Configuring sociotechnical policy mixes for transformative change: Six intervention points

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1. Introduction

The mounting challenge of climate change has led to increasingly urgent calls for rapid and deep decarbonization (SDSN and IDDRI, 2014; Geels et al., 2017; Rockström et al., 2017). As industrial societies are fundamentally underpinned by various socio-technical systems (e.g. mobility, energy, food, housing, healthcare), radical and coordinated changes in their basic mode of operation are called for (Schot and Kanger, 2018; Kanger and Schot, 2018). Work in the sustainability transitions field (Rip and Kemp, 1998; Geels, 2005a; Grin et al., 2010) in particular has focused on identifying the preconditions, driving mechanisms, broad patterns and possibilities for accelerating radical transformations in socio-technical systems (van den Bergh et al., 2011; Markard et al., 2012; Köhler et al., 2019).

In parallel, there has been a growing recognition in the policy studies and innovation policy fields that system innovation requires new policy approaches. Over the past decade a third generation of innovation policy has been emerging (Schot and Steinmueller, 2018). Whereas the first generation (dominant in the post-WWII era) focused on the relation between basic science and its applications and the second one (onward from the 1980s) on accelerating the speed of innovations, the third one aims to tackle the directionality and purpose (Stirling, 2008) of socio-technical systems. Corresponding to each of these generations, it has been suggested that innovation policies might then lead to either market, structural system or transformational system failures (Weber and Rohracher, 2012). In sustainability transitions field this shift has led to a growing interest in the design of "policy mixes" (Kivimaa and Kern, 2016; Rogge and Reichardt, 2016), i.e. mutually supporting instruments and strategies for facilitating and accelerating transformative systems change.

Existing work on policy mixes has been criticized for its over-reliance on single case or small-N research strategies, and insufficient attention to terminology and variable definition. Arguably this has led to a lack of fruitful accumulation of empirical studies as well as insufficient theorization (Howlett and del Rio, 2015). As a response recent work has attempted to improve the conceptual foundations of policy mixes including their design, composition and desirable characteristics (Rogge et al., 2017; Edmondson et al., 2018), to quantify the temporal dynamics of policy mixes in large-N studies (Schmidt and Severin, 2018) and to employ mixed method strategies (Mavrot et al., 2018).

This paper starts from the intuition that whereas the intersection of policy mixes and sustainability transitions literature has so far been productive, the former has yet to make full use of the insights of the latter. This is reflected in two aspects: first, existing literature on policy mixes tends to focus on particular loci of intervention for achieving transformative systems change, but to the relative neglect of other possibilities. Second, save for a few recent exceptions (Lindberg et al., 2018; Rogge et al., 2018) the policy mixes literature has yet to engage with differing pathways of socio-technical transitions. Therefore, this paper aims to reflect on the findings of transitions studies and to use this reflection for broadening the focus of existing policy mixes literature. In addition to informing future studies this exercise enables to offer a theory-based guide for the assessment of existing policies and for the design and implementation of policy mixes. As such the paper focuses on the following questions:

1. What kind of intervention points for transformative systems change can be uncovered from current literature on sustainability transitions?
2. What kind of intervention points for systems change are present in the current literature on policy mixes?
3. What kind of intervention points might be crucial for different transition pathways?

Section 2 presents a brief overview of an influential theoretical framework in the sustainability transitions field, the Multi-level Perspective (Geels, 2005a; Grin et al., 2010; Geels et al., 2017), and its recent extensions to the study of phenomena extending beyond a single system. Section 3 describes the methodological approach of the paper. Section 4 transforms the findings on transitions studies into six policy intervention points for accelerating system shifts, compares the results to the current policy mixes literature and finally, in a somewhat more speculative manner, discusses the possible relations between particular transition pathways and corresponding key intervention points. Section 5 concludes.

2. The Multi-Level Perspective on socio-technical transitions

Transitions can be defined as long-term (50 years and more) shifts from one socio-technical system to another (Geels and Schot, 2010: 11). A socio-technical system refers to a configuration of actors, rules and technologies for the fulfilment of a particular societal function such as communication, food production or transportation. This configuration encompasses the dimensions of science and engineering, economy, policy, everyday life, behaviour and culture. For example, a system of personal land-based transportation entails the mutual alignment of vehicles, road infrastructure, repair shops, dealer networks, production facilities, traffic regulation, users' driving routines and symbolic meanings of the automobile (Geels, 2005a: 147).

The Multi-Level Perspective, or MLP, proposes that transitions come about through interrelated processes on three levels: niche, regime and landscape (Geels, 2002, 2005a). Socio-technical regimes are defined as shared, stable and aligned sets of rules directing the behaviour of actors in a particular system. These rules are embedded in various elements of the socio-technical system, and they shape innovative activities towards a specific trajectory of incremental innovation (e.g. increased fuel efficiency for cars). Radical alternatives to regimes are developed in spaces called niches. These are application areas dominated by specific selection criteria that shield the emerging new and unstable technologies from direct market pressure (e.g. military applications prioritizing performance over costs). Finally, the “landscape” represents exogenous macro-level forces such as wars or demographic changes that shape niches and regimes but are not shaped by them (in short and medium term).

Transitions usually begin when landscape changes put pressure on the dominant regime which initially attempts an internal fix to its problems. For example, 19th century urbanization exacerbated the low-speed problem of horse-drawn carriages, leading to the introduction of horse-drawn rail cars. The same pressures, however, also provided a “window of opportunity” for niches such as bicycles (Geels, 2005a). As the regime becomes further destabilized, it prompts a need for a fundamental transformation of its basic architecture. This involves interactions between the regime and emerging niches and between the niches themselves, e.g. bicycles, trams and automobiles competing with horse-drawn carriages in urban passenger transport (ibid.). Depending on the situation this process can be more or less competitive in nature. As the emerging system stabilizes along various dimensions, establishing new modes of production, distribution and consumption routines, a regime shift is completed. This is reflected in sharp increase in the adoption of the focal technology of the system, e.g. growth in car density in Western European countries after World War II (Mom, 2014: 289). Existing studies have distinguished between various transition pathways (Geels, 2002, 2005b, 2006a, 2006b; Geels and Schot, 2007, 2010).

More recently, some studies have increasingly started to conceptualize various ways in which socio-technical regimes are embedded to their environment. One stream of work has focused on the multiple locational advantages of regimes or their "socio-spatial embeddedness" (Truffer and Coenen, 2012), including informal localized institutions (Raven et al., 2012), natural resource endowments, physical infrastructure (Bridge et al., 2013) or regional industrial specialization (Hansen and Coenen, 2015). Others (Geels and Johnson, 2018; Mylan et al., 2018) have analysed the ways in which radical innovations become embedded to user, business, cultural, regulatory and transnational environments (Kanger et al., 2019). The work on embeddedness has exemplified links between socio-technical systems and their socio-material context, often providing stability for incumbent industries (Sillak and Kanger, 2018).

Another stream has focused on the evolutionary patterns of multiple regimes (Geels, 2007; Papachristos et al., 2013; Geels 2018), involving competition, symbiosis, integration and spill-over (Raven and Verbong, 2009). In particular, the Deep Transitions framework (Schot and Kanger, 2018; Kanger and Schot, 2018) has linked transitions in single systems to long waves involving interconnected systems (Freeman and Louçã, 2001; Perez, 2002) as well as broader continuities in the process of industrialization. This work has turned attention to the co-evolution of socio-technical systems over long time-scales and the need to simultaneously address the common unsustainable directionality of a broad range of systems.

3. Methodology

The transitions studies field is increasingly characterized by systematic reviews of studies on particular aspects such as the role of actors (Fischer and Newig, 2016), experiments (Sengers et al., 2016), theoretical foundations (Savaget et al., 2019) or intermediaries (Kivimaa et al., 2019). As these studies focus on summarizing existing studies it means that they also tend to prioritize the empirically observable. This makes such reviews vulnerable to the criticism of not being able to pick up whether the field itself has been biased in its research efforts. In order to avoid committing the same error for literature on policy mixes in sustainability transitions we therefore started from conceptualizing the logically possible. That is, based on our familiarity with transitions studies (as presented in section 2), we reflected on different factors facilitating transitions and subsequently translated these into six "intervention points" where different policies could be applied. This enabled us to formulate tentative answers to research questions 1 and 3.

In order to answer research question 2 we then conducted a brief theory-guided scoping review, focusing on the following questions: 1) to what extent are different policy intervention points present in the literature on policy mixes and sustainability transitions? 2) how systematically are different intervention points being addressed? 3) how clearly are different intervention points being mentioned? We performed an article search in Science Direct database using the following keywords: ("sustainability transitions" OR "socio-technical transitions") AND "policy mix". The abstract of each article was then reviewed manually to decide whether the article would be included in further analysis or not. The main inclusion criterion was that the study had to make systematic use of both transitions theory and policy mixes. Out of 130 initial items, 69 articles were eventually selected for further review. For each article the following attributes were recorded: presence of particular intervention points (from none to all six), systemicity of treatment (i.e. whether the particular intervention point was an integral part of the analysis or rather mentioned as an off-hand comment), clarity of treatment (i.e. whether the policy mixes were clearly linked to particular intervention points or whether linking these two required a generous amount of interpretation from the reader).

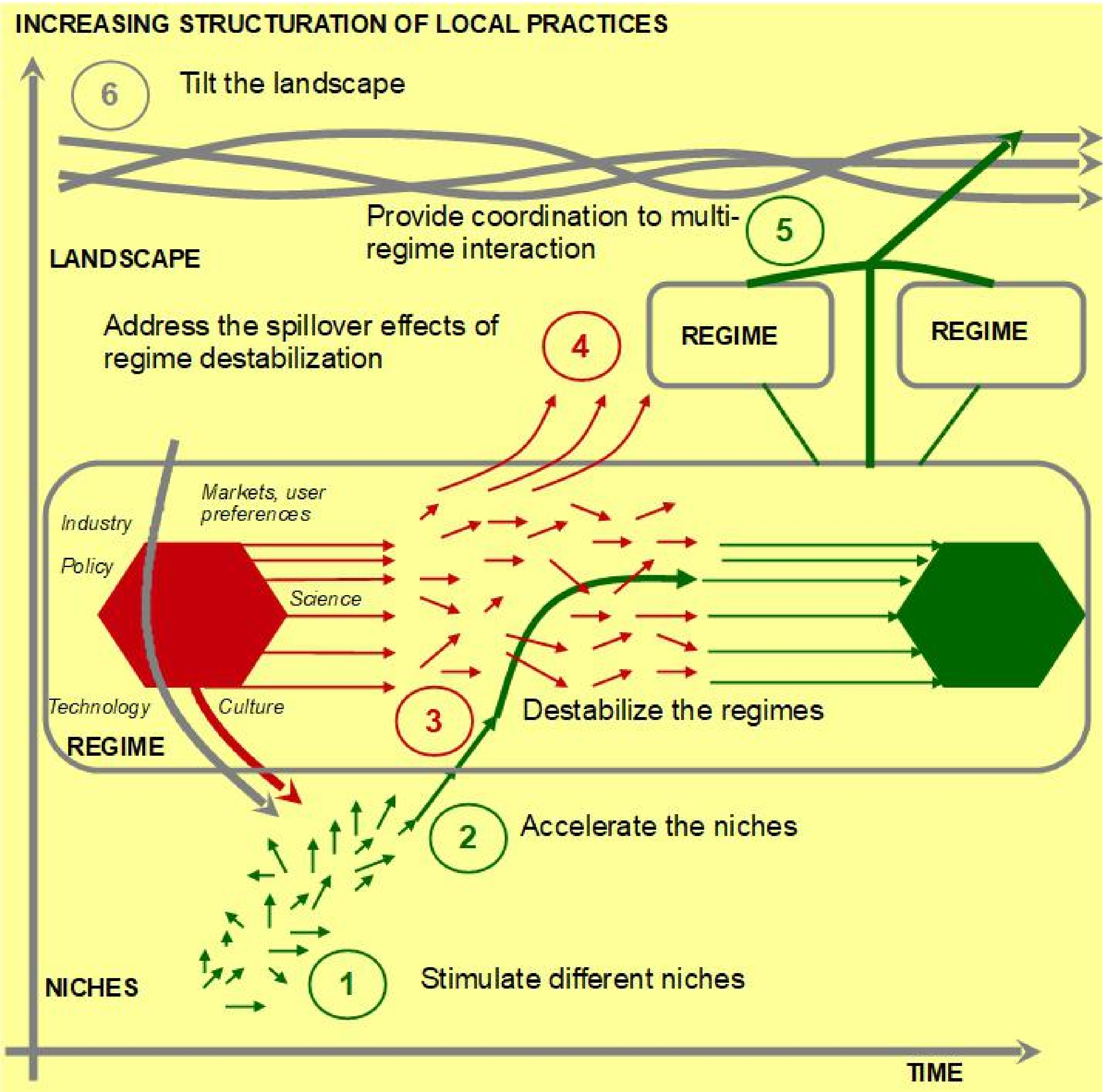
4. Sustainability transitions and policy mixes

In this section we begin from outlining the six policy intervention points, illustrating each with empirical examples from policy practice. We then provide an overview of our literature review, demonstrating its bias and reflecting on the importance of this bias for the design of policy mixes. We move on to identify key intervention points for each transition pathway.

4.1 Six policy intervention points for sustainability transitions

Existing work on transitions (as summarized in section 2) has identified a number of factors facilitating large-scale socio-technical system shifts. These include the inability of the regime to solve its problems internally, the availability of niches challenging the incumbent regime as well as the role of the landscape in destabilizing regimes and providing a window of opportunity for the niches. Later work has also exemplified the need to target the links between the focal system and its broader environment, including the interdependence of socio-technical systems. Based on this we distinguish between six intervention points for facilitating systems change: 1) stimulate different niches; 2) accelerate the niches; 3) destabilize the regimes; 4) address the spill-over effects of regime destabilization; 5) provide coordination for multi-regime interaction; 6) tilt the landscape. Figure 1 provides a visual summary of these intervention points.

Figure 1. Six intervention points for systems change.



4.1.1 Stimulate different niches

MLP identifies itself as a cross-over between sociological approaches and evolutionary economics (Geels and Schot, 2007; Geels, 2010, 2011), encompassing, on one hand, social learning, collective interpretation and power struggles but also the processes of variation, selection and retention. From the evolutionary perspective variety in different niches plays an important role as it presents a pool of alternative solutions for challenging and transforming the incumbent regime. At the same time emerging niches also need to become mature enough to enter the market: therefore, for a certain amount of time some regulatory shielding is often required.

Measures to stimulate niches include R&D funding schemes, public procurement, foresight exercises to create future visions, relaxing certain regulatory conditions etc. (Kivimaa and Kern, 2016: 208-209). What is important for this intervention point is to sustain variety, e.g. supporting biofuels, electric vehicles, driverless vehicles and mobility-as-a-service as alternatives in the mobility system or solar, wind, geothermal energy, community energy projects and decentralized production as alternatives in the energy system.

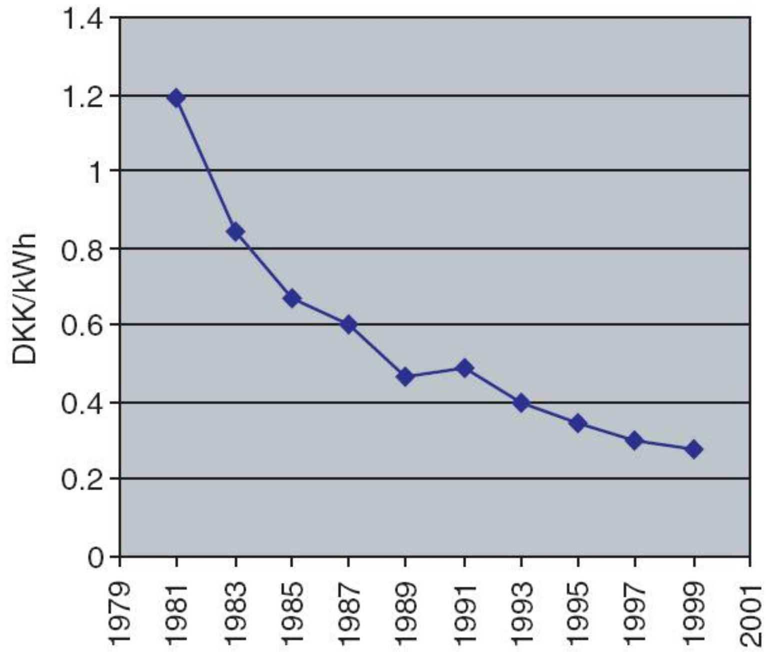
Chinese policy towards new energy vehicles (NEV) is a good example of this kind of stimulation by the government. In 2008 NEVs accounted for almost no share of the Chinese automotive market. Just 7 years later sales reached 330,000, turning China into the largest NEV market in the world. This impressive growth was made possible by government policies that did not pick winners at the niche level where very different competing solutions existed, including hybrids, fuel-cell vehicles and battery electric vehicles. Instead, government policies focused on financing the R&D of all the NEV technologies and intervening on the consumer side by offering purchase rebates to make all NEVs more accessible (Xu and Su, 2016).

4.1.2 Accelerate the niches

Emerging technologies need to cross the “valley of death” between R&D activities and market entry (Schot and Geels, 2008). Furthermore, transitions are about systemic changes, including the combination of technological, organizational and institutional innovations, new user practices and changing cultural meanings. This means that apart from supporting the scale-up of single niches, the latter also need to be aligned to each other to achieve systemic change. Measures to accelerate the niches include the creation of innovation platforms, the introduction of market-based policy instruments, the promotion of entrepreneurship, advice systems for small and medium enterprises, provision of venture capital etc. (Kivimaa and Kern, 2016: 208-209). For example, in the mobility system regulatory intervention might be explicitly targeted at linking electric and driverless vehicles in a mobility-as-a-service business model. In the energy system, state loans might be used to facilitate the commercialization and domestic take-up of solar energy.

Danish R&D investments in wind energy offer a paradigmatic example. From the 1970s researchers started with low-tech windmill designs, took smaller steps in scaling up technologies, and engaged continually in product development. Thus, as the design of hubs, high-quality shafts, mechanical brakes, electronic control systems, components of the yaw-system, and quality gears were undertaken in a collaborative network, costs slowly declined. By 1985, Danish wind turbine manufacturers held 50 percent of the world market and had produced about 700 MW of the 1,500 MW of wind power installed in California. Before consolidation in 2001, four of the world’s largest six wind turbine manufacturers were Danish. Furthermore, the Danes were able to achieve such status in an extremely cost-effective manner. Approximately $2.4 billion was spent on wind energy related R&D worldwide between 1976 and 1995; the Danish government’s R&D funding accounted for about 4.2 percent of this total, while the U.S. government’s funding for wind turbine R&D was nearly 11 times greater (Sawin, 2001: 334-335).

Figure 2. Generation costs of wind turbines in Denmark, 1980 to 2000 (in DKK) (Agnolucci, 2007).



4.1.3 Destabilize the regimes

Transitions do not happen merely when niches are present, even if they are mature and inter-linked to a certain degree. The incumbent regime also needs to become destabilized to allow niches to break through. Measures to destabilize regimes include taxes for putting economic pressure on the regimes, banning of specific technologies and practices, removing subsidies for certain industries or balancing the involvement of incumbents in policy advisory councils with niche actors (Kivimaa and Kern, 2016: 208-209). For example, in the mobility system increased taxation of gasoline-based cars (combined with support for vehicles with alternative fuel sources) might be used to challenge the traditional mobility system. In the energy system the state might cut subsidies for fossil fuel based energy production or, as in the case of Norway's sovereign wealth fund, divest from companies exploring oil and gas (The Guardian, 08.03.2019).

Global efforts at subsidy reform do represent active efforts to destabilize regimes, and they are more prominent than many may realize. Several European states – Austria, Belgium, Czech Republic, Greece, Hungary, Italy, Poland, Portugal, and Slovakia – repealed reduced value added tax (VAT) rates to coal, fuel oil, natural gas, and electricity providers over the previous three decades. These artificially low VAT rates had been implemented to benefit poor households – similar to low VATs given on other "basic needs" such as food. However, the VAT subsidies were eliminated when it was discovered that most of their benefits went to the rich, rather than the poor, since the wealthy tended to consume more energy, and that removal had only a negligible impact on energy market prices but saved drastic amounts of tax revenue for the governments involved (IEEP et al., 2007). Table 1 shows 25 countries over the past sixty years who have implemented substantial subsidy reforms. Their efforts do suggest that subsidy removal and reform can bring substantial positive impacts on energy prices or national economic development.

Table 1. Successful examples of national subsidy reform, 1952 to 2016 (Sovacool, 2017).

Country	Year(s)	Energy Source	Description/Result
Armenia	1994	Electricity	Scaled back electricity subsidies by 22 percent of GDP from 1994 to 2004
Brazil	1990-2002	Oil and gas	Lowered subsidies for oil and gas from 0.8 percent of GDP to revenue generating in 2002
Brazil	1993-2003	Electricity	Lowered subsidies equivalent to 0.7 percent of GDP
Chile	1995	Coal	Removed its subsidies after it became apparent that coal production prices were extraordinarily high ($95 per ton) compared to other countries ($54 in Brazil, $52 for the United States). The removal actually raised incomes by almost 1 percent among all Chilean households and cut emissions of carbon dioxide and particulate matter by nearly 8 percent
China	2015	Oil and gas, electricity	To advance the reform in the pricing and taxation regime for energy- and resource-based products, China plans to revoke selected fossil fuel subsidies so that emissions drop 0.78% per year by 2020
Egypt	2014	Oil and gas, electricity	Policy is implemented using four pillars, namely: set different prices for petroleum products based on energy generation efficiency; increase the efficiency of energy use; provide support to certain sectors to promote switching from conventional energy sources to clean energy sources; and apply the fuel subsidy smartcard system to ensure that subsidies are received by target beneficiaries. Projected to reduce emissions by 14.88% by 2020.
Ghana	2005	Oil and gas	Removed subsidies to the degree that they realigned the price of energy by 50 percent
Indonesia	2005-2009, 2013	Oil and gas	Subsidies declined from 3.5 percent of GDP in 2005 to 0.8 percent in 2009, though they increased recently in 2013 due to protests
Jordan	2005-2012	Oil and gas	Gradually removed all fossil fuel subsidies by 2008, resulting in price increases ranging from 16% for gasoline to 76.5% for LPG. Energy subsidies declined from 5.8% of GDP in 2005, to 2.6% in 2006, to 0.4% in 2010 while in in November 2012 the government of Jordan announced that it had removed the remaining subsidies on oil products
Iran	2010	Oil and gas	Reduced annual growth in the national consumption of petroleum products to zero
Kenya	2001-2008	Electricity	Subsidies dropped from 1.5 percent of GDP in 2001 to 0 percent in 2008
Mauritania	2011	Oil and gas	Subsidies declined from 2 percent of GDP to close to zero in one year
Morocco	2015	Electricity	Has carefully reformed subsidies whilst at the same time expanding investment into renewable energy through ambitious targets and to people through the development of a national safety net. Carbon emissions expected to decline 6.6% by 2030
Namibia	1997	Oil and gas	Removed subsidies equal to about 0.1 percent of GDP
Niger	2011	Oil and gas	Removed subsidies equivalent to 0.9 percent of GDP
Nigeria	2011-2012	Oil and gas	Subsidies declined from 4.7 percent of GDP to 3.6 percent of GDP
Peru	2010	Oil and gas	Lowered subsidies for petroleum equivalent to 0.1 percent of

			GDP
Philippines	1996	Oil and gas	Government successfully removed energy subsidies equivalent to 0.1 percent of national GDP
Philippines	2001-2006	Electricity	Subsidies dropped from 1.5 percent of national GDP to 0 percent
Poland	1998	Coal	Forced the coal sector to improve its efficiency and substantially reduced fiscal transfers
South Africa	1952-1957	Oil and gas	Successfully avoided subsidies and still secured energy supply
Turkey	1998	Electricity	Removal of fossil fuel subsidies put competitive pressure on electricity suppliers and turned their net losses into profitability
Uganda	1999	Electricity	Subsidies declined equivalent to the amount of 2.1 percent of GDP
United Arab Emirates	2014	Oil and gas, electricity	Has introduced a new fuel pricing policy, which will put the UAE in line with global prices to support the national economy, lower fuel consumption and protect the environment. Fossil fuel subsidies will decline 14.41% by 2020
Yemen	2005-2010	Oil and gas	Subsidies dropped from 8.7 percent of GDP in 2005 to 7.4 percent in 2011

4.1.4 Address the spillover effects of regime destabilization

Systems do not exist in isolation but are socio-spatially embedded to their surrounding environment on multiple scales (regional, societal, global) and in multiple ways such as physical infrastructures, existing skills, networks between actors as well as shared cultural background (Hansen and Coenen, 2015). This means that policy action should be aimed at dis-embedding the system from its environment while anticipating and alleviating possible spillover effects of this process. Measures to address the spillover effects of regime destabilization include campaigns to combat the dominant cultural framings of the system, payments to industry for the closure of coal plants, provision of financial and educational support for managing structural unemployment and skill mismatch, or the provision of support for regional diversification of industrial activities (Spencer et al., 2018).

An excellent example here would be the industrial restructuring of the Ruhr valley in Germany. Historically a coal-producing area, the region has been shifting step-by-step since the 1960s towards becoming a green energy producer and a hub of renewable energy industry. The transition of the Ruhr area began with the “Coal Crisis of 1958”, when the price regulation in Germany was ended and it became obvious that exported coal was much cheaper than the German coal. This led to extensive subsidization by the federal government (Storchmann, 2005). At first it was mostly about helping the coal industry survive, but included some government action that ended up enabling a larger transition – mainly founding of new institutions of technical higher education and supporting the diversification of business in the area (Taylor, 2015).

From the 1980s, it became clearer, that the situation needs a more thorough intervention. On the one hand, technology parks and centres were founded and supported to speed up new areas of business in the region (Taylor, 2015). On the other hand, more social protection programs for coal miners, such as compensation mechanisms for lost earnings, money for vocational retraining and extra funding for early retirement in case of closed mines (Storchmann, 2005). Since the 2000s, the economic restructuring of the region was in full swing and in 2007 the decision to close the last operational hard coal mine was made. Government now focused on supporting local projects and initiatives, and programs to generate more of them, while continuing social support for ex-miners (Taylor, 2015).

4.1.5 Provide coordination to multi-regime interaction

The trajectories of socio-technical systems are not only internally created, they also result from the mutually reinforcing developments in multiple systems. For example, the combination of suburbanized housing and individual and privately-owned gasoline-based cars reinforces both the current housing system (cars enable easier access to more remote locations) as well as the mobility system (car ownership is practical in the context of big distances and little public transport). In many ways this challenge mirrors the second one: whereas niche acceleration is about ensuring complementary input-output relations between emerging niches, this one is about breaking already existing links between incumbent systems and forging new ones.

Evidence of this type of intervention can be found from urban transitions (Nevens et al., 2013; Schiller, 2016) as cities eventually involve a configuration of multiple interlinked and overlapping systems. For example, since the 1970s the city of Freiburg in south Germany started to move towards the direction of an ecological city. For this purpose, various measures were employed, including the support for various renewables in the energy system (hydropower, solar, biological fermentation), facilitation of multi-modality in the mobility sustem (area development for quite transportation, policy support for walking and biking), implementation of measures to increase the energy efficiency of buildings in the housing system and so forth. Both urban planning and extensive public involvement have played an important role in this process (Zhao et al., 2017).

4.1.6 Tilt the landscape

This challenge is about changing factors beyond specific systems and niches. It includes participation in international and global negotiations to arrive at collectively binding agreements that would create broader framework conditions for changing the directionality and dynamics of a broad range of socio-technical systems. Examples of these include the Paris agreement to limit the global temperature increase to below two degrees of Celsius or the recent framework by United Nations obliging countries to monitor and track the movement of plastics beyond their borders (The Guardian, 11.03.2019).

Probably the best known example of this approach is the banning of chlorofluorocarbons (CFCs). CFCs refer to a group of stable halogen compounds widely used in variety of applications including refrigeration, solvents, blowing agents, and food freezing in the 1960s and 1970s. They migrate to the stratosphere where they photo-disassociate into chlorine and other compounds. The chlorine reacts with ozone, reducing the ability for ozone to act as a shield for ultraviolent radiation. The depletion of the ozone layer increases ultraviolent levels at the earth's surface and incidents of cancer, damage to crops and aquatic life, and changes in local climate (Schapiro and Warhit, 1983; Harper, 1994). When scientists determined that CFCs were damaging the Earth's ozone layer in the mid 1980s, the international community did not rely on caps, credits, and trading. Regulators responded with the Montreal Protocol in 1987, which was originally aimed at cutting production of CFCs by 50 but later amended to be a complete phase-out of CFCs for all industrialized countries by 1996 (Gorman and Solomon, 2002).

Table 2 provides a summary of all six intervention points.

Table 2. Six intervention points explained.

Strategy	Explanation
Stimulate different niches	Subsidies and regulatory shielding for niches in various systems
Stimulate the scale-up of niches	Providing support for entering the markets and/or creating links between various niches
Destabilize the regimes	Removing various forms of regulatory and financial protection favouring

	incumbents
Address the spillover effects of regime destabilization	Provision of various forms of regional support to manage the broader regional and societal effects of regime destabilization
Provide coordination to multi-regime interaction	Ensuring that the input-output relations between the regimes would be complementary
Tilt the landscape	Participation in international negotiations to arrive at collectively binding agreements that would shape the directionality of locally bounded systems

4.2 Policy intervention points and policy mixes

Having identified the six policy intervention points we subsequently aimed to find out the extent to which these intervention points were present in existing literature on policy mixes employing the sustainability transitions perspective. Our review of 69 articles (see section 2 for search and selection criteria) revealed that 10 articles out of 69 did not contain a reference to a specific intervention point. Of the rest 59 articles different intervention points were mentioned 145 times.

Table 3. Intervention points in policy mixes literature.

Challenge part of the analysis?	Niche stimulation	Niche acceleration	Regime destabilization	Regime spill-over	Multi-regime coordination	Landscape tilting	Sum (% of total)
Challenge implicit and non-systematic	12	9	2	2	0	0	25 (17%)
Challenge explicit but non-systematic	14	13	9	2	0	0	38 (26%)
Challenge implicit but systematic	4	3	1	0	0	2	10 (7%)
Challenge explicit and systematic	25	25	19	2	0	1	72 (50%)
Sum (% of articles)	55 (80%)	50 (72%)	31 (45%)	6 (9%)	0 (0%)	3 (4%)	145

As seen from the table an overwhelming proportion of intervention points (136 or 93.8%) was related to niche stimulation, niche acceleration and regime destabilization. Regime spill-over was an explicit and systematic part of the analysis twice, tilting the landscape once whereas multi-regime coordination was not mentioned at all. The results seem to be matching with the recent qualitative assessment of the policy mixes literature: "Two particular challenges concern destabilization and accumulation" (Edmondson et al., 2018: 3).

To illustrate the significance of this omission let us briefly consider the case of Estonia. As a member of the European Union Estonia is part of the overall effort of the organization to cut its greenhouse gas emissions to 80% below 1990 levels by 2050 (European Commission, 2018). Yet in 2016 Estonian energy sector (including transport) accounted for almost 90% of total greenhouse gas emissions (Estonian Ministry of Environment, 2018). Matters are made worse by the fact that the Estonian energy system is primarily based on oil shale which has a low Energy Return on Investment compared to other fossil fuels (Cleveland and O'Connor, 2011; Hall et al., 2014), substantially contributing to Estonia having one of the largest ecological per capita footprint in Europe (Global Footprint Network, 2017). In order to support the take-up of green technologies the Estonian government has introduced subsidies to renewables (ongoing) and electric vehicles (2011-2014). At the same time it has also continued to subsidize the oil shale industry (the biggest energy company Eesti Energia, producing more than 90% of all electricity in Estonia, is state-owned) and to negotiate for exceptions for the industry on the EU level. Also, little has been done to discourage the dominant mobility practices. As a result Estonia currently ranks among the top three laggards in EU concerning the progress in fighting climate change (Climate Action Network, 2018).

At a glance the situation very much resembles the conclusions of Kivimaa and Kern (2016): similarly to many countries Estonia tends to focus on niche support but very little on regime destabilization. However, one should also be mindful of the fact that since mid-1990s proposals to transform the Estonian energy system have been blocked on three grounds: concerns for energy security, regional unemployment and the potentially resulting political instability. This is partly because of the concentration of oil shale deposits in the north-eastern part of Estonia (close to Russian border), having a regional majority of ethnic Russians in the region and a historical background of a tense situation in the early 1990s when the region attempted to gain an autonomy (Sillak and Kanger, 2018). In other words, the lack of regime destabilization is directly caused by the socio-spatial embeddedness of the industry to its surrounding environment (intervention point 4). Therefore, rather than targeting the regime itself policy measures need to alleviate with anxieties regarding the wider societal effects of the phase-out of oil shale, e.g. through campaigns stressing that the key to energy security lies in decentralized renewable-based energy production (Eesti Taastuvenergia Koda, 2014). Furthermore, attention to multi-regime coordination (intervention point 5) helps to remind that in the context of oil shale based energy production support for electric vehicles is unlikely to contribute to emissions reduction. By adopting a broader view than the existing policy mixes literature our framework thus helps to spot numerous oversights of Estonian energy and transport policy and to understand why the policy actors are acting the way they do.

4.3 Transition pathways and key intervention points

Prior work in MLP has identified a number of transition pathways (Geels and Schot, 2007, 2010) created by different combinations of the intensity of landscape pressure, the capability of the focal regime to withstand external pressure and the maturity of niches. The outcomes range from regime optimization to full-scale replacement of the incumbent regime with the new one. From the policy perspective there seems to be a trade-off between promoting the speed of transitions and managing the uncertainty of change. Therefore, one could argue that not every intervention point as outlined in section 4.1 is equally important for every pathway. That is, different pathways suggest different "key intervention points". These have been summarized in table 1.

Table 1. Transition pathways and key intervention points (adapted from Geels and Schot, 2007: 406-413).

Pathway	Description	Paradigmatic case in transitions studies	Key intervention points
Reproduction	If there is no major landscape pressure, niches do not break through and the regime reproduces itself		Tilt the landscape, coordinate multi-regime interaction
Reconfiguration	Disruptive landscape pressures direct the regime to adopt symbiotic niche innovations triggering further changes in the regime architecture	Traditional factories to mass production (1850-1930) (Geels, 2006a)	Destabilize the regime
Transformation	Disruptive landscape pressure in the context of immature niches enables regime actors to re-direct their activities	Cesspools to sewer systems (1840-1930) (Geels, 2006b)	Accelerate the niches
De-alignment and re-alignment	Sudden landscape pressure in the context of immature niches leads to a competition between niches after which one of them establishes itself as a template for a new regime	Horse-drawn carriages to automobiles (1860-1930) (Geels, 2005b)	Stimulate various niches, accelerate the niches
Substitution	Sudden landscape pressure in the context of mature niches leads to a rapid substitution of the regime	Sailing ships to steamships (1780-1900) (Geels, 2002)	Address the spill-over effects of regime destabilization

The reasoning behind the identification of key intervention points is as follows:

1. In the reproduction pathway niches cannot break through because there is insufficient pressure on the regime. In transition accounts such a pressure is often created by landscape events. Therefore, to break out from this pathway to substantive transformative change tilting the landscape is often required. This can take a form of strategic multi-level action: for example, Imbert et al. (2017) have described how in the EU, both Germany and Italy have managed to push parts of their own national strategies on bioenergy to the EU level, therefore tilting the landscape and having the EU level pressures, in turn, shape transitions in both countries. On a national level shifts in the focal regime might also be indirectly promoted by pushing for changes in another system. For example, strong policy support for the adoption of electric vehicles in the mobility system might create a stronger demand in the energy system to move away from fossil fuels.
2. Reconfiguration pathway has been argued to characterize large technical systems (e.g. electricity, telephone networks) because they cover large geographical areas and include a number of interrelated, often infrastructural technologies (Geels, 2005a: 265-266). Because of their size and scope such systems are likely to be quite resilient to change. This, in turn, increases the possibility that system incumbents will either attempt to block broader change or adopt niche innovations for the purposes of regime optimization (incremental innovation) without altering the overall directionality of the system. In these conditions regime destabilization measures might be required to open up the regime and make it more susceptible to transformative change.
3. Transformation pathway is characterized by a moderate pressure and the presence of a regime clearly receptive to change. However, niches are characterized by relative immaturity. Hence in this particular pathway measure for niche scale-up and alignment become crucial.
4. In the de-alignment and re-alignment pathway cracks in the regime appear far earlier and hence the the uncertainty regarding the combinations of niches constituting the future regime remains higher. Therefore, critical challenges include both stimulating various niches and accelerating existing ones.
5. In the substitution pathway transition is likely to proceed most rapidly, resulting in the highest degree of uncertainty. Wide-ranging structural change is likely to affect a majority of actors related to the incumbent regime. As technologies associated with the former regime quickly become obsolete incumbent firms might experience a rapid decline in market share leading, in turn, to a loss of employment (Burke et al., 2019). This might be made worse by the fact that industries are regionally concentrated and ill-adapted to shifts in their underlying knowledge base (Spencer et al., 2018). In these conditions, anticipation and alleviation of the societal impacts of transitions becomes the most critical issue.

5. Conclusion

This paper has sought answers to three research questions: what are the policy intervention points for systems change suggested by the transitions literature, what is the dominant framing on policy intervention in the literature on policy mixes employing sustainability transitions approach, and what might the key intervention points for each transition pathway? The results suggest that current literature on policy mixes is dominated by the agenda of niche stimulation and regime destabilization to the relative neglect of broader issues, i.e. addressing the spill-over effects of regime destabilization, coordination of multi-regime interaction and tilting the landscape. It was also argued that depending on the transition pathway (reproduction, reconfiguration, transformation, de-alignment and re-alignment, substitution) some intervention points might be more crucial to address than others. Our overall argument implies that a successful policy approach for achieving systems change should likely involve addressing all six challenges.

Our results therefore offer a systematic and theory-based guide for assessing existing policies for systems change. A few possibilities include:

1. Connecting specific policy initiatives to particular intervention points and assessing their efficiency in delivering their goals. To return to the Estonian example: the decision to subsidize the purchases of electric vehicles can be related to the intervention point "accelerate the niches" as it is essentially concerned to the scale-up and diffusion of a specific niche. However, given the short duration of the initiative (2011-2014), it did not achieve its goal as the current share of electric vehicles of all Estonian cars does not exceed 0.2% (Accelerista, 08.01.2019).
2. Mapping the policy mix by connecting all existing initiatives to particular intervention points. This exercise enables to identify gaps in existing policy measures. For example, the provision of subsidies for electric vehicles in Estonia was not coupled with attempts to destabilize the existing mobility regime and to ensure that the growth in the adoption of EVs would be paralleled with a growth in renewables. Therefore, one could argue that the policy initiative failed on multiple dimensions: "accelerate the niches", "destabilize the regime" and "provide coordination for multi-regime interaction".
3. Attempting to assess the intensity of landscape pressure, the resilience of the focal regime and the maturity of niches in order to determine the likely transition pathway. This, in turn, can be used to identity the corresponding key intervention point(s). For example, given the increasing climate change agenda, the increasing cost-effectiveness of solar power and the fragility of the Estonian energy regime (due to oil shale's inherent deficiencies as a source of energy), one might expect the energy transition to unfold through technological substitution pathway. That, however, directs attention to proactively managing the concerns of a large share of the population likely to be affected by these events, e.g. through the buy-out of employees from the oil shale sector by providing a generous benefits package conditional on accepting retirement in a pre-specified time frame.

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