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Designing Policy Mixes for Sustainable Socio-technical Transitions

Title of the paper

The processes of policy mix evolution: Towards a conceptual framework of policy mix feedbacks in socio-technical transitions

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The processes of policy mix evolution: Towards a conceptual framework of policy mix feedbacks in socio-technical transitions

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Understanding how policy-making processes can influence the rate and direction at which socio-technical change occurs is an important, yet underexplored research agenda in the field of sustainability transitions. Some studies have sought to explain how individual policy instruments or new organisations can influence policy-making and the politics surrounding this process. We argue that such individual policy instruments can cause wider feedback mechanisms that influence not only their own future development, but also other instruments in the same area designed to implement an overall strategy. Consequently, by extending the scope of analysis to that of an overarching policy mix allows us to account for multiple policy effects and resultant feedback mechanisms influencing the policy processes that underpin further policy mix change. This paper takes a first step in this regard by combining policy studies and innovation studies literatures to conceptualise the co-evolutionary dynamics of policy mixes and socio-technical systems. We focus on policy processes to help explain how policy mixes influence socio-technical change, and how changes in the socio-technical system also shape the evolution of the policy mix. To do so we integrate insights from the policy feedback literature, and propose a novel conceptual framework for analysis. The framework highlights that policy mixes aiming to foster transformative change need to be designed to create incentives for beneficiaries to mobilise support, while overcoming a number of prevailing challenges which may undermine political support over time. In the paper, we illustrate the framework using the example of the zero carbon homes policy mix in the UK. We conclude with deriving policy and research implications for designing and evaluating dynamic policy mixes for sustainability transitions.

1   Introduction

Understanding the role of policy processes in influencing the rate and direction of socio-technical transitions remains a fundamental challenge in the existing literature on sustainability transitions (Markard et al. 2012). Scholars in this field have sought to facilitate the restructuring of deeply embedded socio-technical systems towards more sustainable ways of fulfilling societal needs such as

energy, transport and housing (Geels 2002, 2004). Policy action is argued to be required to overcome market and system failures (Weber and Rohracher 2012). Moving towards more sustainable configurations requires significant structural changes in existing systems, often instigated by policy to reconfigure market selection environments, user preferences and cultural perceptions (Geels et al. 2016).

However, 'behind policy there is always politics' (Meadowcroft 2011: 73) and political negotiations can have a major influence on the stability or change of policy which in turn influences socio-technical developments. It has been argued that such policy stability is beneficial in creating positive expectations of a path to commercialization for early stage technologies (Foxon et al. 2005). However, it has also been argued that policy needs to be designed in a manner that can account for the changing conditions of the socio-technical system, incorporating enough flexibility to allow for change and revision without deterring investor confidence (Hekkert et al. 2007). Finally, due to the long timeframes involved, the types of policy instruments aimed to foster transitions may change significantly over time to address changing objectives and different stages of innovation (Turnheim et al. 2015). All of this shows that in the context of transition processes it is important to not just study the content of policy instruments (e.g. what level of support is provided for which technology?) but the processes through which instruments are adapted or kept stable over time.

A second challenge in understanding the influence of policy on sustainability transitions is the need to move beyond a focus on single policy instruments towards policy mixes accounting for interacting instruments and corresponding policy objectives. Contributions from various literatures, including innovation studies (Nauwelaers et al. 2009), environmental economics (Lehmann 2010) and policy analysis (Howlett and Rayner 2007), have already sought to explore important aspects of policy mixes; such as the design features of individual instruments in the mix (Kemp and Pontoglio 2011), instrument interactions (del Río González 2006; Nauwelaers et al. 2009), the elements of the mix (Borrás and Edquist, 2013), the policy strategy (Quitzow 2015a), as well as characteristics (Howlett and Rayner 2013; Reichardt and Rogge 2016) and policy processes (Flanagan et al. 2011).

Recently, scholars have called for an integration of these aspects into the study of sustainability transitions, to produce more meaningful insights and recommendations to assist policy makers aiming to foster transitions (Rogge and Reichardt, 2016). Sustainability transitions are complex, multi-faceted processes, involving long time frames, multiple actors, and often a range of both competing and complementary technologies (Geels, 2004). Such complexity means that no single approach, technology, intervention or policy is capable of achieving transformative change, often resulting in large numbers of policy instruments being implemented over time to address multiple objectives (Loorbach, 2010; Kern and Howlett, 2009; Kern et al., 2017). This leads to complex combinations of policy instruments that may not only support novel technologies but also continue to benefit the existing socio-technical regime (Kern and Howlett, 2009; Kivimaa and Kern 2016). Consequently, the ways in which policy mixes evolve over time can have a significant influence on the rate and direction of sustainability transitions (Reichardt et al 2016).

This paper follows suggestions of Flanagan et al., (2011) and Rogge and Reichardt (2016) to take a first step towards better conceptualising the role of policy-making processes in the evolution of policy mixes. Only few studies have already started to draw on prominent policy process theories in the context of transitions to better understand processes of policy change (Markard et al., 2015; Normann 2015, 2017). We complement these early attempts by paying greater attention to policy processes while also considering policy mixes, drawing on the policy feedback literature from the field of policy sciences (Pierson 1993; Patashnik and Zelizer 2009, 2013; Oberlander and Weaver 2015). The policy feedback literature draws attention to the continuous interactions between public policy, the outcomes in society, and how these outcomes affect policy actors in ways that influences politics and subsequent policy-making (Weible 2014: p.13). We suggest this analytical focus offers insights to explain the dynamic and recursive nature of how policy mixes and the socio-technical system co-evolve. Our proposed framework aims to explore how policy mixes stimulate changes in the socio-technical system through policy effects, and how these changes can subsequently generate feedback mechanisms which influence the evolution of the mix.

The remainder of the paper is structured as follows. In section 2, we review two emerging strands of research exploring the role of policy in sustainability transitions: Section 2.1 reviews work on policy processes within transitions, while Section 2.2 reviews the development of policy mix thinking and its application to transitions. In section 3 we review concepts from the policy feedback literature and in section 4 utilise these ideas to conceptualise the co-evolutionary dynamics of policy mixes for sustainability transitions. To illustrate the key concepts presented in the framework, section 5 draws on the zero carbon homes target in the UK, representing an instance where an ambitious policy strategy lost political support over time due to a range of policy effects and feedback mechanisms, ultimately leading to its abandonment. In section 6 we discuss the suitability of the framework in light of the empirical illustration, draw conclusions and provide suggestions for further research.

2   Sustainability Transitions, Politics and Policy Mixes

'Socio-technical systems' are commonly understood as the "linkages between elements necessary to fulfil societal functions" (Geels 2004 p. 900), such as energy, transport, housing and food production (Geels 2002, 2004). A socio-technical transition is a combination of processes leading to a fundamental shift of a socio-technical system (Geels and Schot, 2010). Such a system consists of multi-faceted combination of actors, networks, institutions, artefacts, infrastructure, markets and practices along with cultural and symbolic views and representations (Geels 2004). Consequently, a transition comprises of technological, organisational, institutional, political, and socio-cultural changes whereby the elements of the existing socio-technical system are occasionally complemented, but more commonly replaced, with novel emergent features (Markard et al. 2015). Historical examples include the shift from sailing ships to steamboats (Geels 2002), and from horse-driven carriages to automobiles (Geels 2005).

In this emerging field of sustainability transitions one of the main challenges is to improve the understanding of how policies and policy processes influence transitions (Markard et al., 2012). In the following sections, we review two areas of development within the literature that have sought to address this challenge.

2.1 Policy processes and politics in socio-technical transitions

Policy is widely considered as an integral constituent of transitions towards sustainability (Jacobsson and Lauber 2006). So far, the transitions literature has typically referred to the content of policymaking in terms of objectives, programs, regulations, laws and resource allocation (Markard et al., 2015). It has been argued that a constant realignment of policy with the changing conditions of the socio-technical system is necessary (Hoppmann et al., 2014). Equally, policy change can reduce resources, impact investor confidence, or signal changes in political will. Consequently, how policy changes over time can lead to virtuous or vicious cycles of causation influencing the momentum of transitions (Hekkert et al. 2007).

Moving beyond the content of policies, "[p]olitics refers to the procedural dimension of policy making, with a variety of actors negotiating and interacting to produce public policies" (Markard et al. 2014: 4). Policy-making can be understood as the design, implementation, adaptation and discontinuation of public policies (Sabatier and Weible 2014). States are dependent on prevailing economic structures and industries, creating vested interests as political and economic actors become entangled, often resulting in a high level of influence of incumbent actors on policy decisions (Meadowcroft, 2011). A number of contributions have already sought to help analyse the role of politics in the context of transitions (Baker et al. 2014; Meadowcroft 2009; Meadowcroft and Langhelle 2009; Shove and Walker 2007). Studies have for example focused on the way in which ideas are presented (Kern 2011; Scrase and Smith 2009), the role of coalitions (Hess 2014, 2015; Markard et al. 2015), power relations (Avelino and Rotmans 2009; Avelino 2011; Geels 2014), and policy networks (Normann 2017).

To conceptualise how politics influences policy-making processes, scholars have started to integrate insights from prominent policy process theories (for an overview see Sabatier and Weible 2014), including Sabatier's Advocacy Collation Framework (Markard et al., 2015), Kingdon's Multiple Streams (Normann 2015), and Marsh's Policy Networks Approach (Normann 2017). From these contributions, we know that during transition processes windows of opportunity can allow certain

technologies to gain favourable policy outputs. Yet, over time, changing conditions can cause these windows to close and policy support to be withdrawn (Normann 2015). Similarly, beliefs of actors can change over time, which may influence participation in coalitions (Markard et al., 2015) and the formation of policy networks (Normann 2017). However, determining if such observations are the result of policy driven changes to the socio-technical system is not the focus of these papers.

Recent contributions have explored these dynamics, linking policy processes to the rate and direction of change in the socio-technical system more directly. Hoppmann et al. (2014) highlight the iterative process of policy realignment for solar PV in Germany, responding to the changing conditions of the socio-technical system. Lauber and Jacobsson (2016) also follow the evolution of the German Feed-in-Tariff (FiT), focussing on the politics of empowerment (Smith and Raven 2012) and how changes in the socio-technical system influenced discourses of different actor groups. These papers highlight policy change in response to changes in the socio-technical system, but their conceptualisations of policy-making processes is underdeveloped. Another shortcoming of these papers is that they account for a single policy instrument and its revisions over time, rather than the influence this had on policy-making more widely and especially other elements of the policy mix.

Consequently, we argue that what is still underdeveloped is a conceptualisation of policy-making processes which accounts for the interplay of policy and socio-technical change over time, while simultaneously considering a collection of policies that make up an overarching policy mix. In the following, we therefore review the emerging literature on policy mixes in the field of sustainability transitions.

2.2   *Policy mixes and socio-technical transitions*

Recently, there has been increased attention to considering policy mixes in innovation studies (Flanagan et al. 2011). Scholars of sustainability transitions especially, have argued to extend the scope of analysis beyond individual instruments to that of broader policy mixes (Rogge and Reichardt 2016). Sustainability transitions exhibit several characteristics that make the policy mixes required to

foster transitions distinct, and arguably more challenging than in other areas. This is not only due to a number of interrelated market and system failures (Foxon et al. 2005; Lehmann 2010; Weber and Rohracher 2012) but also due to the required speed and unprecedented scale and complexity of the required changes, involving restructuring of social practices, market arrangements, infrastructures and technologies.

Given these challenges, Rogge and Reichardt (2016) propose a framework for analysing policy mixes for sustainability transitions, drawing from various areas of literature. They argue that it is important to not only look at interacting instruments but to also consider policy strategies as elements of a policy mix. Their policy mix concept thereby acknowledges the need for long-term strategies and objectives to guide transitions (Foxon and Pearson 2007, 2008; Quitzow 2015a; Weber and Rohracher 2012). Drawing on insights from the policy design and innovation literatures (Kern and Howlett 2009; Howlett and Rayner 2007 2013; Alkemade et al. 2011; Foxon and Pearson 2008) they also stress that policy mix characteristics, such as the consistency of the instrument mix with stated policy objectives, may help explain the impact of policy mixes. In line with Flanagan et al. (2011), they also called for increased attention to the underlying "political problem-solving process among constrained social actors in the search for solutions to societal problems – with the government as primary agent taking conscious, deliberate, authoritative and often interrelated decisions" (Rogge and Reichardt, 2016: 1625).

Our contribution focusses on these policy processes, specifically on the effects of policy decisions on socio-technical systems, and the resultant influence of these changes on the evolution of the policy mix. In order to develop a conceptual framework for studying these processes, we draw on the policy feedback literature (Pierson 1993) which we review in the following section.

3   **Analysing policy processes: Insights from the Policy Feedback Literature**

To address the call for a more explicit consideration of policy processes in the field of sustainability transitions we apply insights from the Policy Feedback literature. We have chosen this approach for two main reasons. First, this literature addresses the interdependencies between policies and further policy making. It does so by investigating how the effects of a policy reform (post-enactment) alter subsequent rounds of policy making, which is well suited to our focus on the co-evolution of policy mixes and socio-technical change. Secondly, within the feedback literature there is already an interest in analysing collections of policy reforms[1] as opposed to single instruments. While some authors have focused on single policy instruments (Jordan and Matt 2014), others have drawn attention to the importance of considering several reforms or instruments (Weaver 2010; Oberlander and Weaver 2015). Consequently, we argue that particularly the latter strand with its broader scope lends itself to our purpose.

The policy feedback literature has its roots in historical institutionalism (Pierson 1993) and has more recently integrated insights from Punctuated Equilibrium theory (Oberlander and Weaver 2015; Patashnik and Zelizer 2013; Jordan and Matt 2014; Jacobs and Weaver 2015). It explores mechanisms through which public policies reshape social and state actors' interests and capacities over long periods of time in ways that change the prospects for the policies' future maintenance, expansion, or reversal (Skocpol, 1992). The core argument in this literature is that policies – a term which has been broadly applied - are not merely the products of politics, but also influence politics through societal reconfigurations. Policy alters state capacities, it changes incentives for collective action, and encourages social adaptations that may become difficult to reverse (Patashnik and Zelizer 2013).

In Pierson's (1993) seminal work he identified ways in which policy design can incentivise actors to participate in the policy-making process and shape the political conditions. This early literature seeks to explain the influence of policy through two factors: 'resource effects' (policies as packages of resources that affect interest groups, state capacities and mass publics), and 'interpretive effects' (policies as new sources of information that affect patterns of cognition, understanding and meaning)

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[1] Commonly referred to as programmes or regimes.

(Mettler and Soss 2004: 60). Patashnik and Zelizer (2013) build upon these effects, drawing attention to a third effect: institutional supports that may limit the capacity of a policy to create positive feedback. They argue that failure to uproot these institutional arrangements, or layering new policy alongside the existing arrangements, can generate conflicts among programs and agencies that undermine policy support. Consequently, *layering* is considered much less effective for institutional recalibration than *dismantling* (involving terminating the existing arrangements) (Patashnik and Zeilzer 2013:1077).

Recent scholarship has highlighted that these effects (resource, interpretive and institutional) are better termed 'feed-forward' effects, as they describe post-enactment policy consequences with no complete feedback loop (Schneider and Ingram 2009: 103; Jordan and Matt 2014: 231). These effects "show the feed but not the back (or they just assume the back)" (Campbell 2012: 347). Therefore, following the suggestions of Jordan and Matt (2014), we move towards a conceptualisation of complete feedback loops making a distinction between the forward and backward dimension of feedback processes. We refer to the effects of policy making on the socio-technical system as the '*policy effects*' and the resultant influence on future policy making as the '*feedback mechanisms*' (Section 4.1 and 4.2 respectively).

Policies are not thought to automatically generate feedbacks, but require coalitions to take political action for the effect of a given policy to influence further policy processes (Pierson 1993, 2000). Scholars have conceptualised various feedback mechanisms, including influence on interest groups, altering of administrative capacities of the state (state-building), and changes in political participation (Pierson 1993; Mettler 2002; Béland 2010). In a recent contribution from Oberlander and Weaver (2015), feedback mechanisms are conceptualised into three broad categories: *socio political*, *fiscal* and *administrative* (section 4.2). We consider this contribution the most fully realised conceptualisation of feedback mechanisms to date, while it responds to two criticisms of the existing literature.

Firstly, much feedback literature has narrowly focussed on the occurrence of positive feedback, and has been increasingly criticized for over-determinism (Béland 2010). The underlying assumption of the (positive) feedback literature is that (to some extent) feedbacks will occur, whereby choosing policy alternatives becomes more costly over time, making it increasingly difficult to choose alternatives (Pierson 1993). Therefore, a recent line of scholarship has highlighted the role of negative feedback, and even suggested that negative feedback may have greater influence on policy making (Patashnik and Zelizer, 2009, 2013; Weaver, 2010).

Secondly, as observed by Pierson (2007) over 20 years after his seminal contribution, while scholars have succeeded in providing demonstrations of feedback mechanisms, there had been little progress in translating this into a comprehensive research agenda informing when feedback mechanisms are expected to occur (Patashnik and Zelizer 2013: 1075). Scholars had sought to explain mechanisms of *how* these feedbacks occurred, but less attention was paid to *if* they occur or the conditions under which they may not. Oberlander and Weaver (2015) describe both positive (self-reinforcing) and negative (self-undermining) variations of feedback mechanisms; along with the conditions that would amplify the occurrence of negative feedback mechanisms. Consequently, we draw on these categories in developing our framework (section 4.2).

Empirically, the approach has typically been used to study welfare policies, with most applications situated in the American political system (for a review, see Béland 2010 and Campbell 2012). It has thus been criticized in relation to the limited application to date, but also regarding methodological issues such as selection bias (Mettler and SoRelle 2014). In response to this, more recently applications have diversified, extending to different geographical settings and a broader range of policy areas, including climate policy (Lockwood 2013), and energy policy (Rosenow 2013; Skogstad 2015; Lockwood 2015). In this paper, we further this line of development by crafting a novel conceptual framework for the analysis of the co-evolutionary dynamics of policy mixes and socio-technical change.

4   Sustainability Transitions and Policy Mix Feedbacks: Towards a conceptual framework

In this section we develop a novel co-evolutionary framework to help analyse policy mixes aimed at fostering sustainability transitions (Figure 1): it puts centre stage the co-evolution of policy with changes in the socio-technical system. The key idea is that policy mixes have resource, interpretative and institutional effects on the evolution of the socio-technical system and that in turn developments in the socio-technical system influence the policy subsystem through a range of feedback mechanisms. We conceptualise the feedback mechanisms as influencing the 'policy sub-system' rather than the policy mix directly. A policy subsystem can be conceptualised as the relationships between actors responsible for policy decisions and the 'pressure participants' (Jordan et al. 2004), such as interest groups with which decision makers consult and negotiate (Cairney and Heikkila 2014).

Actors play a central role in the framework as the agents of change in the socio-technical system, who may also participate in the policy subsystem. When considering the influence that actors have on the policy process, the implicit assumption in the transitions literature involves a power struggle between emerging niches and dominant incumbents. We infer from existing literature that the political influence of actor coalitions is related to their ability to mobilize resources (Hess 2014; Markard et al. 2015), where resources can be considered "persons, assets, materials or capital, including human, mental, monetary, artefactual and natural resources" (Avelino and Rotmans 2009: 551). This relates to the ability of actors to secure resources through favourable policy mixes, but also the resources actors can devote to lobbying and the provision of resources to state actors. For example, senior policymakers often delegate responsibility for policymaking to bureaucrats, who seek information and advice from groups (Cairney and Heikkila 2014). Groups exchange information for access to and potential influence within government (ibid). Bureaucracies and other public bodies may develop operating procedures that favour certain sources of evidence and some participants over others, which of itself may be ideational legacies from previous policy outcomes (Béland 2010).
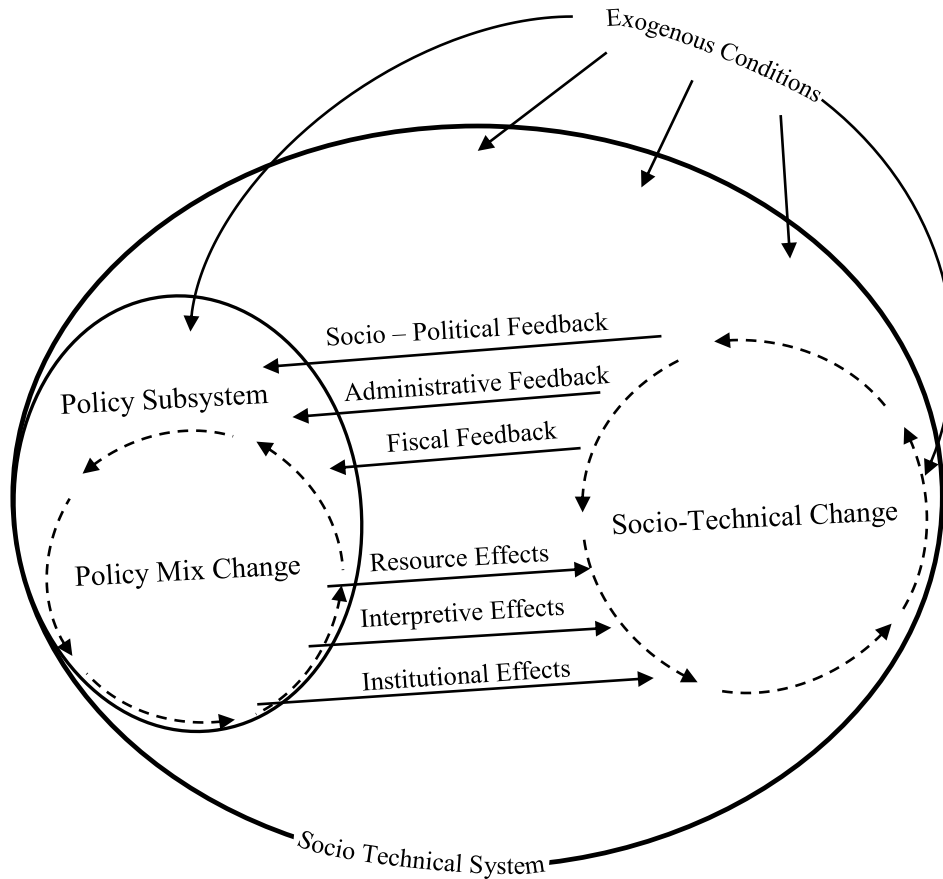
Figure 1 -Dynamic interactions of Policy mix and Socio-Technical System

In the following subsections, we introduce the conceptual elements of the framework. While we describe each in turn, these processes often occur simultaneously, where policy design choices create multiple policy effects, and the forms of feedback that occur often influence each other. Consequently, section 4.4 elaborates potential dynamic interactions.

4.1   Effects of Policy Mix on Socio-Technical System

The policy mix (including strategies, instrument mixes and their interactions) stimulates change in the socio-technical system through policy effects which include resource, interpretative and institutional effects. Policy effects are determined in magnitude and polarity (positive or negative) by choices

(intentional or otherwise) regarding design features of individual instruments, and characteristics of the mix (such as its consistency or credibility).

4.1.1 Resource Effects

The resource effects describe the tangible resources that the policy mix bestows upon groups, providing information and benefits (Pierson 1993; Patashnik and Zelizer 2009). These resources can influence the rate and direction of transitions by accounting for market externalities and overcoming failures (van den Bergh et al. 2006; Weber and Rohracher 2012), supporting knowledge creation through R&D (Hekkert et al. 2007), facilitating demonstration and procurement (Jacobson and Bergek 2011), or creating favourable market conditions for diffusion (Smith and Raven 2012). When considering policy mixes for sustainability transitions, negative effects are expected to arise when resource flows to incumbents are reduced or removed, in addition to the positive effects among niche actors[2]. Policy reforms of this nature can be enacted though manipulating market conditions (e.g. through control instruments), or by curtailing support and subsidies (e.g. tax breaks) for dominant technologies (Kivimaa and Kern 2016).

Ultimately, it is the design features (e.g. level of support) of individual instruments and interactions with other instruments in the mix (Kemp 1997; del Rio Gonzalez 2010; Rogge and Reichardt 2016) which determine the magnitude, type and target actors of resource effects. In the feedback literature, several design features are suggested to influence the extent of the resultant feedback mechanism (section 4.2): these include the size, the visibility and traceability, and duration of benefits, along with the concentration/diffusion of beneficiaries (Campbell 2012).

4.1.2 Interpretive Effects

The policy mix also produces interpretive effects, providing information and changing patterns of cognition, understanding and meaning (Pierson 1993), thereby creating or changing visions and

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[2] Whilst the positive effects are expected to incentivise support from niche actors, the losses bestowed to incumbencies (regime actors) is likely to produce opposition (negative feedback).

expectations of actors (Jacobson and Bergek, 2011; Smith and Raven 2012). A policy strategy (e.g. to promote clean innovation) may establish expectations about future resource effects as it provides guidance and a mandate for the design of individual instruments as well as the composition of the instrument mix. For instance, if actors perceive an instrument as providing insufficient resources to achieve its goals, this inconsistency may negatively influence the cognitions of actors regarding the strength of the political will behind the stated policy objectives, and vice versa (Reichardt et al. 2016). Actors' perceptions can influence investment decisions and innovative activities (Hekkert et al. 2007; Jacobson and Bergek 2011), including engaging in RD&D (Hekkert et al., 2007), the formation of learning networks (Mourik and Raven 2006) and advocacy coalitions to lobby for resources (Bergek et al. 2008).

The interactions of elements of the mix (within the instrument mix, and between the instrument mix and strategies) may also influence interpretive effects of interest groups. This may relate to simple perceptions regarding the amount of resources provided by the instrument mix in aggregate. Commonly however, the complexity of policy mixes means interactions of instruments may not be 'visible' or 'traceable' to actors without expert knowledge, or actors may not be aware of the full extent of the policy mix. We suggest that credibility of the policy mix, the extent to which a mix is considered believable and reliable (Rogge and Reichhardt 2016), will influence the perceptions of actors and have direct effects on their decisions in terms of their investment.

4.1.3   Institutional Effects

In line with Patashnik and Zelizer (2013) we suggest that the extent to which the policy mix dismantles, layers or otherwise reforms institutional arrangements can be considered as *institutional effects*[3]. Sustainability transitions face significant challenges, as they typically need to reform areas long dominated by incumbents, typically with close relationships with state actors (Kern and Howlett 2009), and often seen as a major source of lock-in (Unruh 2000; Walker 2000). Consequently, more

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[3] While referred to as Institutional Supports by Patashnik and Zelizer (2013), we use the term Institutional Effects. The implication of this difference is to draw attention to the intentional actions of policy actors that influence the existing institutional basis of support.

radical reforms are often politically contested, and despite the most robust changes coming from instances of *dismantling* (Patashnik and Zelizer 2013), involving terminating the existing basis of support for the regime (Smith and Raven 2012; Turnheim and Geels 2012), to date we have seen much fewer examples of these so called 'phase-out policies' implemented (Kivimaa and Kern 2016). Examples of 'phase out policies' include, among others, structural changes replacing the established rules embodied in institutions (e.g. legislations), and changing participation in networks to involve both insiders (incumbents) and outsiders (niche actors) (Kivimaa and Kern 2016).

However, simply supporting niche technologies will not foster transitions (Kemp and Rotmans 2004). Even if reforms supporting transitions are legislated, the policy mix will face the ongoing challenge of maintaining political support if reforms threaten to impose losses on powerful groups, providing them with motivation for political participation to oppose the reforms (Patashnik and Zelizer 2013). Thus, to protect a niche as it scales up requires institutional effects that protect it, both from processes within the niche that can de-stabilise it, and against external destabilising processes originating from resistance within the regime (Mourik and Raven 2006). After having conceptualised how policy mix changes have effects on the socio-technical system, the next subsection will discuss how changes in the socio-technical system create feedbacks to the policy subsystem.

4.2   Feedback Mechanisms

Feedback mechanisms contribute to a constant reconfiguration of the policy mix over time. Positive feedbacks can help explain how new policy strategies once enacted can become stable and self-reinforcing, while negative feedbacks help explain why opposition against new policy strategies and supporting instrument mixes can result in loss of political support, resources to be reduced or withdrawn, and consequently reduced momentum of the transition.

4.2.1 *Socio-Political Feedback Mechanisms*

Socio-political feedbacks concern whether public and elite support for a policy mix is reinforced or undermined over time. Such feedbacks can involve three dimensions which we will discuss in tern: cognitive, constituency and agenda feedbacks.

Cognitive feedbacks contribute to mass cognitions regarding the effectiveness and/or efficiency of a policy mix or specific components thereof. For example, the mix may be perceived to be successful or disastrous in achieving the policy objectives (Oberlander and Weaver 2015). Cognitive feedbacks can involve mass publics, especially if the policy mix is widely perceived as providing benefits or imposing losses relative to the status quo (Jacobs and Weaver 2015). Public opinion can also be significant for sustainability transitions if diffusion imposes concentrated losses on the public. This could occur, for example, through highly visible effects such as wind farms altering landscapes and thus incentivising local opposition (Wolsink 2007), or through imposing highly visible costs, e.g. though surcharges on electricity bills for supporting renewable energy (Lauber and Jacobsson 2016).

Constituency feedbacks relate to the question (of) whether the policy mix leads predominantly to the mobilization of supporters or opponents (Oberlander and Weaver, 2015 p.43). This can occur when the policy mix provides sufficient resources to strengthen existing proponents and mobilise supporting coalitions. Conversely, perceptions of losses can strengthen opponents or cause fragmentation of supporting coalitions. In transitions, the dominant coalitions commonly consist of the incumbents, who lobby against major policy changes (Markard et al., 2015; Kern and Smith 2008; Stenzel and Frenzel 2008). However, there are instances where such incumbents are not homogenous in their beliefs. Markard et al. (2015) show that in the Swizz energy transition several of the incumbent energy firms were supportive of policy reforms, suggesting that if firms see transitions as opportunities rather than threats they are more likely to be supportive. Even if incumbents mobilize opposition against reforms, if powerful countervailing coalitions form, the status quo can be protected (Hess 2014; Lauber and Jacobsson 2016).

Agenda feedbacks cover whether the effects of the policy mix on the socio-technical system leads to a consideration of reform options leading to incremental changes of existing policy mix elements or stimulates a search for more dramatic non-incremental reforms (usually in response to a perception of serious and unavoidable policy failings) (Oberlander and Weaver 2015). This form of feedback also influences the odds that policy mix elements remain stable or are subject to revision. How fungible (readily replaceable) the instrument is considered, will influence its prospects for maintenance, revision or termination. For example, if there are no obvious alternatives, opposing groups will struggle to make the case for reform or redesign (Jordan and Matt 2014).

4.2.2   *Fiscal Feedback Mechanisms*

Fiscal feedbacks capture if the policy effects, or the cost of supporting policy mix elements, raise budget strains among financial ministers. The financial ministry is a powerful actor with the ability to control and mobilise resource flows, and can exert substantial influence on the policy process weakening the autonomy of groups normally dominating policy decisions (Oberlander and Weaver, 2015 p.43). For example, quicker than expected uptake of the FiT for solar PV in Germany lead to concerns over the costs of supporting the technology, and resulted in a reduction of resources made available to supporting the technology (Lauber and Jacobsson 2016). In addition, over time, as conditions (e.g. macro-level socio, economic and political trends) change, the priorities of the financial ministry may shift to other policy areas, and/or the perceived costs of supporting the policy mix may change accordingly. In governmental arrangements where the financial ministry has significant influence over policy decisions which have financial implications (e.g. the UK), the resultant feedbacks on the policy-making process are expected to be significant. We suggest that such fiscal effects relate not only to individual instruments, but also the whole policy mix (such as the UK's levy control framework) which may lead to simultaneous changes in resources available for multiple policy instruments implemented towards meeting an overall strategy.

4.2.3   *Administrative Feedback Mechanisms*

Administrative feedbacks influence the capacities of departments or public agencies in charge of policy implementation to implement the policy mix in a way which is perceived as successful by internal and external constituencies, such as policymakers and social actors (Oberlander and Weaver 2015). The reputation of agencies to implement policy successfully can influence their ability to recruit qualified staff . Positive administrative feedback can lead to the expansion of resources or capabilities (Pierson 1993; Béland 2010). For example, a department with high reputation may assimilate a low reputation department, taking on its responsibilities and broadening its mandate. Negative administrative feedback may lead to departmental funding cuts, which may reduce capacities, e.g. by requiring outsourcing of tasks to private actors, and may reduce autonomy of the department.

4.3   *Exogenous Conditions and the Importance of Timing*

As argued above, the interplay between policy effects and feedback mechanisms are linked through changes occurring within the socio-technical system (Hoppmann et al., 2014). However, few policy feedback effects are purely endogenous (Oberlander and Weaver 2015), and are influenced also by exogenous conditions beyond the socio-technical system (ibid; Rosenow, 2013) as well as the timing of interactions (Pierson 2000; Orberlander and Weaver 2015). In the transitions literature, such exogenous conditions (e.g. macro-economic trends, demographic shifts) are conceptualised as the landscape, enacting pressure on the regime (Geels 2002). Exogenous conditions may also include innovation outside the boundaries of the socio-technical system. Similarly, policy learning from policy experiments elsewhere may allow for the consideration of modifications to the policy mix (Jacobs and Weaver 2015). Finally, international governance (UN, EU) may place pressure on national policymakers to implement policy reforms.

Exogenous conditions may influence the policy process resulting in feedback processes becoming more likely to contribute to policy change through focusing events (Pierson, 1993; Jacobs and

Weaver, 2015; Lockwood, 2015; May and Jochim, 2013; Oberlander and Weaver 2015). For instance, self-undermining feedbacks are rarely sufficient cause for policy mix change, often requiring other conditions or events to push policy makers to seek alternatives (Oberlander and Weaver, 2015). Exogenous conditions can also influence the incentives of actors to participate in political action. For example, in Germany, international competition from the Chinese PV industry weakened domestic support coalitions when German PV manufacturers went bankrupt (Lauber and Jacobsson 2016). This undermined the case for supporting the roll-out of (Chinese manufactured) PV modules for actors interested in creating industrial benefits in Germany (ibid; Quitzow 2015b).

Related to how exogenous conditions interact in the framework, it is important to consider timing, and the temporality of feedback mechanisms (Pierson 2000). Poor timing can imply that conflicting objectives in other policy areas, means the policy mix is politically contested from the outset, or that changing exogenous conditions may shift priorities and reduce support for policy mix objectives. Sudden, unexpected changes in market conditions may undermine support for economic instruments almost immediately after their enactment (Patashnik and Zelizer 2009), limiting the potential of other instruments (information, regulation) to achieve policy mix objectives, which may result in negative feedbacks.

Timing also relates if a policy mix is consistent with government norms (Patashinik and Zelizer 2009). Interest groups and coalitions may have to wait until sympathetic politicians gain power in order be successful in influencing policy change (Oberlander and Weaver 2015). Electoral cycles may also change preferences of the state towards style of policy-making, and can render policy reforms vulnerable to revision or termination if the new government is less favourable. However, reforms are more resistant to changes if there is a strong (broad) domestic lobby supporting the policy strategy and corresponding instrument mix. For example, in Germany the Conservative-Social Democrat coalition continued to support the existing instruments in place for renewables after coming to power, at a time when the subsidies were contested, due to the existence of a strong domestic lobby (Lauber and Jacobsson 2016; Geels et al. 2016).

4.4 Dynamic Interactions of Effects and Mechanisms

We now turn to elaborating how the processes described above can interact dynamically, often occurring simultaneously rather than sequentially. We focus on explaining key interaction dynamics, notwithstanding that many more interactions are conceivable. We refer to policy mix effects; Resource [RE] Interpretive [IntE] and Institutional [InstE] on socio-technical change - and the corresponding feedback mechanism; Socio-Political [SPF], Fiscal [FF] and Administrative [AF] - while including the role of exogenous conditions [ExC].

Positive feedbacks are generated when a policy mix creates resource effects that are visible and traceable to government action [RE] (Arnold 1990), stimulating change in the socio-technical system and incentivising supporting constituencies to protect these resources [SPF]. This also creates positive expectations, signalling political commitment from government, and indicating stable investment conditions (reducing risk) [IntE]. Similarly, if resources which are accountable to government action create beneficiaries in the wider public [RE] (Campbell, 2012), certain instruments may gain political support through formation of electoral coalitions or influencing mass cognitions in favour of support for the policy mix [SPF]. Reinforcing mechanisms may be most prominent where policy mixes direct or encourage investment over long timeframes [RE], especially those with high risks (cost), creating vested interests in supporting policy maintenance [SPF] (Arrow 2000).

An instrument could be considered poorly designed if it is overly complex, does not provide sufficient resources, is not well aligned with other instruments in the mix, or if the benefits are widely dispersed and hidden from beneficiaries [RE & IntE] rendering it unable to mobilise support [SPF] (Patashnik and Zelizer 2009). Self-undermining mechanisms have been found to be most prevalent where elements of the policy mix have causal complexity (Jacobs and Weaver 2015), and seek to address multiple objectives, particularly when their success depends on the support of broad publics [RE] (Skogstad, 2016). If actors perceive apparent 'failings' in design of either individual elements or the

mix as a whole [IntE], it can influence opinions of the capabilities of actors charged with design and administration of the mix [AF], and/or indications of limits to the political will towards meeting policy objectives [InE]. For example, policy makers may wish to appear to support an area of development for political benefit (such as electoral payoffs), while being reluctant to devote sufficient resources due to split incentives, close networks between incumbents and state actors, or budget strains [ExC]. Similarly, if the amount of resources (or level of support) provided by an instrument (or combination of instruments) changes over time [RE], this can be interpreted as an indication of the direction of travel [IntE], and the level of political will towards meeting objectives (Rogge et al., 2015). This is most prominent if multiple changes occur (in relatively rapid succession) leading to uncertainty and perceptions of instability [IntE], especially if the evidence presented around policy change is called into question.

Allocation of resources influences the rate and direction of socio-technical change, inducing hard to predict interactions and unintended consequences which increase as layering accumulates and as policy instruments act in a changing social, technical and economic context (Jacobs and Weaver 2015). A policy that generated positive feedbacks (reinforcing and stabilising the policy), under different conditions such as austerity or financial downturn [ExC], may start to generate negative feedbacks. In such cases, fiscal feedbacks may be observed where supporting the policy mix is considered costly by the financial ministry [FF], potentially resulting in less resources being made available [RE]. In the UK, PV diffused much faster than predicted by the Department of Energy and Climate Change (DECC) instigating a sudden review of the FiT less than a year after it had been introduced [FF], leading to bitter court contestations between solar groups and the government, and a 'cut, don't kill' campaign [SPF] (Smith et al 2014).

The feedbacks that occur in the policy subsystem are influenced by participation of niche and regime actors who support/oppose the mix, the level of support from the wider public, and the views held by these actors of how successful the policy mix is in achieving its goals. These aspects are interlinked as, for example, the level of participation from niche actors may influence the extent to which their

interests are represented and consequently how the mix is perceived by other actors. The extent to which media, politicians and industry actors represent benefits or perceived losses to the wider public in comparison to the status quo, can influence the politicisation of supporting the policy mix (Jacobs and Weaver 2015). Public opinion around supporting policy mixes for sustainability transitions can be expected to be of most significance prior to general elections through formation of electoral coalitions (ibid). Public opinion is influenced by the extent to which achieving long-term sustainability objectives are contested by short term issues, such as economic downturn or other crises [ExC], and the perceived cost of supporting the policy mix or specific components thereof.

Increased support [RE & InstE] stimulating a sustainability transition can lead to positive (self-reinforcing) feedback loops in several ways. Firstly, as the new configuration of the socio-technical system matures and niche actors gain market shares, these actors can form increasingly powerful coalitions and networks [SPF] that challenge the ideas presented by regime actors who may lobby to retain the status quo. Secondly, as supply chains are being established and upscaling of production techniques occurs, this can lead to an increased market and improvements in technological performance criteria, such as cost reductions. This strengthens the arguments put forth towards the successes of the policy mix in meeting its objectives [SPF], changing perceptions regarding costs of supporting the policy mix or potential economic benefits [FF] and the capabilities of the policy makers responsible for designing the mix [AF]. Positive feedbacks can be strengthened/ facilitated if the policy mix phases out support for the current regime configuration [RE], or breaks up the institutional structures through targeted instruments [InstE]. Finally, as a transition matures it has increased capacity to generate support if diffusion can lead to widespread visible benefits [SPF]. Conversely if the policy mix does not enable niche actors to upscale [RE & InstE], gain political influence and lobby to protect resources [SPF], the existing networks between incumbents and policymakers are likely to lead to negative feedbacks [SPF] reducing resources for niche actors and technologies while maintaining the status quo [RE & InstE].

5   An Empirical Illustration of the Framework: the UK zero carbon homes target

In this section, we briefly illustrate how the conceptual framework can be applied empirically using the example of the zero carbon homes (ZCH) target in the UK. The ZCH target was introduced in 2007 and entailed the ambition that by 2016 all new domestic homes in the UK should be zero carbon. This case provides a relevant illustration showcasing the utility of the proposed framework for several reasons. First, the ZCH target was intentionally designed as a policy mix with several policy instruments to meet the target. Second, the target was conceived to be very ambitious when introduced. Finally, the case provides a rich illustration of an instance where an ambitious policy reform failed to generate adequate positive policy effects and self-reinforcing feedbacks, leading to its abandonment in 2016

The illustration draws on policy documents, industry journals, secondary literature, government consultations, select committee publications, inquiries, and debates in the House of Commons and House of Lords over the period of 2006-2016. These archival sources are triangulated by ten scoping interviews, conducted face to face with industry actors, interest groups and policy makers, over the period of July-October 2014. For illustrative purposes, we limit the application of the framework to the national scale, considering the UK house building socio-technical system. We identified the relevant national policy mix following the top down approach outlined by Ossenbrink et al. (this issue), thereby considering the target and instruments implemented towards achieving this objective (see Figure 2). Our illustrative case spans the period between September 2006, when the target was first announced, to May 2016 when the target was officially abandoned.
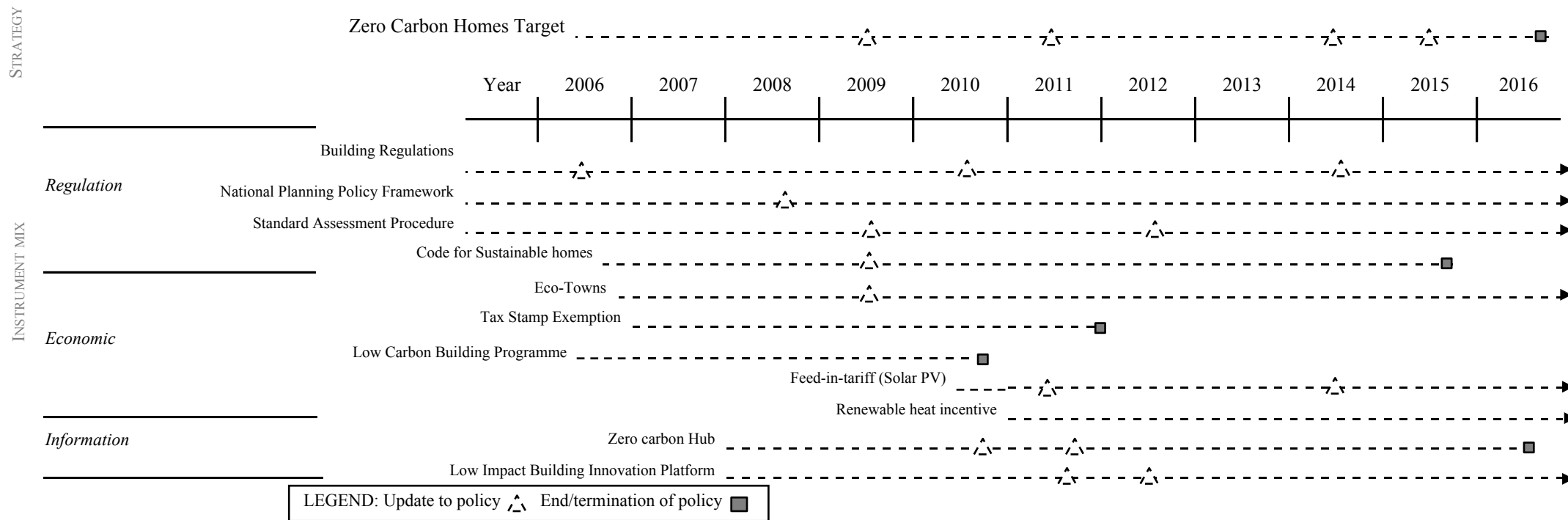
**Figure 2** – Policy Mix for Zero Carbon Homes (Source: own)

5.1   Overview of illustrative case

The zero carbon homes target which sought to promote a radical paradigm shift in the building industry was adopted for a variety of reasons which included pressure from the EU as well as domestic considerations around meeting carbon targets. The target was designed to work primarily through two main instruments, a voluntary instrument known as the Code for Sustainable Homes (CSH)[4], and planned updates to the Building Regulations which became progressively more stringent leading to zero carbon requirements in 2016. An exemption from stamp duty tax (economic instrument) was also announced in 2007 for all ZCH built before 2012. After its announcement, the ZCH target underwent several significant redefinitions, as described in detail by Greenwood (2012, 2015), Heffernan et al., (2015) and Schweber et al., (2015). Also, despite being formally introduced in 2007, a definition of the technical specifications actually required to meet the target was not finalised until 2015. In parallel, another objective was announced by government which was to build three million new homes in the UK by 2020 in order to tackle a crisis in housing prices. At the time of designing the ZCH strategy, this secondary objective was seen to be complimentary with the ZCH target.

In the UK, the house building industry was (and still is) made up of a relatively small number of large volume house builders, and a larger number of low volume builders. In 2007, the top 25 house builders accounted for around 49.5% of completed projects, while the top 5 accounted for 32.6% (Gardiner 2014). Since 1970, the volume of annual new build in the UK has declined by 55.5%, falling from 378,320 new homes to 168,210 in 2015 (Figure 3). This is mainly due to decreased provision (near complete phase-out) of public housing through local authorities in the UK (Sharman 2014). Consequently, the market share of private developers has increased from 49.1% in 1970 to 79.97% in 2015.

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[4] The Code for Sustainable Homes (DCLG, 2008) is the most prominent voluntary sustainability label for housing in England (Heffernan et al., 2015). The code was developed by BRE, a private company formally the research body known as the Building Research Establishment (Greenwood 2012), and managed under the direction of DCLG. The Code is a holistic sustainability rating tool in which homes are rated against indicators in nine categories. Homes can be awarded a star rating between levels 1 and 6, with 6 being the most sustainable (Heffernan et al., 2015).
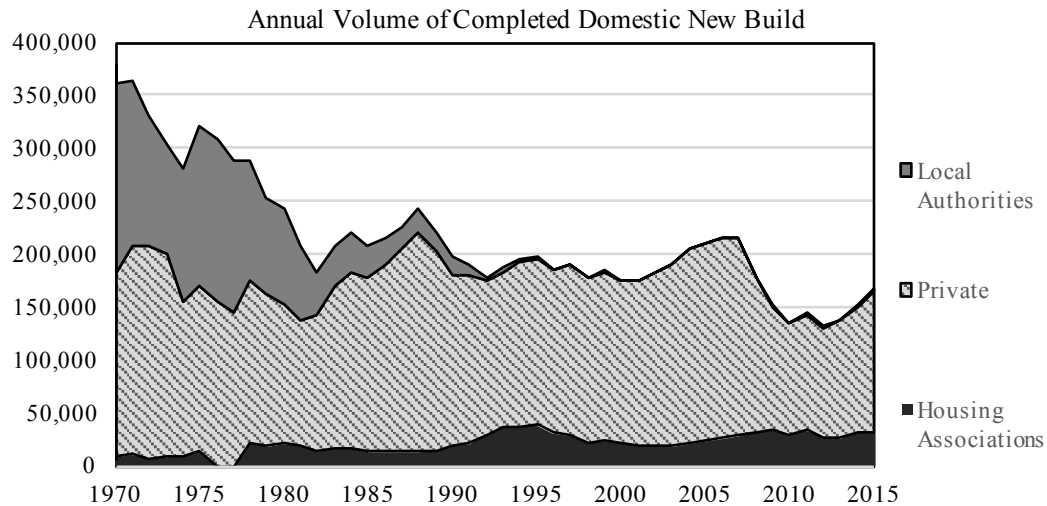
Figure 3 – Annual volume of completed domestic new build. (Source: own. Data: DCLG 2016)

5.2   Illustration of Dynamics of Policy Effects and Feedbacks

Throughout the progression of the ZCH target, a number of policy effects and feedback mechanisms can help to explain the revisions and eventual denouncement of the target. For illustrative purposes, we select three issues that played a key role in these policy processes: lack of comprehensive policy strategy, an overall decline in political will, and regime resistance through lobbying from incumbents. In the following, we will apply our analytical framework to explain how these themes can be understood in terms of negative (-) or positive (+) policy effects (resource effects [RE], interpretive effects [IntE] institutional effects [InstE]) and self-reinforcing (+) or self-undermining (-) feedback mechanisms (socio-political feedbacks [SPF], fiscal feedbacks [FF], and administrative feedbacks [AF]).

5.2.1 Lack of Comprehensive Strategy and Instrument Mix

Industry actors expressed frustrations over the lack of a roadmap to achieve the target, a clear shortcoming in the design of the policy strategy [-AF] (Greenwood 2012). Zero carbon was the objective, but there was little consensus on what form zero carbon housing should take, and what should be done to achieve it. The UK sustainable building niche had emerged from the counterculture movements of the 1960s and 1970s, which placed emphasis on resource use, environmental impact, wastage and energy intensity in conventional building practices (Gibbs and O'Neill 2015). However, dominant designs had not been established within this niche, meaning that it remained largely heterogeneous with a variety of actors advocating different materials, technologies and practices (ibid). To compound this issue, the government's original definition of the ZCH target was a very general one, leaving open several questions which became the subject of significant debate across the building industry (Greenwood 2012). The original targets were widely seen as overambitious [-IntE], leading to frustrations among industry over the leadership capabilities of government [-AF]. In response, the UK Green Building Council (UKGBC)[5] produced a report (2008) showing that the original 100% on-site energy generation requirement for ZCH was unachievable on 80% of sites in the UK.

In response, the Zero Carbon Hub was established [+RE & +InstE], a public private-partnership to act as a steering group towards achieving the target (Schweber et al., 2015). The target was redefined providing clearer guidance for industry on how to meet the target [+RE]. The Hub also produced several task-force reports, highlighting challenges and skill shortages the industry faced in the run up to 2016. However, this information was never translated into a clear roadmap for industry actors of steps to be taken to achieve the target [-RE]. Consequently, even when (re)defined, the policy mix had an objective but lacked a principle plan of how to achieve it, and therefore lacked a *comprehensive* strategy (Rogge and Reichardt 2016). Furthermore, no additional instruments were implemented to address the identified challenges [-RE]. For example, skills, knowledge and training in the supply chain were often highlighted as a major issue, but no policy actions were taken to address this [-RE].

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[5] The UK Green Building Council is advocacy group for the sustainable built environment. UK-GBC membership includes over 400 organisations, from private and public sectors and NGOs.

The indicates that the instrument mix was not comprehensive either, which overall helps explain some of the negative effects and feedbacks.

5.2.2 Decline in Political Will

In 2010, the Labour government was succeeded by a Conservative-Liberal Democrat coalition, which influenced the preferences of policy-making towards a market-based deregulation form of governance, and introduced austerity policies in response to the financial crisis [-ExC]. As reflected in the 2010 spending review, the perceived relative cost of supporting ZCH had clearly increased in the treasury [-FF] and was accompanied by reductions of resources [-RE]. The grant funding of the Zero Carbon Hub was reduced in 2010, and subsequently cut in 2011[6] [-RE]. In the 2011 budget, the target's definition was redefined for a second time, reducing the overall amount of carbon abatement to be made. In addition, implementation of Part L 2013 of the building regulations was delayed by a year and then only reflected a 6% increase on the 2010 regulations[7]. Collectively these changes were largely considered by niche actors to be a weakening of government commitment towards meeting the target [-InE], which seems to have slowed down socio-technical change (ENDS Report 2013). In the words of Jo Wheeler[8] in 2013. "The watering down of the definition of zero-carbon, coupled with the uncertainty surrounding standards for Part L 2013 and 2016 has inevitably resulted in a decline in innovation" (ibid).

The deregulation agenda pursued by the coalition Government, often referred to as cutting 'red-tape', also indicates a reduction in political will in support of the target. This was an attempt to increase the volume of new build in the UK, and we suggest that the ZCH target was simply seen as another regulation impeding increased supply [-SPF], compounded by a general weakening of commitment from the Conservative party towards sustainability goals [-ExC] (Carter and Clements, 2015). Shortly

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[6] Funding was subsequently awarded from government for specific projects, while majority funding was provided by NHBC, while some funding was provided from government on a project specific basis.

[7] This was less than the lowest scenario considered in consultations, which reflected an 8% increase.
[8] Senior policy advisor at the UK Green Building Council (UK-GBC).

after the 2015 election, where Conservatives gained an absolute majority [ExC], the target was disbanded. The denouncement came direct from the treasury, who justified the decision by stating that costs of meeting the target were a tax on development [-FF][9].

5.2.3 Regime Resistance

Finally, we discuss the role that regime resistance had over the development of the ZCH policy mix. In 2007, 'green' or low carbon housing was very much a niche activity (Gibbs and O'Neill 2015), with relatively few low and zero-carbon developments. When first announced, the target created expectations of a potential market for low carbon housing and practices [+IntE] leading to considerable growth of the green housing niche[10]. In the mainstream sector, there was little understanding of the methods required to cut emissions among developers (ENDS Report 2006), who were unwilling to move away from traditional methods (Osmani and O'Reilly 2009; Gibbs and O'Neill 2015). However, the announcement seems to have provided a strong enough market signal to stimulate innovative activity among incumbent actors [+IntE]. For example, Barratt Homes was a founding member of the UK-GBC[11] in 2007 (Seager 2007), and was the first actor to prototype a demonstration of a CSH level 6 property[12].

However, the design of regulatory instruments introduced towards meeting the target favoured 'technical solutions' rather than promoting holistic sustainability (Boschmann and Gabriel 2013: 10; Gibbs and O'Neill 2015: 140). For example, substantial differences between Passivhaus[13] standards and those enshrined in the Code for Sustainable Homes (CSH) meant that a Passivhaus could receive a poor rating under CSH (Gibbs and O'Neill 2015). Consequently, this excluded some actors who adopted a holistic approach to low carbon buildings, limiting the potential for market share of niche actors [-RE], while giving signals of business-as-usual approach to incumbents [-IntE]. This allowed the dominant

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[9] In the inquiry of HM Treasury, the additional average cost of meeting the target incurred per dwelling was estimated as £3,500.

[10] For example, the EcoBuild exhibition has grown from under 1,000 to almost 60,000 visitors and 1,200 exhibitors in 5 years.

[11] When UK-GBC was established in 2007, there were 36 founding members (Seager 2007).

[12] The Barratt Green House, which was showcased among other similar projects in the BRE's Innovation Park.

[13] A design of zero carbon building developed in Germany, popular among some niche actors in the UK.

actors in the sector to retain (or even strengthen) market share [-RE]. In 2007, the top 25 housebuilders by volume produced 49.5% of all new homes, but by 2010 this had increased to 56%. Consequently, the influence of incumbents over policy making was maintained [-SPF] due to the government's dependence on the private sector to deliver high volumes of new houses to address the housing shortage in the UK [-ExC].

Shortly after the implementation of the ZCH target in 2007, the global financial crisis lead to a recession in the UK in 2008 [-ExC]. Pre-tax profits of the ten largest house builders dropped from around £2.5 billion in 2006, to -£3 billion by 2008 (Mathiason 2014)[14]. This reduced innovative activity from the incumbents, who had little incentive to achieve higher levels of efficiency other than meeting the increasing regulation. The policy mix provided little financial support towards delivering low carbon housing for developers [-RE], who already had small margins and cost was a significant factor in decision making. The potential costs of innovative activity towards meeting the increasing regulations [-RE], while already suffering losses from recession [-ExC], increased incentives to lobby against the target [-SPF]. Incumbent actors used the argument that costs of meeting the targets [-RE] conflicted with the Government's competing objectives to build high volumes of new houses. In 2009, a comment made by the House Builders Federation[15] (HBF) reflects this argument, stating that the overall volume of homes built "must not be dented by the zero-carbon target" (ENDS report 2008).

While a large number of niche actors were active in the house building sector, the niche remained heterogeneous and fragmented with various different approaches, practices and technologies favoured by different groups [-InstE] (Gibbs and O'Neill 2015). This reduced the influence of these actors over the policy making process, in comparison with incumbent actors who consisted of fewer, powerful actors who could mobilise resources in their lobbying strategy regarding the (promise of) volume of houses produced [-SPF]. After the denouncement of the target, the UK-GBC organised over 246 senior leaders from organisations (industry actors and interest groups) to write an open letter to the Chancellor George Osbourne (UK-GBC 2015). The letter warned that the abandonment of the ZCH

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[14] These actors subsequently evened balance sheets by 2010, and had recovered to 2006 levels by 2014 (Mathiason 2014).

[15] A trade body representing 80% of the industry

target had "undermined industry confidence in Government" and will "curtail investment in British innovation and manufacturing" [-InE]. Importantly, of the 246 signatories on this letter (UK-GBC 2015b), not one of the 25 top volume house builders over 2007-2010 or the top 20 in 2016 (Building 2016) by turnover appeared on this list (Including Barratt, a founding member of UK-GBC). We suggest the lack of support by these large developers is reflective of the dominant regime's resistance to the targets, and also the political influence that these actors had over government [-SPF].

Overall, this illustration shows the manifold interactions between different policy effects and feedback mechanisms alongside changing exogenous conditions, which together help explain the abandonment of the ZCH target. The proposed framework seems useful in focussing attention on the co-evolution of developments in the policy subsystem and the UK building regime which led to a situation in which positive effects and feedbacks did not sufficiently materialise in order to reduce the influence of the dominant building regime, or maintain political support for the policy mix over time.

6   Conclusions

In this paper, we have proposed an interdisciplinary and original conceptual framework of the co-evolutionary dynamics of policy mixes and socio-technical systems. The core of the framework consists of policy effects influencing developments in the socio-technical system and resulting feedback mechanisms influencing the further development of the policy mix and subsequent developments in the system.

We have illustrated this novel conceptual framework using the example of the UK zero carbon home target and corresponding instrument mix which ultimately failed to stimulate radical change in the building industry, from which we derive three key considerations. Firstly, the lack of a clear roadmap was problematic in that many industry actors did not have the skills or expertise on how to achieve zero carbon buildings, and with the lack of clear guidance and leadership capabilities this seems to have negatively impacted on innovation. A second, related point is that the policy mix was not comprehensive, neither in terms of the strategy nor the instrument mix. We suggest that in turn this led

to negative perceptions of the policy mix' credibility, which were interpreted by actors as the government either lacking the capacity to steer or the capabilities to design effective policy, thereby signaling low political will to achieve the target. Finally, and perhaps most revealing, is the success of incumbent actors in overturning the target, using a competing objective to lobby the government, which appears to have been particularly successful with the treasury. Arguably, this could have been overcome from efforts of the state in the provision of social housing rather than reliance on the private sector to increase build rates, but with declining political will and a Conservative party in power pursuing austerity policy, this was not an option.

More broadly, policy mixes aimed at sustainability transitions will often face ongoing contestation and political opposition. Simply because a target is agreed upon does not mean that this will be met, or survive changes in electoral cycles and short term decision making (due to changes in conditions), without fostering enough support from consistencies and coalitions that mobilise to protect the policy. The value of our co-evolutionary policy mix framework lies in drawing attention to designing comprehensive policy mixes to instigate the desired changes as well as to the policy processes and feedback mechanisms that underlie and influence the extent to which such mixes are successful. It thereby may help generate novel insights for policy makers seeking to achieve transformative change as it directs attention towards designing policy mixes which generate positive feedback mechanisms, thereby strengthening political support over time. Without generating political support, contestation and conflicts with other policy objectives can result in a weakening, dismantling or removal of policy mixes (or respective constituent elements) aimed at fostering transitions. Consequently, we suggest that maintaining political support through creating incentives for participation from supporting groups and constituencies, is fundamental to maintaining momentum in transition processes.

We suggest potential avenues for future research to advance the ideas presented in this paper. First, future studies should extend the evidence base of policy effects and feedback mechanisms through application in detailed case studies. Second, further conceptual and empirical studies should deepen insights on the link between policy mix characteristics and the kinds of policy effects and feedback

mechanisms that are expected to arise. Finally, future work can focus more on multi-level governance considerations whose importance has been demonstrated in other contributions within this special issue (Huang; Bodas Freitag, this issue).

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