

# Executive summary

Strengthening productivity and promoting inclusive and sustainable growth through innovation is high on the agenda of policy makers. Referring to the current slowdown in productivity growth, OECD Ministers meeting in Paris recently[[1]](#footnote-1) agreed that “*there are several possible drivers… including weakness in investment and financial market conditions, a slow diffusion of new technologies, the possible growing market power of incumbent firms and unnecessary or inefficient regulation.”* In doing so, the Ministers implicitly recognised the complexity and interlinkages of the problem of low productivity growth and the need for the OECD to bring to bear its “*cross-disciplinary approach to policy analysis”* to the problem.

System innovation is one such cross-disciplinary approach being developed by the OECD Working Party on Innovation and Technology Policy (TIP) that takes a more systems view towards many of the societal problems that innovation policies aim to address. The concept of system innovation can be characterised as a horizontal approach to innovation policy directed at problems that are systemic in nature such as transitioning towards a low carbon energy and transport systems. It is one that involves engaging a range private and public sector actors and takes a longer-term view in policy. Accordingly, system innovations can be defined as:

* Large-scale transformations in the systems that fulfil societal functions such as housing, mobility, or food (Elzen, 2004).
* The transformations happen through a process of co-evolution between the different elements and actors in socio-technical systems.
* Furthermore, these transitions or transformations occur at multiple levels referred to as the niche level (i.e. an 'area' where there is space for radical innovation, experimentation and learning); the regime level where dominant and stable systems operate; and the landscape or wider political and economic level.

New enabling technologies and firms often emerge at the niche level and can challenge or interact with established technologies, firms, institutions and standards at the regime level. Innovation policies, together with other framework policies, can play a role in removing the barriers to the diffusion and scaling up of these technologies.

This paper explores the implications of the concept of system innovation for many of the policies and tools that are commonly used by governments to support innovation such as priority setting exercises, direct and indirect support to business R&D, clusters policies and technology roadmapping and demonstration projects which are used to bring stakeholders together to identify gaps in the commercialisation of emerging technologies.

Among the main findings are the following:

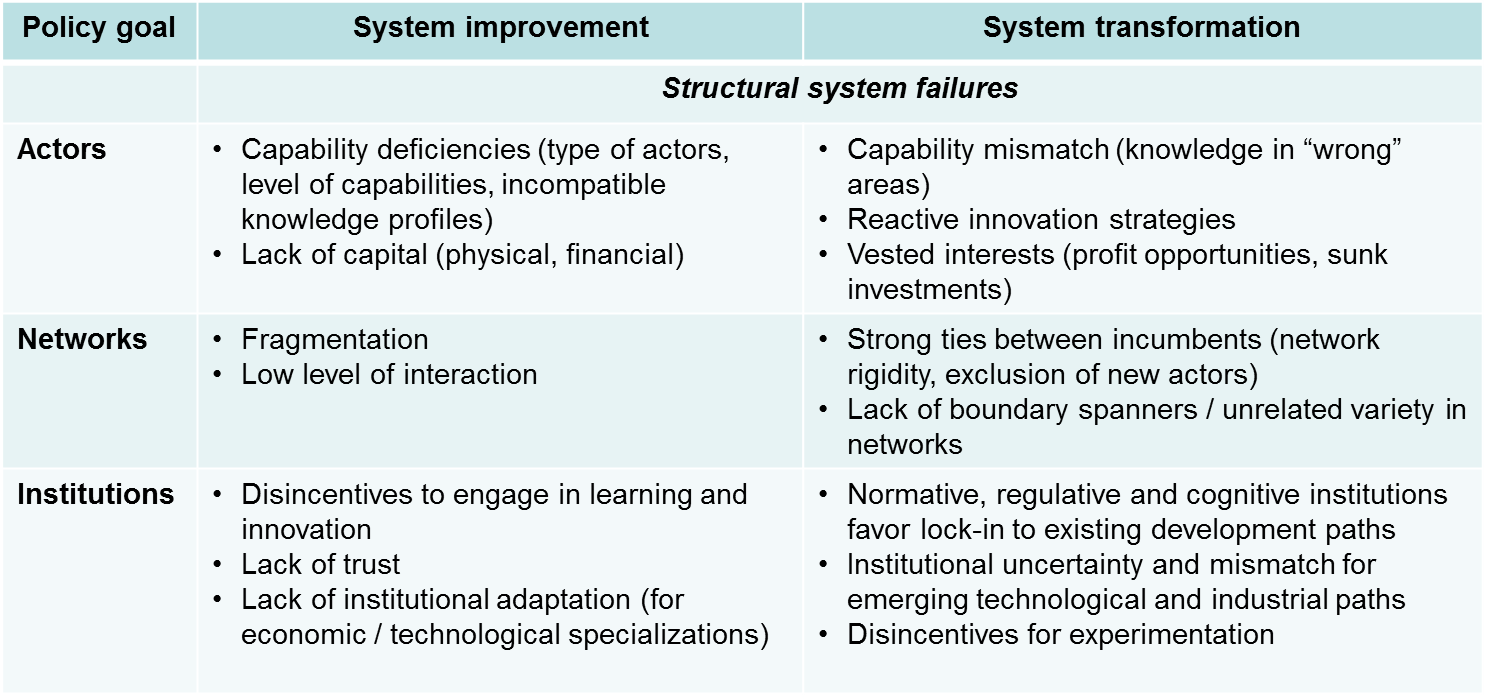
* Meeting the dual challenge of sustainability and growth requires no less than the transformation of the innovation systems that underpin economic sectors from energy, transport and communications to health and waste management.
* These grand societal challenges bring additional market and system failures that justify public intervention for not only supporting R&D but also for steering it in a desirable direction. Examples of additional system failures include network dynamics that protect incumbents or regulations that favour existing technological development paths.
* The process and outcomes of priority setting for the allocation of public support to R&D and innovation plays a huge role in favouring –or not– transitions. From a system innovation perspective, a broader engagement of actors beyond universities and large companies (e.g. civil society organisations, SMEs) is desirable as the need to better embed societal or functional needs in R&D and innovation priority setting exercises.
* Public schemes for business R&D should recognise the risks of system lock-in or lock-out and consider them in policy design by, for instance, differentiating fiscal R&D support by firm size or by taking a more mission-oriented approach (i.e. competitive grants, prizes).
* Cluster initiatives have the potential to either break-up path dependencies and create a ‘lock-out’, or strengthen path dependencies and thereby leading to further lock-in. Hence cluster initiatives can either facilitate or impede sustainability transitions. The latter requires that they explicitly bring the end-user perspective and take up a broad-based approach including members of academia, business, government and civil society and connections to research and innovation international networks;
* Technology roadmapping exercises should look beyond the technology and framed around socio-technical systems in which the technology will function (housing, health, mobility) and connect technologies with end-use application across the entire value chain**.** By taking this end-use approach, roadmaps are better equipped to inform decision making processes which will nevertheless be confronted with the social, economic and political complexities of new technologies. In this way, roadmapping does not only function as a tool to inform decision makers but also as way to mobilise and structure actor networks and develop their foresight capabilities.
* Support to technology demonstration projects should aim to reduce not just the technological uncertainties, but also the uncertainties related to user and system interfaces and the social acceptance of new technologies.

# innovation policies for system transformation[[2]](#footnote-2)

## Introduction

The demand for innovation among policy makers has never been greater and more purposeful. OECD policy makers are looking towards innovation to address the slowdown in productivity growth; to revitalise manufacturing and industry and to enhance social inclusiveness and to achieve a low-carbon economy. Furthermore, environmental, health, educational, or industry and agricultural ministries all have adopted innovation policies as a means not only to improve delivery on their specific “missions” but also to address the grand challenges; from climate change, energy security, to ageing populations and the broader sustainable development goals adopted by the United Nations.

The goals of innovation for growth and sustainability are not incompatible – indeed OECD work on innovation has shown that overcoming the barriers to green innovation – such as the dominance of existing technologies and systems, a regulatory environment that may favour incumbents, or access to capital – could possibly lead to new waves of innovation comparable to those seen with other major technological revolutions (OECD, 2015). Decoupling growth from environmental degradation also requires appropriate market prices, the alignment of many policies (e.g. tax policy, industrial policies) as well as public support to research and innovation (OECD, 2011). There are several problems on the road to achieving sustainability and green growth through innovation however. First, many of the sustainability challenges are inter-related; take for example the transformation of energy and agricultural systems. Second, actor interests and capabilities, markets, network structures, institutions all condition the capacity for public policies to impact on the pace and degree of change, from incremental improvements or the wholesale transformation of a system (Table 1). Third, policies for innovation are no longer the sole domain of science and industry ministries. This means that mobilising innovation to meet these grand challenges will require co-ordination across ministries and at different levels of government (i.e. regions, city, localities) to facilitate change. But the government cannot do this alone. Private action is also needed; and here policy settings and incentives are the key to encourage firms to increase the efficiency of natural resources and increase the adoption of new technologies and innovations for sustainability.

Table 1. Structural failures in socio-technological systems 

Source: Professor Lars Coenen, presentation at the meeting of TIP Steering Group on System Transformation, April 2016.

Meeting the dual challenge of sustainability and growth requires no less than the transformation of the innovation systems that underpin economic sectors from energy, transport and communications to health and waste management. A case in point is the transition towards a bioeconomy. The bioeconomy refers to the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy via innovative technologies. Biomaterials (in particular bioplastics/biopolymers) have the potential to transform important sectors such as construction, textiles, food packaging and make them more sustainable while creating new sources of growth. However, effective management of the transformation will require more sophistication and policy intelligence that takes into account the whole value chain from feed stocks, technology, and regulation to demand articulation by the end users. Lessons from the OECD project on system innovation have shown that policy makers need to rethink the way they fund and support science and technology by;

* Developing new ways to identify and set priorities for research funding and innovation support that can facilitate transitions by engaging incumbents and supporting new entrants.
* Building policy intelligence and new tools such as agent-based modelling; network analysis and dynamic systems analysis to detect and encourage emerging technologies and their diffusion.
* Intensifying co-ordination between policy domains (research, education, tax, regulation etc.), between levels of governance (national, regional, cities) and between stakeholders (public, private and civil society organisations).
* Improving their understanding of the process of transition, of the barriers and the facilitators in specific sectors/technological domains.
* Creating new ways to link research to innovation, including through entrepreneurship and education systems.
* Reviewing mainstream innovation policy initiatives such as R&D tax credits so as to balance incentives for incumbents and new entrants.
* Promoting and experimenting with more “targeted “innovation policy instruments such as public-private partnerships, public procurement of innovation and technology roadmapping and demonstration projects which can be used to manage the process of co-creation in the development of new technologies.

The remainder of this paper presents a series of policy notes that explore the implications of a system innovation for various innovation policy instruments such as priority setting for research and innovation, public support to business R&D, cluster policies and technology roadmapping and demonstration. A second and concurrent strand of this project will identify good practices for designing these innovation policy instruments based on a series of comparative case studies that focus on two key areas: a) emerging technologies and industries such as industry 4.0 initiatives and 3D printing which are part of the next production revolution and; b) green growth initiatives such as renewable ocean energy systems, biofuels and forest-based industries, low carbon vehicles, and autonomous driving vehicles.

# PRIORITY SETTING FOR R&D INNOVATION: a systems perspective

**The quick read**

This policy note looks at priority setting R&D and innovation funding from a “system innovation” perspective. System innovation has a normative agenda, meaning it is not only interested in the pace but also the direction of innovation. Priority setting for the allocation of public support to R&D and innovation is therefore a crucial part of any policy initiative with the aim to facilitate system innovation.

Priority setting is a complex matter and has multiple dimensions (e.g. targeting of actors, goal definition and type of governance approaches, etc.). Based on a review of a variety of approaches to priority setting used by OECD countries, a list of the most important dimensions is constructed. Based on this, five broad approaches are identified.

The strength and weaknesses of these five approaches are then evaluated from a system innovation perspective. A general conclusion is that a broader engagement of actors – beyond universities and large firms - is desirable as is the need to better embed societal or functional needs in priority setting exercises.

## 1. Priority setting in OECD countries

OECD countries differ markedly in their strategies for addressing societal challenges with innovation policy. The following five broad approaches can be identified.

### Prioritising Funding for HEIs

Some countries have developed a national process for identifying challenges to inform their funding of university-based research. These are typically led, and funded by, the main funding Ministry or Agency responsible for research in higher education institutions.

* In Finland, the Strategic Research Council (SRC) at the Academy of Finland provides funding to long-term and programme-based research aimed at finding solutions to the major challenges facing Finnish society. The SRC consists of eight members and a chair appointed by the Government for a three-year term. Stakeholders participate in identifying strategic themes through the use of an on-line survey and invitation-only workshops. The main themes of SRC research programmes are then decided by the Finnish Government. The number of themes chosen is typically around fifteen, and includes, for example, Climate Change, The Future of Living and Housing, Programmable Materials, and The Health and Welfare of Children and Young People.
* In New Zealand, the National Science Challenges (NSCs) are a collaborative mechanism for funding research in higher education institutes and public research institutions which addresses complex, long-term; national-scale issues will have major and enduring benefits for New Zealand. As well as prioritising funding for research in societal challenge areas, the NSCs, aim to increase collaboration between universities and between universities and New Zealand’s Crown Research Institutes (CRIs). A collaborative team from HEIs (and CRIs) must submit a research and business plan for up to 10 years, and a detailed work programme for an initial period of up to five years. Funding is granted for a five year period up, towards the end of which “Challenge collaborations” must submit a further detailed work programme for the subsequent five years. Overseas organisations may take part in a “Challenge collaboration”. Applicants are strongly encouraged to seek co-funding from external partners, including the private sector. National Science Challenges were identified in a three phase process which involved public consultation, prioritisation of potential Challenges by an independent panel of experts chaired by the Chief Science Advisor, and Cabinet consideration and approval of the Challenges. Eleven challenges have been announced including, for example, High-Value Nutrition, Ageing Well, New Zealand’s Biological Heritage and Science for Technological Innovation.

### Prioritising Research for Policy

Some countries have established a process for identifying the policy needs of Ministries/agencies and used this as a basis for funding research that yields results necessary for policy decisions. These include policy research for addressing societal challenges.

* In Belgium, the BRAIN-be programme (Belgian Research Action through Interdisciplinary Networks) is designed to provide the evidence base necessary to enable federal departments to respond successfully to the challenges they face. BRAIN-be is open to universities, public scientific institutions and non-profit research centres. The research funded under the programme should lead to results that are useful for the preparation of policy decisions, particularly those related to topics involving multiple departments. Financing is available for four-year network projects or pioneer projects lasting a maximum of two years. The framework programme is structured around six thematic areas have been agreed across federal Ministries and a Committee comprising representatives of the federal departments and funding agencies oversees detailed annual calls for proposals. Thematic areas include Major societal challenges, Federal public strategies, and Cultural, historical and scientific heritage.
* Australia has a unique interest in and responsibility for leading climate change science in the southern hemisphere. The Australian National Framework for Climate Change Science identifies national priorities where climate change science must deliver information to inform Australia’s policy makers on important decisions to be taken over the next decade. The Framework aims to ensure that Australia has the critical climate change researchers, skills and infrastructure to support government policy on climate change. The Framework sets out a plan by which Australia will address current constraints in people and infrastructure in order to support these capabilities and meet the identified challenges. Key areas where more skilled workers or improved infrastructure are required include earth system modelling, supercomputing and ocean observations. A High Level Coordination Group comprising major funding bodies, key research organisations and senior scientists and chaired by the Chief Scientist oversees the execution of an implementation plan for the Framework.

### Prioritising Funding for Challenge-Collaborations-Of-Scale

Some countries have adopted a more ambitious approach that aims to go beyond a focus on university-based research, or PRO-based research, and seeks to fund challenge-collaborations-of-scale which brings together partners in government, industry and academia to develop solutions to societal challenges. Such initiatives typically involve funding of substantial scale.

* In Singapore, the National Innovation Challenges (NICs) seek to bring together Singapore’s multiple innovation actors and multi-disciplinary research capabilities to develop practical, impactful solutions to national challenges. In addition to improving the lives of Singaporeans by addressing societal challenges, the NICs also aim to harness the potential commercial spinoffs from such challenge-driven innovation. Applications are invited from a consortium of organisations from different fields who come together to form a multidisciplinary project team to collaborate on a proposed project. Potential National Innovation Challenges arose when a similar challenge was faced across several ministries, necessitating a whole-of-government approach. Multidisciplinary teams were then brought together comprising various ministries and agencies, together with the research community, to further develop the challenge and the calls for proposals. Among the NICs currently active is the Energy NIC which aims to bring about significant changes in Singapore’s energy landscape in a whole-of-government effort. Key government agencies have embarked on the development of technology roadmaps in areas such as smart grids, carbon capture and storage/utilisation, green buildings and renewables. Interested non-government parties are encouraged to collaborate with government agencies on the development of these roadmaps.
* In Denmark, the INNO+ Initiative identifies specific areas within broad societal challenge areas where there are favourable conditions for Denmark to strengthen growth and employment through focused innovation initiatives. The Danish Ministry of Science, Innovation and Higher Education led the development of an INNO+ Catalogue in which these opportunity areas are identified. The Ministry invited proposals from a broad range of stakeholders building on the priority areas identified in the Danish research priority exercise Research2020. Through a process of consultation and workshops an INNO+ catalogue was developed, informed by relevant Danish and international analysis, strategies and action plans. The INNO+ Catalogue is intended for use as the basis for priority setting for public support across a range of innovation instruments, including funding for research in higher education, support for R&D in firms, and support for collaborative partnerships. One strand of support, the Societal Innovation Partnerships (SIP) programme under the Innovation Fund Denmark, provides support for challenge-collaborations-of-scale. The SIP provides support for alliances of between five to ten partners, comprising enterprises, national research institutions and public authorities working together on specific societal challenges. Applications are invited for projects along the entire value chain, whether for scientific advances, applied research, experimental development or demonstration and market development.

### Prioritising Support for Existing and Emerging Sectors

Some countries have gone further again and introduced forms of industrial policy to target government support at the development of specific sectors, or specific emerging technologies, which contribute substantially to the solution of societal challenges. Examples include support for low carbon vehicles, especially lower maturity technologies. Support for mature technologies often takes through regulatory, competition and other policies to remove distortion in the prices or market entry barriers.

* + The Netherlands has identified nine top sectors of the Dutch economy in which the Netherlands has a leading position internationally for priority focus of public support. These sectors are now prioritised for targeted government investments in innovation, human capital, reducing the regulatory burden, and for co-investment through tax incentives, loan guarantee schemes and capital investment. The factors used in selecting the top sectors included that the sector must be knowledge-intensive, export-focused and can substantially contribute to solving social challenges. In 2011 these sectors accounted for over 80% of business R&D. Societal challenges play an important role in all the Top Sectors, including for example Energy, Water, Life Sciences and Health, and Agriculture and Food. Top Teams, comprising high-level representatives from industry, public research and government, advise government on actions to ensure the top sectors remain competitive on global markets and advise government on how to undertake sector-specific policies across ministerial portfolios, including education, innovation and foreign policy, and regulation. One outcome of the Top Sectors policy has been to consolidate the research activities of companies, universities and knowledge institutes into joint roadmaps. This has been incentivised, for example, by cash contributions from companies to universities being supplemented by an additional 25% from the Dutch government, and has led to more intense and aligned public-private R&D partnerships. As a result a substantial amount of money for university research has been directed towards topics relevant to the Top Sectors, and through this mechanism, to societal challenges. The nine Top Sectors were an evolution of Dutch industrial policy in that they are largely the sectors previously funded under programmes to support relevant industrial sectors. The ‘selection’ of the 2011 top sectors was justified by the claim that it covered a large proportion of BERD and covered almost all of the major industry sectors in the Netherlands. The Top Sectors approach in the Netherlands focuses on sectors of existing strength.
  + In Korea, a different approach has been adopted. Korea investing heavily in growing new industry sectors based on the development of new and emerging technologies. Korea has been at the forefront of green growth initiatives and aims to be a hub for global green growth. The Korean Green Climate Fund supports R&D, green technology development and green education. The Creative Economy initiative emphasises the role of innovation in addressing social challenges such as Internet privacy. Various R&D programmes for social problem solving, such as sustainable cities, have also been established. Korea is exceptional among OECD countries in having among the highest GERD as a percentage of GDP, and also having among the highest contribution from BERD to its overall GERD among OECD countries. Industry therefore plays a major role, alongside government, in shaping innovation policy in Korea, and Korea’s ambitious approach to addressing societal challenges.

### Prioritising Involvement in International Research Networks

Some countries fund challenge-focused activities at national level, which in turn are part of wider international networks focused on global level challenges e.g. the Global Research Alliance, Horizon2020.

* The Global Research Alliance (GRA) on Agricultural Greenhouse Gases was launched in 2009, led by New Zealand, and brings countries together to find ways to grow more food without growing greenhouse gas emissions. It now has 46 member countries. The GRA focuses on five challenge areas: Paddy Rice, Croplands, Livestock, Soil Carbon and Nitrogen Cycling, and Inventories and Measurement Issues. International groups of researchers, government agencies and farmers have been set up to address these challenge areas by bringing countries together in research collaborations, as well as to share knowledge and best practices, build capacity and capability amongst scientists and other practitioners, and move towards breakthrough solutions in addressing agricultural greenhouse gas emissions. The Global Research Alliance (GRA) was initiated by New Zealand when New Zealand recognised that it had an issue with GHG emissions from their agriculture sector. They noted that this was not just their challenge but a global challenge and initiated the GRA.  This example shows how initiative on the part of a country can be effective in advancing work and profile internationally in a challenge area of national interest.

## 2. Different dimensions of priority setting

Based on this review, we can identify a number of different dimensions in priority setting. By creating a morphological model, the different strategies can be compared and contrasted in a more structured way (Table 2).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Table 2 : Priority setting for system innovation | | | | | |
| **Principal Objective:** | **Prioritising Funding for HEIs** | **Prioritising Funding for Research for Policy** | **Prioritising Funding for Challenge Collaboration of Scale** | **Prioritising Support for Existing and Emerging Industry Sectors** | **Prioritising Involvement in International Research and Innovation Networks** |
| **Which actors are targeted?** | HEIs | HEIs and PROs | Government Ministries and agencies, industry, HEIs and PROs | Industry | HEIs, PROs |
| **How are challenges defined?** | Societal challenges | Societal challenges | Societal needs/end-use domains | Key Sectors | Key Sectors |
| **How are challenges formulated/constructed?** | Bottom-up | Top-down | Top-down | Top-down | Bottom-up (?) |
| **Number of thematic areas defined?** | Typically  10-15 | Typically  5-10 | Typically  1-5 | Typically  1-10 | Typically  1-5 |
| **Functional/ generic aspects of innovation system targeted?** | Building research capacity in HEIs / Increasing collaborations between HEIs and between HEIs and firms | Building research capacity in HEIs and PROs in areas needed to inform policy decisions | Long-term collaborations between multiple innovation actors | Increasing business R&D | International R&D collaboration |
| **Degree of whole of government involvement?** | Mainly Ministry responsible for research in HEIs | Whole of government | Multiple Ministries | Mainly Ministries responsible for enterprise and innovation | Mainly single relevant Ministry |
| **Degree of involvement of international innovation actors?** | Low | Medium | Low | Low | High |

Source: Diercks and Hughes, 2016

## Dimensions of priority setting: a system innovation perspective

Table 1 gives a mixed overview and reveals that countries differ markedly in their objectives for adopting a societal challenge focus for their innovation policies, in the process they use to identify priority challenges, and in the challenge areas they chose to focus on. In addition, more than one priority setting approach can be used within a single country or region. Rather than arguing for one approach over the other, some general reflections are given from a system innovation perspective.

***Principle objectives***

System innovation aims to deal with persistent societal problems by exploring and furthering sustainability transitions (Carayannis et al 2015, Meissner 2015). The policy initiatives largely focus on funding priorities for research activities. Although funding is undeniably a role a government can perform, a system innovation agenda is also about co-ordinating different experiments, strategically protecting niches and about balancing vested interests, informing expectations, shaping common vision, facilitating learning and levering investments (Scrase et al., 2009). Principle objectives could reflect a broader mix.

### Which actors are targeted?

System innovation asks a broad participation from actors from academia, business, government and civil society. This does not necessarily mean that every policy initiative has to take a holistic approach by addressing them all at the same time. However, the different policy initiatives identified show a clear tendency to target HEI’s and other actors who make up the traditional science-base. There are logical explanations for this (the legacy of innovation policy in research policy and Science & Technology, to name one) but this should not be a justification, but rather an encouragement to break with this past and pursue novel policy agendas focussing on a broad range of actors across society.

### How are challenges defined?

Challenges can be defined in several ways. Some policy initiatives take a sector focus. However, the danger this brings is that there is too much emphasis on existing strengths of established industries and also a lack of challenge-led investment in crossovers between the different sectors. Some initiatives apply a broader focus on broad societal challenges such a resource scarcity and climate change. Although useful in creating crossovers between different sectors, these challenges are sometimes criticized for leading towards a focus on the supply-side and narratives around technological fixes (De Haan et al, 2014). A stronger focus on societal or functional needs, as these socio-technical systems include both production and consumption, thereby focusing on both technology and behavioural change. This has been done by only one initiative (Australia).

### How are challenges formulated/constructed?

Considering the fact that most policy initiatives only focus on the research base, it is little surprising that they have a top-down governance approach. Dealing with HEIs or PRO means dealing with a limited set of actors and therefore fits a more traditional technocratic approach. However, when a broader set of societal actors are to be addressed, more inclusive and bottom-up approaches could be beneficial as they will not only shape the priorities, but also help with constructing the necessary actor-networks and foresight capabilities needed to execute the agendas set out during the process or priority setting.

In summary, priority setting for research and innovation is a complex matter and has multiple dimensions (Carayannis et al 2016, Vishnevski et al 2015a). From a system innovation perspective, a broader engagement of actors is desirable as is a stronger focus on societal or functional needs that could be better embedded in priority setting exercises.

rethinking Public support for business R&D for System Innovation

**The quick read**

This policy note looks at public support to firm R&D from a system innovation perspective. This is a highly relevant topic for mainstreaming the concept of system innovation, as the private sector is arguably the most prominent actor in the innovation process and their R&D and innovation activities are crucial in making transitions happen.

However, **public support to business R&D includes a large diversity of policy instruments** supporting the supply, demand and connectivity of firm R&D activities. Aligning all these instruments with the horizontal policy agenda of addressing societal challenges is a formidable task, for which in many cases the devil will be in the detail.

The scope of this note will therefore be limited to highlighting **the relevance of applying the concept of system innovation** by arguing that grand societal challenges such as climate change bring additional market and system failures that justify public intervention for not only supporting R&D but also for steering it in a desirable direction.

Finally, this note explores how the social, economic and technological complexities emphasised by system innovation have some important implications for public support to firm R&D arguing that

* **Supply-side R&D support could facilitate either system lock-in or lock-out**, often depending on the specific context. This should be explicitly considered in policy design by for instance differentiating on firm size or by taking a more mission-oriented approach.
* **R&D support is not only important for producing new technologies but also for facilitating its widespread use**. This is often through non-technical R&D i.e. by developing new business models or learning about user practices. **Support for non-technical R&D** could be operationalised by not only focusing on high-tech companies but explicitly targeting certain **‘systemic actors’**. *i.e* utility companies and city councils fulfilling daily services around mobility or energy.
* **Collaboration in R&D is essential in reconfiguring socio-technical systems**, but needs the involvement of actors outside business and academia and needs to include a diversity of ‘social partners’ such as public authorities, economic operators and citizens alike. **Living labs** provide a promising avenue for this.

In conclusion, the diversity of instruments that currently support firm R&D can be transformed to vital tools for system innovation, but aligning them is not straightforward. **A broader understanding of R&D is helpful to** not only stimulate the supply of technological solutions, but also to support different modes of R&D through collective experimentation that could **produce the crucial non-technological innovations needed.**

## Public Support for Firm R&D

Incentives for research and development (R&D) are among the most popular instruments in the innovation policy toolbox across countries (Veugelers, 2014). The rationale for supporting R&D is that it’s an important driver for (technological) innovation and technological innovation in its turn contributes to growth by increasing factor productivity. In addition, many technological innovations bring a higher standard of living and associated well-being. The justification for policy support is that R&D outcomes often have the nature of a public good, in which knowledge spill overs result in higher public than private gains and government intervention is hence defensible.

### Different types of support

R&D and innovation efforts should focus on a portfolio of technologies selected through a structured mapping exercise that identifies existing domestic resources, skills and knowledge, and the policy frameworks and market mechanisms to support the development and deployment of the desired technologies. Such a process should also help in identifying priority partnerships for international co-operation, and improve efficiency of domestic efforts.

R&D policy instruments for firms can be classified in three main categories: 1) supply-side; 2) demand-side and connectivity policy instruments, all of which can be further specified (OECD-IPP, 2016). This extensive toolbox is difficult to generalise and every instrument has its specific pros and cons, which are often dependent on the specifics of each situation and the details of implementation. A more in-depth discussion falls outside the scope of this policy note.

1. **Supply-side policy support for firm R&D** is most common and is usually further categorised into two groups, direct and indirect support.

* **Direct support** can be offered in a variety of ways, all with slight different rationales. Popular instruments are among others competitive grants, subsidies or loans. In general, the benefits of direct support instruments are that they can be better targeted on key areas. This is useful for those areas that either have a long-time horizon or where public gains are much higher than private gains, for instance basic science or green technologies. Disadvantages of direct support are the relatively high transaction costs (high costs per unit effect), and the chance of backing losers (rather than picking winners), especially when there is no attention to a phase-out schedules in the policy design.
* **Indirect support** is usually offered through tax incentives such as tax breaks for R&D investment, a measurement with relatively low transaction costs and usually considered to be more neutral, although differentiation does take place, for instance on firm size. It’s a mechanism that many countries have introduced or expanded considerably in recent years. Indirect R&D support tends to end up with incumbent parties, especially when policy design gives little attention to differentiation, and is therefore more likely to encourage short-term applied research focused on incrementalism (OECD Observer, 2015). However, a more intelligent design of these instruments can target specific actors, collaborations or areas.

1. **Demand-side policy support for firm R&D** takes the form of **innovation procurement schemes** for R&D related activities. Many OECD countries have shown a growing interest in public procurement policies in recent years. The growing popularity of demand-side policies comes from the recognition that innovation does not only need new supply of knowledge but also a market opportunity. Procurement can help to ‘pull’ innovations into practice and bridge the pre-commercialisation. It re-establishes the importance of linking supply and demand and responds to the frequent perception that traditional singular focus on supply-side policies has significant limitations. Governments support demand more generally through regular public procurement by incorporating innovation-related criteria, but can also focus more specifically on R&D demand through procurement in two ways, depending on the level of market-readiness of the innovation (IPP, 2016).

* procurement of products and services that do not yet exist
* Pre-commercial procurement of R&D, with no guarantee that the goods or services developed will actually be bought.
* Additionally, Innovation inducement prices are increasingly popular due to their ability to target specific (societal) challenges and reaching a wide community of problem solver (Stine, 2009).

1. Connectivity support instruments for firm R&D is usually done by promoting or enhancing collaborative innovation activities between firms and, what may broadly be termed, the science base – i.e. public laboratories and research institutes and Higher Education Institutions, particularly universities (Nesta, 2012). The relevance of connectivity in the innovation process is that ultimately innovation is not about either supply or demand, but about a successful coupling between them. This success depends largely on the ability to bridge the boundaries between various actors to successfully share their range of knowledge, skills, capabilities and competencies (Nesta, 2012).
2. It is common to categorise the collaborative R&D initiatives according to the following elements:

* **Actors**, such as university-industry collaboration, collaboration between large firms and SMEs, and collaboration between local and multinational companies.
* **Type of R&D**, distinguishing between formal and more codified R&D (e.g. patent licencing, research projects, and equity partnerships) and informal or tacit R&D (e.g. human capital mobility, consultations, interactions in conferences and expert groups).
* **Duration of the project**, with short-term collaborations generally deal with a specific R&D project with predefined results and commercial value, and Long-term R&D collaborations are more open-ended focussing on strategic areas rather than specific projects.

## The importance of steering firm R&D towards grand challenges

The private sector is a prominent actor in the innovation process and therefore crucial in addressing societal challenges through innovation. However, additional failures justify public intervention in not only supporting R&D but also steering it in a desirable direction.

### Extended market failures and the need for directionality

The public good characteristics that justify support for private R&D in the first place are magnified in those areas dealing with grand challenges, as they have particularly long time-horizons and large public gains in relation to private gains. Another important market failure is that the external costs of environmentally unfriendly alternatives are usually not internalised (reflected in the price), but transferred to society and the environment (Gokhberg, Meissner 2016). As a result, the challenge faced by policy makers is that the market mechanisms governing the private sector are not likely to support innovation for sustainability.

These extended marker failures thus mean that there is not only a natural deficit of R&D spending, but that the sector most likely to produce innovative technical responses to environmental threats, the private sector, is unlikely to place that innovative capacity at the service of greater sustainability without any policy intervention that does not only incentives the amount of R&D spent, but also the direction in which this money is flowing.

Box 1: Energy R&D and the need for directionality

A study by Skea (2014) of R&D spending in the energy sector exemplifies the issue of market failures and the need for directionality in R&D. Skea shows that a global surge in energy R&D is taking place. However, he observes distinctly different patterns between public and private spending. The vast majority (almost 90%) of public R&D in 2011 targets a diverse portfolio of renewables, energy efficiency and smart grid solutions, with only a small part (a little over 10%) going to fossil fuels, most of which is allocated to CCS (carbon capture and storage). Although data for the private sector is less reliable, a clear pattern emerges of private R&D in 2012 mainly flowing in the direction of the oil & gas sector (96%) with only small part that can be attributed to renewables (4%).

### Additional system failures and the need for new policy models

The notion of market failures can be complemented with the idea of system failures. The logic is that technology is situated in the contexts that enable it to work, i.e. an energy or mobility system. The focal concern is therefore not just with artefacts, but with the larger system of production and consumption of which it is a part (Kemp, 2011). As a result, environmentally sound technologies have to compete on the market with incumbent, embedded in historically evolved large technological systems supported by powerful economic interests (Foray *et al.* 2012).

Grand challenges are increasingly coupled with and aggravated by this structural entrenchment, which is difficult to transform due to these various stabilising lock-in processes leading to path-dependence and entrapment (Unruh 2000). Hence the technical, economic, and social complexities of grand challenges ask for new policy models that look beyond a technological fix (Mowery *et al.* 2010).

One of the models that have been suggested and gaining considerable attention over the last year is that of system innovation. The remainder of this policy note will briefly introduce the concept and discuss its implications for public support to firm R&D.

## A system innovation perspective for public support to private R&D

System innovation represents a broad concept that helps us frame our thinking, and sharpen our understanding of sustainability transitions. It is mission-oriented and can have important, and even radical, implications for the way we think about policies today (OECD, 2015b).

### Fundamentals of System Innovation

* System innovations can be defined as large-scale transformations in the way societal functions such as housing, mobility, or food are fulfilled (Elzen, 2004).
* System innovation is built on a socio-technical understanding of innovation, as these transitions do not only involve technological substitutions but also changes in broader societal elements such as user practices, regulation, industrial networks, infrastructures and cultural meanings (Geels, 2004).
* System innovation happens through a process of co-evolution between these different elements. It is argued that this process of co-evolution goes through multiple phases by following an s-curve with the successive stages of predevelopment, take-off, acceleration and stabilisation (Rotmans, et al, 2001). Furthermore, system innovation is often conceptualised as interacting on multiple levels(Geels, 2002):
* Niches: protected spaces for radical innovation and experimentation;
* Regime: dominant practices, rules and technologies that provide stability and reinforcement to the prevailing socio-technical systems;
* Landscape: wider political, cultural and economic background.

## Implications for public support to private R&D

Drawing on these general lessons from system innovation, this section will briefly review the three categories of supply-side support for firm R&D as introduced in the beginning of this note and discuss some specific policy implications.

### Supply-side (direct and indirect R&D support)

The dominant practices, rules and technologies (regime) in the sectors where grand challenges come to light most prominently (mobility, energy) are dominated by incumbents, and are characterised by large physical infrastructures and corresponding capital investments that can act as additional barriers to firm entry and innovation. A system innovation perspective provides policy justification for taking niche/regime dynamics into account.

One implication of this is that policy makers should be careful in the application and design of especially indirect support through tax incentives, as they are generic and likely to be employed by those actors who are reinforcing the regime. This is confirmed by empirical observations as the OECD finds that “*tax schemes are more likely to encourage short-term applied research and boost incremental innovation rather than contribute to radical breakthroughs” (OECD 2015a, p122).*Furthermore, the example presented in box 1 clearly shows how indirect support in the energy sector – fundamental to addressing climate change – will most likely support innovations that strengthen the current system which is considered to be largely unsustainable.

A possible solution to this is to differentiate on firm size when designing R&D tax incentives as patent analysis shows that most climate-change innovations come from small and young firms (OECD Observer, 2015).

In addition, although direct support has a bad name amongst economist as ‘government cannot pick winners’ recent OECD analysis suggests that direct support measures for mission-oriented R&D may be more effective in stimulating R&D than previously thought. Again, this is particularly the case for young firms that lack the upfront funds to start an innovative project (Westmore, 2013).

### Demand-side (pre-commercial public procurement)

The supply of novelty is an important element of tackling challenges such as climate change. However, a system innovation perspective emphasises the importance of not only producing innovation, but also the necessity to facilitate widespread use of these solutions. The focus from system innovation on end-use domains recognises the importance of demand-side of the equation. This justifies the earlier discussed growing popularity of mission-oriented R&D procurement in OECD member states.

However, a socio-technical understanding of innovation gives more prominence to the interaction between the technical and social complexities of grand challenges. In terms of R&D support through public procurement, system innovation gives insights into how stimulating R&D demand is more than facilitating faster diffusion of a technology, rather, it’s about creating and shaping new socio-technical systems that also involve a number of other(non-technical) innovations around business models, user practices and wider behavioural change.

This means R&D demand must not only flow from central governments to high-tech firms, but that innovation procurement must also be developed by decentralised public intuitions such as city councils or (publicly owned) utility and service companies (e.g. public transport). These so-called **‘**systemic actors’ (Steward, 2012) are locally situated by the nature of the services they provide. Their procurement of R&D activities involve finding new ways of providing services and are likely to be much less high-tech and fit better in what Rip, Joly and Callon (2010) identify as an emerging innovation regime of ‘collective experimentation’ in which ‘society becomes your laboratory’ that stands in contrast with the traditional reliance on what they label as ‘techno scientific promises’.

Finally, the ability of innovation inducement prices to mobilise a big and diverse group of problem solvers around some specific societal challenges is promising. Combined with the ability to excite and inform the larger public makes it a potential tool for system innovation. However, prices might lead to competition rather than cooperation and may lead to wasteful duplication of work. (Stine, 2009)

### Connectivity (collaborative innovation activities)

Collaborative innovation activities can be an important tool for system innovation. A socio-technical understanding of innovation sees the technological artefact as one part of this broader socio-technical system. Collaboration and networking are vital to using effectively the limited RD&D resources.

It therefore emphasises the importance to bridge the boundaries between various actors to successfully share their range of knowledge, skills, capabilities and competencies.

Using collaborative innovation as a tool for system innovation does have some implications in terms of actors, type of R&D and duration of the project:

* **Actors.** These should not only include members from academia or the business sector as system innovation stresses the importance of a diversity of ‘social partners’ in R&D activities such as public authorities, economic operators and citizens alike. Government and government agencies can be partners not just facilitators, and insights around user-driven and citizen innovation (von Hippel, 2005) justify a more prominent place in these projects.
* **Type of R&D.** The ambitious agenda of system innovation could partly be operationalised by a more balanced focus between high-tech and low-tech collaborative innovation activities**.** The earlier mentioned ‘systemic actors’ and locally embedded government agencies could play a facilitating role in this.
* **Duration of the project.** The ability of long-term projects to focus on strategic areas fits better with the end-use and multi-actor perspective of system innovation. A good example is the novel concept of living labs (Dutilleul*et al.,* 2010) as user-centred, open-innovation ecosystem that could provide the societal laboratories needed to make transitions happen.
* **Strategic international collaboration** should be implemented to enable governments to conduct targeted R&D at a lower cost and with less duplication.

## Aligning the policy mix for business R&D

The management (governance) of funding policies is as critical as the level of funding. Improving the structure and co-ordination of the various institutions that have a role in funding is important in the development of low-carbon technologies. Effective and well-designed monitoring and evaluation of the performance of business R&D policies and programmes is key to ensure effective and efficient implementation.

## Concluding remarks

Public support to business R&D support includes a diversity of policy instruments supporting the supply, demand and connectivity of firm R&D activities. Aligning all these instruments with the horizontal policy agenda of addressing societal challenges is a formidable task, for which in many cases the devil will be in the details.

Nonetheless, this policy note argues that system innovation proves to be a useful lens for looking at public support for business R&D in the context of challenge-driven innovation policies. This policy note shows that the diversity of instruments that currently support firm R&D can become vital tools for system innovation. In general, it is argues that a broader understanding of R&D is helpful to not only stimulate the supply of technological solutions, but also to support different modes of R&D through collective experimentation that could produce the crucial non-technological innovations needed.

The policy reforms suggested are sometimes drastic and will need a solid evidence base to be accepted by those responsible for executing the policies. This policy note presents some evidence about discrepancies between public and private R&D and the merits of small firms in addressing climate change. However, further research is needed.

## Bibliography

Dutilleul, B., Birrer, F., Mensink, W. (2010), *Unpacking European Living Labs: Analysing Innovation’s Social Dimensions*, In: Müller, K.; Roth, S.; Zak, M. (eds.): Social Dimension of Innovation, Prag; Linde. 2010.

Elzen, B., Geels, F. and Green, K. (2004*), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*.Edward Elgar Publishing

Foray, D., Mowery, D.C., and Nelson, R.R., 2012. Public R&D and social challenges: What lessons from mission R&D programs? Research Policy, 41 (10), 1697–1702.

Geels, F.W. (2002), *Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study*. Research Policy 31 (8–9), 1257–1274.

Kemp, R. (2011). Ten themes for eco-innovation policies in Europe.S.a.P.I.En.S, (October), 1–19.

Mowery, D.C., Nelson, R.R., and Martin, B.R., 2010.*Technology policy and global warming: Why new policy models are needed* (or why putting new wine in old bottles won’t work). Research Policy, 39 (8), 1011–1023.

Nesta (2012) *Impact of Innovation Policy Schemes for Collaboration. Compendium of Evidence on the Effectiveness of Innovation Policy Intervention*.

OECD (2015a), *The Innovation Imperative, contributing to productivity, growth and well-being*. OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264239814-en.

OECD 2015b, System *Innovation: Synthesis Report*.

OECD Observer, 2015, *Business Innovation and Climate Change: Policy Makers must Favour Dynamism.*

Rip, A., Joly, P. & Callon, M. (2010) *Reinventing Innovation. in M. Arentsen Governance and Innovation*. 1–13.

Rotmans, J., Kemp, R., & Van Asselt, M. (2001) *More evolution than revolution: transition management in public policy*. Foresight, vol. 3 (no. 1), pp. 15-31.

Skea, J. (2014), *The renaissance of Energy innovation, Energy & the Environment*. 7, 21-24

Stine, D. (2009) *Federally Funded Innovation Inducement Prices*, Congressional Research Service, Washington DC.

Unruh, G.C., 2000. Understanding carbon lock-in. Energy Policy, 28, 817–830.

Veugelers (2014) *Mixing and Matching Research and Innovation Policies in EU countries*, Breughel Working Paper 2015/16

von Hippel, E. A., *Democratizing Innovation*, MIT Press, Cambridge, MA, April 2005

## Websites

OECD Innovation Policy Platform (IPP): <https://www.innovationpolicyplatform.org/>

Cluster Policy as a tool for System Innovation

**The quick read**

Clusters are generally understood to be geographic concentrations of inter-related firms, higher education and research institutions, and other public and private entities (OECD 2015, p129). They lead to a number of agglomeration economies and for that reason policy makers proactively stimulate clusters as a strategy for regional competitiveness.

This policy note explores the potential of cluster policy to address grand societal challenges by assessing to what extend ‘green clusters’ can combine these agglomeration economies with wider sustainability benefits. Drawing on the concept of system innovation, it is argued that cluster initiatives can be a tool to support sustainability transitions when they explicitly:

* Include an **end-use perspective** by conceptualising clusters around societal systems of functional needs (*e.g.* mobility, housing, food)
* Take up a **broad-based approach** including members of academia, business, government and civil society.
* Be **aware of niche-regime dynamics** that could either accelerate or impede transitions.

The note suggests that for the average region, the end use perspective is more realistic than the conventional technology led cluster policy which leads every region to questionably aspire to international leadership in bio, ICTs or nano-technologies. Drawing on these more general lessons, some concrete implications for the conventional toolbox of cluster policy instruments are discussed that could be of use to policy makers today.

## Cluster Policy

The OECD defines clusters as geographic concentrations of inter-related firms, higher education and research institutions, and other public and private entities (OECD 2015a, p129). The basic underlying assumption is that, despite dramatic changes that ICT has brought in terms of connecting people and firms, geographic proximity continues to matter in the innovation process. Clustering can lead to locally concentrated labour markets, specialisation in production and the attraction of specialised buyers and sellers. As a result benefits can be found in more efficient sharing of infrastructures and facilities, a greater division of labour between firms, and more efficient matching between economic agents. A number of soft benefits include the flow of ideas and information, for instance when employees change employer, through contacts with common suppliers and through social exchanges (OECD, 2015a).

#### Cluster Policy instruments

Beyond policies to address framework conditions in terms of the regional environment, regulation and finance, an extensive toolbox of instruments has been developed over the years to support clusters. They can be divided in three main categories, namely engaging actors, providing collective services and business linkages, and supporting collaborative R&D and commercialisation (for a comprehensive overview, see OECD, 2010). These might include, but are not limited to:

* Engaging actors
* Identify clusters through mapping and brokering;
* Support networks/clusters through hosting events or offering financial incentives ;
* Providing collective services and business linkages
* Improve capacity through SME business development support, compile general market intelligence, co-ordinate purchasing or establishing technical standards;
* Create a skilled labour force in strategic industries through specialised vocational and university training or collecting and disseminating labour market information;
* Supporting collaborative R&D and commercialisation
* Increase links between research and firm needs through supporting joint projects or co-locating different actors (i.e. science parks, incubators);
* Provide access to finance for spinoffs through advisory services, public guarantee programmes or (supporting private) venture capital.

## Cluster Policy as a tool for System Innovation

The benefits of agglomeration economies associated with clusters have attracted considerable interest by policy makers that do not only want to support economic activity, but also pursue a broader sustainability agenda. An obvious result is a shift in focus toward those clusters that support sustainable economic activities, but Coenen *et al*. (2015) argue that a simple normative shift in focus is insufficient for dealing with grand challenges. *“No matter how technologically advanced and superior solutions are being developed, they are of little value if they are not successfully implemented, used and diffused”.* This diffusion challenge is especially prominent due to the nature of grand challenges, which do not have a singular technological fix, will involve several sectors, and where users, decision-makers and buyers are likely to comprise a diverse group. The remainder of this policy note will explore how cluster policy could be a more effective tool in addressing grand challenges. By drawing on insights from recent literature on system innovation, lessons can be learned about how cluster initiatives targeting sustainable economic activities should differ in important ways from conventional cluster initiatives.

## Implications of the system innovation concept for clusters

When applying the concept of system innovation to clusters, we can draw the following lessons.

* ***A focus on societal functions explicitly includes end-use***. Conventional cluster initiatives often focus on producing innovations around singular technologies or sectors guided by the logic of strengthening the regions’ competitiveness in global markets. However, there is an overwhelming emphasis on the supply-side of clusters and they often lack a focus on another place-based dimension, namely the end-use or demand-side. By conceptualising clusters explicitly around functional needs (*e.g.* housing, mobility, food) greater emphasis can be given to end-use applications of these innovations within the context of the cluster itself. Taking mobility as an example, clusters should thus not only involve the supply-side technology of the electric car industry, but also involve their end-use applications and associated decisions within locally embedded mobility systems. Above all, for the average regionthe end use perspective is more realistic than the conventional technology led cluster policy which leads every region to questionably aspire to international leadership in bio, info or nano-technologies.
* **A socio-technical understanding of the innovation process broadens the conventional notion of clusters.** Although the OECD definition of clusters includes a broad variety of actors (*i.e.* Firms, higher education and research institutions, and other public and private entities) conventional cluster initiatives still largely focus on firms or firm-university relations, with little attention to actors from civil society. While firms remain a central focus, a socio-technical understanding of the innovation process implies that clusters should be broad-based by including a variety of actors and activities. This is a logical implication of the explicit inclusion of end-use practices, as non-firm actors are central to issues of user practices and cultural change. Community members must be integrated to a much higher degree and the inclusion of grassroots groups and community organisations gives direct access to important broad set of stakeholders such as users, consumers, and citizens. Again taking mobility as an example, market and user practises (mobility and drive patterns) and the culture and symbolic meaning (freedom, individuality) are crucial elements in the success of any novel technology in this socio-technical system.
* **The understanding of system innovation as a co-evolutionary process going through different phases and interacting between multiple levels means cluster initiatives can either facilitate or impede sustainability transitions.** ‘Green’ clusters face great challenges associated with deeply embedded existing unsustainable practices that make up the ‘regime’. This is a barrier that is often not as great for other industries. McCauley and Stephens (2012) argue that cluster initiatives have the potential to either break-up path dependencies and create a ‘lock-out’, or strengthen path dependencies and thereby leading to further lock-in. Hence cluster initiatives can either facilitate or impede sustainability transitions.
* **Facilitate.** McCauley and Stephens argue that “regional sustainability clusters can be conceptualized as conveners and coordinators of a collection of niche activities in a region”. They can support the development, demonstration and implementation of new experimental technologies but also broader social practices. Furthermore, green clusters can make use of the same agglomeration economies that apply to conventional clusters, *i.e.* building capacity and networks through locally concentrated labour markets, more efficient sharing of infrastructures and facilities, the flow of ideas and information or creating a brand for the region. As such, green clusters can coordinate resources and cultivate a supportive institutional environment to challenge regime technologies and practices and accelerate transitions.
* **Impede**. On the other hand, Macaulay and Stephens also argue that cluster initiatives usually emerge through, and rely on the support and participation of, *“established business and civic leaders who, in many cases, have been closely associated with the institutions and social practices which co-evolved with and maintain the entrenched regime*.” This means that existing path dependencies within a cluster have the potential to favour technologies or practices that reinforce the status quo or at least favour incremental changes over destabilising transformative changes.

Cluster policy thus raises a paradox as they can either facilitate or impede sustainability transitions. As such, Macaulay and Stephens find that cluster initiatives can play an intermediary role spanning the niche-level activities with regime-level institutions, with the potential to either accelerate or inhibit regime level change. They conclude that whether a cluster will foster change depends as much on governance arrangements as on technological or economic concerns.

## Policy implications

System innovation can have important, and even radical, implications for the way we think about policies today. The goal of this policy note was therefore to explore what its implications are for cluster policy. Applying the concept of system innovation makes clear that the merits of cluster policy in relation to addressing grand challenges such as climate change goes beyond selecting ‘green clusters’ that contribute to some form of ‘green economy’. Clusters have the potential to play a crucial role in not only producing sustainable technologies but also stimulating broader sustainability transitions, but in order to do so the conventional policy toolbox as introduced at the beginning of this policy brief needs changing. This section will briefly discuss each category of cluster policies and highlight some important implications.

### Engaging actors: a broad-based approach and aware of vested interests

It is sensible that government should work with existing and emerging (green) clusters rather than trying to create clusters from scratch. As a result, identifying clusters through mapping and brokering can still be an effective tool in making use of a regional comparative advantage and both support economic activity and pursue a broader sustainability agenda. An important implication of system thinking is that mapping needs to go beyond industrial clusters and should focus on new unfolding socio-technical networks. A good example of such a mapping activity is the EU-funded Climate-KIC transition cities project (Box 1). When brokering, it becomes more important to broaden the scope and also seek connections with civil society. A good example is the Dutch municipality of Bunnikwho created the positon of ‘sustainability broker’ (Box 1).

Although supporting networks/clusters through hosting events or offering financial incentives is still relevant, the multi-level perspective of transitions informs the policy maker to be aware of niche/regime dynamics. Experience shows that these initiatives are often captured by regime players to exert their dominance and protect their vested interest (Kern, 2011). Although incumbents shouldn’t be excluded, niche actors deserve priority treatment. Furthermore, direct incentives are preferred over indirect incentives since providing generic financial incentives have the tendency to end-up with incumbent parties (OECD, 2015a)

### Providing collective services and linkages: both supply and demand, connecting global with local

In general, measures providing collective services and business linkages currently focus too much on firms and the supply of innovations, rather than the demand-side. This shortcoming can be addressed by including a broader variety of actors and focussing on diffusion and end-use. It is important to note that this focus is not new to cluster theory. In the original ‘cluster diamond’ presented by Porter (1990), demand conditions are one of four ‘corners’ and hence elaborately discussed. However, an emphasis on high-tech has overshadowed demand conditions as it is no longer essential to have customers (or indeed suppliers) on the immediate doorstep, as even the smallest tech start-ups are selling and sourcing from a global market from day one. System innovation re-establishes the importance of end-use and demand by implying that although their might exist a ‘global technology opportunity set’ the ability to ‘tap in’ to this is very much dependent on actors who are per definition embedded in a local context. Cluster initiatives and organisations can play an important role in this ‘domestication’ of technology by functioning as intermediaries between what Bathelt (2004) calls the ‘local buzz’ and ‘global pipelines.’

In addition, creating a skilled labour force in strategic industries is still a necessity and specialised vocational and university training should remain a priority. Nonetheless, the broad nature of green clusters and system innovation asks for more than hard skills and need a stronger focus on **soft competencies** such as interpreting systems, envisioning, experimenting, networking and navigating. The outcomes of these activities involving new soft competencies are also good examples of novel collective services that can be provided by cluster initiatives and organisations.

### Supporting collaborative R&D and commercialisation: making transitions happen

Provide access to finance for spinoffs through advisory services, public guarantee programmes or (supporting private) venture capital remains important but are insufficient in the context of system innovation. In addition, a more active or ‘entrepreneurial’ role can be taken by government institutions and important ‘systemic actors ’such as city councils or (utility) companies providing local services (mobility, waste, energy). Conventional cluster initiatives mainly focus on increasing links between research and firm needs through supporting joint projects or co-locating different actors (i.e. science parks, incubators). Including these systemic actors can help to connect the supply-side of innovative science-parks and incubators with the end-use (mobility, food, and housing) needed to make transitions happen.

Box 2: Examples of novel cluster policy instruments

**Climate-KIC Transition Cities: socio-technical cluster mapping**

Transition Cities is a good example of how mapping clusters can be a relevant tool in supporting system innovation. The project identified three main areas around end-use, namely buildings, energy and mobility. The idea is that this approach could move cities away from a narrow supply-side focus on industrial clusters. Its understanding of clusters is also broad in the sense that the project does not only focus on business activity, but instead identifies newly unfolding socio-technical networks. The resulting ‘maps’ are then used as a tool to better understand the local needs and challenges and hence strategically support the further development of these multi-actor clusters. Transition Cities develops this model to help cities move towards a more sustainable future and signal a clearer and more coordinated intent to the market for innovative products and services that are required to achieve it.

**Dutch municipality of Bunnik: sustainability broker**

The municipality of Bunnik identified the need for more connection between the different sustainability initiatives that were emerging in its region. A sustainability broker was appointed with the mandate to facilitate and support interaction between the municipality, its businesses and citizens.

## Bibliography

Bathelt (2004), *Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation.* Progress in Human Geography, vol. 28 no. 1 31-56

Coenen, L.m Hansen, T. & van Rekers, J. (2015), *Innovation Policy for Grand Challenges. An Economic Geography Perspective.Geography Compass, Vol 9, no. 9, 483–496.*

*Elzen, B., Geels, F. and Green, K. (2004), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*. Edward Elgar Publishing

Geels, F.W. (2002*), Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study*. Research Policy 31 (8–9), 1257–1274.

Kern, F. (2011), *Ideas, institutions, and interests: explaining policy divergence in fostering 'system innovations' towards sustainability. Environment and Planning C: Government and Policy*. vol 29, no 6. pp. 1117-1134.

McCauley, S. M. and Stephens, J.C. (2012), *Green energy clusters and socio-technical transitions: analysis of a sustainable energy cluster for regional economic development in Central Massachusetts, United States*. Sustainability Science, vol 7, no. 2, pp 213-225.

OECD (2010), Cluster policies, OECD Innovation Policy Platform, www.oecd.org/innovation/policyplatform/48137710.pdf

OECD (2015a), *The Innovation Imperative: contributing to productivity, growth and well-being.* OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264239814-en.

OECD 2015b, *System Innovation: Synthesis Report. STI Policy Papers, OECD publishing*

Porter, M. (1990), *The Competitive Advantage of Nations, Harvard Business Review*, March-April 1990.

Rotmans, J., Kemp, R., & Van Asselt, M. (2001) *More evolution than revolution: transition management in public policy.* Foresight, vol. 3 (no. 1), pp. 15-31.

Roadmapping for technological transitions  
  
A System innovation perspective

**The quick read**

Roadmapping is a tool developed by industry to connect short-term (technological) capabilities with long-term strategic goals. Policy makers have adopted it and increasingly applied roadmapping in the context of large-scale technological or industrial transitions.

The shift from industry-led to government-led roadmapping changes the scope of the roadmapping exercise. Rather than focussing solely on technical developments, broader social, political as well as technological issues are included. Considering these ‘socio-technical’ dynamics, this policy note argues that a system innovation perspective can be very helpful – maybe even needed.

System innovations can be defines as large-scale transformations in the way societal functions such as housing, mobility, or food are fulfilled. The central thesis of this policy note is that roadmapping should take these societal subsystems as starting point rather than singular technologies, sectors or industries. Taking a concrete end-use perspective can function as a useful tool for long-term socio-technical transitions by connecting long-term visions of society with short-term action.

The remainder of the policy note reviews some essential literature on scenarios, foresight and roadmapping for system innovation and concludes that:

* By framing roadmap exercises around socio-technical systems of functional need roadmaps are better equipped to inform decision making processes that need to deal with social, economic and political complexities such as regulatory, institutional, infrastructural, cultural and behavioural changes;
* Technological expectations formed by participatory vison building can mobilise and structure actor networks and develop their foresight capabilities which will help shape innovation activities and as a result influence technological developments that ultimately occur;
* Participatory backcasting is a promising tool to connect long-term visions with short-term action.

However, this methodology is ambitious and some caution is advised in regards to:

* The long-term perspective and both social and technical elements bring extra challenges in regard to preparation, problem structuring and executing roadmap activities;
* The role of consensus building and legitimacy in participatory vision building and backcasting.

Finally, attention is given on how roadmapping based on system innovation insights can be better integrated in the current policy toolbox by:

* Exploring possibilities to integrate roadmapping with patent analysis;
* Its relevance to other innovation policies (*e.g.* priority setting and demonstrations) .

## Technology roadmapping

Roadmapping is a specific type of technological foresight to match short-term (technological) capabilities with long-term strategic goals. Roadmapping is used to inform decision makers, but the often graphical nature of roadmaps also supports strategic alignment and dialogue between different stakeholders. Furthermore, it is argued that roadmaps helps to nurture forward looking capabilities, making organisations more future-oriented by creating a foresight culture that support organisations in being more responsive to change (for an elaborate overview, see Cagnin *et al.*, 2012).

Technological roadmapping is a tool first used in the private sector. Famous examples are from Motorola and the semi-conductor industry. The tool has grown in popularity over the past two decades and has expanded considerably in scope from a narrow focus on technologies and products to a broader focus on product or technology groups or whole industrial sectors. Roadmapping is also used in technology foresight activities not only explore possible futures, but to develop operational roadmaps for assembling key players around a shared agenda. Roadmapping is being used in the exploration of industry 4.0 activities and the “next production revolution”. By involving participants from different policy domains, these roadmaps can foster policy co-ordination both horizontally (i.e. across policy domains, or between parliament and government) and vertically (i.e. between ministries and executive agencies) (OECD, 2016).

### Roadmapping as a public policy tool for technological transitions

This expansion of scope has led to an active involvement of governments in using roadmaps in public policy to facilitate the development of competitive industries and to push science and technology forward into directions with perceived high potential (McDowell, 2012). Technology roadmapping is most popular at the national and supra-national levels and are less often applied on the sub-national level. They are traditionally more common in north-America (Popper *et al.*, 2007).

More recently, roadmaps are used as a strategic tool for the development of new and emerging technological systems that meet societal goals. Examples are recently developed roadmaps by the European Commission on topics such as energy, resource efficiency and a low-carbon economy, and the IEA/OECD efforts to develop global low-carbon energy technology roadmaps covering the most important technologies (IEA, 2014). In addition, the UN has made roadmapping a central tool for getting started with the implementation of the new sustainable development goals (UN-SDSN, 2015). As such, roadmaps are becoming a popular tool in current discourses on transitions to sustainable or low-carbon economies.

### Roadmapping as a tool for system innovation and socio-technical transitions

This shift from industry-led roadmapping for single product/technology to government-led roadmapping for entire technological systems has changed its nature in three major ways.

1. roadmapping is not only used to facilitate but also to steer the development of technological systems to meet social and normative goals (*e.g.* low-carbon or sustainability)
2. Where industry tends to focus on the short-term, public policy roadmaps take a long-term horizon.
3. Where industry has a strong focus on technical developments, public policy roadmaps usually take broader social, political as well as technological issues into account.

### STI policy roadmaps

In the last decade roadmapping the value of roadmaps was also recognized by science, technology and innovation (STI) policy decision makers at different levels. Roadmaps are often times used to support the implementation (STI) strategies which are developed by policy makers with the aim to maintain and/or improve the STI performance of whole countries and to develop the underlying STI infrastructure to prepare countries for the future. However using roadmapping for STI policy is a very difficult and ambitious task, especially because it applies to both R&D and innovation practices and policies. Hence the major challenge for roadmapping STI policies lies with the development of feasible policy actions and instruments, e.g. the translation into proposals for political practices but less with the integration of different methods for roadmap development. Moreover roadmaps for STI policy need to highlight the causalities and dependencies between different policy instruments at horizontal level and consider the vertical level, e.g. national (federal) policies in the context of regional policy ambitions and measures. Thus the STI policy mix faces 2 main challenges in the design phase already: 1) alignment of STI policy instruments horizontally within the overall policy mix and 2) alignment vertically with regional policy instruments. Overarching these two major challenges remains the implementation of policy instruments which is frequently causing additional efforts and complementary measures.

While maintaining and potentially reshaping the STI policy mix is crucial to consider the path dependency and causality between different STI policy instruments and measures, e.g. undertaking ex-ante assessment of the potential impact of the measures not only on the national and institutional STI performance but also on the policy mix overall. Accordingly the composition of STI policy roadmaps requires stronger and more complex cross impact analysis of STI policy instruments in light of the STI policy mix. STI Policy roadmaps per se should aim at the development of the national STI system if initiated by national or regional governments, e.g. at the national or regional NIS as a whole instead of selected technologies/products or the like. This implies that the analysis of the respective STI policy mix only isn’t sufficient, instead it needs to be complemented by analysis of actors responsible for policy instrument. Actors’ responsibility includes development and also implementation of policy instrument (Carayannis et al 2015).

## Implications of the system innovation concept for policy and technology roadmapping

This combination of normative goals, long-term horizons and socio-technical dynamics has many commonalities with the wider literature on system innovation. A system innovation perspective on roadmapping can be very helpful for improving the effectiveness of roadmapping in this new context of public policy.

Long-term (desirable) futures are central to system innovation governance and as a result, considerable experience has been gained on the use of scenarios, foresight and roadmapping in the context of system innovation. This section aims to provide some main lessons that can be drawn from this.

* A number of historical cases have shown how technologies develop with society in a co-evolutionary manner. This is referred to as the social construction of technology (Pinch &Bijker, 1984) and more recent literature points to the importance of taking these so-called ‘socio-technical’ dynamics into account when dealing with large technological transitions (Rip and Kemp, 1998; Geels, 2002). Just like the general purpose technologies of the past have shaped a plurality of socio-technical systems today, so will the emerging general purpose technologies of today shape a plurality of socio-technical systems in the future. A logical implication for roadmapping is that it should not only cover technology development but should be extended to all system requirements such as regulatory, institutional, infrastructural, cultural and behavioural changes (Hofman and Elzen, 2010).
* One lesson from the system innovation literature is therefore to frame roadmapping exercises around socio-technical systems of functional need (housing, health, and mobility), connecting technologies with end-use application and thereby completing the entire value chain**.** By taking this end-use approach, roadmaps are better equipped to inform decision making processes that also have to deal with social, economic and political complexities.
* Next to informing decision making processes, roadmapping exercises can function as a tool to mobilise and structure actor networks and develop their foresight capabilities (Cagnin *et al.*,2012). Central to these are technological expectations that will help shape innovation activities and as a result influence technological developments that ultimately occur and making governments and other actors to become more adaptive and capable of enacting systemic change (McDowall, 2012). This means however that roadmaps are not necessarily an exercise for expert groups, but that it should be a tool that brings policy, business and societal actors together to better appreciate their mutual positions with regards to future innovation directions (Cagnin*et al.*, 2012) through a process of participatory vison building**.**
* A final point is that it can be challenging to translate long-term visions into short-term action points. The system innovation literature usually uses a back casting approach for this. Back casting can be defined as “generating a desirable future, and then looking backwards from that future to the present in order to strategize and to plan how it could be achieved” (Vertragt and Quist, 2011). Again, this process is often advocated in the form of participatory back casting which is usually performed in the setting of a physical gathering (meeting, workshop) framed around guiding questions (DRIFT, 2011). The benefits of making this process participatory lie in the fact that it not only sets the agenda but also engages those actors responsible for executing it.

### Challenges of roadmapping for system innovation

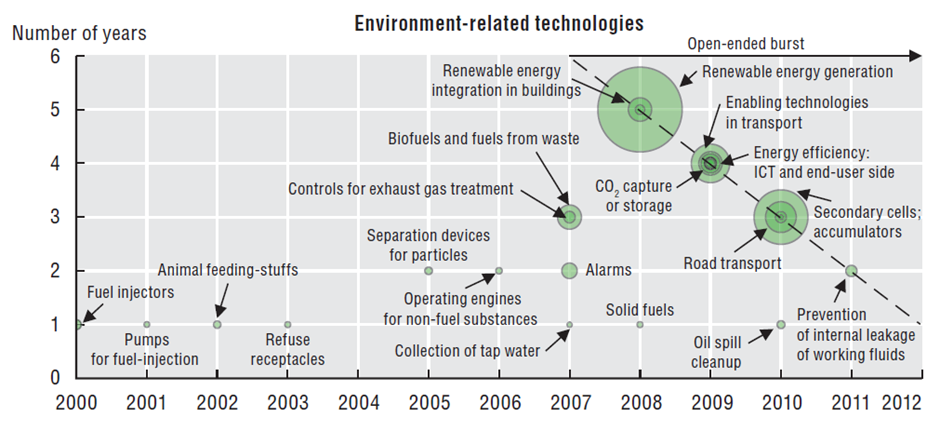
The roadmapping methodology set-out above can be described as ambitious, with the logical implication that this agenda is not without risk. Especially the participatory elements of visioning and backcasting bring questions about who are involved and how they are selected to the centre of the debate. Early experiences in transition management have taught much about the importance that power and politics (*e.g.* regime/niche interactions) plays in these processes, from which important lessons have been drawn (*e.g.* Kern, 2011). More importantly, the community has responded with practical answers. An example of this is a handbook developed by the Dutch Research Institute for Transitions (DRIFT) which gives much attentions to issues such as preparation with practical guidance for team formation, process design, actor analysis, system analysis and the setting-up of a monitoring framework (DRIFT, 2011).

Nonetheless, even when all these steps are taken into account, participatory processes bring challenges when it comes to consensus building and legitimacy. One important lesson to draw is that there does not have to be one outcome, as historical transitions show that a plurality of options are possible and in the end shaped by society, not technology itself (Hofman and Elzen, 2010). Taking this into account, a roadmap can display several pathways rather than one consensus highway.

However, this brings questions of legitimacy to the table, as debates will undoubtedly move towards which scenario is more likely than the other. McDowall (2012) proposes a framework to enhance the legitimacy through the evaluation of four aspects, namely *credibility, desirability, utility and adaptability*, for which a reference can be found in the further reading section.

|  |
| --- |
| Box 4. Credibility of Roadmapping excercises: patent analysis  One way of increasing the credibility of roadmapping is by including patent analysis. Since roadmapping is usually based on expert’s opinions, the objectivity and reliability of roadmapping can be increased by integrating patent analysis into the process (Lee, 2013). Patent analysis is a statistics-based analysis using patent documents. These documents include not only the bibliographic data (e.g. the name of applicant, the date of filing) but also the description of the invention, are a valuable source for the latest technical knowledge. A patent is classified according to technical area based on the International Patent Classification (IPC) and can be accessed through the patent databases, for example the PATENTSCOPE provided by World Intellectual Property Organisation (WIPO).  It is suggested that patent analysis can be used in the roadmapping process to:   * Detect emerging technologies and fields * Analyse the technological strength and weakness of the countries and companies * Identify the technological issues to be solved * Identify key players and related players * Identify key technologies and related technologies.   When applying the concept of system innovation to patent analysis, the analysis could for instance focus on a radical innovation in socio-technical systems, often emerging in a niche. In this context, patent analysis can be used to identify such new fields. More sophisticated forms of patent analysis are more and more equipped to deal with these issues. For example, new fields often arise from the cross-fertilisation of different technologies, which can be identified by measuring the co-occurrence of keywords or IPC codes in patent documents (e.g. Denis, Squicciarini and de Pinho, 2015).  Patent analysis can especially strengthen a roadmapping exercise when it does not only focus on supply-side technologies but also on the demand-side. This can be operationalised by looking at patents that explicitly refer to end-use applications related to societal functions (e.g. mobility, food, housing, health care, energy). In this context, the analysis can be used to find the linkage between technologies and societal problems (e.g. Ittipanuvat et al., 2014).  Furthermore, from the perspective of system innovation, it is important to monitor and recognise the different phases a transition goes through. It goes through four phases of predevelopment, take-off, acceleration and stabilisation (Rotmans, Kemp and van Asselt, 2001). In this context, patent analysis can be used to detect the phases. For example, a new data mining approach, called “DETECTS” (see Dernis, H. et al., 2015, OECD, 2015b) exploits information contained in patents to identify innovative activities whose intensity increases sharply (i.e. “bursts”), compared to previous levels and to the development of innovations in other technology fields.  Figure 1 shows the burst year in X axis, the duration of the burst in Y axis and the burst intensity indicated by the size of the bubble in environment-related technologies. |

Intensity and development speed in environment-related technologies, 2000-12



Source: OECD (2015b)

## Concluding Remarks: the added value of roadmapping in the policy mix

Current policy agendas of steering and accelerating low-carbon transitions bring considerable policy challenges as they apply to long-term normative goals that do not only deal with technological aspects but need to take broader social, economic and political dynamics into account. Large-scale socio-technological transitions are complex and messy, and key challenges lie in engaging different voices, protecting spaces, balancing vested interests, making connections, coordinating experiments, levering investments, facilitating learning and informing expectations (Cagnin *et. al*, 2012). This complexity means that foresight activities do not only need to inform decision-makers by setting of a number of strategic priorities, but also need to support coordination.

This policy note argues that roadmapping for system innovation could be such a coordinating tool. It helps to shape long-term societal visions, and translates them to short term action. By doing this in a participatory way roadmapping does not only function as a tool to inform decision makers but also as way to mobilise and structure actor networks and develop their foresight capabilities.

Some challenges are identified, especially with regards to the participatory nature of vision building and back casting activities. This policy note has discussed some literature that addresses these issues and refers to further readings that present practical solutions for policy makers.

In the end, the success of roadmapping for system innovation will come down to issues of credibility, desirability, utility and adaptability. It is argued that integration with (novel forms of) patent analysis can be an exciting avenue to that these methodologies are not mutually exclusive and can in fact strengthen each other.

In addition, applicability also depends on the place a tool takes up in a broader policy mix. It is argued that roadmap activities for system innovation are very complementary to defining a common research agenda through priority setting. Where priority setting could be done at early stages of a policy cycle, roadmapping is more applicable to later stages of defining concrete strategies though participatory vision setting and back casting. Furthermore, roadmapping for system innovation can be a great tool in a mix that supports actual implementation, as it actively engages those actors responsible for doing so. Roadmapping can thus open up and create experimental spaces for new ideas to emerge and develop, which will be crucial in trying to find novel solutions to grand challenges.

Although roadmapping can be seen as an attractive starting point for policy making, it shouldn’t be seen as a one-off exercise. Technological transitions are long-term projects that are not simply planned, no matter how rigorous foresight activities are executed. Instead, roadmapping should be seen as a tool to structure the continues need for foresight capabilities, in which a continuous reflexive circle is created by shaping visions, back casting, and then going forward again in a process that can best be described as goal-oriented incrementalism (Rotmans, Kemp and van Asselt, 2001).

In addition to the above aspects, STI policy roadmaps need to be integrated in the broader policy decision making and different level STI strategy implementation. Since roadmaps are comparably new tools in the overall policy making sphere one might expect reasonable resistance towards new instruments by the established communities. This is even more the case when it affects the scientific community which might oppose management instruments which originate from industrial management concepts as in the case of roadmaps. The main argument for resisting STI policy roadmaps is probably the uncertainty and the long time horizon underlying the roadmap, scenarios and activities described and also the fact that structuring STI activities and breaking them down to a level which allows effective roadmapping is clearly more ambitious than for comparable narrow focused short term horizon industrial roadmaps. Moreover STI policy roadmaps need to balance the technology and the application aspect carefully. Also there remains the challenge to define strong criteria which are used for evaluating the different roadmap paths. The choice of criteria eventually determines the quality and validity of the roadmaps

Finally there is a challenge to monitor and steer the implementation of the roadmaps in the institutions’ daily operations. Frequently such monitoring schemes are characterized by strong formal reporting procedures which show a tendency to develop bureaucracy. In addition such reporting schemes are in many cases subject of interpretation of the information included in the reports prepared, e.g. the standard problems with measuring and monitoring STI applies here as well (Carayannis et al 2015).

## Bibliography

Cagnin, C., Amanatidou E, and Keenan, M. (2012) *Orienting European innovation systems towards grand challenges and the roles that FTA can play, Science and Public Policy* 39 (2): 140-152.

DRIFT (2011), *Urban Transition Management Manual, Drift, Rotterdam*, the Netherlands.

Denis, H. *et al.* (2015), “*Detecting the emergence of technologies and the evolution and co-development trajectories in science (DETECTS): a ‘burst’ analysis-based approach.”*

Elzen, B., Geels, F. and Green, K. (2004), *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*.Edward Elgar Publishing

Gassler, H., Polt, W., Rammer, C. (2007): *Priority setting in technology policy – historical developments and recent trends.* In: Nauwelaeres, C., Wintjens, R. (Eds.): *Innovation Policy in Europe. Measurement and Strategy.* Edward Elgar Publishers, pp 203-224

Geels, F.W. (2002), *Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study*. Research Policy 31 (8–9), 1257–1274.

Hofman, P. S. &Elzen, P. (2010) *Exploring system innovation in the electricity system through sociotechnical scenarios, Technology Analysis & Strategic Management*, 22:6, 653-670

IEA (2014), *Technology Roadmaps How to Guide*, 2014 edition. Paris, France.

Ittipanuvat, F. *et al.,* (2014), *Linkage between technology and social issue: A Literature Based Discovery approach.*

Kern, F. (2011*), Ideas, institutions, and interests: explaining policy divergence in fostering 'system innovations' towards sustainability. Environment and Planning C: Government and Policy. vol 29, no 6. pp. 1117-1134.*

Lee, S (2013), “*Linking Technology Roadmapping to Patent Analysis*”

McDowall, W., (2012) *Technology roadmaps for transition management: The case of hydrogen energy, Technological Forecasting and Social Change*, 79, 3, p 530–542

OECD (2015a), The Innovation Imperative: Contributing to Productivity, Growth and Well-Being. OECD Publishing, Paris.DOI: http://dx.doi.org/10.1787/9789264239814-en

OECD (2015b), *OECD Science, Technology and Policy Scoreboard 2015*

OECD (2016) Enabling the Next Production Revolution, Interim Report. C(2016)43/REV1. Unpublished working document.

Pinch, T. J., & Bijker, W. E. (1984), *The Social Construction of Facts and Artefacts; or How the Sociology of Science and the Sociology of Technology might Benefit Each Other*, Social Studies of Science, vol. 14, 399-441.

Rip, A., & Kemp, R. (1998),Technological change. In: S. Rayner & E.L. Malone (Eds.), *Human choice and climate change*. Vol. II, Resources and technology. Battelle Press, Columbus, OH, pp. 327-399

Vergragt, P.J., & Quist, J. ( 2011). *Back casting for sustainability: Introduction to the special issue. Technological Forecasting and Social Change* 78, 747-755.

UN-SDSN (2015) *Getting Started with the Sustainable Development Goals, A Guide for Stakeholders, Sustainable Development Solution Network*.

Demonstration Support  
  
A System Innovation Perspective

**The quick read**

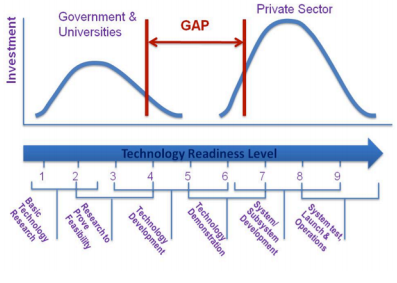
This policy note addresses how a system innovation perspective for technology and demonstration support stresses the importance to actively include a wider variety of actors to facilitate broader learning. It also illustrates the importance of designing demonstrators around concepts, visions or guiding principles rather than technologies. Furthermore, it is suggested that system innovation can function as a useful frame to distinguish between different phases and different types of demonstrators. Finally, system and actor analyses are discussed as an example of how system innovation thinking can be practically applied when designing an appropriate demonstrator.

## Introduction

Technology demonstration projects, also known as demonstrators are used to create awareness among the innovation community / businesses by showing the operation and workability of proofs of concepts which are mostly complex and often too costly and uncertain for companies to operate on their own premises with their sole funds. Furthermore demonstrators illustrate the scientific and technological competences of the S&T community and long term technological solutions which often have a clear practical application yet or which have uncertain applications. The funding of demonstration projects is an innovation policy tool traditionally used to bridge the gap between R&D and widespread commercialisation of a technology. Within the more traditional fields of science and technology management, demonstration is seen as the process of technology development by testing and promoting applications in the field. In more general terms, the goal is to help overcome the many uncertainties involved in order “to shorten the time within which a specific technology makes its way from development and prototype to widespread availability and adoption” (Lefevre, 1984).

Demonstration and development traditionally takes place in the space between proof of feasibility of a technology and its operational development and uptake into the market (Figure 1). This space is corresponds to the technology readiness levels 4 and 6, although there is some debate among technologists of the exact corresponding match between TRL and demonstration given that technologies are increasing converging and interacting so that their stage of development may already quite advanced in some regards but underdeveloped in terms of interoperability with pre-existing systems in which they may be integrated.

**Figure 2 Demonstration: filling the gap between research and the market**



Source: Doern, F. (2015)

However, conventional approaches to demonstration support are criticised for being too technocratic and not taking social and political considerations sufficiently into account, (Kemp *et al.*). As a result, many demonstrations are now not only focusing on technological aspects but are also addressing practical, institutional and wider societal drivers and barriers to widespread diffusion. (Harborne and Hendry, 2009).This has led to a variety of different uses of the term in different disciplines with often very different objectives (Frishammer*et al.,* 2015)

In practice, it is observed that demonstration projects often have *multiple* objectives, and programmes typically shift between technical, economic and commercial goals (Harborne and Hendry, 2009). Although this is considered a positive development, one result is that demonstrations can be seen as a cure-all policy and often have a lack of coherence and miss a well-defined strategy (Frishammer*et al.,* 2015).

This policy note argues that system innovation perspective is valuable for a better understanding of the multiple objectives of demonstrations and will focus on two main aspects

* A system innovation perspective can provide methodological grounding and a clear framework for the use of demonstration with the purpose of facilitating broader learning.
* A system innovation perspective can give policy makers better guidance in when to support what type of demonstration project

This policy note explores the implications of system innovation on demonstration support and suggests how a system innovation perspective can help in design and timing of different type of demonstrators.

### Implications of the system innovation concept for demonstrations

A socio-technical understanding of innovation processes shows that successful technological transitions do not only need technological learning, and need to go together with broader social learning. Schot and Geels (2008) identify seven different types of learning that are of importance, these are:

* technical aspects and design specifications;
* market and user preferences;
* cultural and symbolic meaning;
* infrastructure and maintenance networks;
* industry and production networks;
* regulations and government policy;
* societal and environmental effects.

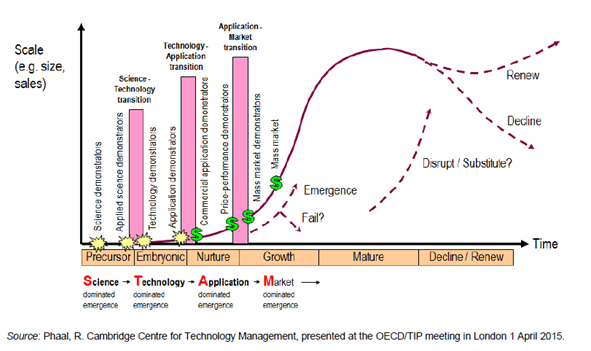
Many of these different types of learning do not simply need accumulation of facts and data, *i.e.*first-order learning, but also demands changes in cognitive frames and assumptions, i.e. second-order learning (Schot *et al*.). The literature suggests two ways of enabling broader learning in experiments, these are:

* Include different actors that are usually considered as outsiders. In other words, users, their daily routines and their social context (*e.g.,* household or community) should be taken more seriously as much of the learning has to be done by them. Looking at smart0grid demonstration projects, Verbong *et. al.* show that the preference set of users should not be considered as a given, and more can be than simply trying to adjust behaviour through (price) incentives. Instead, Verbong *et al*. argue that by making users central and active actors in demonstrations they can be considered as possible solutions, and not only as barriers, for further technological diffusion (Verbong*et al.*).
* Redirect demonstrations more towards concepts, visions and guiding principles rather than technologies. In this respect, the transition management literature stresses the importance of creating these visions before starting experiments. (Schot and Geels, 2008)

### Different types of demonstrations, different levels of maturity

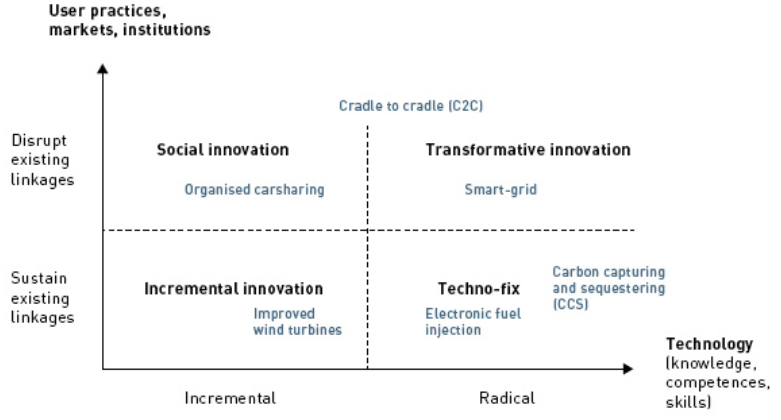
Demonstration support is a popular tool to promote technologies with high-potentials that are not market-ready yet. Phaal (2015) therefore stresses the importance of identifying the different phases a product can go through before reaching market maturity. Depending on the identified uncertainties, Phaal argues that demonstrator can focus on science, applied science, technology, application, commercialisation, price‑performance or mass-market. Identifying these different phases is important in designing a demonstration project that actually addresses the key issues. For instance, if the key uncertainties are still purely of a technological nature, there is usually less need to support large-scale demonstration at that point.

Figure 3. Technology phases, transitions and demonstrations



The above model is helpful but still has a strong focus on technology-push, in which science invents, industry applies and society conforms (Rip *et al.*, 2010). However, system innovation tells us that technology can be seen as socially constructed in a co-evolutionary process between the artefact and its users. This implies that the domestication of technologies in societal systems of functional needs is dependent on the way people interact with them. Nevertheless, there are differences between types of innovations and the relative importance of user-interactions. Figure two is a matrix depicting four different types of innovations, showing to what extend these innovations are technologically radical and to what extend they disrupt existing linkages in markets, user practices and institutions.

Figure 4. Classification of innovation based on technology and market/user practices (Kemp, 2009)



Source: DRIFT, 2011

This matrix provides a framework to not only assess the different phase of technological development, but also the different natures of innovations which have implications for the type of learning that is needed.

Box 4. System and Actor analysis as guidance for demonstrator design

The two frameworks presented above are helpful in in understanding different phases and types of demonstrators. This final section aims to bring more practical guidance and argues that a structured system analysis and actor analysis are helpful for the design of a demonstrator, as proposed by the Dutch Research Institute for Transitions (DRIFT).

**System Analysis**

Having an integrated overview of the system is essential to identify the main system’s properties, interactions and problems and can be seen as a tool to determine the phase and type of the innovation. DRIFT (2011) proposes a four-step process for doing a system analysis, consisting of:

* Define the boundaries of the system in space, time and theme (e.g. emission reduction for transport in Paris);
* Structure the system by relevant stocks and create indicators for them (e.g. amount of cars, amount of bikes, air pollution);
* Collect data to evaluate stocks and indicators;
* Analyse the data, focusing on the current state of the system, its development over time, the relationships between the indicators, etc. A system innovation perspective also draws specific attention to analysis of the dominant culture, structure and practices (regime), as well as emerging alternatives (niches) and major landscape pressures (DRIFT, 2011).

The result will help to bring insightful views on major issues and tensions and be used to design demonstrator projects.

**Actor Analysis**

An actor analysis is obviously closely related to a system analysis. From a system innovation perspective it is particularly important to not only focus on resources actors can bring to a project, but put a strong emphasis on competences. In this regard it is especially important to bring together actors with a diversity of competences and backgrounds (DRIFT, 2011).

## Bibliography

DRIFT (2011), *Urban Transition Management Manual, Drift, Rotterdam*, The Netherlands.

Doern, F. (2015), An Assessment of Technology Roadmaps for Advanced Manufacturing, Manitoba, Canada.

Elzen, B., Geels, F. and Green, K. (2004), *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*. Edward Elgar Publishing

Frishammar, J., Söderholm, P., Bäckström, K., Hellsmark, H. and Ylinenpää, H. (2015), *the role of pilot and demonstration plants in technological development: synthesis and directions for future research, Technology Analysis & Strategic Management*, 27:1, 1-18

Harborne, P. and Hendry, Cp, *Pathways to commercial wind power in the US, Europe and Japan: The role of demonstration projects and field trials in the innovation process, Energy Policy*. Volume 37, Issue 9, September 2009, Pages 3580–3595

Kemp, R., Schot, J., and Hoogma, R. (1998), *Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management, Technology Analysis & Strategic Management*, 10 (1998), pp. 175–195

Kemp, R. (2011). *Ten themes for eco-innovation policies in Europe*.S.a.P.I.En.S, (October), 1–19.

Lefevre, S.R.,1984. *Using demonstration projects to advance innovation in energy. Public Administration Review*, Nov/Dec, pp. 483–490.

OECD (2015a), *System Innovation: Synthesis Report*.

Rip, A., Joly, P. &Callon, M. (2010) *Reinventing Innovation. in M. Arentsen Governance and Innovatio*n. 1–13.

Rotmans, J., Kemp, R., & Van Asselt, M. (2001*) More evolution than revolution: transition management in public policy*. Foresight, vol. 3 (no. 1), pp. 15-31.

Schot, J. and Geels, F. (2008), *Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy, Technology Analysis & Strategic Management* Volume 20, Issue 5.

Carayannis E.G., Meissner D., Edelkina A. (2015) Targeted innovation policy and practice intelligence (TIP2E): concepts and implications for theory, policy and practice. The Journal of Technology Transfer, doi: 10.1007/s10961-015-9433-8

Meissner D. (2015) Developing ‘Green Thinking’ Towards Sustainability. International Journal of Social Ecology and Sustainable Development, 6(3), iv-vii, July-September 2015

Vishnevskiy K., Karasev O., Meissner D. (2015a) Integrated roadmaps and corporate Foresight as tools of innovation management: The case of Russian companies, Technological Forecasting and Social Change. 2015. Vol. 90, part B. No. January. P. 433-443.

[Vishnevskiy K.](https://www.hse.ru/en/org/persons/4435519), [Grebenyuk A. Y.](https://www.hse.ru/en/org/persons/4435512), [Kindras A.](https://www.hse.ru/en/org/persons/14267979), Meissner D. (2015b) [Integration of roadmapping and scenario planning for implementing science, technology and innovation strategic priorities – the case of Russia](https://publications.hse.ru/en/view/164823419) // International Journal of Foresight and Innovation Policy. 2015. Vol. 10. No. 2-4. P. 126-144.

Carayannis E., [Grebenyuk A. Y.](https://www.hse.ru/en/org/persons/4435512), Meissner D. [Smart roadmapping for STI policy](https://publications.hse.ru/en/view/181847399) // Technological Forecasting and Social Change. 2016

Gokhberg L., Meissner D. (2016) [Seizing Opportunities for National STI Development](https://scholar.google.ru/scholar?oi=bibs&cluster=260015047523894296&btnI=1&hl=en). In Gokhberg L., Meissner D., Sokolov A. editors Deploying Foresight for Policy and Strategy Makers - Creating Opportunities Through Public Policies and Corporate Strategies in Science, Technology and Innovation., Springer Heidelberg/ New York/ Dordrecht/ London .

1. Excerpts from the 2016 Ministerial Council Statement "Enhancing Productivity for Inclusive Growth"(C/MIN(2016)8/FINAL). [↑](#footnote-ref-1)
2. The paper was prepared by the OECD Secretariat, principally by Gijs Diercks, Daeyhun Oh, Shizuo Oya and Mario Cervantes, who provided overall direction and co-ordination. The Secretariat thanks Ian Hughes of Ireland for substantive input to the policy note on priority setting. [↑](#footnote-ref-2)