HOW

to build effective policy mixes supporting eco-innovation?

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Outlook 8

How to build policy mixes for transformative eco-innovation?

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Key messages

Policy makers should consider the wider policy mix when designing, implementing and evaluating both individual instruments and policy portfolios aiming at providing support for eco-innovation.

This has significant implications for governance and processes of policy-making from agenda setting to evaluation.

Policy design and assessment procedures (such as ex ante impact assessments) should take into account the wider policy mix, rather than focusing on the benefits and costs of individual interventions in isolation.

A successful policy mix should be: credible; associated with clear long-term goals; coherent, consistent and comprehensive; sufficiently stringent to drive real change; and embedded within governance arrangements that allow for experimentation, learning and evaluation.

1 INTRODUCTION

Policy for transformative eco-innovation necessarily crosses traditional policy domains (such as innovation policies, energy policy, environmental policy). This can easily result in policies that are mutually inconsistent, or that miss opportunities to generate positive synergies.

The literature on policies in support of transformative eco-innovation, which is reviewed in this Outlook, has increasingly emphasized the need for policies to act in concert, as a coherent policy mix. A key message from this review is the importance of a broader perspective on the governance of eco-innovation. Rather than comparing, selecting and evaluating specific policy instruments, a policy mix perspective requires an ongoing and broader evaluation of how multiple policies and policy instruments interact and co-evolve.

This Outlook provides an overview of key issues related to policy mixes in the context of transformative eco-innovation. The Outlook reviews the relevant evidence and theory, and suggests key lessons for those developing and evaluating policy mixes.

2 SYSTEMIC POLICIES FOR SYSTEMIC CHALLENGES: FROM TINBERGEN TO THE POLICY MIX

Traditionally, much discussion of policy analysis has been informed by the 'Tinbergen Rule' – the idea that each policy goal should be addressed with a single policy instrument. Yet it has become increasingly clear that policy is best understood not as a collection of distinct programmes and instruments, but as a policy mix.

The growth in interest in policy mixes comes partly from a recognition that the real-world of policymaking does not correspond with the simple versions presented in policy textbooks. Policy making is frequently a messy business. New policies build on existing regulatory powers, institutions, and 'grandfathering' provisions; old policies leave a legacy of legal structures, definitions and organisational capabilities. Policymakers rarely have the luxury of a clean slate, and the messy reality is that complex multi-instrument and multi-objective policy mixes are the norm, rather than the exception.

The interest in policy mixes is also motivated by a recognition that many policy do-mains—particularly eco-innovation—involve systemic problems that require systemic policy responses. Single policy instruments are simply not appropriate for complex combinations of market and systems failures, or when the direction of development of socio-technical systems must be re-oriented towards sustainability.

Despite widespread recognition of the value of a policy mix perspective, formal processes for policy appraisal have tended to remain focused on single interventions. Until recently, formal guidance on conducting policy appraisal (ex ante Impact Assessments, for example) typically paid little attention to potential policy interactions. The last decade has seen increasing attempts to tackle appraisal of policy mixes (see, for instance, the EU's 'fitness check' procedure, which aims precisely at evaluating groups of policy interventions).

This Outlook provides an overview of key issues related to policy mixes in the context of transformative eco-innovation. The Outlook reviews the relevant evidence and theory, and suggests key lessons for those developing and evaluating policy mixes.

3 POLICY MIX FOR ECO-INNOVATION

3.1 What is a policy mix?

Policy mixes are defined by Kern and Howlett as 'complex arrangements of multiple goals and means which, in many cases, have developed incrementally over many years' (Kern and Howlett, 2009, p.395). In the policy mix perspective, policy instruments are considered in the context of a wider policy, regulatory and political context in which they are designed and implemented.

Rogge and Reichardt (2016) proposed an extended concept of policy mix for sustainability transitions. The authors point out that most research has been based on a narrow definition of policy mix seen as 'interacting instruments aimed at achieving objectives in a dynamic settings' (ibid., p.1623). They argue that policy mix ap-proached from the point of view of sustainability transitions requires a broader scope to encompass its complexity, policy processes and the role of long terms strategies and targets.

3.2. Evidence on policy mixes for eco-innovation

Eco-innovationis simultaneously influenced by many policy instruments. The role and impact of different policy instruments differ depending on the type of innovation, its maturity, level of disruptiveness as well as innovation capacity of actors targeted by direct or indirect policy support. Research analysing effects of policy intervention on eco-innovation has mostly focused on impacts of individual policy instruments (Bergek and Berggren, 2014; Horbach et al., 2012; Kemp and Pontoglio, 2011).

More recently, policy researchers point to the importance of the entire policy mix, including strategies and targets, instruments and processes, in assessing effects of policies on eco-innovation and sustainability transitions (Flanagan et al., 2011; Reichardt and Rogge, 2016). The empirical research focused on effects of combinations of policy instruments on eco-innovation, rather than on impacts of specific policy instruments, is a relatively new but fast-growing field. This review focuses on the emerging body of research focused on effects of policy mixes on eco-innovation, including evidence from qualitative case-study research as well as from empirical econometric and modelling studies. The latter, however, focus on a narrower understanding of policy mix focusing on combinations of selected policy instruments. Despite a highly context-dependent nature of policy mix, a review allows for distilling several stylised facts about what we know about effective combinations of policy instruments to support eco-innovation.

Combinations of innovation and environmental policy instruments are more effective in supporting eco-innovation than any single policy instrument

Policies supporting eco-innovation combine strategic objectives and instruments from different policy domains. These include transversal policies, most notably science, innovation and technology (STI) policy and environmental policy, as well as sectoral policies, such as energy, transport and climate policy. Combinations of innovation instruments with environmental regulation are more effective in supporting eco-innovation than any single policy instrument.

Researchers point out that innovation policy has to be complimentary with (and cannot substitute) environmental regulation, notably emissions pricing. This general view is accepted by innovation researchers (Foxon and Pearson, 2008; Cunningham et al., 2013; Kivimaa and Kern, 2016; Rogge and Reichardt, 2016), political scientists (Howlett and Lejano, 2013; Howlett and Rayner, 2007; Kern et al., 2017) as well as increasingly by economists (Jaffe et al., 2005; Fischer and Newell, 2008; Newell, 2010; van den Bergh, 2013; del Rio, 2017; Costantini et al., 2017).

Long-term vision and targets are key elements of policy mix for eco-innovation

Foxon et al (2008) identify long term objectives as a key element of policy regime for eco-innovation. Researchers point out that long-term commitments, stability, reliability and predictability of policy are all key features that increase credibility of policy and build confidence of market actors (Polzin et al., 2015; Uyarra et al., 2016).

The role of long-term vision and targets was demonstrated empirically in studies focused on the importance of climate targets for companies'innovation strategies and investment decisions (Rogge et al., 2011; Schmidt et al., 2012; Polzin et al., 2015). Schmidt et al. (2012) identify long-term mission reduction targets as an important trigger of RD&D. Polzin at al (2015) report that a clear long-term policy commitment (strategic planning and insitutionalisation), specificly energy strategy, was conducive to investments in renewable energy technolgies as institutional investors favoured a long-term framework with a clear vision. Their study confirms the strong role of a long-term strategy in an effective policy mix.

Policy mixes supporting eco-innovation need to balance support for technology variety and deployment of mature clean technologies

The policy mix for eco-innovation needs to ensure balance between, on the one hand, technological diversity to avoid technological lock-ins and, on the other hand, support for deployment of mature eco-innovations that can contribute to achieving environmental goals in the short-to medium-term. Policy mix with an ambition to provide support for research, development and deployment of eco-innovation should comprise a combination of technology-specific and market-based instruments (Kemp and Pontoglio, 2011; Azar and Sandén, 2011; del Río and Bleda, 2012; van den Bergh, 2013). The choice of instruments depends on the policy goal, implementation context as well as the maturity and disruptiveness of the supported innovation.

Azar and Sandén (2011) argue that policies with an explicit goal to support for eco-innovation cannot be technology neutral in practice. The dichotomy between technology neutral and technology specific policy instruments is obsolete as policy instruments supporting innovation always provide support to a specific technology but at different 'technology hierarchy level'. A policy that is 'specific' on a certain technology level might be perceived as 'neutral' on the hierarchy level below. Thus the debate about whether or not government should engage in "picking winners" is a distraction: the issue is the level at which government choices are made.

Policy makers have to decide how specific the policy mix should be rather than choose between neutral and technology-specific support. Investments in large-scale infrastructural projects (e.g. electric urban mobility, railway networks, smart grids, waste infrastructure) are examples of instruments which by their nature cannot be technology neutral. For example, investment in waste incinerators without ensuring waste sorting can lead to wasting secondary resources and prevent development and deployment of re-use and recycling technologies and practices.

Unintended effects of focusing eco-innovation policy mix on too narrowly or too broadly defined technology hierarchy levels may lead to negative societal or environmental impacts related to supporting the production and use of selected sub-optimal technology or product. It may also effectively lock out emerging technologies with higher learning potential (Schmidt et al., 2016). Authors suggest that focusing policy support on application of technology instead of technology itself may prevent unintended technological lockins. Figure 1 shows technology hierarchy levels and relevant deployment policy instruments.

In order to reflect the full policy mix for eco-innovation, the illustration should be complimented with STI policy instruments, which can also be designed to be more or less technology specific (Azar and Sandén, 2011). The STI instruments range from generic instruments supporting absorption capacity of actors within innovation system (e.g. business advisory services for SMEs) to a more specific support focused on specific technology field (e.g. industrial R&D for a specific technology area or application or a support for cleantech clusters active in a selected area). Innovation policy also supports non-technological innovation, which can be crucial for effective adoption of clean technology or improvement of manufacturing processes.

Figure 1. Technology hierarchy levels and relevant deployment mechanisms

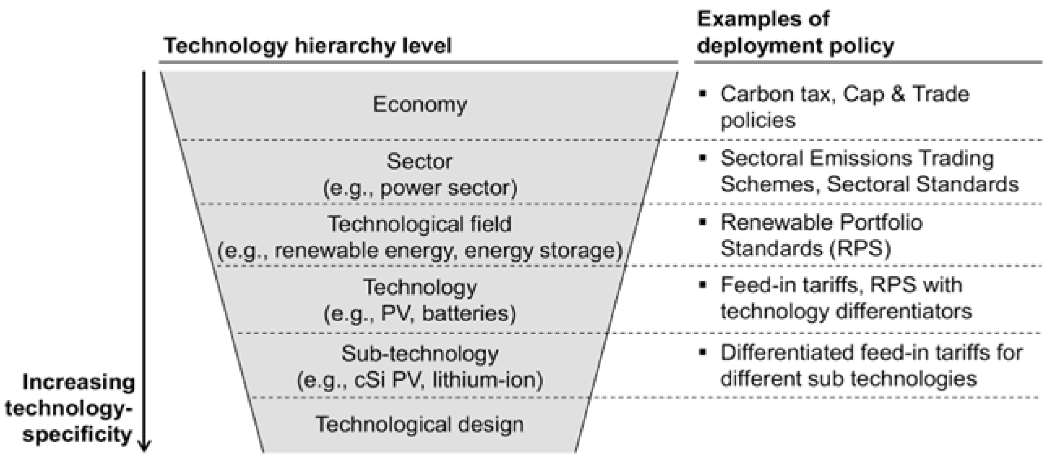

Fig. 2. Technology-specificity, technology hierarchy levels and examples of deployment policies – adapted from Winskel et al. (2013).

Source: Schmidt et al 2016

Policy for eco-innovation needs to be catered for the maturity of technology

Effective policy mix needs to be adapted to the maturity of the supported eco-innovation area and technology (Altenburg and Pegels 2012). Supporting emerging innovation area will need an emphasis on different policy instruments than providing support for large-scale deployment of mature technology. Direct support for research, development and demonstration is crucial in early stages. Targeted subsidies (e.g. FIT) are appropriate once the technology is proven on a commercial scale. Subsidies can be phased out when the technology is fully competitive and the existing alternatives are less sustainable. Market-based instruments become more effective when technology is relatively mature and more likely to attract private research.

IIn order to be effective, knowledge-intensive policy mixes for eco-innovation require particularly long-time horizons which allow to follow innovation from R&D stage to commercialisation.

Azar and Sandén (2011) offer a similar reasoning. They argue that market-oriented policies (e.g. carbon tax or a cap-and-trade system) are more effective when applied to mature technologies. Market-based instruments need to be complemented and balanced by other policies that foster a broad range of technologies and policies that lock-out technologies which are detrimental for health and environment.Technology-specific market-oriented policies (e.g. FIT) are appropriate to commercialize emerging technologies and bridge the gap between innovation and large-scale diffusion. Dedicated market support should be given to technologies with a high competitive potential which can benefit from learning and economies of scale enabled by policy intervention.

Policy mix for eco innovation needs to be adapted to the needs and capacities of actors in the targeted sectors, regions and innovation value chain

Policy mix has to be designed taking into account specific needs of actors along innovation value chain, in particular barriers and drivers of their engagement in innovation activity. Polzin et al (2015) demonstrated empirically that impact on institutional investors decisions of the same policy instruments differed between sectors of RE. The argue that policy should recognise it and implement technology-specific policies recognising specific contexts of intervention. They concluded that investors' decisions in invest in RE are motivated by instrument mix. The common feature of the relevant instruments is an influence on the return side of investments, i.e. higher income through grants and subsidies and lower capital costs through FITs support their openness towards RE investments. Tax regulation, on the other hand, does not necessarily have conducive effects as many institutional investors already have a tax optimised corporate structure (Polzin et al., 2015).

Designing and implementing policy mix for eco-innovation needs appropriate timing and sequencing of policy interventions

Designing policy considering the maturity of technology and capacity of actors calls for appropriate timing and sequencing of policy instruments (OECD 2015). Policy for emerging innovation niches, for example, may consist of combination of foresight and networking combined with the technology-neutral instruments. A more specific support is called for at the take-off phase when further development may require technology specific funding (including subsidies and taxes). When an area is mature explicitly technology-specific instruments may be slowly phased out. Appropriate timing and sequencing of interventions requires a strong policy intelligence (OECD, 2015). Figure 2 suggests combinations of instruments or different stages of transition.

(Next page) Figure 2. Policy instrument mixes for different stages of transition.

Table 3.4 Main policy contributions according to transition stages

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

Source: OECD Secretariat.

Source: OECD 2015

Effective policy mixes for eco-innovation require system evaluation and policy learning capacity

Designing effective policy instrument and portfolios for eco-innovation requires a systemic view on both policy mix and innovation systems (Arnold, 2004; Kemp, 2011; Magro and Wilson, 2013). Evaluating effects of policy mixes for eco-innovation is particularly challenging as it requires transdisciplinary knowledge and expertise which are usually not used in evaluations and impact assessments of research and innovation policy. Evaluating policy mix is highly challenging due to its complexity. This challenge has been recognised in the literature (Cunningham et al., 2013; Kivimaa and Kern, 2016; Magro and Wilson, 2013; Rogge and Reichardt, 2016; Smith et al., 2010). Authors point to conceptual and methodological challenges of evaluating policy mix but, at the same time, consider conducting systemic policy mix assessments crucial for improving policy design and implementation (Cunningham et al., 2013). To date, however, there has been only a limited reflection on how to assess, let alone measure, wider socio-economic and environmental impacts of policy mixes.

Del Rio (2017) illustrates importance of capacity to critically analysing alternative policy mix designs. Del Rio discusses the case of energy and climate policy mix with a focus on interactions between a market-based cap-and-trade scheme (the European Union Emissions Trading Scheme - EU ETS) and renewable energy targets for deployment of electricity from renewable energy sources (RES-E). The combination of ETS and RES-E received criticism from economists who claimed that RES-E is an expensive option to reduce CO2 emissions and that support for RES-E deployment may negatively interact with the ETS by reducing the CO2 price.

Del Rio suggests that the critics did not fully take into account empirical evidence and did not consider implications of alternative instrument choices and design features of instruments. He argues the interactions between the ETS and RES-E depend on the choice of instruments and design features of speciffic instruments. Del Rio illustrates differences between combinations of ETS with a quantity-based tradable green certificates (TGCs) and combination of ETS with price-based feed-in tariff (FIT). He argues that the CO2 price might be more likely to decrease under a price-based RES-E support instrument, such as FIT, than under a quantity-based one, such as TGCs. This may be caused by an effective reduction of the stringency of the CO2 cap as a result of increased RES-E generation: FITs have shown to be more effective than TGCs in increasing RES-E deployment. This may, however, indirectly encourage investment in fossil fuels.

Del Rio argues that coordination between the RES-E and CO2 targets are easier under a quantity-based RES-E instrument than under a price-based one. The CO2 emissions avoided under TGCs are easier to calculate than under FITs which makes it easier to adjust the CO2 cap accordingly. Del Rio points out that the reduction of CO2 prices would not occur under a carbon tax as the carbon price (tax rate) would not be affected by RES-E deployment as it occurs under ETS where RES-E deployment affects the CO2 allowance price. He calls for further analysis on the impact of different instruments on the interactions between policies.

4 TOWARDS TRANSFORMATIVE ECO-INNOVATION POLICY

The rationale for policy intervention for transformative eco-innovation stems from the nature and scale of market and system failures preventing innovation needed to achieve sustainable development. Put simply, system failures require system innovation. System innovation requires policies designed and implemented in a systemic manner.

This section provides short evidence-based descriptions of key characteristics of policy mixes for eco-innovation emerging from the literature. Rogge and Reichardt (2016) usefully distinguish between policy mix characteristics and assessment criteria. The latter are well-established ex-ante and ex-post criteria applied in impact assessments and evaluations of single policy instruments, such as effectiveness, efficiency, equity or feasibility. The former group comprises terms speciffically used for characterising the policy mix. They include most notably consistency, coherence, credibility or comprehensiveness (OECD, 2003; Foxon and Pearson, 2008; Howlett and Rayner, 2007; Kern and Howlett, 2009; Rogge and Reichardt, 2016). Rogge and Reichardt (2016) argue characteristics may impact effectiveness and efficiency of policy mixes.

This review focuses in the core characteristics of policy mix, including consistency, coherence, comprehensivenessand credibility, as well as characteristics specifically relevant for policy mixes supporting ambitious eco-innovation goals such as directionality, stringency, experimentation and adaptability.

Directionality

Directionality refers to the direction, orientation or mission guiding design and implementation of policy intervention towards a desired transformative change (Weber and Rohracher, 2012; Reichardt and Rogge, 2016). Directionality can be introduced to policy mix by identification of major challenges in policy visions, setting specific policy goals and targets as well as translating those goals into criteria guiding policy implementation. In the context of eco-innovation directionality means recognising environmental sustainability challenges as challenges for innovation policy, and more concretely integrating them into objectives, targets and implementation criteria of innovation policy mix.

Schot and Steinmueller (2016) introduced the notion of 'framings' of innovation policy. The third framing - 'transformative change' - calls for an ambitious innovation policy to direct and drive sustainability transitions. This framing requires multi-sectoral innovation policy reconciling economic, social and environmental goals.

The OECD underlined the need for horizontal (or cross-cutting) approaches to innovation policy addressing wider societal and environmental goals, the so-called 'third-generation' innovation policy, more than a decade ago (OECD 2005). The third-generation innovation policy was expected to transcend traditional vertical policies and inter-link with other policies such as scientific research, education and training, environmental policy, transport, health, etc. If placed in the MONIT taxonomy, innovation policy focused on eco-innovation falls under the set of policies which aims at both better quality of life and natural environment as well as at increased competitiveness and higher economic growth. In terms of its scope and integration, it can vary from largely sectoral innovation policies, in which eco-innovation is supported within many policy domains, to a multi-sectoral integrated and coherent innovation policy.

Stringency

Stringency addresses the ambition level of an instrument and is typically associated with regulatory and economic instruments, such as emissions standards or emissions trading(Rogge and Reichardt, 2016). Botta and Kozluk (2014) define stringency as the "cost" imposed on polluting or other environmentally harmful activity. They argue that stringency can be analysed in relation to one instrument (e.g. regulation) and to the whole policy mix.

Stringency is usually considered to have positive impact on innovation (Rogge et al., 2011; Schmidt et al., 2012; Botta and Kozluk, 2014). Rogge et al (2011) find that the innovation impact of the EU Emissions Trade System has been limited because of the scheme's initial lack of stringency.
Based on their empirical study of firms' perceptions of EU ETS, Schmidt et al. (2012) argue that policy stringency is a critical element of a policy mix that can steer the rate and direction of technological change toward low carbon technologies.

Consistency, coherence and synergy

Numerous studies call for increased consistency and coherence of policy mix for eco-innovation (Foxon et al., 2004; Kemp and Rotmans, 2005; Foxon and Pearson, 2008; Reid and Miedzinski, 2008; Kemp, 2011; Rogge and Reichardt, 2016). The need to study consistency and coherency rests on the assumption that improved consistency of policy instruments and better coherence of policy processes may both contribute to higher effectiveness and efficiency of policy mix.

Failure to ensure consistency and coherence may result in decreased effectiveness or give rise to unintended effects called "escape routes" by van den Bergh (2013) or rebound effects by Vivanco et al (2015). Van den Bergh (2013) gives the following examples such unintended effects:

- Direct market support of clean energy leading to more energy use because of lower prices of clean energy and lower prices for fossil fuels caused by competition from clean energy (green paradox).

- Ecolabels and regulations offering no encouragement for further environmental improvements in the absence of dynamic adjustments.

- Carbon policies causing production to shift to countries with less stringent carbon policies causing a global increase in carbon emissions.

- Carbon policies creating new risks and increases in other pollutants.

Rogge and Reichardt (2016) point to the lack of clarity and different definitions of consistency and coherence in the literature. They propose to distinguish between the two terms. Consistency is to capture "how well the elements of the policy mix are aligned with each over, thereby contributing to the achievement of policy objectives. It may range from the absence of contradictions to the existence of synergies within and between the elements of the policy mix." They distinguish between consistency on different levels, including consistency of the policy strategy (i.e. alignment of objectives across different relevant strategies and policies), instrument mix (i.e. positive, neutral or positive interactions between instruments), and consistency of the instrument mix with the policy strategy (i.e. the ability of the policy strategy and the instrument mix to work together in a unidirectional or mutually supportive fashion). The more consistent policy mix the more effective and efficient it becomes.

Rogge and Reichardt (2016) relate coherence to the policy making processes and mechanisms. Coherence is about "synergistic and systematic policy making and implementation processes process of policy making contributing – either directly or indirectly – towards the achievement of policy objectives. "Coherence can be achieved via structural, organisational and procedural mechanisms, including strategic planning (e.g. joint planning initiatives), coordinating structures (e.g. innovation councils) or communication networks. They consider two main approaches for improving policy coherence are policy integration and policy coordination. Coordination strives at aligning the tasks and efforts of public sector organizations by e.g. enhancing information flows through formal mechanisms (e.g. establishment new policy departments such as departments bringing together energy and climate as in the UK and Denmark). Policy coherence becomes particularly important for polices aiming at enabling system innovation. System innovation, however, "aims to achieve much more than coherence or policy alignment since it involves actors outside government, notably firms and civil society, and takes a longer-term view" (OECD, 2015).

OECD (2003) places consistency and coherence in the broader concept of policy integration. It differentiates three different levels of policy integration: policy coherence, policy coordination and policy consistency. Policy consistency means ensuring that individual policies are not internally contradictory. Policy coordination means getting the various institutional and managerial systems, which formulate policy, to work together. Policy coherence goes beyond coordination and consistency and is defined as a process of "ensuring the systematic promotion of mutually reinforcing action, by the concerned government and non-government players, in order to create and maintain synergies towards achieving the defined objective" (OECD, 2003). Policy coherence is not possible without striving for internal consistence and improving mechanisms of policy coordination. The challenge of ensuring policy coherence appears as a key in the context of multi-dimensional and multi-actor policy supporting eco-innovation(Reid and Miedzinski, 2008).

OECD (2003) differentiates between three types of policy coherence: horizontal, vertical and temporal. Horizontal coherence is to ensure that individual objectives and instruments developed by various entities are mutually reinforcing.

Strengthening the inter-connectedness of policies and promoting a 'whole-of-government' perspective are ways of promoting the horizontal coherence. The challenge of policy for eco-innovatin equires that governments cooperate internally across different ministries and departments responsible for different policy fields. The fields most commonly concerned with eco-innovation are environmental policy, science and technology policy, economic policy, innovation policy, transport policy, energy policy and agricultural policy. This list is not exclusive as de facto all policy fields can be directly or indirectly concerned. The collaboration should involve both executive and legislative bodies if more profound systemic changes are sought (e.g. legislative bodies need to be engaged if regulatory changes are envisaged).

Vertical coherence is about ensuring that the practices of agencies and autonomous bodies, as well as the approaches of sub-national levels of government, are mutually reinforcing with overall policy commitments. "Programme efficiency" is one way of stressing the need for vertical coherence, and the issue of ensuring compliance across levels of government is a typical expression of this dimension. The subsidiarity principle, understood as designing and implementing strategies and policy instruments at the most appropriate level, can help in ensuring vertical policy coherence (Reid and Miedzinski, 2008).

Temporal coherence is to ensure that policies continue to be effective over time and that longer-term commitments are not contradicted by short-term decisions. Temporal coherence is also about how policies work out as they interact with other policies or other forces in society, including whether future costs are taken into account in today's policy-making. This is probably the most challenging task in the process of developing a sustainable innovation policy as it includes long term sustainability goals, which often are perceived as opposed to short-term economic ambitions. The transition management approach (Kemp and Rotmans, 2005) is an example of an approach, which accommodates both long- and short-term action.

Policy researchers point out that perfect policy consistency and coherence may be impossible to achieve in reality due to inherent differences between actors involved in designing and implementing policy instruments (Carbone, 2008; Rogge and Reichardt, 2016). Policy makers have to recognise complexity of real world policy mixes and adapt their strategies accordingly (Flanagan et al, 2011). Howlett and Rayner (2013) propose strategic policy patching as a realistic policy strategy for improving consistency and coherence of policy mix. They argue there are two approaches to policy design aiming at the increased consistency and coherence: policy packaging or policy patching. Policy packaging refers to a policy design process in which previous policies are discarded and a new policy package is introduced (replacement). Policy patching, on the other hand, refers to a gradual change of policies they liken to upgrading operating systems and is understood "much in the same way as software designers issue 'patches' for their operating systems and programmes in order to correct flaws or allow them to adapt to changing circumstances" (Howlett and Rayner, 2013).

Comprehensiveness

The scale of sustainability challenges influences the scope and nature of the policy mix applied to address them. The perception of the problem limited to the market failure can be associated mainly with the market-based and economic instruments. The need of systemic overhaul of production and consumption patterns and the notion of system failures requires a more comprehensive policy mix comprising many mutually supporting instruments, and different ways of designing, implementing and evaluating policies. See Figure 4 for the suite of selected policy instruments which can provide incentives for transformative eco-innovation.

Comprehensiveness is, therefore, one of the key characteristics of policy mix for eco-innovation (Rogge and Reichardt, 2016). Comprehensiveness typically means that policy intervention is designed, implemented and evaluated considering the systemic nature of innovation and the complexity and transversal nature of societal and environmental challenges facing innovation system. Comprehensive policy mix is characterised by, first, instrument mix including complimentary types of instruments (e.g. market pull, technology push and systemic instruments) which respond to different challenges and different levels of technology maturity and, second, by policy processes and governance mechanisms (notably coordination, learning and collaboration) enabling such a systemic approach.

Figure 3. Policy measures with a potential to foster transformative innovation

	Policy instruments	How they can offer support to eco-innovation
Regulations and standards	Environmental protection regulations	Provides incentives to innovate to comply with environmental performance targets. Provides disincentives for free riders by introducing penalties.
	Product and industrial process standardisation	Provides incentives to innovate to comply with environmental and social performance standards for products and processes
	Extended Producer's Responsibility	Provides incentives for producers to significantly improve environmental performance of their products and services
	Labels and certification	Promotes eco-innovative products and processes by providing information to customers
	Intellectual property rights	Encourages companies to engage in eco-innovation activity, opens access to knowledge important for diffusion of eco-innovation
	Trade policy (e.g. tariffs)	Removes barriers to trade in eco-innovative goods and services; opens access to knowledge important for eco-innovation diffusion; also imposes barriers on environmentally harmful goods and services
Economic and financial instruments	R&D funding	Provides direct support for R&D underpinning disruptive eco-innovation
	Innovation funding for companies	Provides direct support for eco-innovation activity
	Equity support to venture and seed capital	Provides equity dedicated to eco-innovation; de-risks eco-innovation investments
	Feed-in-tariffs and similar subsidy schemes	Provides financial incentives to adopt and diffuse eco-innovative technologies
	Tradable permit systems (including emissions trading)	Provides financial incentive to improve environmental performance by pricing externalities
	Removal of subsidies for environmentally harmful activities	Removes distortion from markets and brings level playing field for eco-innovators
Public procure-ment and demand support	Green public procurement	Creates local markets for eco-innovative goods and services
	Pre-commercial (R&D and innovation) procurement	Creates markets for transformative eco-innovative goods and services
	Support to private demand	Provides incentives for customers to purchase eco-innovative goods and services (vouchers, tax cuts)
Fiscal instruments	Tax incentives for R&D for companies	Tax reduction (CIT) for companies undertaking R&D underpinning eco-innovation
	Tax incentives for technology adopters	Tax reduction (CIT) for companies adopting eco-innovation with environmental and social benefits
	Environmental taxation	Tax reduction (CIT) for companies undertaking R&D underpinning eco-innovation
	Removal of tax reliefs for environmentally-harmful sectors	Removes distortion from markets and brings level playing field for eco-innovators
Industrial policy	Clusters, industrial zones, and science and technology parks	Encourages specialisation in eco-innovation in regions with high potential and/or need for goods and services with environmental and social benefits
	Technology platforms and networks	Promotes information and knowledge sharing on eco-innovation
	Roadmaps and foresight	Creates shared vision, commitments and roadmaps for investment and development of eco-innovation
Capacity building and information provision	Business advisory services for SMEs	Promotes skills and knowledge relevant for eco-innovation
	Local entrepreneurship and business incubation support	Promotes local entrepreneurship focused on eco-innovation
	Technology transfer and matching	Promotes transfer of eco-innovative technologies
	Market intelligence services	Promotes information and knowledge sharing on eco-innovation (reduces information asymmetry)

Experimentation

Experimentation does not often appear in the policy mix studies. It is, however, one of key features of ambitious policy supporting eco-innovation. Schot and Steinmueller (2016) argue that transformative innovation policy shouldenable experimentation with options "beyond the narrow boundaries set by incumbents". In order to be transformative and not end up as isolated single experiments, experimentation should be embedded in policy mixes, and be given a dedicated space in broader regulatory, organisational and institutional frameworks (Chataway et al., 2017).

This embedded approach to experimentation is largely inspired by Strategic Niche Management (SNM) (Schot et al., 1994; Kemp et al., 1998). Acore assumption of theSNMapproach is that "sustainable innovation journeys can be facilitatedby modulating of technological niches, i.e. protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices, and regulatory structures." (Schot and Geels, 2008). Experimentation is considered key for ensuring diversity, learning and network development. At the same time, however, too much diversity may hamper innovation by fragmenting resource investments, generating uncertainty and riskand slowing down the emergence of stable rules (Schot and Geels, 2008).

Credibility

It has long been recognised that long-run policies must be credible to be effective, and that there is a tension between credibility and flexibility.

Rogge and Reichardt (2016) define credibility as "the extent to which the policy mix is believable and reliable, both overall and regarding its elements and processes". They argue that credibility may be positively or negatively influenced by a range of factors, including the commitment from political leadership, consistent and coherence policy mix, introduction of formal targets into instruments, competences of public administration, or effective coordination between ministries and delegation of competencies to independent agencies. Credibility of the policy mix may play an important factor determining the effectiveness of the policy mix.

The important role of the perceived credibility of policy mix by stakeholders has been confirmed by a number of recent studies. Bödeker and Rogge (2014) conducted a case study of solar PV in Germany based content analysis of the industry journal Photon (1996–2012). The analysis suggests that the most relevant determinants of the perceived policy credibility were the stability and temporal consistency of the policy mix and the commitment from political leadership.

In their study on the German off-shore wind sector Reichardt and Rogge (2016) analyse innovation impact of the characteristics of the policy mix on companies. They find that the consistency and credibility of the policy mix have been important incentives for eco-innovation. The results suggested that political credibility and stability can temporarily compensate for the lack of consistency and comprehensiveness of instrument mix. On the other hand, shortcomings in other policy mix characteristics can reduce the level of credibility of policy frameworks. Rogge et al (2011) find that the innovation impact of the EU Emissions Trade System has been limited because of the scheme's initial lack of stringency and predictability. In the UK, Uyarra et al. (2016) confirm that the concerns about the policy coherence and consistency of policy mix can lead to questioning policy credibility,and may negatively influence innovation activities by SMEs active in low carbon innovation.

Various 'commitment' mechanisms have been proposed to bolster the credibility of policy measures. Levin et al (2012) and Brunner et al (2012) suggest a number of ways in which policies can be made 'sticky', i.e. difficult to change. Governance arrangements around the UK Climate Change Act 2008, which included the establishment of legislated carbon budgets and the creation of a statutory body (the Committee on Climate Change) to report on government progress, provide an example of an attempt to embed some of these principles in UK climate policy.

5 POLICY MESSAGES: HOW TO BUILD POLICY MIXES FOR SYSTEMIC CHALLENGES

A key message from this review is the importance of a broader perspective on the governance of eco-innovation. Rather than comparing, selecting and evaluating specific policy instruments, a policy mix perspective requires an ongoing and broader evaluation of how multiple policies and policy instruments interact and co-evolve.

At its most basic, this suggests a need to revise the guidance used to develop formal policy development and appraisal, such as guidance on the preparation of ex ante impact assessments. The necessity of assessing policies within a wider policy mix should be a core requirement for effective appraisal, and this has implications for the kinds of criteria that are used in policy appraisal. Appraisals of policy mixes might pay greater attention to, for example, the degree of consistency and coherence. The Outlook also suggests key ingredients for a successful policy mix for transformative eco-innovation. Policy mixes must be:

- Credible, associated with governance arrangements that reduce the perceived likelihood of policy change.
- Associated with a clear long-term vision and set of goals.
- Coherent, consistent and comprehensive.
- Sufficiently stringent to drive real change
- Embedded within governance arrangements that allow for experimentation, learning and evaluation.

The overall policy lesson stemming from literature is that policy makers need to consider policy mix when designing, implementing and evaluating both individual instruments and policy portfolios aiming at providing support for eco-innovation. This realisation has significant implications for governance and processes of policy-making from agenda setting to evaluation (Weber and Rohracher, 2012). The policy mix approach requires that previously independently designed strategies, goals and instruments become mutually reinforcing.

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11. How to account for macro-economic framework conditions in designing eco-innovation policy?

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