built during the 1960s and 1970s in Sweden (the so-called Million Program) with particular focus on the Malmö Innovation Platform, an initiative partly financed by VINNOVA. Renovation of the Million Program residential areas is becoming increasingly urgent and represents a major window of opportunity for the development of more sustainable cities in Sweden in social, ecological, and economic terms. Despite great need, an obvious market and the potential for innovation in this area, the pace and depth of renovation is much slower than what would be desirable. Major bottlenecks are suitable incentives, financing models, coordination and practical verification of technical solutions. The Malmö Innovation Platform uses the need of renovation of the Million Program as an engine for a wider process of change towards a sustainable city. The Platform is a result of an increased awareness of the importance of a systemic approach and collaboration solutions such as P/PPs. The aim is to experiment with innovative financing models and to get politics, industry, society and academia involved. Currently there is a lack of policies and instruments in the housing area in Sweden, even if the support for research and development related to the built environment has increased in recent years. There are many ways in which the national government could facilitate the transition towards sustainable renovation. First of all, its priority needs to be established.

**Broader transition aim/goal**

Transition towards sustainable renovation of multi-family residential areas built during the 1960s and 1970s.

**Current transition stage:** Pre-development

Transition towards sustainable renovation is in a very early phase. There are still very few examples of scalable sustainable renovation projects in Sweden.

**Transition mechanisms and bottlenecks**

Drivers:

Obstacles:

- Acute need for technical renovation of a large number of apartments
- Long-term commitment by many Swedish cities to be among the world leading cities in terms of sustainable development

- Investment in generally housing at low level
- Pace of renovation too slow
- Renovation is competing with new construction of housing for policy attention
- Current renovations not ambitious enough, e.g. in terms of energy efficiency
- Investment in high energy efficiency is currently not attractive in purely economic terms
- No extensive, co-ordinated, large-scale policy initiatives have yet been taken and at present

**Describing Policy**

Key policy actor(s):

- Ministries and government agencies at national level whose activities affect conditions within the housing sector and municipalities.
- European Commission (international)

Key measure(s):

- Measures within the framework of energy policy (e.g. research funding from Swedish Energy Agency)
- Measures aimed at making cities more sustainable ecologically, socially, economically and culturally
- a) Broad investment support (earlier)
- b) Research and innovation funding through the Research Council Formas and VINNOVA (both have increased in recent years)
- Measures aimed at promoting growth-inducing industrial innovation (e.g. measures to increase the innovation capacity of construction sector)

Although there has been a bias towards new construction, some measures have dealt with renovation specific issues

*Among the measures may be mentioned:*

- The establishment of a new National Renovation Centre in 2014 at Lund University and subsequent major funding by Formas of research related to renovation with close links to the centre.

- *Establishment of an Innovation Platform in the City of Malmö*, partly financed by VINNOVA (under its program of Challenge-drive Innovation). Stated goal is to stimulate development within six different work packages in a co-ordinated manner:
- Technical development of buildings
- Physical development of residential areas
- Social and economic development for residents
- Joint Action
- New financing and business models and urban global innovations arena

**Policy lessons:**

- Social and energy efficiency aspects of renovation need to be considered in an integrated way
- New financing models which internalize social costs and benefits are needed
- Facilitation of transition would require a shared vision among ministries and agencies (e.g. through a roadmap).
- A need of a predictable long-term schedule for minimum energy standards
- No obvious individual policy measures or actions which would ensure a take-off.
- Individual niche projects are unlikely to effectively contribute to the start of a system transition unless they are conceived and performed within a larger long-term framework that places the individual projects in an organized learning loop and gradually moves the cost-performance of integrated solutions to a level where large-scale implementation can be achieved on a routine basis.
- More attention needs to be given to the inter-linkages between different urban subsystems and to the interplay between social, economic and engineering aspects.

## United Kingdom — Long-term care system

**Summary:**

In the UK, the elderly care system is shifting from residential care, based on nursing homes, to a new model which emphasizes the care of the elderly in their own homes. Both an ageing population and financial pressures force governments to re-think their approaches to elderly care. Assisted-living technology can help enable elder citizens to stay independent longer than is currently possible. The goal is to use new technology to monitor people at home and transfer the data to health and care facilities. The shift is expected to take decades; hence the project is still in an early phase. There are two main lessons learned: barriers to system change can be closely interconnected (technical, procurement, cultural values, fragmented policies), which is why policy needs to respond to this interconnectedness. Secondly, uncertainty is particularly important in this case and needs close attention to deliver successful elderly care. This makes a holistic approach necessary, as one particular political actor will not be able to overcome all challenges at once. Uncertainties, also with respect to business models, are addressed through the economic and business models of ALIP.

**Broader transition aim/goal**

Transition from residential care in hospitals, nursing homes and care homes to a new emphasis on treating and supporting individuals in their own homes

**Current transition stage:** Take-off

Assisted living technologies have some commercial success, but the market has not been growing recently.

**Transition mechanisms and bottlenecks**

Drivers:

- Pressure on public sector budgets
- 
- Commercial opportunities for business

Obstacles:

- Technical limitations and high cost
- Fragmented public procurement
- Innovations face obstacles to their diffusion through the National Health Service (NHS) and social care
- Awareness and culture as restrictions to demand
- Fragmented policy environment
- Health and social care reform (e.g. uncertainty)

**Describing Policy**

Key policy actor(s):

- Innovate UK (national)
- Department for Business, Innovation & Skills (national)
- Department of Health (national)
- Devolved administrations (regional)
- European Commission (international)

Key measure(s):

*Assisted Living Innovation Platform (ALIP)* (focus of case study); created by Innovate UK (formerly Technology Strategy Board) in 2007; Stated goal: support UK businesses and the health and care sector to develop innovative, cost-effective, user-centred technology and services for independent living.

Core instruments of the ALIP platform:

- Collaborative Research & Development (CR&D)
- Health Tech and Medicines Knowledge Transfer Network.
- Economic & business models
- Delivering Assisted Living Lifestyles at Scale
- Stakeholder engagement.

Priorities of ALIP:

- To transfer and share knowledge between different actors (industry sectors, health and care professionals, users etc.)
- To tailor assisted living services to the needs of the end user
- To design desirable and affordable technologies.
- To design technologies that are interoperable

**Policy lessons:**

- Policy response needs to be holistic in order to address interconnected failures; that is, it needs to address the various barriers in a coordinated and comprehensive way.
- Policy response needs to be adaptable and to learn from its experiences because of the uncertainty that accompanies system innovation

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[1] . Though Harich's model is theoretical and provides only the results of simulations, recent work by Turner (2014) suggests that in the case of environmental degradation, empirical trends over the past four decades are consistent with the scenario of no mitigation. This has led some to talk of an ecological paradox: "the curious simultaneity of an unprecedented recognition of the urgency for radical ecological political change, on the one hand, and an equally unprecedented unwillingness and inability to perform such change, on the other" (Blühdorn, 2011, p. 36).

[2] While the superior efficiency of perfect competition is well-established in theory, it assumes a market with identical goods, which is clearly not the case in markets for knowledge. The most efficient outcome possible in this case is monopolistic competition, described as a market with many buyers and many sellers producing differentiated goods. However, in reality many technology markets are characterised by much graver deviations from the competitive ideal, ranging from oligopolistic competition (many buyers, few sellers) to (quasi-)monopolies (many buyers, very few or even one seller). In practice, estimating the efficiency costs associated with various degrees of imperfect competition is difficult, which may explain why it is a sparsely used rationale for intervention in STI matters.

[3] In addition to the obvious static efficiency penalties of monopsony, there is evidence that demand concentration can have negative dynamic effects too. Arora et al. (2009) examine the evolution of inter-firm division of labour among suppliers in the chemical industry and find that it is positively associated with the number of users and negatively associated with average size of users. Their findings suggest that in two alternative markets of equal size, the market with fewer buyers is associated with reduced division of labour in supply.