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Zero Carbon Homes in the UK? Analysing the co-evolution of policy mix and socio-technical system

Duncan L. Edmondson ^{a,*}, Karoline S. Rogge ^{a,b}, Florian Kern ^c

a SPRU—Science Policy Research Unit, Jubilee Building, University of Sussex, Brighton, BN1 9SL, UK

b Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI), Breslauer Straße 48, 76139 Karlsruhe, Germany

c Institute for Ecological Economy Research (IÖW), Berlin, Germany

Abstract

Understanding how policy and policy-making processes can influence the speed and direction of socio-technical change is an important, yet underexplored research agenda in the field of sustainability transitions. This paper is the first application of a novel analytical framework which conceptualises the co-evolutionary dynamics of policy mixes and socio-technical systems, by complementing the sustainability transitions and policy mix literatures with insights from policy feedback theory. Our paper is an in-depth empirical case study of the zero carbon homes policy mix in the UK which sought to promote radical change in the UK house building system. Our paper makes three contributions. First, it makes an empirical contribution by analysing an example of an ambitious policy strategy in the housing sector where various policy effects and feedback mechanisms led to a loss of political support for the target, eventually leading to its abandonment, and only limited change within the socio-technical system. Second, our paper produces novel insights about the effects of policy mix credibility on socio-technical change, and the underlying feedback mechanisms which influence its formation and loss. Finally, based on our empirical analysis we propose conceptual refinements to the co-evolutionary framework and suggest avenues for future research explaining the dynamics of feedbacks between policy mixes and socio-technical systems. From the empirical analysis a key finding is that policy mixes need to be effectively designed in order to produce positive feedback from the outset, through the creation of resources, provision of clear information and the creation of credibility, and reforming conflicting institutional supports. In the case, ineffective initial design led to uncertainty and inertia, which did not generate sufficient positive feedback to withstand adverse economic and political conditions later on, which ultimately contributed to the abandonment of the policy mix.

1. Introduction

Understanding the role of policy, policymaking and politics in shaping sustainability transitions is a fundamental challenge. Policy is widely considered as an integral aspect of transitions (Drews and van den Bergh 2016; Markard, Suter, and Ingold 2016), and arguably can be used to accelerate the rate of change (Kern and Rogge 2016). Neo-classically derived policy recommendations typically involve internalising environmental externalities to address the corresponding market failure in the under-provision of environmental protection, but transition scholars have identified a number of structural and transformational system failures which also require policy intervention (Weber and Rohracher 2012; Wieczorek and Hekkert 2012). Policy suggestions, amongst others, include creating protective spaces for novel sustainability innovations (Raven et al. 2016; Smith and Raven 2012), creating new networks to accelerate learning and technological development (Geels et al. 2016), and establishing shared long term visions and expectations (Kemp et al. 2007; Rotmans and Loorbach 2010).

Beyond the type of policy instruments (e.g. regulation, market-based instruments) and their specific design, the process of policymaking itself has been argued to be of relevance as well (Markard et al. 2012, Rogge and Reichardt 2016). Policymaking refers to the process through which policies are designed, implemented, adapted and discontinued (Sabatier and Weible 2014). Transition scholars argue that policymaking needs to be iterative and reflexive, in order to adapt to the changing conditions of the socio-technical system as a transition unfolds (Voß and Kemp 2015). To better understand policymaking processes, transition scholars have started to draw on prominent policy process theories (for a review see Kern & Rogge 2017). Other studies link policymaking to socio-technical change more directly, where the two elements co-evolve over time (Hoppmann et al. 2014; Lauber and Jacobsson 2016b). Despite some conceptual advances on the interactions of technological change, politics and policy processes (Edmondson et al. 2018; Meckling et al. 2017), these dynamics remain empirically understudied in the transitions literature (Schmidt & Sewerin, 2017).

Sustainability transitions are, by nature, inherently political (Meadowcroft 2009, 2011), and often contested by powerful actors who typically have vested interests in maintaining the status quo (Kern & Howlett 2009; Avelino & Rotmans 2009). Most states have close relationships with powerful incumbents, which contributes to lock-in of existing socio-technical configurations (e.g. see Unruh 2000 on carbon lock-in). For instance, some policy instruments which could radically change the socio-technical system, such as implementing a stringent carbon tax which would impose significant losses on powerful actors, are generally considered politically unfeasible (Drews and van den Bergh 2016).

To compound these challenges, the speed at which sustainability transitions need to occur, and the scale and complexity of the required changes are unprecedented. Consequently, single 'silver bullet' policy instruments cannot address the interrelated multiple market and system failures (Foxon et al. 2005; Weber and Rohrer 2012), and many governments try to tackle these complex challenges with a variety of policy initiatives (e.g. see Kern et al. 2017 on energy efficiency). Several publications have contributed to this growing research strand focussing on policy mixes for sustainability transitions, such as transitions to sustainable energy systems (for a review see Rogge et al. 2017).

Of these contributions, Rogge & Reichardt (2016) propose a framework for analysing policy mixes for sustainability transitions which extends the scope of analysis from individual policies (and their interactions) to that of an overarching policy mix which captures policy strategies and instrument mixes, as well as policymaking and implementation processes associated with policy mix elements. They also argue that the impact of policy mixes on socio-technical change may be better understood through considering policy mix characteristics such as consistency, coherence, comprehensiveness and credibility (Costantini et al 2017, Rogge and Schleich 2018). Empirical evidence on policy mix *credibility* (which captures the extent to which the policy mix is considered believable and reliable), suggests a link with other policy mix characteristics, such as the overall consistency of the policy mix (Rogge and Dutschke 2018). If shortcomings in a policy mix are unaddressed by policymakers this may indicate a lack of political commitment or inadequate capabilities of government to design an effective policy mix.

We follow the call of Flanagan et al. (2011) to pay increased attention to the policy processes, as well as to their coherence, i.e. to the synergistic and systematic nature of the policy processes which underpin the evolution of the policy mix (Rogge & Reichardt 2016). Several recent contributions in the transitions literature have explored the role of politics and policy processes (Markard et al. 2016; Normann 2015), but importantly, have only focussed on single policy instruments. Moreover, there are few co-evolutionary analyses of policy change and socio-technical change. Hoppmann et al. (2014) is a notable example, but their conceptualisation of the policymaking processes is underdeveloped, and follows a single policy instrument and technology. This paper addresses these shortcomings in the literature by drawing on the conceptual framework proposed by Edmondson et al (2018), which builds on insights from policy feedback theory (Pierson 1993, 2000; Beland 2010; Campbell 2012) in order to understand the co-evolution of policy mixes and socio-technical change. Policy feedback theory has been argued as a promising approach for such co-evolutionary analysis (Kern and Rogge 2017; Roberts et al. 2018), because of its focus on the effects of policy design and implementation on subsequent rounds of policy making.

Empirically, we chose the UK Zero Carbon Homes (ZCH) policy mix, an ambitious strategy intending to phase-out unsustainable practices and technologies while mainstreaming sustainability in the domestic built environment. In doing so the paper contributes to research on housing within sustainability transitions literature. Previously, contributions have focussed on: the role of niche governance for eco-housing (Smith 2006), multiple niche interactions (Baker and Lester 2017), interaction dynamics between niche and regime (Berry et al. 2013; Smith, 2007), the role of intermediaries (Martiskainen and Kivimaa 2018a), and residential retrofit (De Laurentis et al. 2017). In addition to several contributions focussing attention to transition dynamics in the UK (Bergman et al. 2007, 2008; Gibbs & O'Neill, 2015), there has also been research on housing innovation in other countries, such as Australia (Foong et al. 2017; Moore & Doyon, 2018), and cross-country comparisons of zero/near-zero policies (Moore et al. 2014; Pan and Ning 2014). However, while there is attention to governance and policy as a driver of change within these contributions, the role of politics and policymaking processes is often underplayed. Secondly, while policy mix conceptualisations have been considered (see Kern, Kivimaa, & Martiskainen, 2016), their effects on housing transition dynamics is underexplored.

There are a number of key findings about housing transitions in the UK, and specifically for ZCH, which are of relevance for our analysis here. Greenwood (2012) draws attention to the difficulties of coordinating policy design and implementation, and find several challenges affecting the processes of establishing and defining the ZCH target. In particular, three interrelated issues are most significant: i) a lack of evidence on the performance of low/zero carbon buildings being available; ii) decisions being made at a ministerial level; and iii) industry lobbying for vested interests. Collectively, these factors obscured attempts to evaluate evidence and implications of policy decisions, but the role of intermediary (Martiskainen and Kivimaa 2018) the Zero Carbon Hub, helped alleviate some of these issues (Greenwood 2012). Other key issues regard: the skills and knowledge of industry to deliver the implementation of a housing transition in the UK (Greenwood, 2010; Heffernan et al., 2015), due to differences from conventional practices and competencies (Payne 2013); and industry concerns over higher technical standards increasing costs (McLeod et al. 2012), combined with uncertainty over whether these costs could be recouped through higher market values (Meins et al. 2010).

This paper builds on these insights to combine factors of the policymaking process with developments in the rest of the socio-technical system, by focussing on the co-evolutionary dynamics between them. Doing so helps understand how the transition unfolded over time, and helps explain the eventual denouncement of ZCH. Accordingly, the analysis we present follows the ZCH policy mix's co-evolution with the low carbon house-building sector in the UK from 2006 (when the target was announced) until 2016 (when the target was disbanded), paying attention to interplay of policy mix

change and socio-technical change processes. We find the mix initially stimulated change and showed signs of positive feedbacks with the potential for a self-reinforcing virtuous cycle to emerge, but over-time started to produce negative feedbacks, resulting in its abandonment. This observation makes it an interesting case, since much of the policy feedback literature would predict that initial positive feedback leads to a self-reinforcing dynamic.

Thereby, we make three contributions to the literature. First, we provide the first empirical application of a novel conceptual framework on policy mix feedbacks in sustainability transitions, which contributes to the growing literature on housing transitions. Second, we generate novel insights about the role of policy mix credibility in stimulating socio-technical change, and subsequently, maintaining political support. Third, we propose refinements to the conceptual framework for studying policy mix feedbacks in sustainability transitions. The analysis seeks to answer two research questions: i) *how policy effects and feedback mechanisms influenced the co-evolution of the zero carbon homes policy mix and the socio-technical system*, and ii) *why the zero carbon homes target got abandoned*. In doing so, we derive policy recommendations for governing transition processes.

The remainder of the paper is structured as follows: Section 2 introduces the analytical framework, section 3 outlines the methodology, and section 4 introduces the research case. We present the findings of our case study in section 5 and discuss these in section 6. Section 7 offers conclusions and avenues for future research.

2. Policy mix feedback in socio-technical systems: a co-evolutionary framework

In order to answer the proposed research questions above, the nature of our analysis is the co-evolutionary dynamics of policy mix change and socio-technical change, which contributed to the eventual abandonment of the zero carbon homes policy mix. Pan and Ning (2014), suggest that Zero Carbon Building (ZCB) policies co-evolve with their regulatory, social and geographical contexts, and present “a conceptual model of ZCB policies as socio-technical systems” (Pan and Ning 2014: 96). However, the model that they present is overly simplistic for several reasons. First, is that the model lacks mechanisms of interaction of policy with other aspects of the socio-technical system. Second, while claimed that the “contexts interact with each other”, again there are no mechanism of interaction. Third is that the conceptualisation of ‘policies’ is un-refined and does not address the design and coordination of policy mixes or the interactions of multiple policy instruments. With these limitations in mind, for our analysis we apply a co-evolutionary conceptual framework developed by Edmondson et al. (2018) (see figure 1), which focusses on the interaction mechanisms of policy and socio-technical

change, while also incorporating a nuanced conceptualisation of comprehensive policy mixes (based on Rogge and Reichardt 2016).

At its core the framework captures the co-evolution of policy mix change and socio-technical change. It proposes that policy mix change influences the rate and direction of socio-technical change through *policy effects*, while socio-technical change can affect subsequent policymaking through *feedback mechanisms*. That is, this co-evolutionary framework elaborates how policy *outputs*, i.e. elements of the policy mix, can influence policy *outcomes*, i.e. socio-technical change, namely through the effects the mix has on the socio-technical system. It also explains how policy *inputs* can affect policy-making processes through the influence feedback mechanisms and exogenous conditions have on the policy subsystem, thereby explaining changes in the policy mix. Importantly, the framework emphasises the role of actors as the agents of change: actors are influenced by policy effects, and seek to influence policymaking through feedback mechanisms.

The *socio-technical system* is a main component of the framework and captures the “linkages between elements necessary to fulfil societal functions” (Geels 2004: 900), consisting of multi-faceted combination of actors, networks, policies, institutions, artefacts, infrastructure, markets and practices along with cultural and symbolic views and representations (Geels, 2004). The existing configuration in the socio-technical system consists of social groups (supply chain, users, research, production, public authorities and societal groups), physical artefacts (technology, infrastructure) and institutions (formal and informal) (Geels, 2005). The existing policy mix is therefore part of the socio-technical system. Supporting sustainability innovations can help foster the emergence of novel socio-technical configurations. As these emerging configurations scale up, they may change the structural components of the dominant configuration. Such socio-technical change [STC] can occur through several possible transition pathways involving adaption and replacement of structural components (Geels et al., 2016; Geels & Schot, 2007).

Another key component is the *policy subsystem* which captures the groups of actors involved in the policymaking process (government departments, elected ministers, consultants, experts and ‘pressure participants’ such as lobbyists). Policy subsystem change [PSC] relates to substituting actors involved in the policy process or their respective roles, and/or the views and opinions of the actors involved. We expand on Edmondson et al. (2018), by considering the *policy mix* as the codified outcomes of negotiations of actors who are active in the policy subsystem. The mix’s elements are therefore the output of the process of policy mix change [PMC] (Fig.1). The mix’s elements consist of an overall strategy addressing a policy problem (an objective and principle plans towards achieving it) and the policy instruments implemented towards achieving the policy objective. Importantly, we consider the

process through which elements are (attempted to be) added/removed/revised (not simply the final outcome in terms of changes to the policy mix elements) as policy mix change **[PMC]**. Accordingly, proposed changes may have effects on the socio-technical system even if they are not adopted.

The framework captures the influence of the policy mix on the socio-technical system through *policy effects* which influence actor behaviour, thereby leading to a reconfiguration of the socio-technical system. Policy effects change as the policy mix does, but even when the policy mix is stable (no change) it will continue to have effects. There are three policy effects: *resource*, *interpretive* and *institutional* effects¹. *Resource effects* **[RE]** describe the allocation of resources that affect interest groups, state capacities and mass publics (Mettler & Soss 2004: 60). The influence of resource effects on socio-technical change depends on several variables, including the amount and duration of resources provided (Patashnik & Zelizer 2009, 2013), and how dispersed, visible and traceable to government action the resources are (Campbell 2012). *Interpretive effects* **[IntE]** describe the information a policy mix provides, affecting patterns of cognition, understanding and meaning (Mettler & Soss 2004: 60). Information can be provided through both the codified outputs of policymaking (e.g. instruments), but also through the processes by which the policy mix changes (including implementation). *Institutional effects* **[InstE]** describe the interaction of the mix with the wider institutional structure of the socio-technical system (Patashnik and Zelizer 2013). Failure to reform existing constraining institutional arrangements may limit the mix's transformative capacity and its ability to generate positive feedback (Patashnik and Zelizer 2009). For instance, existing rules and arrangements may structure how policy instruments are implemented, enforced or evaluated. Institutional effects thus include, for example, reforming such rules, creating new agencies or expanding formal networks which may be necessary to successfully implement the mix².

The framework differentiates between three main types of feedbacks: *socio-political*, *fiscal* and *administrative* feedback mechanisms (Oberlander and Weaver 2015). *Socio-political feedback* **[SPF]** comprises of three dimensions: cognitive, constituency and agenda. Cognitive feedback relates to how well the mix (or its elements) are perceived to be performing by actors in the policy subsystem. Constituency feedback relates primarily to whether the mix mobilises supporters or opponents. Agenda feedback is whether policy alternatives are considered by actors in the policy subsystem. *Fiscal feedback* **[FF]** relates to whether the costs of supporting the policy mix over time raise concern to powerful actors, notably the finance ministry. Finally, *administrative feedback* **[AF]** relates to the public bodies in charge of policy design and implementation, and can lead to strengthening or weakening of

¹ While considered separately for analytical purposes, a single policy change commonly produces multiple effects simultaneously.

² These may require further revision as the policy mix and socio-technical system change over time.

internal morale, sense of mission, external reputation, external political support, and the ability to recruit qualified staff (Oberlander and Weaver, 2015).

The framework also captures how a socio-technical system is also affected by *exogenous conditions* [ExC], including social, political and economic trends, along with innovation and policy learning from outside the system. Exogenous conditions can affect the system in four main ways. First is the direct effects on socio-technical change, such as economic trends affecting market conditions. Second, they can amplify or constrain the influence of feedback mechanisms on policy change. For example, feedback mechanisms are more likely to contribute to policy change when coupled with focusing events that bring attention to policy problems (Jacobs and Weaver 2015; May and Jochim 2013). Third, exogenous conditions can affect the policy subsystem directly. For instance, a general election will replace ministers from the previous government. This may affect the influence that feedback mechanisms have on the policy process, if supporters/opponents resonate more closely with the ambitions or ideology of the new government. Finally, international agreements such as the COP21 Paris Agreement or EU 2030 targets can place pressure on national policymakers to implement policy reforms. The timing of policy change in relation to changing conditions exogenous to the system can significantly affect the impact of a policy mix, and its prospects of maintaining political support over time (Oberlander and Weaver 2015; Patashnik and Zelizer 2009; Pierson 2000). For example, changes in political and economic conditions may render the mix more susceptible to negative feedback, while adverse conditions at the time of implementation may generate opposition from the outset.

The framework's conceptual elements interact dynamically over time, and can result in the occurrence of *feedback loops*. Positive feedbacks, which maintain or strengthens support, are likely to lead to steady resource flows in favour of transitions which makes successive positive feedbacks more likely (virtuous cycle). Conversely, negative feedbacks may limit the capacity of the policy mix to become stable, and can reduce support and resources for the transition. Over time, reduced resources may result in successive negative feedback occurring (vicious cycles) leading to the policy mix being revised or terminated.

Figure 1 - Dynamic interactions of the policy mix and the rest of the socio-technical system.

Source: Edmondson et al. (2018).

3. Methodology

For answering our research questions on *how policy effects and feedback mechanisms influenced the co-evolution of the zero carbon homes policy mix and the socio-technical system, and the reasons for its eventual denouncement*, we chose a qualitative research design, conducting a case study which allows for tracing of the phenomena over time (Yin 2014). Process tracing has been used by case study researchers “either to uncover evidence of causal mechanisms at work or to explain outcomes” (George and Bennet 2005:9). Process tracing therefore allows for the development and testing of theory focussing attention on processes, and the causal mechanisms linking causes to effects (Beach 2017; George and Bennett 2005; Tansey 2007). This is well suited to our focus on co-evolutionary dynamics of the zero carbon homes policy mix and the UK house building socio-technical system.

We drew on two main sources of evidence (archival and interviews), which were used in two stages of analysis. First, we collected archival data for the period 2006-2016 (**Table 1**). This included newspapers, industry journals, white papers, green papers, consultations, statements, written and oral references in the House of Commons and House of Lords, select committee inquiries, and a Treasury enquiry. Based on a freedom of information request we also received access for all minutes, agendas and supplementary documents from all meetings of the Zero Carbon Task Force (TF1-115 **Appendix A**). Based on this data, important events were arranged chronologically, including changes in the socio-technical system and the policy mix. For the former, we looked for quantitative and qualitative information on demonstration projects, annual built rates, research and development activities, activities of key market actors and industry development. For the latter, we included changes in the policy strategy and the instrument mix. Based on this preliminary analysis we derived four main phases of activity in which different co-evolutionary dynamics of policy mix and the socio-technical system could be observed. These phases relate to: i) the initiation of the policy mix (2006-2008), ii) the expansion of resources and capacities, and redefinition of the target (2008-2010), iii) austerity, reduced resources and reduced ambition (2010-2013), and iv) the dismantling of the policy mix (2013-2016). For the resulting timeline of events (see supplementary material) we also created a simplified visualisation (see fig 4 in section 3).

Table 1 - Type, Source and Quantity of Archival Data.

Type of archival data	Data Source	Quantity
Policy documents – Government responses to consultations, publications (white papers), speeches, impact assessments	http://webarchive.nationalarchives.gov.uk/20120919183345/http://www.communities.gov.uk/ https://www.gov.uk/	137
2016 Task Force - meeting minutes, agendas, supporting documents/reports	Freedom of information request to Department of Communities and Local Government (DCLG)	115 (See Appendix A)
Zero carbon hub publications	http://www.zerocarbonhub.org/recent-publications	148
Industry journals	https://www.endsreport.com/ https://www.building.co.uk/ https://www.cibsejournal.com/ https://www.architectsjournal.co.uk/	603 articles - reviewed for relevancy and reduced to 112
Secondary literature	https://www.scopus.com	25 academic papers
Inquiries	https://www.parliament.uk	71 written responses in Treasury inquiry 99 written responses in 'Home energy efficiency and demand reduction' inquiry, Energy and Climate Change Committee Documents reviewed using search terms "zero carbon homes" and "allowable solutions".
Debates in the House of Commons and House of Lords over the period of 2006-2016	https://hansard.parliament.uk/	260 spoken references 22 written statements Occurrences resulting from search terms 'Zero Carbon Homes' and 'Code for Sustainable Homes'
Letters (to government ministers)	Various	3
Media	https://www.theguardian.com/uk https://www.telegraph.co.uk/ https://www.ft.com/?edition=uk https://www.independent.co.uk/	427 occurrences - reviewed for relevance using search terms "zero carbon homes", "eco-towns" and "code for sustainable homes". Reduced to 67.

We then conducted interviews with 18 experts (see table 2) who were selected based on their knowledge of and involvement in relevant processes, while also seeking a balance between different actor groups (policy-makers, NGOs, industry, academic, experts). We interviewed until three criteria were satisfied: i) we felt that a number of sufficiently different perspectives were represented; ii) a saturation in responses started to appear; and iii) the interviews sufficiently contributed to the triangulation of archival data. Interviews were based on a semi-structured questionnaire, were conducted face-to-face and over telephone in the period from August until October 2018, and lasted on average 79 minutes. They were supported by the timeline visualisation which enabled us to validate this event timeline with experts, and look for additional information.

Table 2 - Overview of interview participants.

Interviewee	Actor type	Actor group	Format	Date	Duration (minutes)
1	UK-Green Building Council	NGO	Face to face	31/08/2017	90
2	World Wildlife Fund/Task force/ UK-Green Building Council/Zero Carbon hub	NGO	Telephone	17/08/2017	50
3	NGO/advocacy group	NGO	Telephone	23/09/2017	90
4	Manufacturing – advocacy group	Industry/ Manufacturing/ NGO	Face to face	3/10/2017	90
5	Manufacturing – advocacy group	Industry/ Manufacturing/ NGO	Telephone	18/09/2017	105
6	Manufacturing/ Zero Carbon Hub	Industry – manufacturing	Telephone	2/10/2017	90
7	House builder/Zero Carbon Hub/ National House Building Council	Industry	Face to face	12/10/2017	90
8	Developer	Industry - developer	Face to face	4/10/2017	90
9	House Builders Federation	Industry - developer	Telephone	1/12/2017	45
10	Chartered Institutions of Building Service Engineers	Expert/ industry	Telephone	17/11/2017	90
11	Consultant/Zero Carbon Hub	Industry/ Expert	Telephone	24/10/2017	90
12	Consultant/Zero Carbon Hub	Industry/ Expert	Face to face	11/09/2017	90
13	Expert/ academic	Expert	Telephone	5/09/2017	90
14	Academic	Expert	Face to face	26/10/2017	60
15	Civil servant/Carbon Trust	Policy maker/ Expert	Face to face	7/09/2017	90
16	Minister/Department of Communities and Local Government	Policy maker	Face to face	17/10/2017	50
17	Office of the Deputy Prime Minister/ Local Area Building Control	Policy maker	Face to face	14/09/2017	90
18	Building Research Establishment/Housing association	Policy maker/ Industry	Face to face	13/10/2017	60

We followed a 'framework analysis' methodology for analysis of collated data (Ritchie and Spencer 1994). Interviews were transcribed verbatim and then indexed using NVivo11 to deductively code for four phases with nodes derived from our framework. We also coded 'other' as sub-nodes of both policy effects and feedback mechanisms, to account for any phenomena not captured by the framework³. We ran multiple queries to investigate the relationships between elements of the framework, using matrix-coding queries to look for overlaps. In doing so, we examined whether the interviewees agree with each other and whether there were significant differences in responses, e.g. between interviewees from different actor types. We triangulated our interviews with our archival data to ensure the robustness of our findings. Collectively these sources allowed for a rich analysis of co-evolutionary mechanisms.

³ However, since the research was designed to look for evidence of the main a priori conceptual components, most data was expected to fit the framework (Ritchie and Spencer 1994).

4. Research case

For the first application of the co-evolutionary framework on policy mixes for sustainability transitions we chose the UK zero carbon homes strategy which was intentionally designed as a policy mix, including a number of interacting instruments. This is a highly illuminating case because it offers an example of an incomplete transition attempt (in terms of material differences in the UK socio-technical system) based on an ambitious policy target which included the phase-out of dominant technologies and practices. As such, the application of the framework can help us understand why transitions may lose support and to derive recommendations for more successful policy mixes. In the following, we provide an introduction to the UK housebuilding socio-technical system and the zero carbon homes policy mix as a background to the case study.

4.1. UK House-building socio technical system

Demand for new housing in the UK is around 280,000 new homes a year (roughly 1% of total housing stock), due to net migration and a trend towards smaller properties (Kay 2017). Current build rates do not match this demand, as in 2016 only 190,310 new houses were built (ONS 2017a). Low supply has created a 'housing crisis', with housing prices increasing 74% since 2006, despite the recession (fig.3). Build rates have declined since 1970 by 47%, largely due to a drop in the provision of social housing through local authorities in the UK by 99% (DCLG 2017). Consequently, the housebuilding industry is dominated by private developers, whose market share has increased from 48% in 1970 to 81% in 2016 (fig. 2). To address the highly politicised issue of housing supply, at the time of launching the zero carbon homes policy mix (2006), government also announced an ambition to build 3 million homes by 2020, of which 1 million would be zero carbon.

Figure. 2 -Annual Volume of Completed Domestic New Build (1970-2016). Data Source: DCLG (2017)

The private sector housebuilding industry accounts for 22% (largest contributor) of total construction output in the UK (Statista 2018). Market actors comprise of a relatively small number of high volume house-builders (producing 1000s of new homes per year), and a larger number of low volume builders. The Home Builders Federation (HBF) is a trade association representing large private sector house-builders and its members deliver around 80% of new homes, while the Federation of Master Builders (FMB) is a trade body representing SMEs. In 2007, the top 25 house-builders accounted for around 50% of completed projects, while the top 5 accounted for 33% (Building 2008). By 2018, the share of these top 5 builders had increased to 39% (Building 2018).

Figure 3 - Average Price (£) of UK property 2006-2016. Data source: ONS (2017b)

4.2. Zero Carbon Homes policy mix

The zero carbon homes target was designed as a net-zero approach to housing, aiming for all new housing post 2016 to contribute zero emissions for their operation (DCLG 2006). This overall strategy would be achieved through a combination of energy efficiency improvements to reduce energy use for heating/cooling, cooking and appliances, and complemented by small-scale renewables to offset any remaining emissions (DCLG 2006). The target was ambitious, accounting for unregulated energy

emissions⁴, which exceeded European and international standards. After the target's announcement in 2006, a number of different policy instruments were implemented towards achieving the overall strategy, comprising of regulations and funding schemes. We used a top down perspective to identify instruments (Ossenbrink et al. 2018), and classified them according to three large categories of instruments used in public policy (Table 3): (1) regulatory instruments, (2) economic and financial instruments, and (3) soft instruments (Borras and Edquist 2013:11). The main implementation of the target was through the national building regulations, which were pre-existing prior to the implementation of the mix but were updated.

Table 3 - Zero Carbon Homes policy mix.

Policy mix element	Name	Element Function	Started	Redefined/modified	Terminated
Strategy	Zero Carbon Homes target	Target	2006	<ul style="list-style-type: none"> - 2007 (treasury) - 2008 (consultation) - 2010 (standard for 2010 building regulations decided) - 2011 (removal of unregulated energy use) - 2013 (marginal increase in the 2013 building regulations) - 2014 (small sites exemption and removal of requirements for micro-renewables) 	<ul style="list-style-type: none"> - 2015 (denounced) - 2016 (officially disbanded)
Instrument Mix	Building regulations - Part L (energy)	Regulatory	1985	<ul style="list-style-type: none"> - 2006 (aligned with target)⁵ - 2010 (implemented as planned) - 2013 (postponed to 2014 and only marginal increase) - 2016 (Part L was not implemented) 	N/A
	Zero carbon task force	Soft instrument	2006	2010 (terms changed and housing minister stopped attending meetings)	2014 (final meeting)
	Code for sustainable homes	Soft instrument	2007	<ul style="list-style-type: none"> - 2010 (modified to align with the new definition of the target) - 2014 (plans to terminate) 	N/A Still active
	Tax stamp duty exemption	Economic and Financial (market pull)	2007	N/A	2011 (ended - as planned)
	Eco-Towns	Economic and Financial (supply push)	2007	2009 (commitment to 4 of the 10 originally proposed sites) 2010 (only 1 town would be built to original standards)	2011 (no further sites awarded)
	Carbon challenge	Economic and Financial (supply push)	2007	2008 (additional sites added) 2010 (funding reductions)	2012 (no additional sites awarded)
	AIMC4	Economic and Financial (R&D)	2008	N/A	2011 (ended - as planned)
	Zero carbon hub	Fiscal (grant funding)	2008	2010 (funding withdrawn apart for specific projects)	2016

⁴ Post occupancy emissions associated with appliances.

⁵ While the building regulations did not start in 2006, they were updated at the start of our analysis and became aligned with the overall strategy. For the purposes of this analysis, they can be considered as part of the policy mix at that point.

5. Co-evolutionary analysis of the zero carbon homes policy mix and the house-building socio-technical system in the UK (2006-2016)

The following subsections present our co-evolutionary analysis, structured into four phases between 2006-2016 (for an overview, see fig 4 and table 7). Each phase starts with a period of significant changes to the policy mix, and is analysed according to a) the policy effects produced and their influence on socio-technical change, and b) the feedback generated and its influence on the policy mix change. We also pay attention to interactions of the socio-technical system and policy mix with exogenous conditions.⁶

5.1. Phase 1: Initiation of the zero carbon homes policy mix (2006-2008)

The zero carbon homes target announced in 2006 was implemented through increments to the national building regulations occurring in 2010, 2013 and 2016 [PMC]. A non-mandatory regulation for holistic building sustainability was also introduced in 2007, the Code for Sustainable Homes (CSH). The CSH was a rating system with levels ranging from 0-6, where the energy requirements of the highest level (6) were aligned with the zero carbon target (interviews 15,18). The CSH was intended to provide clarity and indicate the trajectory of future building regulations, allowing market actors to experiment with new designs based on these standards (DCLG 2006b). By the end of this phase, level 3 of the CSH was used in publicly funded buildings to set a standard higher than the 2006 national building regulations and provide a stimulus for innovation (interview 7,10).

Resources in this phase were limited [RE], but several announcements were made of potential funding opportunities [PMC->IntE]. Most notably was the announcement of five 'eco-towns', large scale developments of 5,000-20,000 houses to be built to zero-carbon standards on publically commissioned land (ENDS 2007). Eco-towns were intended to accelerate housing delivery and serve as large-scale demonstration projects for zero carbon housing. After a change of leadership in the Labour Party, the ambition was increased to 10 eco-towns (potentially 200,000 new homes) by the new Prime Minister who was a key advocate of the policy (interview 1). The sites proposed were previously undeveloped (green-field), and would be fast-tracked through the planning system. As the availability of land has significant impact on costs, and planning permission on 'green-field' sites is typically difficult to attain, this was an attractive offer to developers (interview 7) [ExC->PMC->IntE].

⁶ We use abbreviations to refer to the conceptual components of the framework: Policy mix change [PMC], Resource effect [RE], Interpretive effect [IntE], Institutional effect [InstE], Socio-technical change [STC], Socio-political feedback [SPF], Fiscal feedback [FF], Administrative feedback [AF], Exogenous conditions [ExC], Policy subsystem change [PSC].

Figure 4 - Timeline of key developments in the socio-technical system in the period 2006-2016

Smaller-scale funding was also available through the 'carbon-challenge' for medium scale 'eco-villages' (100-750 homes), also built to zero carbon standards [PMC->RE] (Morby 2010). Similar to the Lochiel Park Green Village in Australia (Berry et al. 2013), these villages would allow for experimentation with new designs and technologies, and were intended to assist the delivery of the larger-scale towns [RE->STC]. The first site - Hanham Hall - was awarded to Barratt Homes in 2007 (Jansen 2007). Finally, there was a tax exemption for new homes built to the zero carbon standards before 2011 (Gov 2016). The tax exemption was meant to benefit consumers, reducing the overall costs of buying a new home. However, while several instruments were implemented, the co-ordination of these towards meeting an overall strategy (consistency) has been criticised by some interviewees. *"I think it [was] 'scatter-gun policymaking' to an extent. You announce something and then you announce some incentives but you haven't really worked out what you are incentivising yet, and that was sort of the missing piece."* (interview 1).

These policy changes were introduced within the existing institutional arrangements, rather than reforming them [PMC->InstE]. Most notably was the legal requirements regarding how compliance with building regulations are evaluated and enforced. The only requirement to satisfy building regulations in the UK is to submit a design specification for the standards of the new build [PMC->IntE&InstE] (interview 17). Consequently, there is no legal requirement to evaluate the real performance of buildings after construction [InstE]. Thus, many sites are value-engineered during construction, and materials are replaced with cheaper, less-effective components [PMC->Inst&IntE->STC] (interviews 1,15,18). Another issue relates to skills shortages of site operatives lower down the supply chain, to effectively install components and technologies (interview 7). Accordingly, there is a commonly acknowledged 'performance gap' between as-designed specification and the final building [STC] (interview 1,2,4,6,7,9,18).

A notable change of institutional effects was the establishment of a political steering group to help deliver the target, the Zero Carbon Task Force [PMC->InstE]. *"The reason for the task force was that it was [...] such a big change in terms of the policy for housing. They needed a controlling panel to make sure, at the very highest level, it was understood by both government and industry."* (interview 7). The purpose of the group was to act as a platform in the policy process in which different stakeholders could discuss with the housing minister about future actions to be taken in achieving the target [PSC] (interview 2). The task force was convened by the housing minister and included representation from house-builders and manufacturers, yet the micro-renewables industry seems to have

been excluded, despite requesting representation⁷ (TF11). Consequently, the opinions of this industry were excluded from the formal policymaking procedure [-SPF]. The implications this had on the policymaking process can be seen later in the trajectory of the target, as the need to include on-site renewables was eventually removed from the requirements, being replaced by an abatement mechanism.

The most notable policy effect was the expectations of future resources [IntE], considered a commercially attractive opportunity to potential beneficiaries (interviews 1,2,6). *"The government wants us to do this and is pushing money into it, so let's try and pick up on some of that."* (interview 1). Combined with perceptions of strong political commitment [IntE], this led to the establishment of UK-GBC⁸ [STC], and helped elicit support from some major house-builders [+SPF]. However, the eco-towns policy also generated negative feedback from the general public (NIMBY-ism) who protested against the proposals, and led to political opposition from the Conservative Party (CP) [-SPF]. Another issue involved different definitions for the target announced by DCLG and Treasury (finance ministry) with the introduction of the tax exemption. This meant that actors weren't sure how to proceed [IntE], leading to inertia in the initial phase, with the exception of some experimentation with prototypes on the BRE innovation park (interviews 1,2,7,10,14). The lack of clarity regarding the target [IntE] motivated UK-GBC to produce a report assessing the feasibility of the current target [STC], which was presented to the task force [+SPF] (TF15). This led to suggestions from house-builders to introduce the option of off-site carbon mitigation (TF17-20), and proposals for a new definition including 'allowable solutions'⁹.

The overall inertia in this phase led to the recommendation (made in the Callcutt review on Housing Delivery), that government should form a new delivery body, acknowledging a capability deficit to effectively implement the target [-AF] (interviews 2,6).

"The Callcutt review made the recommendation that there needed to be some sort of formal body. The 2016 Zero Carbon Task Force [had] met a number of times, but there was a sense [that] the great and the good would come together, say 'oh yes how's it all going?', 'oh, well, not a lot has happened yet' and then they went off again. [So] we thought [...] unless this is operationalized

⁷ The Renewable Energy Agency (REA) is the trade body representing the micro renewables sector. REA wrote a letter to the task force voicing support for the target and requesting representation. However, reviewing the attendees at subsequent meetings, REA were not represented.

⁸ UK Green Buildings Council.

⁹ Allowable solutions was the term given to these off-site solutions. These were initially defined as alternative options for carbon abatement to be achieved locally, such as large-scale solar or wind developments.

in some way we [will] keep coming back to exactly the same point, getting nowhere.”
(interview 2).

In terms of co-evolutionary dynamics, a lack of clarity and consistency of policy mix elements led to little change within the socio-technical system, highlighting the need for policy mix change [**PMC->IntE->STC->-SPF&-AF**].

5.2. Phase 2: Resource expansion, redefinition and recession: the emergence of an opposing coalition (2008-2010)

Acknowledging the identified issues from the previous phase [**+SPF&-AF**], government worked towards re-defining the target [**PSC->PMC**] (Gibbs and O'Neill 2015), and launched the Zero Carbon Hub (ZCHub) [**PMC->InstE**]. The redefined target comprised of three aspects: a Fabric Energy Emission Standard (FEES), carbon compliance and allowable solutions (Heffernan et al. 2015; Schweber et al. 2015). FEES set the expected level of efficiency of the building fabric, while carbon compliance captured the amount of abatement on-site through the use of renewable energy. The allowable solutions component was originally planned as an abatement fund for local carbon mitigation, without requiring it to be 100% on-site (DCLG 2009c) (interviews 1,4,18). The ZCHub received grant funding from government [**PMC->RE**], enabling it to serve as an autonomous research group working towards redefining the target and identifying and overcoming potential barriers. This helped provide clarity [**IntE**] and to form new networks, helping simulate innovation [**RE&InstE->IntE->STC**]. *“The Zero Carbon Hub provided a lot more direction [...] this was very much seen as government helping to fund the industry to do something. So it helped to foster a sort of collaborative element to an extent.”* (Interview 1).

There was also additional funding allocated in this phase through the carbon challenge, AIMC4, and commitment to funding four of the proposed eco-towns [**PMC->RE**]. This helped maintain perceptions of political commitment throughout the phase [**IntE**] (interview 1,2,6,10). Another significant institutional effect in this phase resulted from the Planning and Energy Act 2008 [**PMC**] which introduced mandatory use of the ‘Merton Rule’ by local councils, effectively allowing local councils to require higher levels of sustainability in their planning permission applications [**InstE**], and was implemented in many boroughs of London [**STC**] (interviews 1,7,11,12,16). Combined with the Introduction of ‘Home Information Packs’ [**PMC**] which required all new homes to have a sustainability rating [**IntE**], there was increased applications of the code of sustainable homes (mainly level 3 and some level 4) [**STC**] (table 5). This was a strong stimulus for innovation [**STC**], helping promote the uptake of new products into mainstream use, including the adoption of Forest Stewardship

Council certified timber [STC] (interview 11,12,18). We consider these socio-technical changes as the emergence of a potential virtuous cycle [PMC->RE&IntE&InstE->STC->SPF].

Figure 5 - Percentage change of property value (2006-2016). Source: HM Land Registry.

As the transition started to gain momentum, however, the UK moved into recession [ExC] and the construction sector was one of the worst affected sectors. House prices dropped by 16% by the end of 2008 (fig. 5) (Osborne 2009) and the pre-tax profits of the ten largest house-builders dropped from around £2.5 billion in 2006 to over -£3 billion by 2008 (Mathiason 2014)¹⁰, leading to 25% job losses in the sector (Peacock 2010) [ExC->STC]. Typically, during periods of 'bust' in the construction industry, job losses commonly impact innovative actors worse, leading to reduced capabilities (interviews 1,2,6,7,10). The adverse market conditions and drop in profits also meant that there was less resources available for innovation. The recession also impacted specific instruments, most notably eco-towns. Under tighter economic conditions [ExC] the overall budget was reduced [PMC->RE] (Hope 2008). More importantly, the lack of regulation of the financial sector was blamed for the economic crisis [ExC], which increased attention to the role of regulations [PSC]. Consequently, the proposals to fast-track the planning system were revoked [PMC] (Arnold 2009). Following this change, DCLG produced a report estimating only marginal profits for developers of eco-towns [RE], which undermined the expectations created throughout the first phase [IntE]. By 2009, Labour committed to funding 4 eco-towns [PMC->RE], but the proposals were now less attractive [IntE], and under tight economic conditions [ExC], house-builders became more vocally opposed to the target [-SPF]. HBF claimed it was unachievable (Goodchild and Walshaw 2011), and led to the narrative that the target

¹⁰ These actors subsequently evened balance sheets by 2010, and had recovered to 2006 levels by 2014 (Mathiason 2014).

may impact on the delivery of new homes [STC->SPF] (Ends 2008). However, resource allocation through the carbon challenge [RE] helped maintain support of some house-builders, notably Barratt Homes [+SPF]. In spite of growing opposition [-SPF], political commitment to the target remained strong under Labour [PSC], and the support of some powerful actors [+SPF] meant no changes to the target were made [PMC].

Table 4 - Number of constructed properties according to CSH level.

Number of constructed properties to levels 0-6 of CSH (post-construction)							
Code level	0	1	2	3	4	5	6
2008-2009	0	0	1	58	4	2	0
2009-2010	49	34	75	4326	290	37	7
2010-2011	114	54	113	18208	1579	62	24
2011-2012	234	106	335	32384	6299	136	111
2012-2013	369	152	28	36150	9642	268	91
2013-2014	465	120	248	31823	12459	55	14
2014-2015	506	40	113	18749	7561	64	15
TOTAL	1737	506	913	141698	37834	624	262

The UK came out of the recession by the end of this phase, however recovery was the slowest in recorded history [ExC] (Owen 2015). Despite adverse market conditions [STC], throughout this phase progress was made through the CSH [IntE->STC] and the activities of the zero carbon hub, who conducted research on how to operationalise the target [RE->STC]. Participation in the hub from various parts of industry may have also helped safeguard the target's credibility [PMC->IntE] (interview 1), and led to a peak of activity from 2009-2011. Notably, the number of CSH level 3 homes increased significantly [STC] (table 4), which contributed towards reducing the costs of achieving the code (DCLG 2011).

5.3. Phase 3: Election, austerity, increasing opposition and a weakening supporting coalition (2010-2013)

In the third phase several detrimental changes to the policy mix occurred [PMC], including significant reductions of resources available (current or anticipated) [RE&IntE]. These changes can partially be attributed to a significant change in the policy subsystem [PSC]. The 2010 election [ExC] led to a new coalition government between the Conservative Party (CP with 306 seats) and the Liberal Democrats (LD with 57 seats) [PSC]. In general, the conservative party are less supportive of climate change

mitigation (Carter and Clements 2015), and place greater emphasis on economic growth [ExC->PSC]. Therefore, the appointment of CP ministers as the most senior positions within DCLG, and the finance ministry was an important change [PSC].

In response to the recession, the government implemented austerity measures, and consequently the costs of supporting the policy mix became considered as an unnecessary expense. This resulted in various funding schemes being cut [PSC->PMC->RE] (interviews 1,10,11), including: ending the grant funding for the ZCHub [PMC->RE] effectively removing its research autonomy [PMC->InstE]; requiring that only one of the four planned eco-towns would be built to the original (sustainability) standards [PMC->RE&IntE]; and reducing funding available through the carbon challenge [PMC->RE]. These reductions of resources significantly weakened the incentive for developers to support the target [PMC->RE&IntE&InstE->STC->SPF] (interviews 1,15). *"There was a strong move away from it because there was no longer the promise of money [...] and I think that was part of what was pushing it"* (Interview 1). Combined with the cuts, no additional instruments were added to the mix to address any identified problem areas, support innovation or stimulate demand [PMC], which helped re-stabilise the existing socio-technical system [STC].

These policy mix changes, originated from reconfigurations within the policy subsystem, which under austerity measures was dominated by Treasury throughout this phase [PSC&-FF->PMC->RE] as one interviewee argued: *"Treasury is all powerful and especially so in times of austerity. So the recession gave them even more power than they had before."* (Interview 17). With the ongoing housing crisis in the UK, treasury prioritised delivery of new houses over how efficient these were (interviews 1,2,3, 8,10,15,16,18). This is reflected in the amount of resources dedicated to housing delivery and stimulating the market through 'First Buy' and 'Help to Buy' policies. By 2013, the new government had committed £15.8 billion to assisting first time buyers get onto the property market (table 5). Importantly, no sustainability requirements were included in these policies, which clearly reflected the government's reprioritisation. This reprioritisation also meant that anything considered to impact on the volume of supply became opposed by treasury. Consequently, the opposing coalition had more influence, using the narrative that the costs of meeting the target would reduce the rate of housing delivery [SPF&PSC->PMC].

Treasury's dominance also affected other aspects of the policy mix. Following the target's previous redefinition to include allowable solutions (abatement fund), this component was appropriated by Treasury, labelling it as a tax and under their mandate [PSC->PMC] (interviews 10,16). Consequently, throughout this phase, little progress was made towards defining component, as Treasury refused to sign-off on proposal [PSC->PMC] (interview 16). The target was then subsequently weakened prior to the main development of the first zero carbon demonstration [PMC]. One interviewee suggested this

was due to lobbying from house-builders after the early phases and trials had proved costly and difficult to achieve. “*When they realized how horrible and difficult this was, they thought [...] we can't have it supplied to our mass housing market because we will be in the water unable to swim.*” (Interview 15). This change made it significantly easier to achieve the target, for example it reduced the estimated costs of solar PV needed to develop this demonstration project alone by £2million [PMC->IntE->STC] (ZC Hub 2011).

Table 5 - Funding mechanisms available within zero carbon homes policy mix compared to housing delivery

<i>Policy instrument</i>	<i>Resources available</i>	<i>Beneficiaries</i>	<i>Start date</i>	<i>Revision</i>	<i>End/ termination</i>
Eco-towns	Potential 5 towns of 5,000-20,000 houses	House-builders	2007	2007 - Ambition increased to 10 towns. 2009 - Ambition reduced to probable 2. 2010 - £60 million committed to supporting 4 sites. 2010 - Announcement that only one town would be required to be built to the original standards.	2014
Carbon challenge	Funding for medium scale demonstration projects	House-builders	2007	2010 – HCA funding cuts (60%)	2011 (no additional sites awarded)
Tax stamp duty exemption	Exemption from tax stamp duty on	General public	2007	N/A	2011 (31 houses were eligible)
AIMC4	£3.4 million funding awarded (one off)	House-builders	2009	N/A	2011
Zero Carbon Hub	£500,000 a year	House-builders, Manufacturers	2008	2010 - Funding cut (20%) 2011 - Funding ended (some resources available for specific projects)	2016
<i>Other funding for driving housing market (no sustainability requirements)</i>					
First Buy	£250 million	General public	2011	N/A	2013
Help to Buy	£15.5 billion	General public	2013	N/A	2016

Along with these changes, there was also diminishing political commitment to the task force throughout this phase [PMC->IntE] (interviews 1,2,7). In its first meeting under the new government, the CP housing minister proposed changing the terms of the task force (TF 62&65). After which, it met less frequently, the CP housing minister stopped attending meetings, and the only ministerial representation was from LD junior ministers responsible for the building regulations [PMC->Inst] (TF6-115). “*It got*

down-graded and passed down to more junior ministers responsible for Building Regs rather than the Housing Minister" (interview 2). Whilst these LD ministers were supportive and engaged with the target, ultimately CP ministers needed to approve decisions, meaning that overall political influence of the task force was undermined [PSC].

Collectively, these policy mix changes signalled by the end of this phase that government was not committed to the target [PMC->IntE] (interviews 1,10,11,15,18). As several house-builders began to detect this, they increased opposition by intensifying lobbying efforts [PMC->IntE->STC->SPF] (interviews 1,7). *"It was picking up on a political agenda more than it coming directly from the house-builders. The fact that you had this government that specifically set out to reduce regulation of businesses"* (interview 1). This simultaneously weakened the supportive coalition [-SPF], as those actors who hoped to gain a competitive advantage had less certainty (increasing risk) as the policy mix lost credibility [PMC->IntE->STC->-SPF]. Most notably, this culminated when the 2013 building regulations were delayed by 6 months, and when published only included a marginal increase of 6%, which was lower than any of the values considered throughout the consultation phase [PMC->IntE->STC]. Moreover, the recommendations of the ZCHub to amend regulations to apply to as-built performance, were excluded. The delay, and the outcome of the consultations produced a strong interpretive effect that the government were not committed to the target. It also meant that the amount of abatement needed in the final stage was increased, while the amount of time left before 2016 was reduced [PMC->IntE].

Some individuals within companies remained supportive because they thought it was the right thing to do. *"There was no longer the sort of the financial incentive, it was then being carried by people who thought it was the right thing to do"* (Interview 1). This was in spite of the policy mix and socio-technical configuration, not because of them [SPF] (interviews 1,10). *"There were some individuals trying to do some quite neat things in several companies, to a greater or lesser extent, in spite of the system and not because of it."* (Interview 10). For example, the CEO of Barratt remained supportive as one of the major proponents of the agenda (interviews 1,2), but there was increasing pressure from stakeholders to resist the target (interview 15). These changes resulted in the emergence of a co-evolving vicious cycle. By the end of 2013 the supportive coalition was significantly weakened, and resulted in all house-builders withdrawing from the supporting coalition [PMC->IntE->STC->SPF], or as expressed by one interviewee: *"after 2013 those voices [on the supportive side] started to go quiet"* (interview 1).

5.4. Phase 4: Dismantling of the zero carbon homes policy mix (2013-2016)

The final phase involved several policy mix changes dismantling the zero carbon homes policy mix. In the absence of a strong supporting coalition, policy changes reinforced an emerging co-evolutionary vicious cycle, which culminated in the eventual denouncement of the target.

As outlined above, by the end of the previous phase, the Zero Carbon Task Force¹¹ met less frequently, without the housing minister, and had diminishing influence in the policymaking process. In January 2014, the task force had its final meeting (TF115) [PMC], which removed the formal policy network thereby changing the policy process [InstE]. By this phase the manufacturing sector was still broadly supportive of the target, but felt increasingly 'shut-out' of DCLG¹² (interviews 4,5). *"It became a point that they didn't talk to us and I don't know why, [but] there was total disengagement from DCLG [...] We certainly feel that we're shut out from DCLG on everything."* (Interview 4)

After the abolishment of the task force a number of further changes to instruments and the target itself occurred [PMC]. The first of which was proposals to remove the CSH (Mark 2014). Next, the Infrastructure Bill published by government June 2014 further revised the target, removing the need for on-site renewables by allowing the abatement fund to offset emissions. With this announcement, a small sites exemption was also announced. *"I don't think I've been as critical of a policy proposal as we were of that one."* (Interview 10). This was largely considered as a loop-hole [IntE], which would allow developers to avoid compliance with building regulations by phasing sites in rounds of 10 units [STC] (Parliament 2014, interviews 10,16). *"It's ridiculous ... if you go ahead with the small sites exemption it's better than not going ahead...[and] my successors found that if they were going to get the go-ahead at all then small sites exemption would have to be there, but once you got there of course, you got big sites exemptions."* (Interview 14)

The 2015 general election was won by a conservative majority, changing the policy subsystem [ExC->PSC]. While LD ministers had been less influential throughout the previous government, their political support was considered to have kept the target alive, despite being significantly weakened by this point (interviews 1,2,14). In their absence after the election there was no remaining support from within government [PSC]. Shortly after the election, the target was denounced [PMC]. The announcement came from the treasury, who had already opposed the target throughout the coalition government. Their announcement was made without consulting other departments, highlighting the dominance of the finance ministry by this stage. *"By that stage it was a case of, my mind is made up*

¹¹ The Zero Carbon Task Force was the steering group established under the Labour Government in 2007 to help implement the target.

¹² The Department of Communities and Local Government is the department responsible for setting the building regulations and the target was under their mandate.

don't confuse me with the facts. A justification was provided but it wasn't an evidence based decision." (interview 10). In a final attempt to maintain the target, UK-GBC sent an open letter to the chancellor asking for the government to reconsider its decision [PMC->IntE->STC->SPF]. However, there were no volume house-builders included in the 246 signatories (UK-GBC 2015), and because the announcement was direct from treasury, UK-GBC did not expect the letter to have any impact (interview 1). The government's decision was also opposed by the House of Lords [PMC->IntE->STC->SPF]. The Lords put forward an amendment to reinstate the target but were defeated by a margin of four votes and the target was officially abandoned in 2016.

Phase	Policy mix change	Policy effects	Exogenous conditions	Socio-technical system change	Policy subsystem change	Feedback Mechanisms
1. 2006-2008	<ul style="list-style-type: none"> • Introduction of target • Launch of Code of Sustainable Homes • Eco-towns • Carbon challenge (Eco-villages) announced and Hanham Hall site awarded • Exemption from Stamp Duty Land Tax (SDLT), which included a different definition of target • Foundation of the task force • Callcutt review on housing delivery commissioned 	<ul style="list-style-type: none"> • Resource effects <ul style="list-style-type: none"> - limited in this phase - Carbon Challenge - SDLT exemption for new zero-carbon homes • Interpretive effects <ul style="list-style-type: none"> - expectation of future resources - strong indication of political commitment - lack of clarity of policy definitions (target and eco-towns) - concerns over potential cost from house-builders • Institutional effects <ul style="list-style-type: none"> - establishment of new platforms for policymaking(Task Force) - Regulatory enforcement unreformed 	<ul style="list-style-type: none"> • High political attention to climate change • All party consensus on Climate Change Act 2008 	<ul style="list-style-type: none"> • Initial support from some major house-builders • Foundation of UKGBC • KingSpan Light house, and Barratt Green House built on the BRE innovation park • Growth in property market 	<ul style="list-style-type: none"> • Labour Government • Yvette Cooper (HM DCLG¹³ 2006-2007) • Ruth Kelly, John Denham(SS DCLG¹⁴ 2007-2008) • Gordon Brown (Chancellor – Treasury 2006-2007; 2007 – Prime Minister) - Support from treasury • Task force - Micro renewables industry not represented in task force 	<ul style="list-style-type: none"> • Support from several major house-builders and HBF chairman Stewart Baseley [+SPF] • Incremental changes to policy mix suggested [+SPF] • Suggestion to establish delivery body though Callcutt review [-AF, +SPF] • Support from manufacturing sector and micro renewables industry (REA) [+SPF] - REA less influential as excluded from task force [-SPF] • Public opposition to eco-towns [-SPF]

¹³ HM DCLG - Housing minister, Department of Communities and Local Government

¹⁴ SS DCLG - Secretary of state, Department of Communities and Local Government

2. 2008- 2010	<ul style="list-style-type: none"> • Establishment of Zero Carbon Hub • HCA established • Target redefined through consultation • Reduced ambition of eco-towns • AIMC4 • Carbon Challenge – 3 additional sites 	<ul style="list-style-type: none"> • Resource effects <ul style="list-style-type: none"> - increased in this phase - ZC hub - AMIC4 - Carbon Challenge • Interpretive effects <ul style="list-style-type: none"> - strong indication of political commitment despite recession - increased concerns over costs amplified by recession • Institutional effects <ul style="list-style-type: none"> - establishment of new platforms for policymaking (changes through HCA, ZC Hub) - Regulatory enforcement unreformed 	<ul style="list-style-type: none"> • Recession 	<ul style="list-style-type: none"> • Increased uptake of the code drives innovation in new materials leading to widespread adoption (e.g. certified timber). • Work starts on Hanham hall in 2009, but is delayed (due to recession). • Hanham hall design originally uses a CHP system and district heating • Hub operating as autonomous research institution 	<ul style="list-style-type: none"> • Labour Government <ul style="list-style-type: none"> - John Denham (SS DCLG) - Caroline Flint (HM DCLG 2008-2009) - Margret Beckett (HM DCLG 2009) - John Healy (HM DCLG 2009-2010) • Task Force • ZC Hub <ul style="list-style-type: none"> - research role on delivering target through 5 works streams - influential in redefining the target - hub's recommendations for FEES incorporated into 2010 building regulations 	<ul style="list-style-type: none"> • Increasing opposition from builders due to the recession [-SPF] • Redefinition of target after feasibility questioned [+SPF] • Political opposition to eco-towns from Conservative Party [-SPF]
3. 2010- 2013	<ul style="list-style-type: none"> • 2010 building regulations (contested) • Eco-towns abandoned • Cuts/removal of hub funding • HCA budget cut by 60% • Target reduced (un-regulated energy removed) • 2013 building regulations delayed 	<ul style="list-style-type: none"> • Resource effects <ul style="list-style-type: none"> - significant cuts to resources through scale back of eco-towns, removal of grant funding for the Hub, scale back of carbon challenge - small amount of research funding tendered to ZC Hub • Interpretive effects <ul style="list-style-type: none"> - signals a reprioritisation of government towards volume of supply - delays to 2013 building regulations means target less feasible • Institutional effects <ul style="list-style-type: none"> - task force changes terms under new government - ZC Hub loses autonomy with funding cut - Regulatory enforcement unreformed - ZC Hub's recommendations to change regulations to 'as-built' performance ignored by DCLG 	<ul style="list-style-type: none"> • Election leads to new government • Political ideology shift, austerity and deregulation • Rapidly declining costs of solar PV • Less political attention to climate change • Political resistance to 'green crap' 	<ul style="list-style-type: none"> • Barratt start construction on the main site at Hanham Hall 2011 • AIMC4 finished 2011 • PV becomes the principle way of achieving 'carbon compliance' • Limited evidence of 2010 building regulations in new builds • Manufacturers up-scale production lines anticipating the increase in building regulations 	<ul style="list-style-type: none"> • Coalition Government: Conservative Party (CP) <ul style="list-style-type: none"> - Treasury dominates subsystem (Chancellor George Osborne) - Eric Pickles (SS DCLG) - Grant Shapps (HM DCLG 2010-2012) - Mark Prisk (HM DCLG 2012-2013) - Kris Hopkins (HM DCLG 2013) - Bandon Lewis (HM) • Liberal-democrats (LD) ministers <ul style="list-style-type: none"> - Andrew Stunnell (2010 - 2012) - Don Foster (2012- 2013) - Stephen Williams (2013) • Task Force <ul style="list-style-type: none"> - no engagement from housing minister (CP) - engagement from LD ministers but low political influence • ZC Hub <ul style="list-style-type: none"> - research role hampered through reduced resources - recommendations for 2013 regulations ignored by government 	<ul style="list-style-type: none"> • House-builders start pushing back harder which seems to resonate with new (CP) government [-SPF] • Barratt construct test units, projected costs generates opposition from stakeholders [-SPF] • Treasury reduced autonomy of DCLG and enforced austerity reducing resources in response to recession [-FF] • Lib Dem ministers supportive of target but not as powerful [+SPF] • Poor reputation of DCLG due to changes made during this phase [-AF]

4. 2014- 2016	<ul style="list-style-type: none"> • Delay to 2013 building regulations • Consultation on removal of CSH • Small sites exemption • Denouncement of target • Amendment from the Lords to reinstate target defeated by a margin of four votes • Target officially abandoned - Housing and Planning Bill 	<ul style="list-style-type: none"> • Resource effects <ul style="list-style-type: none"> - no additional funding allocated - small amount of research funding for allowable solutions mechanism, but project cancelled after 1 month • Interpretive effects <ul style="list-style-type: none"> - zero carbon homes agenda seen as increasingly under threat • Institutional effects <ul style="list-style-type: none"> - task force disbanded - ZC Hub closes - Regulatory enforcement unreformed 	<ul style="list-style-type: none"> • 2015 Election • Change to conservative majority government 	<ul style="list-style-type: none"> • System stabilises through resistance to change 	<ul style="list-style-type: none"> • Coalition (2014 - 2015) <ul style="list-style-type: none"> - Treasury dominates subsystem (Chancellor George Osborne) - Eric Pickles (SS DCLG 2014-2015) - Stephen Williams (LD) (2014-2015) • Conservative Party (2015-2016) <ul style="list-style-type: none"> - Greg Clark (SS DCLG 2015-2016) - Brandon Lewis (HM DCLG 2014-2016) • Task Force <ul style="list-style-type: none"> - disbanded (Jan 2014) • ZC Hub <ul style="list-style-type: none"> - low influence - disbanded 2016 	<ul style="list-style-type: none"> • Weakened supporting coalition and no supporting house-builders [-SPF] • Opposition from parts of the industry and some politicians to small sites exemption [+SPF] • Denouncement appealed by UKGBC but weak supportive coalition weak [-SPF] - denouncement opposed by the Lords [+SPF]
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6. Discussion

Our analytical framework proposes that in order to be successful, policy mixes need to induce changes in the socio-technical system leading to the creation of self-reinforcing (positive) feedback mechanisms. This is particularly the case for sustainability transitions, which are commonly contested by powerful incumbents (Kern and Howlett 2009), requiring positive feedback mechanisms to overcome potential negative ones. In the following, we discuss three main insights from our empirical case of relevance for understanding and governing the co-evolutionary dynamics of policy mixes and socio-technical change. First, we reflect on how a potential virtuous cycle can be offset and turn into a vicious cycle; second, we consider key design limitations which prevented the policy mix from producing more positive feedback; third; we highlight the role of credibility in the co-evolution process. Based on these findings we propose changes to the conceptual framework.

6.1. How was a potential virtuous cycle offset and turned into to a vicious cycle?

We found that a potential virtuous cycle started to emerge in the early phases due to support from some major house-builders, along with the manufacturing and micro renewables sectors. Resource allocation, combined with the interpretive effects of strong political commitment, expectation of future resource allocation, and potential competitive advantage, attracted support from some large incumbent house-builders. In particular, the proposed large-scale eco-towns provided the main incentive for some high-volume house-builders to support the transition, as they stood to benefit by fast-tracking the planning system. In essence, we find a similar phenomenon to Markard et al. (2016) where incumbents are not homogenous in their beliefs and if such actors view transitions as an opportunity, they are more likely to be supportive. This helped attract the support of these powerful actors, which is a key aspect of scaling-up niches, facilitating transitions (Kivimaa and Kern 2016). These large-scale demonstration projects also offered an opportunity for price-performance improvements as these niche technologies were rolled-out on a larger scale, while subsidising the incurred costs on industry by offsetting them with reduced costs of the land.

However, the potential for a virtuous cycle to emerge was partly offset due to adverse effects of the recession on the housebuilding socio-technical system. The market conditions led to large scale job losses and a decline in investment and innovation, and the first medium-scale demonstration project was delayed. The anticipated costs of meeting the target, while in difficult financial conditions, started

to generate negative feedback from house-builders. However, resource allocation, perceptions of strong political support, and the sustained expectations of future resources, retained the support of some house-builders (expected beneficiaries), meaning the rising opposition to the target was partially offset.

A vicious cycle started after resources supporting the mix were removed, following the 2010 general election as part of austerity measures introduced by the new government. Importantly, the housing standards required for the four large scale demonstration projects were also reduced (apart from one site), meaning that these beneficiaries had less incentive to innovate and improve energy performance. Innovation declined and very few demonstration projects were built, making the prospects of meeting the target progressively harder. As the target continued to lose credibility there was little incentive for the previously supportive house-builders to continue to engage in innovation, and there were no resources available to help create positive feedback. Moreover, these changes signalled weakening political commitment, making investments higher risk and undermining perceptions of potential competitive advantage, giving no incentive for further investment.

From the case we can see that the original strategy included both small-scale and large-scale demonstration projects, which intended to help scale-up the previously niche technologies and practices by providing protective space, to nurture innovation while shielding from mainstream market pressures (Smith and Raven 2012). This was also accompanied by a longer term 'stretch and conform' strategy to change the mainstream selection environment through incremental regulation, which would necessitate the phasing-out of technologies and practices embedded in the regime (Kivimaa and Kern 2016). However, as the protection for the niche was removed by abandoning the demonstration projects, and after losing the support of powerful regime actors who had supported the transition, the niche could not scale-up sufficiently. It was perhaps inevitable that the target would fail since the niche had not scaled-up and become part of the mainstream building practices, needed to deliver the technologies at scale. Instead, what we saw was a succession of changes weakening the requirements, and the introduction of an abatement fund to offset carbon emissions rather than the radical innovations needed to achieve these changes.

In the policy feedback literature, it is often argued that once a policy starts to generate positive feedback it can become locked-in and stable, making it harder to change to alternative policy options (Pierson 1993, 2000). However our case indicates that changing exogenous conditions (notably economic) can trigger a response in government (austerity), reducing the resources made available, which can turn previously positive feedback into negative (Oberlander and Weaver 2015). This highlights how the timing of policy mix implementation, relative to the endogenous and exogenous conditions of the socio-

technical system, can drastically affect the prospects of a mix to generate positive feedback (Patashnik and Zelizer 2009).

While some conditions are unexpected and unpredictable, how the government responds to these conditions (more broadly and with regards to the policy mix) can dramatically influence the relative success of policy mixes supporting sustainability transitions. Ideally, policymakers wanting to support transitions should aim to maintain credibility, through sustained political commitment, combined with continued allocation of resources throughout a recession. Doing so can help maintain positive feedback, but undermining either of these aspects will likely cause negative backlash (Kemp et al. 2007). Therefore, our main recommendations towards withstanding adverse exogenous effects is to maintain credibility, but we acknowledge the difficulties in doing so due to currently turbulent political conditions. One potential avenue towards achieving this would be de-politicising environmental/transitional policymaking processes (Kuzemko 2016) by creating a new veto player, reducing the scope of the enacting government for retrenchment (Lockwood et al. 2017). Doing so would protect the policy mix, incentivise investment and support through sustained long-term resource allocation, and/or improving investor confidence through strong political leadership and commitment to the policy mix's objectives by producing clear and believable resource effects.

6.2. What limitations prevented the mix from producing more positive feedback?

To help understand the impact of the policy mix and its ability to produce positive feedbacks we consider the effects that the policy mix produced and how these influenced the socio-technical system. The resource effects were primarily grant funding for large-scale demonstration projects, and were mostly distributed to the major house-builders who otherwise had little incentive to support the target (Table 6). We suggest that such 'one-off' allocations of resources do not require recipients to mobilise to protect them. Once already allocated these benefits cannot be later withdrawn, unlike social policies such as the provision of healthcare providing long-term benefits which need continuous protection. This implies that resource allocators should have foreseen subsequent rounds of funding to maintain support from beneficiaries. Even though resources which are episodic or of short duration are generally less effective at creating positive feedback than continuous resources (Campbell 2012), it is still more effective than one-off allocations as seen in this case when subsequent rounds of funding for the eco-towns and the carbon challenge were cancelled. Over time, as beneficiaries make sunk investments (for example in RD&D) their support for the policy is likely to become stronger as they seek to protect their investments, and/or gain potential competitive advantages over less innovative firms, which may

stimulate the creation of learning networks (Mourik and Raven 2006). However, in our case the recession happened early on in the process, before any demonstration projects had started, and before there had been significant investment from any of the early beneficiaries. That meant that when the resources available were later cut, the mix had not stimulated strong positive feedback and the incentive to support the target was undermined, making it susceptible to negative feedback.

The way the policymaking process was organised was also a key factor in the case. Our findings highlight how the institutional setting (who was allowed to participate) also affects the potential for the mix to create positive feedback. The sector which stood to benefit most from the target's implementation was the micro-renewables industry. The original requirement for all carbon abatement to be achieved on-site placed emphasis on micro-renewables, expanding the market significantly. Component manufacturers also stood to gain, but their main market is retrofit, and the volume house-builders (who already have market share) stood to benefit the least. However, this industry was seen as outsiders by the housing sector, and the Renewable Energy Association (a trade body representing the micro-renewables industry), was not represented in the Task Force, despite requesting participation. Their exclusion from the policymaking process meant that their support for the policy mix had little influence. Consequently, it is unsurprising that closer to 2016 the role of micro renewables was first reduced, and then removed from the target in 2014, permitting carbon mitigation to be achieved through the use of an abatement fund, something that the housebuilding industry had lobbied for. This highlights the importance of building the right coalitions to drive policy (Hess 2014, 2015). Similarly, in the later phases the manufacturing sector (the other main beneficiary) felt that they were excluded from policymaking processes, and DCLG ceased correspondence. This reflects the close relationship formed between house-builders and state actors (primarily Treasury), due to the contribution of the housing market to the UK economy. It also points to the importance of including a variety of actors (including new entrants) at the negotiation table and highlights the limitations of an incumbent actors orientated policy approach as taken in the UK (Geels et al.2017). Moreover, the increments to building fabric efficiency (increased market for components) were implemented through the 2010 and 2013 (very marginal) updates to the building regulations. This reduced the incentive for the energy efficiency component-manufacturers (insulation, windows etc.) to support the target, as the target's final implementation would not have had much (or any) impact on their market.

Another key limitation was the lack of engagement with the general public, the other main beneficiary through potential cost savings on energy bills. However, these are long-term benefits which have low visibility, and due to the relatively low price of energy in the UK, are not particularly significant. More importantly, these potential future benefits never materialised as the target was abandoned. Consequently, it is difficult for the general public to mobilise to protect something that they have not

received yet, and for the most part are unaware of. In addition, there is currently low market demand for zero carbon housing. Some argue that energy efficiency of housing is not reflected in property values in the UK (Meins et al. 2010; Osmani and O'Reilly 2009), although there is also evidence to suggest that the market does respond when information is adequately and systematically disclosed (Fuerst et al. 2013). This raises opposition from house-builders who (claim that they) cannot recover the costs of building to higher regulations. One way of potentially generating support from the public as beneficiaries would be through the provision of social housing. If combined with promoting energy efficiency, then people may mobilise to protect the provision of social housing, rather than for higher sustainability standards. However, provision of social housing seems to be opposed by conservative party ideology, meaning this may only be possible after a change in government.

6.3. How are perceptions of policy mix credibility formed and how do these influence socio-technical change?

In the early stages, the policy mix had some credibility due to strong political commitment, and provision of resources, but a lack of clarity about what was needed to meet the target and an initial period of redefinition of the target caused some inertia. The first reformulation of the target helped improve credibility and create positive expectations (Mourik and Raven 2006), leading to a peak of activity in the sector. However, later, when resources were withdrawn and political support diminished, these and perceptions of credibility and expectations were undermined. We also consider the previously mentioned limitations (limited and one-off allocation of resources, exclusion of some actors in the policymaking process, and lack of engagement with the general public) to have negatively affected the credibility of the mix over time. This links to other work on credibility in the literature on policy mixes for sustainability transition (Rogge and Dutschke 2018), as over time the mix became less comprehensive (funding mechanism removed) and the processes became less coherent (less inclusive and decisions lacking evidence base), which contributed to overall loss of credibility.

A significant issue with the implementation of the policy mix was how building regulations in the UK are measured and enforced. There are no requirements to evaluate buildings post-construction, and the regulations are based on an 'as-designed' specification. The difference between the as-designed and as-built performance of buildings can vary significantly (De Wilde 2014), for various reasons, including components being 'value-engineered' during the build-phase, replacing components with cheaper ones which may not perform as well. These findings are in line with previous work on ZCH (Heffernan et al. 2015) and the results of the performance gap report produced by the Zero Carbon Hub (Zero Carbon Hub 2014). More importantly, even in instances where the performance of buildings has been found to not meet the required regulations, there has never been a prosecution, fine or any other form of legal

consequence for non-compliance with energy efficiency regulations. We argue the lack of a robust enforcement mechanism meant that the regulations carried no consequence, which undermined the credibility of the policy mix as a whole and effectively allowed developers to opt-out of making their product more efficient (Pan and Garmston 2012).

We also found that feedback mechanisms can influence the credibility of the mix in four ways. First, through the respective strength of the supportive/opposing coalitions (SPF-constituency feedback). If incumbents are supportive of the mix, it makes the prospects of achieving its goal more credible, which may influence other actors to also support the agenda. Conversely, as we saw in our case, as powerful actors stopped supporting the policy mix this undermined credibility, and resulted in a further weakening of the supporting coalition. Second, we suggest that cognitive feedback (SPF) is directly related to credibility of the mix. If specific instruments or the mix as a whole are considered to be ineffective or poorly performing, and these are unaddressed by policy makers, the mix may be considered less credible. Another contributor to the mix's reduced credibility was policy subsystem change and fiscal feedback. Following the election the treasury dominated the subsystem, who then considered the cost of supporting the policy mix as an unnecessary expense. Under austerity, treasury cut all resources and reduced autonomy of other actors. As it became apparent to actors that the treasury opposed the target, this undermined the credibility of the mix as a whole. Finally, we consider administrative feedback to influence the credibility of the mix. If widespread perceptions are that the government lacks the capabilities to properly design and implement the mix, it may reduce credibility of the mix and dis-incentivise investment and support.

These considerations suggest credibility is closely related to the occurrence of virtuous or vicious cycles. From our case, progress was initially made when the mix was considered credible, but for various reasons the mix became considered less credible, which only intensified after the vicious cycle started. Based on this we argue that policy makers are well advised to enhance the credibility of the policy mix by providing sufficient and sustained resources, resolving any limitations or constraining institutions, and through synergistic and systematic policymaking and implementation processes to help improve investor confidence.

6.4. Refinement of the framework

Based on our empirical analysis, we propose a number of refinements to the framework proposed by Edmondson et al (2018):

First, the framework draws attention to the role and influence of the finance ministry, commonly underplayed or not treated as an important actor with its own interests in most of the transitions literature. The attention to fiscal feedbacks throughout the analysis helped explain the resource cuts that occurred in 2010, and the reluctance to devote any further resources to the mix. However, our application suggests that the current definition of fiscal feedback is too narrow to capture the observed phenomena in full. Currently, it only captures how the costs of supporting a policy mix may raise concerns among powerful actors, notably the finance ministry (following Oberlander & Weaver 2015). In our case, however, opposition to the target from the treasury was not due to direct budget strains, but due to the potential costs on the overall national economy (which the finance ministry was concerned about) and potential backlash, which may affect the government's re-election prospects (Jacobs and Weaver 2015). Similar phenomena have been observed in the case of both the UK (Smith et al. 2014) and German feed in tariffs for solar PV (Lauber & Jacobsson 2016), where costs of supporting the technology were borne by the bill payer and not the finance ministry. Consequently, we suggest extending the definition of fiscal feedback to consider both the direct costs on government budget, and societal economic costs (current or anticipated) of supporting the mix (which can also raise concerns among powerful actors).¹⁵

Table 7 - Interactions of exogenous conditions with socio-technical system and policy subsystem

System	Direct interaction	Indirect interaction
Level		
Policy subsystem	<p>Changes of individuals, and ideologies of actors in the policy subsystem. May be caused by a change in government. Can make certain feedback stronger if it resonates with the ideas of policy makers in the policy subsystem.</p> <p><i>Example: In our case, several changes occurred through the rotation of ministers in certain roles. Also, notably, there was a complete replacement of leading policymaking actors after the general election in 2010, and a partial reshuffle in 2015 (removal of Liberal Democrats). This change of policy actors led to decreased political support as the Conservative government were less interested in taking actions for climate change.</i></p>	<p>Influence from international agreements which place pressure on policymaking actors in the policy subsystem.</p> <p><i>Example: In our case, the EU Buildings Directive helped generate momentum to implement national policies. Later the NZB 2020 target was actually seen to be a constraining factor as the national policy did not match the requirements.</i></p>

¹⁵ Even if the reduced energy use would offset the initial capital cost in the long term.

Socio-technical system	<p>Changes which influence the endogenous conditions of the socio-technical system may contribute to producing (or changing any existing) feedback. Such conditions may include economic trends changing market conditions, new market actors from outside the system, and innovation from outside the system which can introduce policy options.</p> <p><i>Example: In our case, we observed that a change in the economic conditions of the country led to the generation of negative socio-political feedback, which had previously been mostly positive (or at least neutral). Later, the change of government changed the finance ministry's perceptions of the relative costs of supporting the mix and led to negative fiscal feedback.</i></p>	<p>The influence of exogenous conditions may not result in the formation of new feedback mechanisms, but may affect the endogenous conditions of the socio-technical system in ways that amplifies or constrains existing feedback mechanisms occurring.</p> <p><i>Example: In our case the recession negatively affected market conditions, which gave greater influence of the opposing coalition, and after the change in government (and policy subsystem) the opponents of the policy mix were more influential.</i></p>
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Second, the application of the framework also highlighted a potential expansion of the definition of administrative feedback's influence on policymaking. The finance ministry came to dominate the policy subsystem towards the later phases. This meant that the autonomy of the department previously responsible for policy design and implementation (DCLG) was reduced. Moreover, the changes to the mix in these later stages came direct from the finance ministry, without consulting other departments. However, the current definition of administrative feedback does not capture how the reputation of the government as a whole, and its capabilities, changed. It only narrowly considers the particular government department responsible for implementation (DCLG). Therefore, since the role of this department in the policy process was diminished, it does not capture the phenomenon adequately. Consequently, opinions of actors regarding the capabilities and reputation of the respective government departments (administrative feedback), based on the policy changes occurring later in the timeline, are outside the scope of analysis (because the opinions were traced back to finance ministry, not DCLG). We therefore suggest extending the definition of administrative feedback to include all government departments who have a role in the policy mix' evolution. Therefore, in situations where the policy subsystem is dominated by the finance ministry, administrative feedback would relate primarily to the finance ministry (who are making the decisions about changes to the policy mix).

Third, from our empirical application we can also reflect on the proposed interactions of exogenous conditions and the socio-technical system, and its co-evolution with the policy mix over time. Much of the feedback literature commonly only considers exogenous shocks, major events that shift policy makers' attention. Jordan & Matt (2014), expand on these ideas to some extent with their consideration

of exogenous conditions and give some examples, but do not propose specific typologies of interaction dynamics. We build on ideas from the transitions literature and our empirical findings to conceptualise mechanisms of interaction. More precisely, we derive direct and indirect interactions occurring within the policy subsystem and the socio-technical system, for each of which we provide examples from the case to illustrate these dynamics (Table 7).

These direct and indirect interactions, resulting in changes within the policy subsystem and the creation of and/or amplification/minimisation of feedback mechanisms, contribute to the transitions literature more generally. They help understand how landscape conditions interact with the socio-technical system, the under-conceptualisation of which is a critique of this literature (Geels 2011). The prosed interactions constitute how changes in the landscape may result in policy change, broadly considered a key component of sustainability transitions. The effects of the recession on the housing transition in the UK provides an empirical example, in line with the call of Geels (2011) to better conceptualise landscape dynamics, of how it can re-stabilise the existing socio-technical system rather than reinforcing the transition.

The changing, temporal aspect of landscape conditions, which may initially de-stabilise, and the re-stabilise the socio-technical system, is related to the concept of 'windows of opportunity' (Normann 2015). What our analysis shows is that in such windows, policymakers need to design policy to generate enough positive feedback so that if this window is closed, the transition has generated enough momentum to sustain without the supporting conditions which provided the initial stimuli for change, and moreover, to withstand potentially negative stimuli. To do so, policymakers need to create both resource effects (financial support for R,D&D), and interpretive effects (clarity and credibility), along with reforming constraining institutional supports. Arguably, had the design of the ZCH policy mix had provided more clarity through a well-defined target, and provided more support through strategic and consistent instruments, more progress could have been made in the first phase, which instead was a period of inertia within the socio-technical system. Later, when the policy mix was improved, the recession had already effected the economic conditions making progress slower. Consequently, there was not enough positive feedback generated in the first four years to withstand when the change in political conditions after the 2010 election. At this point the transition, which was finally gaining momentum, was undermined through significant changes to the policy mix under the new government, leading to the emergence of a vicious cycle and the abonnement of the policy mix.

7. Conclusions

In the context of sustainability transitions, several authors have argued that due to the complexity, scale, and urgency of sustainability transitions, analyses should move towards studying multiple policy instruments and their interactions (Rogge et al. 2017). In particular, we follow the call for increased attention to the underlying policymaking processes (Flanagan et al. 2011; Rogge and Reichardt 2016), offering the first empirical study to combine a consideration of policy processes in an integrated deductive co-evolutionary analysis of policy mix change and socio-technical change. This goes beyond the existing literature by analysing specific mechanisms of how co-evolutionary dynamics play out in practice (these mechanisms are flagged throughout the analysis, e.g. [RE->STC->SPF->PMC]).

Our paper makes three contributions to the sustainability transitions literature:

First, empirically our study follows a unique case with a very ambitious target being introduced to radically transform the house-building socio-technical system in the UK. Initially, we observed some increasing momentum, but then a vicious cycle set in, slowing progress and raising opponents to the target. Over time the target lost the support of powerful actors in the advocacy coalition. Eventually, the target, vulnerable due to its weakened supportive coalition, was denounced, instigating significant backlash in the transition to a low carbon housing system in the UK. Such cases of attempted, but ultimately unsuccessful transitions, can help analysts identify important negative dynamics and make policy recommendations of how these could be potentially avoided.

Second, the paper generates novel insights about the role of policy mix credibility, both regarding the factors which influence it and its impact on the socio-technical system. This contributes to the emerging discussion about the role of credibility in policy mixes for sustainability transitions (Rogge and Dutschke 2018). Credibility was considered as a strong influence in the case, but it was beyond the scope of this paper to explore the role of all policy mix characteristics and their interactions with mechanisms in the framework. We suggest that systematically integrating policy mix characteristics into the framework could be a useful avenue for further work. In particular, the mechanisms of the framework could be used to help explain how certain policy mix characteristics influence socio-technical change, and factors to consider when analysing them.

Finally, conceptually the paper makes a contribution through applying a theoretically derived co-evolutionary framework to an empirical case, and proposing three conceptual refinements on this basis. The first refinement is to extend the definition of fiscal feedback beyond simply budget strains arising from supporting the policy mix, to also consider the societal economic costs (current or anticipated) on the national economy. As a second refinement we widen the definition of administrative feedback to relate to all government departments responsible for policy making, and the impact this has on the

overall perceptions of government capabilities. As a third refinement we more explicitly define interaction mechanisms of exogenous conditions on the socio-technical system. More precisely, we propose that exogenous conditions have direct and indirect influences on the policy subsystem and the socio-technical system.

We would also like to highlight three possible avenues for further work. In our case study we found that implementation of the mix at both the local and national level was of significance. The local level was important though implementation of the CSH in its planning requirements, and the role of local authorities as building control officers. Currently, the framework under-conceptualises vertical interactions between levels of policy mixes (Howlett, Vince, and Del Río 2017). We suggest that such vertical interactions could be explored in further work. In addition, the analysis also brought attention to the role of coalitions throughout the co-evolution of the policy mix and the housebuilding socio-technical system. In the policy feedback literature such coalitions are captured by interest groups, but a more nuanced view of the role of coalitions could complement the framework. Accordingly, further co-evolutionary work could integrate ideas from the Advocacy Coalition Framework. Finally, it was beyond the scope of this paper to unpack the policymaking process in terms of the difference between design and implementation, which could also be a potential avenue for further work.

We hope the empirical and conceptual contributions made in this paper can assist in the analysis of policymaking processes for sustainability transition policy mixes, by drawing attention to how design choices can influence the socio-technical system, which then generates feedback mechanisms affecting subsequently policymaking. Such feedback mechanisms are crucial for maintaining the momentum of transition processes, particularly in the early phases when the conditions providing a window of opportunity may be temporal and prone to change. This places emphasis on designing policy mixes effectively, with the intention of creating positive feedback, from the outset of the policy mix, rather than needing multiple revisions due to defective initial design. Of course, in order to do so is dependent on government capabilities to design and implement policy mixes. We hope that the insights generated can help inform transitions literature regarding how policymaking processes can affect the extent to which the support of powerful actors can be attained, but also how inconsistent instrument design and incoherent policy processes can reduce credibility, increase risk and limit progress towards achieving transitions.

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Appendix A

Date	Title	Reference
070131	- Minutes	TF1
070328	- 2016 Concordat	TF2
070328	- Agenda	TF3
070515	- Agenda	TF4
070515	- 2016 Concordat vs4	TF5
070328	- Zero Carbon definition paper1	TF6
070515	- Minutes	TF7
070613	- 2016 Commitment	TF8
070613	- Agenda	TF9
070613	- Minutes	TF10
070613	- HBFTaskforce2	TF11
071024	- Agenda	TF12
070613	- Opinion polling	TF13
071218	- Agenda	TF14
071024	- Minutes	TF15
071218	- Minutes	TF16
080311	- Agenda	TF17
080311	- Minutes	TF18
080311	- Part L SAP progress report March 08 Mar	TF19
080311	- Appendices ZC Homes delivery hub scope long version 7 Mar 08 Paper A3	TF20
080311	- Taskforce meeting CPA paper SAP Amendments and Additions Paper C	TF21
080311	- ZC Homes delivery hub scope long version 7	TF22
080605	- Agenda	TF23
080311	- Zero Carbon Homes delivery hub summary Final paper A1	TF24
080605	- Minutes	TF25
080605	- P NHBC Presentation Consumer Marketing	TF26
080605	- Paper B 2016 Taskforce Delivery Hub	TF27
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References

- Avelino, F. and J. Rotmans. 2009. "Power in Transition: An Interdisciplinary Framework to Study Power in Relation to Structural Change." *European Journal of Social Theory* 12(4):543–69.
- Baker, Emma and Laurence Lester. 2017. "Multiple Housing Problems: A View through the Housing Niche Lens." *Cities* 62:146–51.
- Beach, Derek. 2017. *Process-Tracing Methods in Social Science*. Vol. 1.
- Beland, D. 2010. "Reconsidering Policy Feedback: How Policies Affect Politics." *Administration & Society* 42(5):568–90.
- Bergman, Noam, Lorraine Whitmarsh, and Jonathan Köhler. 2007. "Assessing Transitions to Sustainable Housing and Communities in the UK." *International Conference on Whole Life Urban Sustainability and Its Assessment* 1–31.
- Bergman, Noam, Lorraine Whitmarsh, and Jonathan Köhler. 2008. "Transition to Sustainable Development in the UK Housing Sector : From Case Study to Model Implementation." *Environmental Sciences* (August):39.
- Berry, Stephen, Kathryn Davidson, and Wasim Saman. 2013. "The Impact of Niche Green Developments in Transforming the Building Sector: The Case Study of Lochiel Park." *Energy Policy* 62:646–55.
- Building. 2018. Top 150 contractors and housebuilders 2018. Building Digital Edition: 27 July 2018. <https://www.building.co.uk/digital-editions/building-digital-edition-27-july-2018/5094845.article>
- Building. 2018. Top 150 contractors and housebuilders 2008. <https://www.building.co.uk/focus/top-150-contractors-and-housebuilders-2008/3118735.article>
- Campbell, Andrea Louise. 2012. "Policy Makes Mass Politics." *Annual Review of Political Science* 15(1):333–51.
- Carter, Neil and Ben Clements. 2015. "From 'greenest Government Ever' to 'Get Rid of All the Green Crap': David Cameron, the Conservatives and the Environment." *British Politics* 10(2):204–25.
- Costantini, V., Crespi, F., & Palma, A. (2017). Characterizing the policy mix and its impact on eco-innovation: A patent analysis of energy-efficient technologies. *Research Policy*, 46(4), 799–819. <https://doi.org/10.1016/j.respol.2017.02.004>
- DCLG (Department for Communities and Local Government). 2006b. Code for Sustainable Homes: a step change in sustainable home building practice.
- DCLG (Department for Communities and Local Government). 2008b. Definition of Zero Carbon Homes, Impact Assessment. London.
- DCLG (Department for Communities and Local Government). 2009a. Planning Policy Statement: eco-towns. A supplement to planning policy 1. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7773/pps-ecotowns.pdf
- DCLG (Department for Communities and Local Government). 2009b. Definition of Zero Carbon Homes, Impact Assessment (London: DCLG).
- DCLG (Department for Communities and Local Government). 2009c. Sustainable New Homes - The Road to Zero Carbon (London: DCLG). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/8557/1415525.pdf

- DCLG, (Department for Communities and Local Government), 2006. Building A Greener Future: Towards Zero Carbon Development. , (December), pp.1–44.
<http://www.communities.gov.uk/archived/publications/planningandbuilding/buildinggreener>.
- DCLG. 2011. *Cost of Building to the Code for Sustainable Homes. Updated Cost Review*.
- Drewe, Stefan and Jeroen C. J. M. van den Bergh. 2016. “What Explains Public Support for Climate Policies? A Review of Empirical and Experimental Studies.” *Climate Policy* 16(7):855–76.
- Edmondson, D. L., F. Kern, and K. S. Rogge. 2018. “The Co-Evolution of Policy Mixes and Socio-Technical Systems: Towards a Conceptual Framework of Policy Mix Feedback in Sustainability Transitions.” *Research Policy*.
- Edmondson, Duncan L., Florian Kern, and Karoline S. Rogge. 2018. “The Co-Evolution of Policy Mixes and Socio-Technical Systems: Towards a Conceptual Framework of Policy Mix Feedback in Sustainability Transitions.” *Research Policy* (March 2018):1–14.
- ENDS (the ENDS Report). 2007. Plans for zero carbon homes set out.
<http://www.endsreport.com/article/17669/plans-for-zero-carbon-homes-set-out>. (accessed 14/04/2017)
- ENDS (the ENDS Report). 2008. Slow progress on green homes.
<https://www.endsreport.com/article/19571/slow-progress-on-green-homes>. (accessed 14/04/2017)
- ENDS (the ENDS Report). 2009a. House builders question zero carbon target.
<https://www.endsreport.com/article/21443/housebuilders-question-zero-carbon-target>. (accessed 20/04/2017)
- ENDS (the ENDS Report). 2009a. Housebuilders question zero-carbon target.
<https://www.endsreport.com/article/21443/housebuilders-question-zero-carbon-target>. (accessed 15/04/2017)
- ENDS (the ENDS Report). 2009b. Zero carbon homes defined.
<https://www.endsreport.com/article/20153/zero-carbon-homes-defined>. (accessed 13/04/2017)
- ENDS (the ENDS Report). 2011. MPs attack government drift on green taxes.
<https://www.endsreport.com/article/29552/mps-attack-government-drift-on-green-taxes>. (accessed 24/04/2017)
- Flanagan, Kieron, Elvira Uyarra, and Manuel Laranja. 2011. “Reconceptualising the ‘policy Mix’ for Innovation.” *Research Policy* 40(5):702–13.
- Foong, Daphne, Paul Mitchell, Nadine Wagstaff, Elizabeth Duncan, and Phil McManus. 2017. “Transitioning to a More Sustainable Residential Built Environment in Sydney?” *Geo: Geography and Environment* 4(1):1–11.
- Foxon, T. J., R. Gross, A. Chase, J. Howes, A. Arnall, and D. Anderson. 2005. “UK Innovation Systems for New and Renewable Energy Technologies: Drivers, Barriers and Systems Failures.” *Energy Policy* 33(16):2123–37.
- Fuerst, Franz, Pat McAllister, Anupam Nanda, and Peter Wyatt. 2013. *Final Project Report: An Investigation of the Effect of EPC Ratings on House Prices*.
- Geels, Frank. 2005. “Co-Evolution of Technology and Society: The Transition in Water Supply and Personal Hygiene in the Netherlands (1850-1930) - A Case Study in Multi-Level Perspective.” *Technology in Society* 27(3):363–97.
- Geels, Frank W. 2004. “From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory.” *Research Policy* 33(6–7):897–920.
- Geels, Frank W. 2011. “The Multi-Level Perspective on Sustainability Transitions: Responses to

- Seven Criticisms." *Environmental Innovation and Societal Transitions* 1(1):24–40.
- Geels, Frank W., Florian Kern, Gerhard Fuchs, Nele Hinderer, Gregor Kungl, Josephine Mylan, Mario Neukirch, and Sandra Wassermann. 2016. "The Enactment of Socio-Technical Transition Pathways: A Reformulated Typology and a Comparative Multi-Level Analysis of the German and UK Low-Carbon Electricity Transitions (1990–2014)." *Research Policy* 45(4):896–913.
- Geels, Frank W. and Johan Schot. 2007. "Typology of Sociotechnical Transition Pathways." *Research Policy* 36(3):399–417.
- George, Alexander L. and Andrew Bennett. 2005. *Case Studies and Theory Development in the Social Sciences*. MIT Press.
- Gibbs, David and Kirstie O'Neill. 2015. "Building a Green Economy? Sustainability Transitions in the UK Building Sector." *Geoforum* 59:133–41.
- Goodchild, Barry and Aimee Walshaw. 2011. "Towards Zero Carbon Homes in England? From Inception to Partial Implementation." *Housing Studies* 26(6):933–49.
- Greenwood, Dan. 2012. "The Challenge of Policy Coordination for Sustainable Sociotechnical Transitions: The Case of the Zero-Carbon Homes Agenda in England." *Environment and Planning C: Government and Policy* 30(1):162–79.
- Gov.2016. HMRC internal manual. Stamp Duty Land Tax Manual. HM Revenue & Customs. <https://www.gov.uk/hmrc-internal-manuals/stamp-duty-land-tax-manual/sdltm20700> (accessed 14/03/2017)
- Hatchwell, P. 2013. DCLG scales back ambition for energy efficiency in Building Regulations. ENDS report. <https://www.endsreport.com/article/40235/dclg-scales-back-ambition-for-energy-efficiency-in-building-regulations>. (accessed 12/04/2017)
- HBF. 2010. Member briefing – the 2010 spending review. House Builders Federation. https://www.hbf.co.uk/documents/5412/Member_Briefing_-_THE_2010_SPENDING_REVIEW_-20-Oct-2010.pdf. (accessed 24/04/2017)
- Heffernan, Emma, Wei Pan, Xi Liang, and Pieter de Wilde. 2015. "Zero Carbon Homes: Perceptions from the UK Construction Industry." *Energy Policy* 79(2015):23–36.
- Hess, David J. 2014. "Sustainability Transitions: A Political Coalition Perspective." *Research Policy* 43(2):278–83.
- Hinsliff, G. 2008. Flagship eco-town plan falters in tough climate. <https://www.theguardian.com/environment/2008/oct/26/ecotowns-green-building>. (accessed 20/04/2017)
- Hope, C. 2008. Eco-towns do not offer 'sustainable living'. <https://www.telegraph.co.uk/news/earth/earthnews/3345805/Eco-towns-do-not-offer-sustainable-living.html>. (accessed 15/04/2017)
- Hoppmann, Joern, Joern Huenteler, and Bastien Girod. 2014. "Compulsive Policy-Making - The Evolution of the German Feed-in Tariff System for Solar Photovoltaic Power." *Research Policy* 43(8):1422–41.
- Howlett, Michael, Joanna Vince, and Pablo Del Río. 2017. "Policy Integration and Multi-Level Governance: Dealing with the Vertical Dimension of Policy Mix Designs." *Politics and Governance* 5(2):69.
- Innovate UK. 2014. Future building. The Low Impact Building Innovation Platform. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/408711/Future_Building_-_the_Low_Impact_Building_Innovation_Platform.pdf. (accessed 12/04/2017)
- Jacobs, Alan M. and Robert K. Weaver. 2015. "When Policies Undo Themselves: Self-Undermining

- Feedback as a Source of Policy Change.” *Governance* 28(4):441–57.
- Jordan, Andrew and Elah Matt. 2014. “Designing Policies That Intentionally Stick: Policy Feedback in a Changing Climate.” *Policy Sciences* 47(3):227–47.
- Kemp, René, Derk Loorbach, and Jan Rotmans. 2007. “Transition Management as a Model for Managing Processes of Co-Evolution towards Sustainable Development.” *International Journal of Sustainable Development & World Ecology* 14(1):78–91.
- Kern, Florian and Michael Howlett. 2009. “Implementing Transition Management as Policy Reforms: A Case Study of the Dutch Energy Sector.” *Policy Sciences* 42(4):391–408.
- Kern, Florian, Paula Kivimaa, and M. Martiskainen. 2016. “The Development of Energy Efficiency Policy Mixes : The Case of Buildings in Finland and the UK.” 1–36.
- Kern, Florian and Karoline S. Rogge. 2016. “The Pace of Governed Energy Transitions: Agency, International Dynamics and the Global Paris Agreement Accelerating Decarbonisation Processes?” *Energy Research and Social Science* 22:13–17.
- Kern, Florian and Karoline S. Rogge. 2017. “Harnessing Theories of the Policy Process for Analysing the Politics of Sustainability Transitions: A Critical Survey.” *Environmental Innovation and Societal Transitions* (October):0–1.
- Kivimaa, Paula and Florian Kern. 2016. “Creative Destruction or Mere Niche Support? Innovation Policy Mixes for Sustainability Transitions.” *Research Policy* 45(1):205–17.
- Kuzemko, Caroline. 2016. “Energy Depoliticisation in the UK : Depoliticisation Destroying Political Energy in the UK :”
- Lauber, Volkmar and Staffan Jacobsson. 2016a. “The Politics and Economics of Constructing, Contesting and Restricting Socio-Political Space for Renewables - The German Renewable Energy Act.” *Environmental Innovation and Societal Transitions* 18(November):147–63.
- Lauber, Volkmar and Staffan Jacobsson. 2016b. “The Politics and Economics of Constructing, Contesting and Restricting Socio-Political Space for Renewables – the Case of the German Renewable Energy Act.” *Environmental Innovation and Societal Transitions* 18:147–63.
- De Laurentis, Carla, Malcolm Eames, and Miriam Hunt. 2017. “Retrofitting the Built Environment ‘to Save’ Energy: Arbed, the Emergence of a Distinctive Sustainability Transition Pathway in Wales.” *Environment and Planning C: Politics and Space* 35(7):1156–75.
- Lockwood, Matthew, Caroline Kuzemko, Catherine Mitchell, and Richard Hoggett. 2017. “Historical Institutionalism and the Politics of Sustainable Energy Transitions: A Research Agenda.” *Environment and Planning C: Government and Policy* 35(2):312–33.
- Mark, L. 2014. It’s official: government to scrap Code for Sustainable Homes. <https://www.architectsjournal.co.uk/news/its-official-government-to-scrap-code-for-sustainable-homes/8660376.article>. (accessed 11/04/2017)
- Markard, Jochen, Marco Suter, and Karin Ingold. 2016. “Socio-Technical Transitions and Policy Change - Advocacy Coalitions in Swiss Energy Policy.” *Environmental Innovation and Societal Transitions* 18:215–37.
- Markard, Jochen, Steffen Wirth, and Bernhard Truffer. 2016. “Institutional Dynamics and Technology Legitimacy – A Framework and a Case Study on Biogas Technology.” *Research Policy* 45(1):330–44.
- Martiskainen, Mari and Paula Kivimaa. 2018a. “Creating Innovative Zero Carbon Homes in the United Kingdom — Intermediaries and Champions in Building Projects.” *Environmental*

- Innovation and Societal Transitions* 26(August 2017):15–31.
- Martiskainen, Mari and Paula Kivimaa. 2018b. "Creating Innovative Zero Carbon Homes in the United Kingdom — Intermediaries and Champions in Building Projects." *Environmental Innovation and Societal Transitions* 26(June 2017):15–31.
- May, Peter J. and Ashley E. Jochim. 2013. "Policy Regime Perspectives : Policies , Politics , and Governing." 41(Cmmi):426–52.
- McCarthy, M. 2008. The Big Question: What are eco-towns, and how green are they in reality? <https://www.independent.co.uk/extras/big-question/the-big-question-what-are-eco-towns-and-how-green-are-they-in-reality-5545719.html>. (accessed 05/06/2017)
- McLeod, Robert S., Christina J. Hopfe, and Yacine Rezgui. 2012. "An Investigation into Recent Proposals for a Revised Definition of Zero Carbon Homes in the UK." *Energy Policy* 46:25–35.
- McWhirter, S. 2010. Coalition deal wavers on zero carbon targets. <https://www.wwf.org.uk/updates/coalition-deal-wavers-zero-carbon-targets>. (accessed 27/03/2017)
- Meadowcroft, James. 2009. "What about the Politics? Sustainable Development, Transition Management, and Long Term Energy Transitions." *Policy Sciences* 42(4):323–40.
- Meadowcroft, James. 2011. "Engaging with the Politics of Sustainability Transitions." *Environmental Innovation and Societal Transitions* 1(1):70–75.
- Meckling, Jonas, Thomas Sterner, and Gernot Wagner. 2017. "Policy Sequencing toward Decarbonization." *Nature Energy* 2(12):918–22.
- Meins, Erika, Holger Wallbaum, Regina Hardziewski, and Annika Feige. 2010. "Sustainability and Property Valuation: A Risk-Based Approach." *Building Research and Information* 38(3):280–300.
- Mettler, Suzanne and Joe Soss. 2004. "The Consequences of Public Policy for Democratic Citizenship: Bridging Policy Studies and Mass Politics." *Perspectives on Politics* 2(1):55–73.
- Morby, A. 2010. Largest UK zero carbon homes project wins funding. <http://www.constructionenquirer.com/2010/10/15/largest-uk-zero-carbon-homes-project-wins-funding/>. (accessed 12/04/2017).
- Moore, Trivess and Andréanne Doyon. 2018. "The Uncommon Nightingale: Sustainable Housing Innovation in Australia." *Sustainability (Switzerland)* 10(10):1–18.
- Moore, Trivess, Ralph Horne, and John Morrissey. 2014. "Zero Emission Housing: Policy Development in Australia and Comparisons with the EU, UK, USA and California." *Environmental Innovation and Societal Transitions* 11:25–45.
- Normann, Håkon E. 2015. "The Role of Politics in Sustainable Transitions: The Rise and Decline of Offshore Wind in Norway." *Environmental Innovation and Societal Transitions* 15:180–93.
- Oberlander, Jonathan and R. Kent Weaver. 2015. "Unraveling from Within? The Affordable Care Act and Self-Undermining Policy Feedbacks." *The Forum* 13(1):37–62.
- ONS (Office for National Statistics). 2017a. Total number of households by region and country of the UK, 1996 to 2017. <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/adhocs/005374totalnumberofhouseholdsbyregionandcountryoftheuk1996to2015>
- ONS (Office for National Statistics). 2017b. UK House Price Index Statistical bulletins. Office for national statistics.

- <https://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/housepriceindex/previousReleases>
- Osmani, Mohamed and Alistair O'Reilly. 2009. "Feasibility of Zero Carbon Homes in England by 2016: A House Builder's Perspective." *Building and Environment* 44(9):1917–24.
- Ossenbrink, Jan, Sveinbjorn Finnsson, Catharina R. Bening, and Volker H. Hoffmann. 2018. "Delineating Policy Mixes: Contrasting Top-down and Bottom-up Approaches to the Case of Energy-Storage Policy in California." *Research Policy* (April 2017).
- Osbourne, H. 2009. House prices fall by 16% in 2008. <https://www.theguardian.com/money/2009/jan/06/house-prices-fall-in-december>
- Owen, J. 2015. Recovery of UK economy is the slowest since records began, say unions
- Pan, Wei and Helen Garmston. 2012. "Compliance with Building Energy Regulations for New-Build Dwellings." *Energy*.
- Pan, Wei and Yan Ning. 2014. "A Socio-Technical Framework of Zero-Carbon Building Policies." *Building Research & Information* 43(April):94–110.
- Parliament. 2014. Infrastructure Bill [Lords]. 08 December 2014. Volume 589. [https://hansard.parliament.uk/Commons/2014-12-08/debates/14120810000001/InfrastructureBill\(Lords\)#contribution-14120836000033](https://hansard.parliament.uk/Commons/2014-12-08/debates/14120810000001/InfrastructureBill(Lords)#contribution-14120836000033). (accessed 27/03/2017).
- Patashnik, E. and J. Zelizer. 2009. "When Policy Does Not Remake Politics: The Limits of Policy Feedback." *Annual Meeting of the American Political Science Association, Toronto, Canada* 1–39.
- Patashnik, Eric M. and Julian E. Zelizer. 2013. "The Struggle to Remake Politics: Liberal Reform and the Limits of Policy Feedback in the Contemporary American State." *Perspectives on Politics* 11(04):1071–87.
- Paton, E. 2015. Barratt CEO Mark Clare steps down. <https://www.ft.com/content/7167d310-d456-11e4-8be8-00144feab7de>. (accessed 07/05/2017)
- Peacock, L. 2010. Construction jobs worst hit during recession. <https://www.telegraph.co.uk/finance/jobs/8078937/Construction-jobs-worst-hit-during-recession.html>. (accessed 03/05/2017)
- Pierson, Paul. 1993. "Policy Feedback and Policy Change." *World Politics* 45(4):595–628.
- Pierson, Paul. 2000. "Increasing Returns, Path Dependence, and the Study of Politics." *The American Political Science Review* 94(2):251–67.
- R.Mourik and Rob Raven. 2006. "A Practitioner's View on Strategic Niche Management Towards a Future Research Outline." (December):37.
- Raven, Rob, Florian Kern, Bram Verhees, and Adrian Smith. 2016. "Niche Construction and Empowerment through Socio-Political Work. A Meta-Analysis of Six Low-Carbon Technology Cases." *Environmental Innovation and Societal Transitions* 18:164–80.
- Reichardt, Kristin and Karoline Rogge. 2016. "How the Policy Mix Impacts Innovation: Findings from Company Case Studies on Offshore Wind in Germany." *Environmental Innovation and Societal Transitions* 18:62–81.
- Ritchie, Jane and Liz Spencer. 1994. "Qualitative Data Analysis for Applied Policy Research." Pp. 173–94 in *Analyzing qualitative data*, edited by A. Bryman and B. Burgess. London: Routledge.
- Roberts, Cameron, Frank W. Geels, Matthew Lockwood, Peter Newell, Hubert Schmitz, Bruno Turnheim, and Andy Jordan. 2018. "The Politics of Accelerating Low-Carbon Transitions: Towards a New Research Agenda." *Energy Research and Social Science* 44(February):304–11.

- Rogge, Karoline S. and Elisabeth Dütschke. 2018. "What Makes Them Believe in the Low-Carbon Energy Transition? Exploring Corporate Perceptions of the Credibility of Climate Policy Mixes." *Environmental Science and Policy* 87(February):74–84.
- Rogge, Karoline S., Florian Kern, and Michael Howlett. 2017. "Conceptual and Empirical Advances in Analysing Policy Mixes for Energy Transitions." *Energy Research and Social Science* 33(October):1–10.
- Rogge, Karoline S. and Kristin Reichardt. 2016. "Policy Mixes for Sustainability Transitions : An Extended Concept and Framework for Analysis." *Research Policy* 45(8):1620–35.
- Rotmans, Jan and Derk Loorbach. 2010. "II . 3 Conceptual Framework for Analyzing Transitions." *Transitions to Sustainable Development Long Term Transformative Change* (i).
- Sabatier, Paul and Christopher Weible. 2014. *Theories of the Policy Process*. Routledge.
- Sceptre investment management, 2007. UK Housebuilding.
[http://www.sceptrefunds.co.uk/articles/UK Housebuilding.pdf](http://www.sceptrefunds.co.uk/articles/UK%20Housebuilding.pdf).
- Schmidt, Tobias S. and Sebastian Sewerin. 2017. "Technology as a Driver of Climate and Energy Politics." *Nature Energy* 2(6):17084.
- Schweber, Libby, Tim Lees, Jacopo Torriti, Libby Schweber, and Tim Lees. 2015. "Framing Evidence : Policy Design for the Zero-Carbon Home." *Building Research & Information* 43(February):37–41.
- Shapps, G. 2010. We're lifting burden from the backs of builders. Ministerial statement.
<https://www.gov.uk/government/news/were-lifting-burdens-from-the-backs-of-builders>
- Smith, Adrian. 2006. "Governance Lessons from Green Niches: The Case of Eco-Housing." Pp. 41–62 in *Framing the Present, Shaping the Future: Contemporary Governance of Sustainable Technologies*, edited by J. Murphy. London: Earthscan,.
- Smith, Adrian. 2007. "Translating Sustainabilities between Green Niches and Socio-Technical Regimes." *Technology Analysis and Strategic Management* 19(4):427–50.
- Smith, Adrian, Florian Kern, Rob Raven, and Bram Verhees. 2014. "Spaces for Sustainable Innovation: Solar Photovoltaic Electricity in the UK." *Technological Forecasting and Social Change* 81(1):115–30.
- Smith, Adrian and Rob Raven. 2012. "What Is Protective Space? Reconsidering Niches in Transitions to Sustainability." *Research Policy* 41(6):1025–36.
- Statistica. 2018. Construction industry structure UK.
<https://www.statista.com/statistics/565511/construction-industry-structure-uk/>
- Tansey, Oisín. 2007. "Process A Case Tracing and Elite Interviewing : Sampling for Non-Probability Process Tracing : Definition." *PS: Political Science and Politics* 40(4):765–72.
- Thomas, D. 2014. Barratt CEO Mark Clare steps down. <https://www.ft.com/content/7167d310-d456-11e4-8be8-00144feab7de>. (accessed 12/05/2017)
- UK-GBC. 2015. Open letter to George Osborne on zero carbon policy.
- Unruh, G. C. 2000. Understanding carbon lock-in. *Energy policy*, 28(12), 817-830.
[https://doi.org/10.1016/S0301-4215\(00\)00070-7](https://doi.org/10.1016/S0301-4215(00)00070-7)
- Voß, J.P. and Kemp, R., 2015. *Sustainability and reflexive governance: introduction*. Technische Universität Berlin. <http://nbn-resolving.de/urn:nbn:de:kobv:83-opus4-68521>
- Warren, A. 2013. A disaster for energy efficiency inside DCLG. ENDS report.
<https://www.endsreport.com/article/42181/a-disaster-for-energy-efficiency-inside-dclg>. (accessed 14/05/2017)

- Weber, K. Matthias and Harald Rohracher. 2012. "Legitimizing Research, Technology and Innovation Policies for Transformative Change: Combining Insights from Innovation Systems and Multi-Level Perspective in a Comprehensive 'failures' Framework." *Research Policy* 41(6):1037–47.
- Wieczorek, Anna J. and Marko P. Hekkert. 2012. "Systemic Instruments for Systemic Innovation Problems: A Framework for Policy Makers and Innovation Scholars." *Science and Public Policy* 39(1):74–87.
- De Wilde, Pieter. 2014. "The Gap between Predicted and Measured Energy Performance of Buildings: A Framework for Investigation." *Automation in Construction* 41:40–49.
- Yin, Robert K. 2014. *Case Study Research Design and Methods*. 5th ed. Sage Publications.