ROUTLEDGE HANDBOOK OF ENVIRONMENTAL POLICY

Edited by Helge Jörgens, Christoph Knill, and Yves Steinebach

First published 2023

ISBN: 978-0-367-48992-2 (hbk)
ISBN: 978-1-032-50311-0 (pbk)
ISBN: 978-1-003-04384-3 (ebk)

Chapter 24

POLICY MIXES FOR ADDRESSING ENVIRONMENTAL CHALLENGES

Conceptual Foundations, Empirical Operationalisation, and Policy Implications

Karoline S. Rogge and Qi Song

DOI: 10.4324/9781003043843-28

The funder of the Open Access version of this chapter is European Research Council

earthscan from Routledge

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

24

POLICY MIXES FOR ADDRESSING ENVIRONMENTAL CHALLENGES

Conceptual Foundations, Empirical Operationalisation, and Policy Implications

Karoline S. Rogge and Qi Song

24.1 Introduction

The systemic nature of today's complex and often interconnected environmental challenges, such as the climate crisis or biodiversity loss, and their urgency require multi-faceted but often politically contested policy interventions that go beyond the realm of environmental policy and single policy instruments. This calls for the combination of policies addressing these environmental challenges by coordinating interventions across multiple policy fields, governance levels, and socio-ecological systems. For such a broad perspective on policy mixes – as a combination of policy strategies and instruments designed and implemented across multiple dimensions – we draw on the transitions literature, which has argued that effective policy mixes need to aim at the transformation of our existing unsustainable systems of production and consumption (Rogge and Reichardt, 2016). Such transformation is also referred to as "system innovation" and can be stimulated through policy mixes for "creative destruction" (Kivimaa and Kern, 2016): on the one hand, adopting policies supporting the creation of novel solutions – be they technological, social, or business model innovations, for example – and on the other hand further accelerating transformation processes by simultaneously implementing policies that phase out unsustainable fuels, technologies, or practices. For this, much can be learned from the literature on policy mixes for sustainability transitions which will be introduced in this chapter.

Over the past two decades increasing attention has been given to the role that policy mixes play in promoting environmental innovation and sustainability transitions. However, research initially has focused on policy mixes in a narrow sense, namely on the interaction between different policy instruments and their optimal combination in instrument mixes (Bouma et al.,

DOI: 10.4324/9781003043843-28

2019; Kern et al., 2019). In the last decade, increasing attention has been given to the role that policy mixes – also referred to as policy packages or policy portfolios – play in sustainability transitions in different sectors, such as in energy (Rogge et al., 2017), transport (Givoni et al., 2013), industry (Scordato et al., 2018), agri-food (Kalfagianni and Kuik, 2017), or forestry (Scullion et al., 2016). This newer line of interdisciplinary policy mix thinking for addressing environmental and sustainability challenges combines insights from various disciplines (Kern et al., 2019; Quitzow, 2015), in particular environmental economics and policy (Braathen, 2007; Lehmann, 2012), but also policy sciences (Capano and Howlett, 2020; Howlett et al., 2015) and innovation and transition studies (Flanagan et al., 2011; Rogge and Reichardt, 2016), with the latter two complementing the predominant analysis of instrument interactions with other important aspects of policy mixes. It is this emerging interdisciplinary literature on broader policy mixes for transitions towards more sustainable systems of production and consumption that is the focus of this chapter.

The formulation and implementation of policy mixes for addressing environmental and sustainability challenges can be justified by multiple policy rationales (Bouma et al., 2019; Weber and Rohracher, 2012). To be specific, the interdisciplinary policy mix literature stresses that *market failures*, such as the negative externalities of greenhouse gas emissions (Edenhofer et al., 2013) and other externalities (Lehmann et al., 2019), are an important but not the only justification for policy intervention (Jacobsson et al., 2017). Instead, the development of environmentally friendly solutions also requires an awareness of structural as well as transformational system failures (Weber and Rohracher, 2012).

That is, it is not seen as sufficient to internalise environmental externalities associated with environmental challenges. Instead, effective policy mixes also need to tackle *structural system failures* associated with environmental innovation and investment, such as failures in building up low-carbon infrastructure (e.g. aligning electricity grids and storage with the requirements of new low-carbon technology) and in adjusting existing institutions to sustainable solutions (e.g. reforming electricity market designs) (Bak et al., 2017; Patt and Lilliestam, 2018).

In addition, addressing environmental and sustainability challenges and thus reaching policy commitments tackling them, such as the Paris Agreement for limiting climate change, also requires that *transformational system failures* are considered when designing such policy mixes. These include, for example, the provision of a clear direction (e.g. through the elaboration of shared visions, unambiguous guidance for sustainable solutions, and coordination of actors involved in the transformation process). Transformational system failures, to give another example, also include the need to overcome policy silos through better coordination across policy fields (e.g. environmental policy and industrial policy) and governance levels (e.g. the national and regional level) (Nemet et al., 2017; Uyarra et al., 2016). Single policy instruments, such as carbon pricing or a pollution tax, are not able to address all of these failures, thereby justifying the implementation of broader policy mixes (Bouma et al., 2019; del Río, 2017; Tvinnereim and Mehling, 2018).

In this chapter, we first provide an overview of how policy mixes have been defined and how this varies across different disciplinary perspectives, followed by an introduction to an emerging interdisciplinary understanding of broader policy mixes (*conceptualising policy mixes*). We then introduce two methodological approaches for delineating policy mixes addressing environmental challenges *(delineating policy mixes)*. Thereafter, we provide a synthesis of empirical policy mix insights and their policy implications for the concrete example of climate policy mixes (*informing policy mix design*). Finally, we discuss areas that warrant more attention in future research on policy mixes addressing environmental challenges (*research outlook*).

24.2 Conceptualising Policy Mixes

In this section we first provide an overview of the different definitions of policy mixes in the three main disciplines that have significantly contributed to policy mix research. Based on this, we then introduce an interdisciplinary framework for a broader policy mix concept that we find particularly suitable for guiding future research on policy mixes addressing environmental challenges.

24.2.1 Defining Policy Mixes

The ambiguous meaning of the term "policy mix" has raised a series of challenges for researchers in identifying the scope and focus of their research. In this section, we therefore start by providing an overview of key policy mix definitions applied in different disciplines, namely environmental economics, policy studies, and innovation and transition studies (see Table 24.1).

This overview shows that policy mix definitions reflect the different research foci present in the different disciplines, but also that definitions vary within and across disciplines. First, research grounded in *environmental economics* has been largely focusing on instrument interactions and the design of optimal instrument mixes (Braathen, 2007; Lehmann, 2012). In that sense, this line of research would more accurately be better referred to as instrument mix research. A prime example of this are studies investigating the interaction effect of emissions trading and other policy instruments such as support for renewables (Sorrell and Sijm, 2003). Second, research in *policy studies* typically defines policy mixes as a combination of multiple instruments and goals (Howlett and Rayner, 2013; Kern and Howlett, 2009), and has been largely focusing on the sequencing and evolution of policy mixes over time (Howlett, 2009; Taeihagh et al., 2013). In doing so, policy scholars have often characterised the consistency and coherence of the resulting policy mixes, while, however, neglecting policy mix impacts.

Table 24.1 Three main disciplines addressing policy mixes with exemplary definitions

	Environmental economics	*Policy studies*	*Innovation and transition studies*
Example 1	Instrument mixes are defined as a situation in which "several – instead of one – policy instruments are used to address a particular environmental problem" (Braathen, 2007, p. 186).	"Policy mixes are complex arrangements of multiple goals and means which, in many cases, have developed incrementally over many years" (Kern and Howlett, 2009, p. 395).	"A policy mix is defined as: The combination of policy instruments, which interact to influence the quantity and quality of R&D investments in public and private sectors" (Cunningham et al., 2009, p. 3).
Example 2	"Polluting sources may be affected directly or indirectly by several policies addressing the same pollution problem. This is referred to as a policy mix" (Lehmann, 2012, p. 71).	"Policy mixes or portfolios feature the use of combinations of different kinds of policy tool – market based, hierarchical, network and others – whose exact configuration changes from location to location" (Rayner et al., 2017, p. 473).	"Policy mixes favourable to sustainability transitions need to involve both policies aiming for the 'creation' of new and for 'destroying' (or withdrawing support for) the old" (Kivimaa and Kern, 2016, p. 206).

Source: Own compilation of policy mix definitions using matrix logic from Rogge et al. (2017).

Finally, *innovation and transition studies* have focused initially on instrument mixes promoting technological change; but, particularly in studies investigating sustainability transitions, it has extended its scope to policy mixes promoting system innovation (Kivimaa and Kern, 2016). In addition, and regardless of the disciplinary grounding, policy mix studies have applied a variety of definitions of different aspects of policy mixes (Rogge and Reichardt, 2016), for example regarding the terms "consistency" or "coherence" of policy mixes. Such conceptual and terminological diversity complicates the synthesis of insights from policy mix research, but provides a rich foundation for an interdisciplinary conceptualisation of the term "policy mix" that combines the strengths of the respective approaches.

24.2.2 Interdisciplinary Conceptual Framework

Such an extended interdisciplinary framework for analysing complex policy mixes for environmental innovation and sustainability transitions, which builds on all three disciplinary traditions, has been proposed by Rogge and Reichardt (2016). Their broader conceptualisation not only offers a comprehensive and clearly defined policy mix concept but also provides resourceful guidance for developing future empirical studies. According to their work, a policy mix refers to "a combination of the three building blocks elements, processes and characteristics, which can be specified using different dimensions" (Rogge and Reichardt, 2016, p. 1622). Their conceptualisation has integrated most conceptual advances from the earlier policy mix literature: inspired by innovation studies it highlights long-term strategies by introducing policy strategy as one policy mix element; drawing on policy studies it captures associated policy processes and different types of policy mix characteristics; and building on environmental economics it also captures the importance of policy instrument design.

As Figure 24.1 shows, the first building block of this extended policy mix concept – policy mix *elements* – incorporates both policy strategies and instrument mixes articulated and introduced by associated governing entities in addressing specific policy challenges and fulfilling certain policy functions (Rogge and Reichardt, 2016). First, considering the role of the

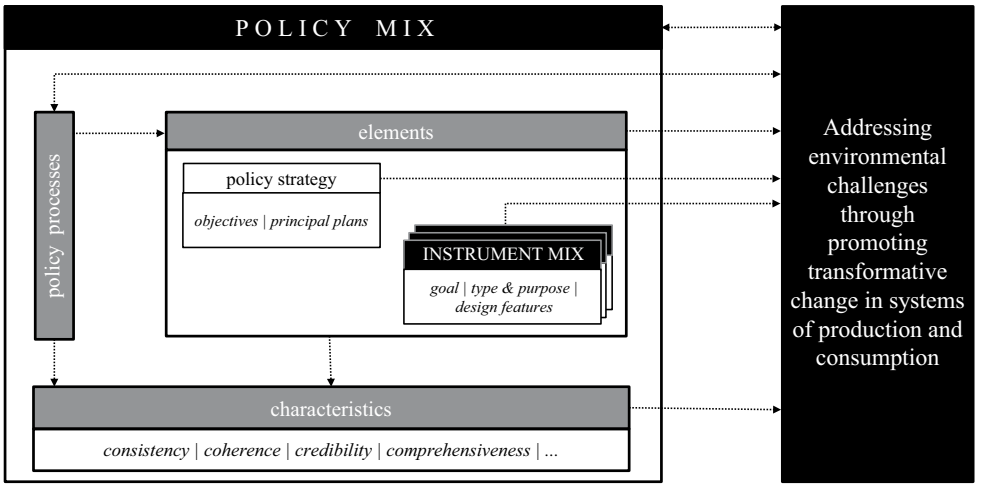

Figure 24.1 Implications of extended conceptual framework for investigating policy mixes for environmental challenges.

Source: Adapted from Rogge and Reichardt (2016) and Rogge (2019).

long-term horizon in designing real-world transformative policy solutions (Voß et al., 2009) underlines the importance assigned to policy strategies as the first part of this building block. Such policy strategies include a set of policy objectives – clarified by quantifiable targets – and the principal plans for materialising them. Second, various types of policy instruments, associated with specific goals and different design features, and their combinations in instrument mixes, are conceptualised as the second part within this building block. This implies that the conventional focus on instrument interactions is considered to be only one of several aspects relevant to the analysis of policy mix elements (Rogge and Reichardt, 2016). As a result, the extended policy mix framework offers researchers a more precise guidance on how to delineate the scope of complex policy mixes composed of both strategic and instrumental components. Therefore, the broader policy mix concept also explicitly distinguishes the two previously overlapping conceptual constructs of "policy mix" and "instrument mix".

Drawing on intellectual discussions within policy studies, the second building block – *policy processes* – suggests more dedicated attention to the associated policy processes that shape the concrete content of the policy mix elements (Rogge and Reichardt, 2016). Given the existence of controversial political dynamics (Meadowcroft, 2009) and complex power relationships (Stirling, 2014) observed in developing transformative policy solutions addressing environmental problems, the introduction of this building block enables researchers to critically examine the role of various actors with divergent beliefs, expectations, and interests in formulating and implementing policy strategies and instruments. The black-boxed decision-making mechanisms embedded in governing complex environmental issues, therefore, are invited to be unpacked by mobilising well-developed policy process theories and perspectives for interdisciplinary investigations of the politics and policies involved in governing sustainability transitions (Kern and Rogge, 2018). One example of such interdisciplinary policy mix analysis concerns the co-evolution of policy mix change and socio-technical change (Edmondson et al., 2019) that enable insights into the systemic dynamics and causal links across policy subsystems and the socio-technical systems.

Moreover, the third building block – policy mix *characteristics* – captures various attributes of the focal policy mix, specifying the nature of policy mix elements and the features of associated policy processes for informing. These characteristics are meant to describe and evaluate the design and impact of complex, real-world policy mixes (Rogge and Reichardt, 2016), and in the following we introduce four of them. First, the consistency of policy mix elements captures the degree of contradictions or synergies across three different but interconnected levels: within policy strategies, within the instrument mix, and between strategies and instruments. Second, recognising the role of policy coordination and policy integration in dealing with cross-sectoral policy challenges (Magro et al., 2014; Trein et al., 2021), the coherence of policy processes is also included in this third building block to underline the analytical importance of synergistic and systematic policy formulation and implementation processes for understanding the performance of real-world policy mixes (Rogge and Reichardt, 2016). Third, the credibility of policy mixes is also highlighted by the extended policy mix framework as another core characteristic which is considering how well target groups believe and trust in the policy mix – a critical factor for addressing environmentally related policy issues such as climate change (Nemet et al., 2017). Finally, a fourth policy mix characteristic that has received significant attention is the comprehensiveness of policy mixes. It captures the existence of different policy instrument types (e.g. economic, regulatory, and information tools, identified environmental policy researchers) and instrument purposes (e.g. technology-push, demand-pull and systemic concerns, highlighted by innovation scholars), as well as the extensiveness of actor involvements in associated policy processes (Rogge and Reichardt, 2016).

24.3 Delineating Policy Mixes

After having introduced the relevant terms and conceptual linkages of a broader policy mix concept, in this section we provide an overview of how to measure such real-world policy mixes. Indeed, despite the emergence of an increasing number of studies investigating real-world policy mixes (Kern et al., 2019), the absence of widely recognised standards for operationalising such mixes hampers the synthesis of the current empirical evidence. This section therefore introduces two methodological approaches – the top-down approach and the bottom-up approach – for delineating policy mixes, thereby providing consistent guidance for best practices in conducting empirical research programmes in this area (Ossenbrink et al., 2019).

24.3.1 The Top-Down Approach

Viewing the elements of focal policy mixes, implicitly or explicitly, as the outputs of associated policy processes navigated by a set of key governing entities at certain governance levels, for the top-down approach the identification of the overarching strategic intent is the key analytical clue to identifying relevant policy strategies and instruments (Ossenbrink et al., 2019). Following this approach and applying it to environmental challenges, the empirical investigation of a focal policy mix should start by scoping the stated environmental goals, for example in terms of reducing greenhouse gas emissions. Analysts then need to specify which governance level(s) and policy field(s) to include in their analysis of the focal policy mix, and for these identify the relevant governing entities. Depending on the research question this could be, for example, the environmental ministry at the national level, but could also be extended to include environmental ministries at other governance levels, or even might be extended to further policy fields if involved in pursuing the particular environmental goal. Analysts will then identify the corresponding policy strategies and supporting policy instruments implemented by the identified governing entities, typically by utilising publicly available data from secondary sources, such as agency and ministerial publications, program reports, and regulatory and legislative documents (Howlett et al., 2006). Although more and more online field-specific policy databases and observatories facilitate the mapping of relevant policy mix elements (Meissner and Kergroach, 2021), field-specific knowledge or professional expertise will still be important for such top-down policy mix mappings, for example in compiling the list of relevant governing entities, in formulating a string for keyword-based policy document searches, or in developing a theory-informed codebook for documentary analysis.

The availability of in-depth reports and strategic documents collected from these secondary sources can help researchers to obtain a quick overview of the focal policy mix. As Ossenbrink et al. (2019) note, some high-quality policy or industry reports may already have provided a detailed list of core public agencies, milestone policy documents, and key events in their focused policy issues, and researchers thus can use the insights from such summarising documents to lay the foundation for their own empirical analysis. In some cases, researchers can start systemic mapping work by analysing formalised strategy documents in the focal policy field(s), as these documents "not only articulate a set of policy objectives but typically also define a set of governmental actors" (Quitzow, 2015, p. 237). For instance, in their research concerning sustainable energy transitions in China, Li and Taeihagh (2020) capture the strategic elements of the focal policy mix (i.e. policy objectives and principal plans) by scoping all energy-relevant statements in China's Five-Year Plans – one of the most influential strategic document series at the national level, which also informs the subsequent keyword-based search for identifying specific policy instruments and their mixes supporting the aforementioned strategic elements.

In order to validate and complement these secondary data sources, expert interviews with competent officials and policy elites could be conducted to refine preliminary findings on the composition of the policy mix derived from the desktop analysis (Ossenbrink et al., 2019). Such expert interviews, in this case, can also help analysts to understand underlying policy formulation and implementation processes, or policy mix impacts. That is, such interviews can also go beyond the pure mapping of policy mix elements and already include further analytical steps, thereby enabling researchers to gain empirical evidence with respect to explaining complex political dynamics and causal mechanisms. In this line, as the example provided by Xu and Su (2016) shows, expert interviews with elite policy actors not only help researchers to obtain professional accounts of the rationale and dynamics of observed policy changes, but can also provide a valuable opportunity to access internal documents and confidential transcriptions in revealing invisible background information, which becomes particularly relevant for a comprehensive policy mix analysis which incorporates not only policy outputs but also the policy-making processes leading to them, as well as policy mix impacts.

24.3.2 The Bottom-Up Approach

In contrast, the bottom-up approach to delineating policy mixes pays more attention to the impact of a policy mix, which highlights the analytical importance of identifying the specific impact domain influenced by policy instruments and strategies (Ossenbrink et al., 2019). Here, it is thus key to start with the identification of a well-bounded focal impact domain, such as the diffusion of an environmentally friendly technology in a given country (e.g. electric vehicles as part of transitions to e-mobility). For the focal impact domain, scholars then need to identify relevant actors and all policy instruments that influence their activities throughout the bottom-up data collection and analysis process. That is, one can regard these actors – in the selected geographical scope – as the recipients of policy instruments from potentially various governance levels and policy fields, and thus use their accounts to sketch the big picture of the relevant focal policy mix (Ossenbrink et al., 2019). Perhaps most important for this bottom-up approach is that the role of some unintentional policy impacts of instruments from other policy fields or governance levels can be captured by researchers, shining a light on the layering structure of focal policy mixes and helping to identify otherwise potentially overlooked but relevant policies (Kern et al., 2017; Sovacool, 2009). However, as Ossenbrink et al. (2019) point out, the inductive nature of this bottom-up approach requires considerable research efforts in collecting and synthesising diverse insights from multiple relevant actors, so several research design issues, such as case selection rationales and the availability of research resources, need to be critically considered.

Defining the focal impact domain is a critical and challenging step when applying the bottom-up approach. Ideally, scholars should first identify the environmental, social, technological, and/or economic dimensions of interest. In this regard, the narrower these dimensions can be defined, the simpler data collection and analysis will be. As an illustrative case, Ossenbrink et al. (2019) define their impact domain as the economic dimension of energy storage in California's residential photovoltaic self-consumption, which is much narrower than the mentioned strategic intent of their top-down approach (i.e. the policy mix for energy storage in California). One key reason for formulating narrow impact domains is the limited resources that researchers can typically mobilise for conducting their projects. Indeed, if the definition of the focal impact domains is too broad, there would be very long lists of massive actors on the table, which are likely not possible for researchers to comprehensively cover in their data collection and analysis. In addition, the complexity of real-world policy mixes will be more

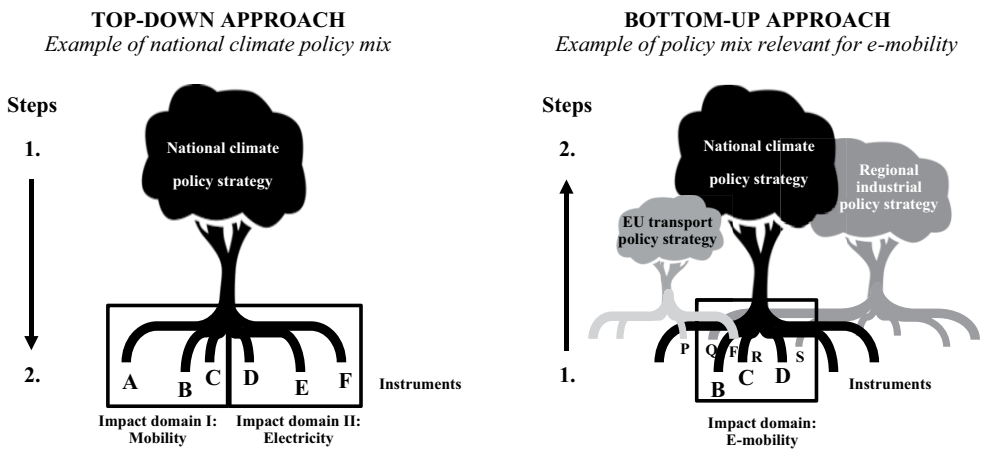

Figure 24.2 Illustration of top-down and bottom-up approach to delineating policy mixes.

Note: The figure shows that the relationship between policy mixes (tree, with the treetop = strategy, and roots = instruments) and impact domains (soil) is not one-to-one, which means as illustrated on the left, a given policy mix (e.g. the black one) may, intendedly or unintendedly, affect multiple impact domains (e.g. I and II), and as illustrated on the right, a given impact domain (e.g. e-mobility) can be affected by the elements of multiple policy mixes (e.g. the grey, black, and blue ones, though in reality these will typically be many more) – here the trees represent several policy fields (e.g. climate, industrial, and transport) and different governance levels (e.g. EU, national, regional) influencing the impact domain.

Source: Adapted from Ossenbrink et al. (2019).

challenging to handle, the larger the system boundaries are. However, it is also true that in times of increasingly interconnected systems researchers and policymakers alike might have to engage with multi-system policy mixes, and such consideration of complex policy mixes may enable the identification of synergies and conflicts of key relevance for policy mix effects. For example, and as visualised in Figure 24.2 (left-hand side), research investigating the decarbonisation of the transport sector through its electrification could take as a top-down starting point the climate policy strategy, but zoom in on the mobility and electricity system as main impact domains. Alternatively, following the bottom-up approach researchers could choose e-mobility as the impact domain of interest (or even more narrowly, electric vehicles), and then map all policy instruments that influence actors in this domain. As visualised in Figure 24.2 (right-hand side), this may lead to the identification of policy mix elements at different governance levels (EU, national, regional) and different policy fields (climate, industrial, and transport policy).

Regardless of approach, policy data collection and analysis should be seen as an iterative process in which it is beneficial to combine both secondary data (e.g. policy documents and academic literature) and primary data (e.g. interviews and participant observations). Considering the relevant actor networks in selected geographical scales, scoping reviews of the existing academic and grey literature can help researchers in terms of identifying representatives of each actor group. Snowballing techniques, moreover, should also be considered as a complementary method for finding relevant, but previously overlooked, actors. The collection and classification of policy instruments – which then can be traced back to relevant policy strategies at various governance levels and policy fields – could also be informed by existing theories at the initial stage (e.g. Kivimaa et al., 2017; Kivimaa and Kern, 2016).

Based on the guideline proposed by Ossenbrink et al. (2019), this section has introduced two archetypical analytical procedures for delineating policy mixes in line with the relevant

research question. However, as Ossenbrink et al. (2019) also suggest, there is no best solution targeting all policy mix studies across different research contexts, and researchers need to find a way that fits their own research projects with their unique research questions. Moreover, the two approaches are complementary to each other, and when combined enable comprehensive insights. Yet such a combination does require significant time and effort and thus may not be possible in many instances, when it will be more important to choose the most appropriate delineation approach to proceed with for further empirical inquiries.

24.4 Informing Policy Mix Design: The Example of Climate Change

Having discussed terminology and delineation of policy mixes, we now turn to empirical insights gained on policy mix design and its impacts regarding addressing environmental challenges. As most policy mix studies have so far focused on tackling climate change, in this section we synthesise the main insights gained from the literature investigating broader climate policy mixes and their relevance for sustainability. In total, we derive seven findings with real-world policy relevance. Each of these insights are summarised in one sentence, and further elaborated in the following paragraph.

24.4.1 Coordinating the Design of Policy Mixes to Meet Multiple Policy Objectives Can Reduce the Overall Costs of Achieving Sustainability Objectives

Governments typically pursue multiple policy objectives beyond greenhouse gas mitigation, such as energy security, air quality, health, or energy access. The existence of such multiple policy objectives provides a rationale for coordination in policy mix design, as it allows policymakers to strive for synergies and to minimise trade-offs (Howlett and del Rio, 2015; Obersteiner et al., 2016). Integrated model studies suggest that well-designed transformative climate policy mixes paying attention to the co-benefits of climate mitigation for non-climate policy objectives can reduce the overall cost of achieving multiple sustainability objectives (von Stechow et al., 2015).

24.4.2 Climate Policy Mixes Need to Be Credible to Accelerate Low-Carbon Transitions

Long-term targets are an important element of climate policy mixes as they provide guidance to strategic investments and innovation (Schmidt et al., 2012). However, to be credible and effective they need to be backed up by stringent and consistent policy instruments (Rogge and Schleich, 2018). Given the outstanding importance of policy credibility for low-carbon investment and innovation shown in modelling studies (Bosetti and Victor, 2011; Faehn and Isaksen, 2016), several attributes have been identified in the literature to assess the extent to which policy mixes are believable and reliable (Jakob, 2017; Nemet et al., 2017): the design of rules (e.g. Are targets reviewed periodically?), transparency and trust (e.g. Does an independent authority oversee target achievement?), political economy and distribution (e.g. Are policies compensating losers of stringent climate policy?), and robustness (e.g. Are multiple policy instruments in place, potentially also at different governance levels?). Empirical evidence for Germany demonstrates that companies' perceptions of the credibility of the policy mix relevant for renewables can be linked not only to the existence of well-aligned instruments but also to the coherence of climate policy-making processes and the existence of ambitious

phase-out policies for societally undesirable energy technologies (Rogge and Schleich, 2018). The literature thus suggests multiple avenues for enhancing climate policy credibility, which is key for accelerating low-carbon transitions.

24.4.3 Comprehensive, Balanced, and Consistent Instrument Mixes Can Help Drive Low-Carbon Transformative Change

The interdisciplinary literature on policy mixes points to the importance of evaluating policy mixes through their characteristics, such as comprehensiveness (capturing the extensiveness of policy mixes, e.g. in terms of whether a policy mix addresses all market and system failures), balance (capturing whether policy support is balanced between different instrument purposes), and consistency (capturing the alignment of policy instruments and the policy strategy) (Rogge, 2019). For example, for the case of energy efficiency policies in OECD countries it has been shown that a comprehensive instrument mix which balances technology push instruments supporting research and development (such as public R&D funding) and demand-pull instruments creating a demand for energy efficient products (such as through an energy tax) is beneficial for innovation in energy efficiency (Costantini et al., 2017). Similarly, comprehensive instrument mixes that include carbon pricing, policies supporting new low-carbon technologies, and a moratorium on coal-fired power plants may not only be politically more feasible than stringent carbon pricing, but may also limit efficiency losses and lower distributional impacts (Bertram et al., 2015). In addition, policy mix consistency has been identified as an important driver of low-carbon transformative change, particularly for renewable energy (Lieu et al., 2018; Rogge and Schleich, 2018).

24.4.4 Phasing Out Policies Supporting Carbon-Intensive Fuels, Technologies, or Practices Can Accelerate Low-Carbon Transitions

Climate policy mixes can be differentiated into policies supporting low-carbon niches (e.g. feed-in tariffs for renewable energy) and those destabilizing existing carbon-intensive regimes (e.g. reduction of subsidies for fossil fuels). If climate policy mixes contain both elements of creation and destruction – and thus do not only aim for the support of innovation but also its flipside of exnovation (capturing the termination of fossil-based technological trajectories in a deliberate fashion) – they stand a greater chance of accelerating low-carbon transitions (David, 2017; Kivimaa and Kern, 2016). Such destabilization policies include control policies (e.g. stringent carbon pricing), significant changes in regime rules (e.g. reform of the design of electricity markets), reduced support for dominant regime technologies (e.g. removing tax deductions for private motor transport), changes in social networks and replacement of actors (e.g. more balanced representation of incumbents and new entrants in policy advisory councils), and changes in organisational and institutional practices (e.g. enhanced coordination between governing entities from different policy fields) (Kivimaa and Kern, 2016; Kivimaa et al. 2017). Analysis has so far been done through the perspective of technological innovation systems and their functions, such as for Norway's transport and energy sector (Ćetković and Skjærseth, 2019), Sweden's pulp and paper industry (Scordato et al., 2018), and Finland's building sector (Kivimaa et al., 2017). In addition, computable general algorithm (CGE) modelling for China's fossil fuel subsidy reform found that integrating both creation and destabilization policies is able to reduce rebound effects and make the policy mix more effective (Li et al., 2017).

24.4.5 Transformative Climate Policy Mixes Have to Navigate Resistance from Vested Interests

Climate policy mixes create not only winners (e.g. low-carbon entrepreneurs, future generations) but also losers (e.g. incumbents with vested interests, neighbours of low-carbon infrastructure projects, coal miners at risk of job loss) (Geels, 2014; Rosenbloom, 2018). A broader understanding of climate policy mixes thus takes into consideration that low-carbon transitions are contested and deeply political processes (Kern and Rogge, 2018; Roberts et al., 2018). For example, it has been argued that such resistance justifies supplementing carbon pricing with other policies that are designed for limited impact on incumbents while supporting new entrants (Passey et al., 2012). Another option is the design of short-term policies which might help to provide later entry points for more ambitious climate policy (Kriegler et al., 2018). In this context the sequencing of policies has been discussed as a way to build coalitions for climate change, starting with green industrial policy (e.g. supporting renewable energies through feed-in tariffs) and introducing carbon pricing (or making it more stringent) when supportive coalitions of ambitious climate policy have been formed (Meckling et al., 2015). In addition, low-carbon technological innovation can play a key role in ratcheting up climate policy over time, for example through cost reductions and job creation (Schmidt and Sewerin, 2017). However, apart from such positive policy feedbacks there can also be cases of negative policy feedback, for example arising from ineffective policy instruments, competing policy objectives, exogenous factors (such as the financial crisis), and global dynamics (such as international competition). The resulting negative policy feedbacks may over time lead to a weakening of ambitious policy targets, as has been the case with the UK zero-carbon homes target introduced in 2006 but which was eventually scrapped in 2016 (Edmondson et al., 2019). This calls for dedicated attention to the co-evolution of policy mixes and socio-technical systems occurring through resource, interpretative, and institutional effects (e.g. increase of public R&D support for low-carbon solutions, information provision at climate policy conferences, expanding state capacities for policy evaluation, and/or enforcement), and their socio-political, administrative, and fiscal feedbacks (e.g. mobilisation of supporters vs opponents, avoiding or causing budgetary strains, and strengthening vs weakening of implementing agencies' reputations).

24.4.6 Accelerating Decarbonisation Calls for Enhancing Policy Coordination across Governance Levels and Policy Fields

Low-carbon transitions cannot only be slowed down through resistance from vested interests, but also through a lack of public acceptance (Bicket and Vanner, 2016). Therefore, several interdisciplinary studies have incorporated stakeholder views, for example by applying Q methodology in the case of building-integrated photovoltaics in Singapore (Chang et al., 2019) or transport backcasting scenarios with multi-criteria analysis in Spain (Soria-Lara and Banister, 2018). Similarly, the public acceptance of climate policy has been increasingly investigated, for example through choice experiments for sustainable passenger transport in China, Germany, and the USA (Wicki et al., 2019) or for climate change mitigation policies in the Czech Republic, Poland, and the UK (Ščasný et al., 2017). In addition, the emerging energy democracy literature argues for policy mixes that resist the dominant energy agenda (e.g. by ending subsidies for fossil fuels and supporting those dependent on jobs in fossil fuel industries), that reclaim the energy sector (e.g. by normalising public control of energy production and consumption), and that restructure the energy sector (e.g. by governing energy systems as a commons) (Burke and Stephens, 2017).

24.4.7 Systematic Mapping of the Policy Mix Is a Precondition for Policy Mix Analysis and Design

Accelerating low-carbon transitions can be supported by policy mixes spanning multiple governance levels (e.g. local, regional, national, supranational, and international) and policy fields (e.g. climate, energy, industry, economy, innovation, environment). Siloed rather than integrated policy mixes have been identified as bottleneck to low-carbon transitions, such as in the case of South Korea's renewable energy policy (Yoon and Sim, 2015). Policy coordination provides an avenue to manage trade-offs between different policy objectives and to seek policy synergies, although coordination is no panacea and may require institutional remedies, given the complexity, uncertainty, and cross-cutting character of transition processes (Gebara et al., 2019; Matti et al., 2017). An example includes urban planning where local authorities can use a variety of instruments that assist in implementing both planning and energy policy targets (Petersen and Heurkens, 2018) and where mainstreaming climate policy with urban planning can lead to win–win strategies (Viguié and Hallegatte, 2012). Another example includes power added to climate-relevant bureaucracies as a result of international and domestic climate policies, which can impact the direction and practical policy limits for climate change policy (Rahman and Giessen, 2017).

In conclusion, while these seven key insights of relevance for policymakers and others interested in effective climate policy mixes are not meant to represent a complete list and were specifically derived from the literature on climate policy mixes, we argue that many of these insights may be transferable to other environmental challenges. Future research on policy mixes addressing environmental challenges other than the climate crisis, such as the dramatic loss of biodiversity or plastic pollution in oceans, could help to clarify general and context-specific insights on effective policy mixes.

24.5 Research Outlook

In this chapter, we have outlined conceptual foundations and empirical approaches and advances of policy mix research and how these enable the provision of policy implications for tackling environmental challenges, such as climate change. In the final section, we now turn to what we consider to be three key research areas for further advancing much-needed insights on real-world policy mixes addressing environmental challenges. These three areas include capturing transformative change, incorporating multi-level governance settings, and rethinking policy regimes.

24.5.1 Capturing Transformative Change

Addressing environmental challenges for redirecting and accelerating socio-technical change towards sustainability calls for policy mixes which become transformative by targeting not only one but several system functions and/or policy intervention points (Kanger et al. 2020; Kivimaa and Kern, 2016).

Adopting an extended framework drawing from technological innovation systems, strategic niche management, and other innovation and transition studies insights (Hekkert et al. 2007; Schot and Geels, 2008), Kivimaa and Kern (2016) complement the seven well-established "creative" functions supporting green niches (e.g. plant-based meat substitutes), with four "destruction" functions aimed at destabilizing unsustainable regimes (e.g. stringent and compulsory sustainability standards for animal farming).[1] By doing so, this framework allows for the

evaluation of the comprehensiveness and balance of policy mix elements that goes well beyond the separation of policies supporting the development of new technologies and practices and their adoption by consumers. As such, it probably could be applied to most environmental challenges.

In contrast, Kanger et al. (2020) propose a more deductive approach drawing on the multi-level perspective (Geels, 2004) to identify six key policy intervention points that policy mixes can target to influence transition processes – covering the environmentally innovative niche, the existing unsustainable regime, and external developments at the so-called landscape level. For example, to accelerate low-carbon energy transitions policies should not only stimulate the development of low-carbon niche technologies such as solar PV, but also need to create substantial market demand for these by reducing support for unsustainable regimes such as coal-based energy generation – which up to this point is in line with Kivimaa and Kern's approach. In addition, they also call for cushioning the repercussions of associated structural changes through dedicated policies, such as skills retraining and job creation for redundant coal miners. Another policy intervention point they identify are cross-sectoral trends and their coordination, such as greater electricity demand and thus expansion needs for renewable energies due to electrification of other sectors such as mobility and heat. Finally, given the global nature of many pressing environmental challenges, policymakers would also be well advised to attempt to tilt the general framework conditions, for example through binding international environmental agreements. Note that the combinations of policy efforts targeting various intervention points depend on the type of transition pathway of any given system and can change over time.

Despite drawing on different theoretical approaches to investigate the functional role of policy mixes in achieving transitions, similar insights can be derived from both for designing truly transformative policy mixes. For instance, the importance of public support concerning various niche technologies has been highlighted in both contributions. A particular strength of the "creative destruction" framework developed by Kivimaa and Kern (2016) is its provision of a toolbox to link policies to relevant socio-technical system functions. Meanwhile, Kanger et al. (2020) add a "global sense" to the analysis, especially regarding their systematic thinking about the role of policy mixes in different transition pathways. As they argued, the formulation and deployment of effective policy mixes will depend on the comprehensive mapping of all possible loci for accelerating socio-technical changes. In this sense, future research may benefit from drawing on and extending both approaches for deepening our understanding of the role of transformative policy mixes in accelerating desired system changes addressing environmental challenges (Kivimaa and Rogge, 2022).

24.5.2 Multi-Level Governance Settings

The role of multi-level governance settings, including both vertical and horizontal governance levels, has been highlighted by recent policy mix research (Howlett and del Rio, 2015) and will likely play an important but differentiated role in addressing the various current and future environmental challenges and crises. The recognition of this governance level dimension brings a series of future analytical challenges for which we would like to emphasise three aspects.

First, regarding the elements of multi-level policy mixes we expect the inclusion of policy strategies and instruments from different governance levels to significantly increase the challenge of delineating policy mixes, particularly those addressing global challenges such as the climate crisis. In this case, the environmental policy strategies of governing entities as well as the impact domains of transformative policy mixes addressing global or cross-sectoral environmental challenges may easily become too complex for scholars, policy analysts, and

decision-makers alike for comprehensively mapping and harmonising all policy strategies and instrument mixes across different administrative levels and policy departments (Ossenbrink et al., 2019). Consequentially, there will be practical limits to seeking synergies and avoiding contradiction.

Second, considering policy processes associated with multi-level policy mixes, both formulation and implementation processes of a multi-level policy mix tend to be very different from a single-level policy mix (Howlett and del Rio, 2015; Weber and Rohracher, 2012). For example, Magro and Wilson (2019) noted that current place-based innovation policy mixes require new governance arrangements and processes across different governance levels to be able to properly consider the multi-level aspect of formulating and implementing policy mixes in real-world contexts. In addition, as found for the case of solar water heating in Shandong, China, there may be at least two types of vertically interactive patterns – bottom-up and top-down – in multi-level policy mixes (Huang, 2019). Such patterns could evolve from unidirectional types towards highly complex bidirectional modes with the co-evolutionary development between policy mixes and a focal industry.

Third, evaluating the impact of multi-level policy mixes further complicates the already substantial challenge of evaluating policy mixes rather than single policy instruments. This is true even for analysts tasked with assessing the impact of single policies when in fact their impact can only be properly understood when considering interactions with other policies in the focal policy mix, including the same from other governance levels than the focal one. In this regard, Rogge and Schleich (2018) have shown for the case of renewable energies in Germany that policy mix characteristics, especially consistency and credibility, can help in evaluating the impact of policy mixes rather than attempting to differentiate the effects of single policy instruments, at least when asking actors in the impact domain. Thereby policies originating from multiple governance levels can be captured in actors' overall perception of the policy mix, while actors also appear to be able to differentiate between policy mix credibility across different governance levels (Rogge and Dütschke, 2018). Similarly, Mavrot et al. (2019) point out the impacts of the perceived implementation environment on the reactions and subsequent behavioural changes of target groups, which suggests that the degree of policy acceptance should be particularly noticed in analysing multi-level policy mixes.

24.5.3 Rethinking Policy Regimes

Finally, taking seriously the complex formulation and implementation processes behind policy mixes implies the need for an institutional reconfiguration of different policy regimes (e.g. the environmental policy regime and the innovation policy regime) towards an integrated one. In this regard, and recognising complex overlaps and systemic interactions of innovation systems and policy processes, Foxon and Pearson (2008) underlined the importance of promoting the development of a sustainable innovation policy regime by bringing together separate innovation and environmental policy regimes that on their own cannot provide sustainable support for addressing long-term sustainability challenges. This point is particularly related to current observations of complex policy mixes. As Rogge and Reichardt (2016) pointed out, the consistency and coherence of policy mixes across policy fields is one of the core issues in future research, as possible conflicts between different policy fields might lead to ineffective policy mixes. Such a heightened role of joined-up policy mixes across different policy fields may be particularly significant for the formation and stimulation of sustainable industries (Gomel and Rogge, 2020; Magro and Wilson, 2019).

Current research, however, has mainly investigated policy mix elements consisting of instruments from single policy fields, while associated dynamic policy processes and coordination between different governing entities has not been well-studied. This is supported, for example, by Greco et al. (2022) who refer to a policy mix including environmental policy and innovation policy as a "cross-instrumental policy mix" and investigated the effect of this on eco-innovations by using datasets from the Mannheim Innovation Panel concerning German firms. Based on their findings they suggest that decision-makers in various public agencies should better cooperate and coordinate their separate policy efforts in formulation and implementation processes of both innovation and environmental policies. Similarly, for the case of resource efficiency, Wilts and O'Brien (2019) have argued that the formulation and implementation of policy mixes "must" go beyond the conventional environmental policy regime in terms of achieving transformative change of whole socio-technical systems. This implies that the strategic coordination between governing entities across multiple policy regimes will therefore be critical in employing effective cross-cutting policy mixes. However, existing governance arrangements do not yet ensure sufficient capacities in terms of achieving such coordination processes (Kivimaa and Sivonen, 2021; Wilts and O'Brien, 2019), suggesting future research and practice around policy mixes addressing environmental challenges should pay greater attention to such governance, coordination, and capacity challenges.

Box 24.1 Chapter Summary

- Presenting an extended conceptual framework for policy mix research.
- Highlighting the role of policy strategies and associated policy processes.
- Summarising two analytical approaches for delineating complex policy mixes.
- Providing an example of global climate change for informing policy mix design.
- Suggesting three key research areas for future investigations on policy mixes.

Acknowledgement

This chapter was written within the EMPOCI project which has received funding from the European Research Council under the European Union's Horizon 2020 research and innovation programme (grant agreement No 852730).

Note

1 These four were later extended by a fifth "destruction" function concerning institutional routine and policy coherence (Kivimaa et al., 2017).

References

Bak, C., Bhattacharya, A., Edenhofer, O., & Knopf, B. (2017). Towards a comprehensive approach to climate policy, sustainable infrastructure, and finance. *Economics*, *11*(1), 1–13. https://doi.org/10.5018/economics-ejournal.ja.2017-33

Bertram, C., Luderer, G., Pietzcker, R. C., Schmid, E., Kriegler, E., & Edenhofer, O. (2015). Complementing carbon prices with technology policies to keep climate targets within reach. *Nature Climate Change*, *5*(3), 235–239. https://doi.org/10.1038/nclimate2514

Bicket, M., & Vanner, R. (2016). Designing policy mixes for resource efficiency: The role of public acceptability. *Sustainability*, *8*(4), 366. https://doi.org/10.3390/su8040366

Bosetti, V., & Victor, D. G. (2011). Politics and economics of second-best regulation of greenhouse gases: The importance of regulatory credibility. *The Energy Journal*, *32*(1), 1–24. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol32-No1-1

Bouma, J. A., Verbraak, M., Dietz, F., & Brouwer, R. (2019). Policy mix: Mess or merit? *Journal of Environmental Economics and Policy*, *8*(1), 32–47. https://doi.org/10.1080/21606544.2018.1494636

Braathen, N. A. (2007). Instrument mixes for environmental policy: How many stones should be used to kill a bird? *International Review of Environmental and Resource Economics*, *1*(2), 185–236. http://dx.doi.org/10.1561/101.00000005

Burke, M. J., & Stephens, J. C. (2017). Energy democracy: Goals and policy instruments for sociotechnical transitions. *Energy Research & Social Science*, *33*, 35–48. https://doi.org/10.1016/j.erss.2017.09.024

Capano, G., & Howlett, M. (2020). The knowns and unknowns of policy instrument analysis: Policy tools and the current research agenda on policy mixes. *SAGE Open*, *10*(1). https://doi.org/10.1177/2158244019900568

Ćetković, S., & Skjærseth, J. B. (2019). Creative and disruptive elements in Norway´s climate policy mix: The small-state perspective. *Environmental Politics*, *28*(6), 1039–1060. https://doi.org/10.1080/09644016.2019.1625145

Chang, R., Cao, Y., Lu, Y., & Shabunko, V. (2019). Should BIPV technologies be empowered by innovation policy mix to facilitate energy transitions? - Revealing stakeholders' different perspectives using Q methodology. *Energy Policy*, *129*, 307–318. https://doi.org/10.1016/j.enpol.2019.02.047

Costantini, V., Crespi, F., & Palma, A. (2017). Characterizing the policy mix and its impact on eco-innovation: A patent analysis of energy-efficient technologies. *Research Policy*, *46*(4), 799–819. https://doi.org/10.1016/j.respol.2017.02.004

Cunningham, P., Nauewelaers, C., Boekholt, P., Mostert, B., Guy, K., Hofer, R., & Rammer, C. (2009). *Policy Mixes for R&D in Europe*. United Nations University, Maastricht Economic and Social Research Institute on Innovation and Technology. https://www.research.manchester.ac.uk/portal/en/publications/policy-mixes-for-rd-in-europe(e83b3c90-625d-484e-9306-32a3ec71afe8).html

David, M. (2017). Moving beyond the heuristic of creative destruction: Targeting exnovation with policy mixes for energy transitions. *Energy Research & Social Science*, *33*, 138–146. https://doi.org/10.1016/j.erss.2017.09.023

del Río, P. (2017). Why does the combination of the European Union Emissions Trading Scheme and a renewable energy target makes economic sense? *Renewable and Sustainable Energy Reviews*, *74*, 824–834. https://doi.org/10.1016/j.rser.2017.01.122

Edenhofer, O., Hirth, L., Knopf, B., Pahle, M., Schlömer, S., Schmid, E., & Ueckerdt, F. (2013). On the economics of renewable energy sources. *Energy Economics*, *40*, S12–S23. https://doi.org/10.1016/j.eneco.2013.09.015

Edmondson, D. L., Kern, F., & Rogge, K. S. (2019). The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions. *Research Policy*, *48*(10), 103555. https://doi.org/10.1016/j.respol.2018.03.010

Faehn, T., & Isaksen, E. T. (2016). Diffusion of climate technologies in the presence of commitment problems. *The Energy Journal*, *37*(2), 155–180. https://doi.org/10.5547/01956574.37.2.tfae

Flanagan, K., Uyarra, E., & Laranja, M. (2011). Reconceptualising the 'policy mix' for innovation. *Research Policy*, *40*(5), 702–713. https://doi.org/10.1016/j.respol.2011.02.005

Foxon, T., & Pearson, P. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: Some features of a sustainable innovation policy regime. *Journal of Cleaner Production*, *16*(1, Supplement 1), S148–S161. https://doi.org/10.1016/j.jclepro.2007.10.011

Gebara, M. F., Sills, E., May, P., & Forsyth, T. (2019). Deconstructing the policyscape for reducing deforestation in the Eastern Amazon: Practical insights for a landscape approach. *Environmental Policy and Governance*, *29*(3), 185–197. https://doi.org/10.1002/eet.1846

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W. (2014). Regime resistance against low-carbon transitions: Introducing politics and power into the Multi-Level Perspective. *Theory, Culture & Society*, *31*(5), 21–40. https://doi.org/10.1177/0263276414531627

Givoni, M., Macmillen, J., Banister, D., & Feitelson, E. (2013). From policy measures to policy packages. *Transport Reviews*, *33*(1), 1–20. https://doi.org/10.1080/01441647.2012.744779

Gomel, D., & Rogge, K. S. (2020). Mere deployment of renewables or industry formation, too? Exploring the role of advocacy communities for the Argentinean energy policy mix. *Environmental Innovation and Societal Transitions*, *36*, 345–371. https://doi.org/10.1016/j.eist.2020.02.003

Greco, M., Germani, F., Grimaldi, M., & Radicic, D. (2022). Policy mix or policy mess? Effects of cross-instrumental policy mix on eco-innovation in German firms. *Technovation*, *117*, 102194. https://doi.org/10.1016/j.technovation.2020.102194

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413–432. https://doi.org/10.1016/j.techfore.2006.03.002

Howlett, M. (2009). Process sequencing policy dynamics: Beyond homeostasis and path dependency. *Journal of Public Policy*, *29*(3), 241–262. https://doi.org/10.1017/S0143814X09990158

Howlett, M., & del Rio, P. (2015). The parameters of policy portfolios: Verticality and horizontality in design spaces and their consequences for policy mix formulation. *Environment and Planning C: Government and Policy*, *33*(5), 1233–1245. https://doi.org/10.1177/0263774X15610059

Howlett, M., Kim, J., & Weaver, P. (2006). Assessing instrument mixes through program- and agency-level data: Methodological issues in contemporary implementation research. *Review of Policy Research*, *23*(1), 129–151. https://doi.org/10.1111/j.1541-1338.2006.00189.x

Howlett, M., Mukherjee, I., & Woo, J. J. (2015). From tools to toolkits in policy design studies: The new design orientation towards policy formulation research. *Policy & Politics*, *43*(2), 291–311. https://doi.org/10.1332/147084414X13992869118596

Howlett, M., & Rayner, J. (2013). Patching vs packaging in policy formulation: Assessing policy portfolio design. *Politics and Governance*, *1*(2), 170–182. https://doi.org/10.17645/pag.v1i2.95

Huang, P. (2019). The verticality of policy mixes for sustainability transitions: A case study of solar water heating in China. *Research Policy*, 48(10), 103758. https://doi.org/10.1016/j.respol.2019.02.009

Jacobsson, S., Bergek, A., & Sandén, B. (2017). Improving the European Commission's analytical base for designing instrument mixes in the energy sector: Market failures versus system weaknesses. *Energy Research & Social Science*, *33*, 11–20. https://doi.org/10.1016/j.erss.2017.09.009

Jakob, M. (2017). Ecuador's climate targets: A credible entry point to a low-carbon economy? *Energy for Sustainable Development*, *39*, 91–100. https://doi.org/10.1016/j.esd.2017.04.005

Kalfagianni, A., & Kuik, O. (2017). Seeking optimality in climate change agri-food policies: Stakeholder perspectives from Western Europe. *Climate Policy*, *17*(sup1), S72–S92. https://doi.org/10.1080/14693062.2016.1244508

Kanger, L., Sovacool, B. K., & Noorkõiv, M. (2020). Six policy intervention points for sustainability transitions: A conceptual framework and a systematic literature review. *Research Policy*, *49*(7), 104072. https://doi.org/10.1016/j.respol.2020.104072

Kern, F., & Howlett, M. (2009). Implementing transition management as policy reforms: A case study of the Dutch energy sector. *Policy Sciences*, *42*(4), 391–408. https://doi.org/10.1007/s11077-009-9099-x

Kern, F., Kivimaa, P., & Martiskainen, M. (2017). Policy packaging or policy patching? The development of complex energy efficiency policy mixes. *Energy Research & Social Science*, *23*, 11–25. https://doi.org/10.1016/j.erss.2016.11.002

Kern, F., & Rogge, K. S. (2018). Harnessing theories of the policy process for analysing the politics of sustainability transitions: A critical survey. *Environmental Innovation and Societal Transitions*, *27*, 102–117. https://doi.org/10.1016/j.eist.2017.11.001

Kern, F., Rogge, K. S., & Howlett, M. (2019). Policy mixes for sustainability transitions: New approaches and insights through bridging innovation and policy studies. *Research Policy*, *48*(10), 103832. https://doi.org/10.1016/j.respol.2019.103832

Kivimaa, P., Kangas, H.-L., & Lazarevic, D. (2017). Client-oriented evaluation of 'creative destruction' in policy mixes: Finnish policies on building energy efficiency transition. *Energy Research & Social Science*, *33*, 115–127. https://doi.org/10.1016/j.erss.2017.09.002

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, *45*(1), 205–217. https://doi.org/10.1016/j.respol.2015.09.008

Kivimaa, P., & Rogge, K. S. (2022). Interplay of policy experimentation and institutional change in sustainability transitions: The case of mobility as a service in Finland. *Research Policy*, *51*(1), 104412. https://doi.org/10.1016/j.respol.2021.104412

Kivimaa, P., & Sivonen, M. H. (2021). Interplay between low-carbon energy transitions and national security: An analysis of policy integration and coherence in Estonia, Finland and Scotland. *Energy Research & Social Science*, *75*, 102024. https://doi.org/10.1016/j.erss.2021.102024

Kriegler, E., Bertram, C., Kuramochi, T., Jakob, M., Pehl, M., Stevanović, M., Höhne, N., Luderer, G., Minx, J. C., Fekete, H., Hilaire, J., Luna, L., Popp, A., Steckel, J. C., Sterl, S., Yalew, A. W., Dietrich, J. P., & Edenhofer, O. (2018). Short term policies to keep the door open for Paris climate goals. *Environmental Research Letters*, *13*(7), 074022. https://doi.org/10.1088/1748-9326/aac4f1

Lehmann, P. (2012). Justifying a policy mix for pollution control: A review of economic literature. *Journal of Economic Surveys*, *26*(1), 71–97. https://doi.org/10.1111/j.1467-6419.2010.00628.x

Lehmann, P., Sijm, J., Gawel, E., Strunz, S., Chewpreecha, U., Mercure, J.-F., & Pollitt, H. (2019). Addressing multiple externalities from electricity generation: A case for EU renewable energy policy beyond 2020? *Environmental Economics and Policy Studies*, *21*(2), 255–283. https://doi.org/10.1007/s10018-018-0229-6

Li, H., Bao, Q., Ren, X., Xie, Y., Ren, J., & Yang, Y. (2017). Reducing rebound effect through fossil subsidies reform: A comprehensive evaluation in China. *Journal of Cleaner Production*, *141*, 305–314. https://doi.org/10.1016/j.jclepro.2016.09.108

Li, L., & Taeihagh, A. (2020). An in-depth analysis of the evolution of the policy mix for the sustainable energy transition in China from 1981 to 2020. *Applied Energy*, *263*, 114611. https://doi.org/10.1016/j.apenergy.2020.114611

Lieu, J., Spyridaki, N. A., Alvarez-Tinoco, R., Van der Gaast, W., Tuerk, A., & Van Vliet, O. (2018). Evaluating consistency in environmental policy mixes through policy, stakeholder, and contextual interactions. *Sustainability*, *10*(6), 1896. https://doi.org/10.3390/su10061896

Magro, E., Navarro, M., & Zabala-Iturriagagoitia, J. M. (2014). Coordination-mix: The hidden face of STI policy. *Review of Policy Research*, *31*(5), 367–389. https://doi.org/10.1111/ropr.12090

Magro, E., & Wilson, J. R. (2019). Policy-mix evaluation: Governance challenges from new place-based innovation policies. *Research Policy*, *48*(10), 103612. https://doi.org/10.1016/j.respol.2018.06.010

Matti, C., Consoli, D., & Uyarra, E. (2017). Multi level policy mixes and industry emergence: The case of wind energy in Spain. *Environment and Planning C: Politics and Space*, *35*(4), 661–683. https://doi.org/10.1177/0263774X16663933

Mavrot, C., Hadorn, S., & Sager, F. (2019). Mapping the mix: Linking instruments, settings and target groups in the study of policy mixes. *Research Policy*, *48*(10), 103614. https://doi.org/10.1016/j.respol.2018.06.012

Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences*, *42*(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z

Meckling, J., Kelsey, N., Biber, E., & Zysman, J. (2015). Winning coalitions for climate policy. *Science*, *349*(6253), 1170–1171. https://doi.org/10.1126/science.aab1336

Meissner, D., & Kergroach, S. (2021). Innovation policy mix: Mapping and measurement. *The Journal of Technology Transfer*, *46*(1), 197–222. https://doi.org/10.1007/s10961-019-09767-4

Nemet, G. F., Jakob, M., Steckel, J. C., & Edenhofer, O. (2017). Addressing policy credibility problems for low-carbon investment. *Global Environmental Change*, *42*, 47–57. https://doi.org/10.1016/j.gloenvcha.2016.12.004

Obersteiner, M., Walsh, B., Frank, S., Havlík, P., Cantele, M., Liu, J., Palazzo, A., Herrero, M., Lu, Y., Mosnier, A., Valin, H., Riahi, K., Kraxner, F., Fritz, S., & van Vuuren, D. (2016). Assessing the land resource–food price nexus of the Sustainable Development Goals. *Science Advances*, *2*(9), e1501499. https://doi.org/10.1126/sciadv.1501499

Ossenbrink, J., Finnsson, S., Bening, C. R., & Hoffmann, V. H. (2019). Delineating policy mixes: Contrasting top-down and bottom-up approaches to the case of energy-storage policy in California. *Research Policy*, *48*(10), 103582. https://doi.org/10.1016/j.respol.2018.04.014

Passey, R., Bailey, I., Twomey, P., & MacGill, I. (2012). The inevitability of 'flotilla policies' as complements or alternatives to flagship emissions trading schemes. *Energy Policy*, *48*, 551–561. https://doi.org/10.1016/j.enpol.2012.05.059

Patt, A., & Lilliestam, J. (2018). The case against carbon prices *Joule*, *2*(12), 2494–2498. https://doi.org/10.1016/j.joule.2018.11.018

Petersen, J.-P., & Heurkens, E. (2018). Implementing energy policies in urban development projects: The role of public planning authorities in Denmark, Germany and the Netherlands. *Land Use Policy*, *76*, 275–289. https://doi.org/10.1016/j.landusepol.2018.05.004

Quitzow, R. (2015). Assessing policy strategies for the promotion of environmental technologies: A review of India's National Solar Mission. *Research Policy*, *44*(1), 233–243. https://doi.org/10.1016/j.respol.2014.09.003

Rahman, M. S., & Giessen, L. (2017). The power of public bureaucracies: Forest-related climate change policies in Bangladesh (1992–2014). *Climate Policy*, *17*(7), 915–935. https://doi.org/10.1080/14693062.2016.1197093

Rayner, J., Howlett, M., & Wellstead, A. (2017). Policy mixes and their alignment over time: Patching and stretching in the oil sands reclamation regime in Alberta, Canada. *Environmental Policy and Governance*, *27*(5), 472–483. https://doi.org/10.1002/eet.1773

Roberts, C., Geels, F. W., Lockwood, M., Newell, P., Schmitz, H., Turnheim, B., & Jordan, A. (2018). The politics of accelerating low-carbon transitions: Towards a new research agenda. *Energy Research & Social Science*, *44*, 304–311. https://doi.org/10.1016/j.erss.2018.06.001

Rogge, K. S. (2019). Policy mixes for sustainable innovation: Conceptual considerations and empirical insights. In *Handbook of Sustainable Innovation* (pp. 165–185). Edward Elgar Publishing. https://www.elgaronline.com/view/edcoll/9781788112567/9781788112567.00016.xml

Rogge, K. S., & Dütschke, E. (2018). What makes them believe in the low-carbon energy transition? Exploring corporate perceptions of the credibility of climate policy mixes. *Environmental Science & Policy*, *87*, 74–84. https://doi.org/10.1016/j.envsci.2018.05.009

Rogge, K. S., Kern, F., & Howlett, M. (2017). Conceptual and empirical advances in analysing policy mixes for energy transitions. *Energy Research & Social Science*, *33*, 1–10. https://doi.org/10.1016/j.erss.2017.09.025

Rogge, K. S., & Reichardt, K. (2016). Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Research Policy*, *45*(8), 1620–1635. https://doi.org/10.1016/j.respol.2016.04.004

Rogge, K. S., & Schleich, J. (2018). Do policy mix characteristics matter for low-carbon innovation? A survey-based exploration of renewable power generation technologies in Germany. *Research Policy*, *47*(9), 1639–1654. https://doi.org/10.1016/j.respol.2018.05.011

Rosenbloom, D. (2018). Framing low-carbon pathways: A discursive analysis of contending storylines surrounding the phase-out of coal-fired power in Ontario. *Environmental Innovation and Societal Transitions*, *27*, 129–145. https://doi.org/10.1016/j.eist.2017.11.003

Ščasný, M., Zvěřinová, I., Czajkowski, M., Kyselá, E., & Zagórska, K. (2017). Public acceptability of climate change mitigation policies: A discrete choice experiment. *Climate Policy*, *17*(sup1), S111–S130. https://doi.org/10.1080/14693062.2016.1248888

Schmidt, T. S., Schneider, M., Rogge, K. S., Schuetz, M. J. A., & Hoffmann, V. H. (2012). The effects of climate policy on the rate and direction of innovation: A survey of the EU ETS and the electricity sector. *Environmental Innovation and Societal Transitions*, *2*, 23–48. https://doi.org/10.1016/j.eist.2011.12.002

Schmidt, T. S., & Sewerin, S. (2017). Technology as a driver of climate and energy politics. *Nature Energy*, *2*(6), 1–3. https://doi.org/10.1038/nenergy.2017.84

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, *20*(5), 537–554. https://doi.org/10.1080/09537320802292651

Scordato, L., Klitkou, A., Tartiu, V. E., & Coenen, L. (2018). Policy mixes for the sustainability transition of the pulp and paper industry in Sweden. *Journal of Cleaner Production*, *183*, 1216–1227. https://doi.org/10.1016/j.jclepro.2018.02.212

Scullion, J. J., Vogt, K. A., Winkler-Schor, S., Sienkiewicz, A., Peña, C., & Hajek, F. (2016). Designing conservation-development policies for the forest frontier. *Sustainability Science*, *11*(2), 295–306. https://doi.org/10.1007/s11625-015-0315-7

Soria-Lara, J. A., & Banister, D. (2018). Evaluating the impacts of transport backcasting scenarios with multi-criteria analysis. *Transportation Research Part A: Policy and Practice*, *110*, 26–37. https://doi.org/10.1016/j.tra.2018.02.004

Sorrell, S., & Sijm, J. (2003). Carbon trading in the policy mix. *Oxford Review of Economic Policy*, *19*(3), 420–437. https://doi.org/10.1093/oxrep/19.3.420

Sovacool, B. K. (2009). The importance of comprehensiveness in renewable electricity and energy-efficiency policy. *Energy Policy*, *37*(4), 1529–1541. https://doi.org/10.1016/j.enpol.2008.12.016

Stirling, A. (2014). Transforming power: Social science and the politics of energy choices. *Energy Research & Social Science*, *1*, 83–95. https://doi.org/10.1016/j.erss.2014.02.001

Taeihagh, A., Givoni, M., & Bañares-Alcántara, R. (2013). Which policy first? A network-centric approach for the analysis and ranking of policy measures. *Environment and Planning B: Planning and Design*, *40*(4), 595–616. https://doi.org/10.1068/b38058

Trein, P., Biesbroek, R., Bolognesi, T., Cejudo, G. M., Duffy, R., Hustedt, T., & Meyer, I. (2021). Policy coordination and integration: A research agenda. *Public Administration Review*, *81*(5), 973–977. https://doi.org/10.1111/puar.13180

Tvinnereim, E., & Mehling, M. (2018). Carbon pricing and deep decarbonisation. *Energy Policy*, *121*, 185–189. https://doi.org/10.1016/j.enpol.2018.06.020

Uyarra, E., Shapira, P., & Harding, A. (2016). Low carbon innovation and enterprise growth in the UK: Challenges of a place-blind policy mix. *Technological Forecasting and Social Change*, *103*, 264–272. https://doi.org/10.1016/j.techfore.2015.10.008

Viguié, V., & Hallegatte, S. (2012). Trade-offs and synergies in urban climate policies. *Nature Climate Change*, *2*(5), 334–337. https://doi.org/10.1038/nclimate1434

von Stechow, C., McCollum, D., Riahi, K., Minx, J. C., Kriegler, E., van Vuuren, D. P., Jewell, J., Robledo-Abad, C., Hertwich, E., Tavoni, M., Mirasgedis, S., Lah, O., Roy, J., Mulugetta, Y., Dubash, N. K., Bollen, J., Ürge-Vorsatz, D., & Edenhofer, O. (2015). Integrating global climate change mitigation goals with other sustainability objectives: A synthesis. *Annual Review of Environment and Resources*, *40*(1), 363–394. https://doi.org/10.1146/annurev-environ-021113-095626

Voß, J.-P., Smith, A., & Grin, J. (2009). Designing long-term policy: Rethinking transition management. *Policy Sciences*, *42*(4), 275–302. https://doi.org/10.1007/s11077-009-9103-5

Weber, K. M., & Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Research Policy*, *41*(6), 1037–1047. https://doi.org/10.1016/j.respol.2011.10.015

Wicki, M., Fesenfeld, L., & Bernauer, T. (2019). In search of politically feasible policy-packages for sustainable passenger transport: Insights from choice experiments in China, Germany, and the USA. *Environmental Research Letters*, *14*(8), 084048. https://doi.org/10.1088/1748-9326/ab30a2

Wilts, H., & O'Brien, M. (2019). A policy mix for resource efficiency in the EU: Key instruments, challenges and research needs. *Ecological Economics*, *155*, 59–69. https://doi.org/10.1016/j.ecolecon.2018.05.004

Xu, L., & Su, J. (2016). From government to market and from producer to consumer: Transition of policy mix towards clean mobility in China. *Energy Policy*, *96*, 328–340. https://doi.org/10.1016/j.enpol.2016.05.038

Yoon, J.-H., & Sim, K. (2015). Why is South Korea's renewable energy policy failing? A qualitative evaluation. *Energy Policy*, *86*, 369–379. https://doi.org/10.1016/j.enpol.2015.07.020