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Why are Material Efficiency Solutions a Limited Part of the Climate Policy Agenda? An application of the Multiple Streams Framework to UK policy on CO_2 emissions from cars

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ABSTRACT

The Multiple Streams Framework is applied to investigate why material efficiency solutions are a limited part of the climate policy agenda. The case study under investigation is the UK agenda to reduce greenhouse gas emission from cars. Evidence from 14 semi-structured interviews, document analysis and academic studies is used to develop and substantiate the arguments made. In the UK, inefficient material use is only perceived as a problem in so far as it increases in-use vehicle emissions, which disadvantages some material efficiency solutions. The appeal of material efficiency solutions is further limited by a lack of real-world and modelling evidence, creating uncertainty around the anticipated costs and impacts of any policy intervention. Recent political developments are unlikely to make the UK government more receptive to the problem of greenhouse gases arising from inefficient material use in the future. This is further compounded by policy lock-in. Although a small community of policy entrepreneurs are promoting material efficiency solutions, they have disparate priorities, which impacts their effectiveness. The insights from this paper can inform future research and policy entrepreneurship to increase the likelihood of material efficiency solutions becoming a larger part of the climate policy agenda. The problem of climate change is too significant for any potential solutions to remain underexplored by policy-makers in the UK and the rest of the world. © 2017 The Authors. Environmental Policy and Governance published by ERP Environment and John Wiley & Sons Ltd

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Introduction

MITIGATION POLICIES HAVE BEEN INSTIGATED IN THE UK, AND THE REST OF THE WORLD, TO REDUCE LIFE CYCLE GREENHOUSE GAS (GHG) emissions from cars. However, material efficiency solutions remain a limited part of the UK policy agenda and policy mix. This paper applies the Multiple Streams Framework (MSF), as developed by Kingdon (2003), to explore why this is the case.

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Given the potential severity and the immediacy of the climate change challenge, policy practitioners should consider all potential options for mitigating GHG emissions. For over 20 years however, reducing demand for emissions-intensive materials, such as steel and aluminium, through efficiency improvements has remained a potentially significant yet under-explored strategy (ECOSOC, 1996; IPCC, 2014). This is despite emerging empirical evidence that material efficiency solutions could be critical complements to supply-side mitigation and energy efficiency initiatives (Milford *et al.*, 2013; IEA, 2015).

Material efficiency refers to the ratio of material inputs per unit of product or service output. Allwood and Cullen (2012) identify six strategies for material efficiency improvement: (1) reducing the mass of material inputs, (2) reusing material without re-melting, (3) extending product lifetimes, (4) using products more intensively, (5) diverting manufacturing scrap and (6) reducing manufacturing yield losses. In the absence of any rebound effect, these strategies lead to a reduction in material demand and GHG emissions.

Demand for materials is derived from customers purchasing products, which deliver services. Policy initiatives aimed at incentivizing material efficiency improvements should therefore reflect differences in the way products are made, used and treated at the end of their life. Cars, primarily purchased to provide personal mobility, are multi-material products manufactured in international supply chains. Globally, new car production drives demand for around 130 Mt of material inputs per annum (Wells, 2010). On average, 80% of the mass of a new car consists of iron, steel, aluminium, rubber and plastics (ACC, 2015), which are all produced via GHG emissions-intensive processes. Further GHG emissions are released during the manufacturing, use and disposal of a car. Given the life cycle GHG emissions contribution of cars, many mitigation policies have been proposed and instigated around the world.

In the UK, relatively more policy attention is given to the problem of GHG emissions from driving cars, also referred to as 'in-use' emissions. Material efficiency solutions, which have the potential to reduce GHG emissions during other life-stages of a car, are a relatively small part of the policy agenda. A number of explanations can be conceived, and may relate to: the UK policy and political landscape; the characteristics of material efficiency solutions themselves; and the community of individuals inside and outside of government developing UK policies and the timing of their activities and interactions. Theoretical models of the policy-making process help with identifying, organizing and understanding these contributory factors to provide a comprehensive explanation of a current policy agenda.

Below we review a selection of these models that seek to explain how a climate policy agenda is formed. The MSF by Kingdon (2003) is identified as most appropriate for structuring a discussion on why material efficiency is a limited part of the UK policy agenda to reduce life cycle GHG emission from cars. We then outline the study method used and the discussion, structured around the MSF's component parts, is subsequently detailed. The final section summarizes these findings and suggests future areas of research and entrepreneurship.

Literature Review

This section begins with an overview of key models in the policy literature that seek to explain when, and under what conditions, a policy agenda is formed. The section continues with a summary of empirical studies that apply one model, the MSF, to explain how different solutions become part of, or are omitted from, the climate policy agenda.

Theoretical Models of the Policy Process

Policy formation in the real world is complex. Theoretical models provide a conceptual framework for managing that complexity and help individuals overcome any presuppositions that limit their understanding of the policy-making process (Weible, 2014). In the stylized 'stages' model, with its origins in Lasswell (1956), the process begins with defining a public problem that requires government attention. Problems, and possible solutions, are discussed by institutions, the media and the public and these discussions constitute the 'policy agenda'. Policy-makers will enact some of these solutions and this subset constitutes the policy mix.

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In the 'stages' model, problem definition and agenda-setting are followed by policy formation, implementation and evaluation. This process is iterative and non-linear as policy evaluation prompts further consideration of how a problem is defined. However, the stages model has been criticized for its lack of causal theory and testable hypotheses, descriptive inaccuracies, top-down bias, omission of interactions between stages and levels of governance (Weible, 2014).

Other models focus more on 'how' rather than 'when' a policy agenda is established. Baumgartner and Jones' (1993) Punctuated Equilibrium Theory (PET) shows how information flows mean issues rise and fall on the policy agenda, causing policy-makers to either reinforce or reconsider existing policies. Policy-makers and organizations experience bounded rationality and capacity constraints, meaning that policies usually change incrementally. However, under certain conditions policy-makers are compelled to, and are able to, dramatically alter the policy agenda. The Advocacy Coalition Framework (ACF), in Sabatier and Jenkins-Smith (1993), also assumes cognitive and organizational capacity constraints. In the ACF, actors with similar policy beliefs form coalitions to influence parts of the policy-making process. Conflicting coalitions interact, revising and refining their beliefs and eventually compromising to influence the policy agenda. Both the ACF and the PET focus on longer-term dynamics of policy stability and change over a timeframe of at least a decade (van Overveld *et al.*, 2010). However, there is little observable change in the prominence of material efficiency solutions in the global climate policy mix over the last 20 years, which make these models less applicable.

The MSF, by Kingdon (2003), explores how policy-makers come to define and pay attention to some solutions, but not others such as material efficiency. Unlike the ACF and PET, which focus mainly on the behaviour and learning of actors and institutions, the MSF also explores how the characteristics of the solutions being presented determine their appeal. The MSF comprises three largely independent metaphorical 'streams' of problems, policies and politics. In the 'problem stream', issues are brought to policy-makers' attention through indicators, focusing events and feedback on existing policies. Temporal, resource and cognitive constraints limit a policy-maker's capacity to focus on new problems (Zahariadis, 2014). In the 'policy stream', solutions are debated, refined and then either discarded or endorsed by the policy community. This community comprises individuals inside and outside government involved with shaping policy. In the 'policy stream', the characteristics of a solution are a key determinant of how it will be received by the policy community. Solutions need to be technically feasible to implement and aligned with prevailing normative values. Consensus from within the policy community can also help a solution rise to prominence. In the 'politics stream', internal interests (e.g. party ideology) and external features (e.g. public opinion, social movements and interest groups) encourage governments to focus on particular problems and solutions. Policy entrepreneurs internal and external to government attempt to couple their preferred solutions to a particular public problem. Coupling occurs during occasional 'policy windows'. Windows may be opened by compelling problems or events in the political stream, such as the election of a new government, or in the problem stream, for example a national disaster acting as a focusing event (Jones *et al.*, 2016). Coupling means a public problem is recognized, policy solutions are available and there is political motivation to address it. Successfully coupled solutions form the policy agenda and, if enacted, become part of the policy mix. The MSF is considered the most appropriate model for examining material efficiency because it can be applied over a shorter time frame than the ACF and PET, it can explain long periods of stability without needing a comparative period of change and it can be used to examine why particular solutions, such as material efficiency, are not given government attention (Figure 1).

Application of the MSF to Climate Change

In a review of the MSF's empirical impact, Cairney and Jones (2016) conclude that the metaphorical abstraction in the framework's component parts make it universally applicable to any time and place. This abstraction, coupled with the multifaceted problems from climate change, have produced a diverse literature base. Three broad categories of study can be identified, namely those that: (1) focus on individual elements in the MSF; (2) provide an ex-post interpretation of the origins of climate policies; and (3) investigate why particular solutions are not a large part of the climate policy agenda.

The first category, focusing on individual elements in the MSF, provides some indication that it may not be exhaustive. Hermansen (2015) examines how reduced deforestation was reframed as a climate policy solution in Norway and concludes that the MSF gives inadequate consideration to the role of policy entrepreneurs in problem

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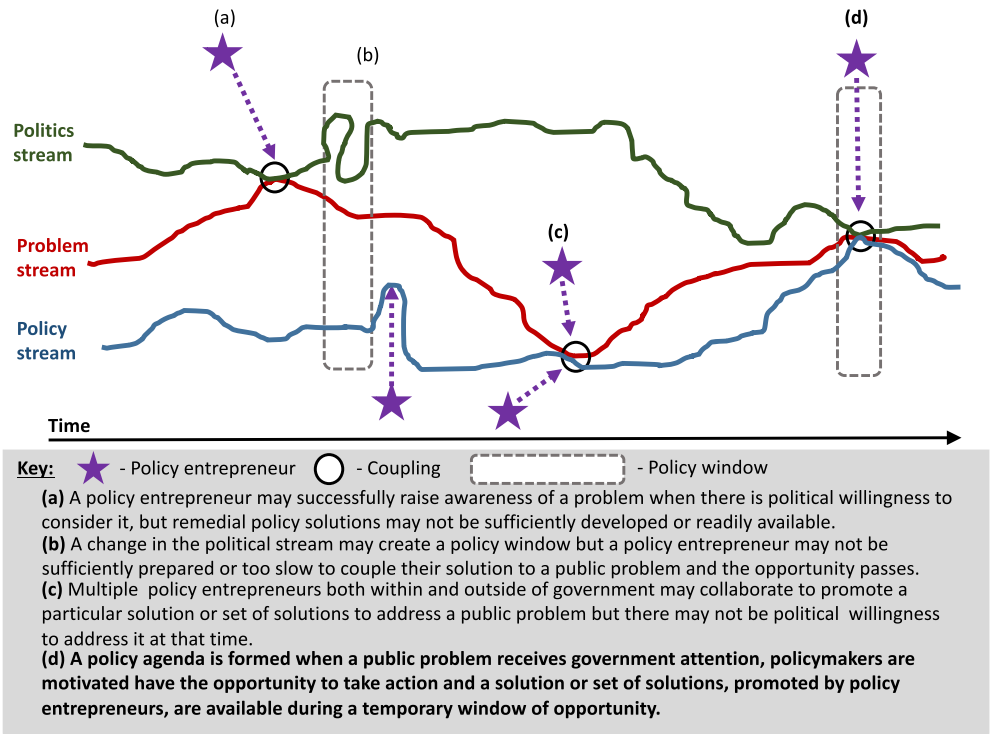

Figure 1. Schematic of the multiple streams framework (MSF) and scenarios in which a policy agenda may (d) or may not be formed (a, b, c). [Colour figure can be viewed at wileyonlinelibrary.com]

framing and opening policy windows. Beeson and Stone (2013) also focus on entrepreneurship and show that the MSF does not fully consider how the characteristics of a problem will influence a policy entrepreneur's ability to couple their preferred solution. Climate change was identified as a very contentious public issue in Australia. Following the recommendations of Zahariadis (2014), these studies often combine the MSF with other theories or quantitative techniques to increase its explanatory power. Buhr (2012) uses institutional theory to extend the MSF, showing institutional entrepreneurship also contributed to the expansion of the European Union Emissions Trading Scheme (EU ETS) to include aviation emissions. In an econometric study using household data, Krosnick *et al.* (2006) investigated the 'national mood' towards climate change in the United States, showing it is shaped by external influences (e.g. political rhetoric and media exposure) and factors such as an individual's trust in the source material along with their cognitive skills and prior knowledge about climate change.

The second category of study applies the MSF to structure an ex-post discussion on the origins of a climate policy. Brunner (2008), for example, combines evidence from semi-structured interviews with document analysis to show how climate change was reframed as an opportunity for industrial reform in Germany, arguing that this led to more stringent permit allocation in Phase II of the EU ETS. A common challenge with this second category of study is identifying all the relevant events and actions preceding a policy. There is also a risk that presuppositions create a bias when selecting evidence. Some studies, such as Keskitalo *et al.* (2012) managed this risk by collating large amounts of primary data (94 interviews) and applying the MSF to compare adaptation policy outcomes in different European countries. Both Lorenzoni and Benson (2014) and Carter and Jacobs (2013) combine the MSF with other theoretical models to further substantiate their explanation of what led to a change in UK political discourse on climate change between 2006 and 2010. This second type of study can also highlight areas for further theoretical refinement or debate in the MSF. For example, in a study on the origins of the Zero Emission Vehicle rule in California, Collantes and Sperling (2008) argue that the assumption of stream independence is oversimplified, as poor air quality in the 'problem stream' shaped the 'politics stream' and the policy response.

Three studies fall in the third category, which apply the MSF to explain why particular problems or solutions are not a larger part of the climate policy agenda. Yusuf *et al.* (2016) conclude that solutions to combat rising sea levels,

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due to climate change, are under-developed, under-funded and not proven as technically or financially feasible. Parag and Eyre (2010), focusing on politics and entrepreneurship, explain the lack of interest in personal carbon trading policies in the UK. They could not identify any dedicated advocacy groups and suggest that personal carbon trading forces the public to confront their individual contribution to climate change, which might be politically unappealing. Hagerman *et al*. (2010) also consider entrepreneurship and examine why there is a limited joint conservation and climate change agenda. From semi-structured interviews, informal discussions and participant observation with sustainability experts, the authors conclude that there is a general reluctance to challenge commonly held beliefs about conservation and climate change and there is uncertainty about how the two issues are connected.

The third category of study shows that the MSF is appropriate for investigating why a particular solution is not a large part of the climate policy agenda. No studies were found which applied the MSF to understand a lack of policy support and discourse around material efficiency solutions in any sector, region or at any level of governance. This paper addresses this gap by applying the MSF to investigate why material efficiency solutions are currently only a limited part of the UK policy agenda to reduce GHG emissions from cars.

Methods

The method is informed by Cairney and Jones (2016), a good practice guide to applying the MSF. It includes semi-structured interviews to gather evidence that is not currently published elsewhere. Interview insights are triangulated with document analysis to refine and substantiate the discussion section of this paper.

Description of Method

Twenty-one individuals shaping UK policies to reduce GHG emissions from cars were contacted. Thirteen agreed to participate in semi-structured interviews between May and September 2016 (Table 1). Interviews lasted between 30 and 60 min and some interviewees came from the same organization. The non-governmental organizations (NGOs) were selected because public sector interviewees indicated their understanding of material efficiency and/or GHG emissions from cars was informed by these organizations, although not exclusively.

A list of open-ended questions was prepared in advance of the interviews (Table 2). The list was informed by the questions in Kingdon (2003) and Collantes and Sperling (2008). These studies apply the MSF to investigate transport and climate policy agendas. Questions were designed to elicit information about each of the five categories in the MSF, namely: (1) problem stream, (2) policy stream, (3) politics stream, (4) policy entrepreneurship and (5) policy window, while maintaining a natural discussion. Additional questions were added before each interview to reflect each interviewee's policy and operational focus.

Interviews were transcribed verbatim, analysed and coded to reflect where the text related to the five categories in the MSF. Excerpts were allocated when the transcript referred to a category's component part. For example, text was ascribed to the 'problem stream' when interviewees discussed 'indicators' and any synonyms. Using Atlas.ti, a qualitative data analysis software program, all quotes in each category were examined to develop initial arguments on why material efficiency is currently a limited part of the UK policy agenda to reduce GHG emissions from cars.

Arguments were tested, confirmed, refined or discarded using secondary evidence from policy documents and journal articles. Documents included: ministerial policies and strategies, press releases, responses to policy consultations, innovation funding briefs, NGO reports, minutes of committee meetings and government datasets. Following the guidance on document analysis by Bowen (2009), each document was skimmed (superficial examination), read (thorough examination) and interpreted to establish content and themes. Interviewees were invited to review interview quotes from their transcripts to ensure accurate characterization. By triangulating multiple sources of data, the authors aimed to build a rigorous, robust and systematic explanation of why material efficiency is currently a limited part of the UK policy agenda to reduce GHG emissions from cars.

The chosen qualitative approach is considered suitable for this exploratory study as it provides flexibility to identify multiple-interactive processes that shape the current UK policy and political context. Furthermore, it may be challenging to operationalize the MSF components using measurable, quantitative variables (Jones *et al*., 2016).

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Name of organization	Role in UK policy-making
Her Majesty's Treasury	Economics and finance ministry. Coordinates and allocates public spending between departments – including grants for ultra low emissions vehicles (ULEVs). Setting tax policy – including road tax. Aims to ensure government spending delivers value-for-money and achieves long-term sustainability objectives
Department of Business, Energy & Industrial Strategy* (BEIS)	Ministry brings together responsibilities for business, industrial strategy, science, innovation, energy and climate change. Responsible for the UK's industrial strategy including ambitions for automotive supply chain decarbonization and long-term competitiveness. Collates and publishes data on domestic GHG emissions (production-based accounting)
Department of the Environment, Food & Rural Affairs	Ministry responsible for safeguarding the UK's natural environment. Broad policy remit including: treatment of end-of-life vehicles, local air quality, resource efficiency and the circular economy. Collates and publishes data on GHG emissions embodied in goods and services purchased in the UK (consumption-based accounting)
Office for Low Emissions Vehicles(OLEV)	Cross-ministerial team within BEIS and the Department for Transport (DfT) providing research and investment support for ULEVs. Responsible for encouraging new business initiatives, supporting manufacturing capacity building and developing charging infrastructure strategy for ULEVs
The Committee on Climate Change	Independent body advising the UK government's on how to meet the 2050 carbon target and interim carbon budgets. Monitors the UK's progress in reducing domestic emissions and conducts economic and policy analysis
Innovate UK	National innovation agency. Runs frequent competitions for funding. Works with OLEV and the Advanced Propulsion Centre (Figure 2) to deliver public sector financing for product, process and business model innovation in the automotive sector
Transport & Environment	Brussels-based non-governmental organization (NGO) promoting sustainable development in transport through research, debate and campaigns. Recently campaigned to revisit GHG emissions testing procedures in the European automotive industry and pushed for policies that support the uptake of electric vehicles
Ellen MacArthur Foundation	UK-based NGO working to promote a circular economy agenda among government, business and academia
Waste & Resources Action Programme (WRAP)	UK-based NGO working with government, businesses and communities to deliver practical solutions to improve resource efficiency

Table 1. Interviewees' place of work

*During the interview period the Department of Energy and Climate Change merged with the Department of Business, Innovation and Skills to form the Department of Business, Energy and Industrial Strategy.

Study Limitations

Although the method was carefully designed and built on existing studies, several limitations remain. First, there is ongoing academic debate about the comprehensiveness of the MSF, and therefore the arguments presented in the Discussion should be viewed as the principal reasons why material efficiency is a limited part of the UK climate policy agenda. Second is the challenge of selecting a representative sample of interviewees. Efforts were made to ensure individuals worked on different policy issues, had different operational responsibilities and were at different levels of seniority. Finally, this study focuses on the national policy agenda, which means that differences in policy discourse at the regional level, as found in Storch and Winkel (2013), may not be fully captured and could be further investigated.

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1. Personal background
What is your role in the organization?
2. Programmes
What are the main programmes relevant to emissions from cars that your team works on?
What's the split between embedded and in-use emissions?
How did these particular initiatives come to be the main topics?
What other options were considered?
Has anything happened during your time in the organization to make you re-evaluate GHG mitigation efforts related to cars?
What indicators do you collect on these programmes?
3. Collaboration
How does your team work with other organizations?
Who do you work with?
How is your work informed by other organizations?
4. Looking ahead
What proposals will be prominent in 2–5 years' time for reducing emissions from cars?
What does a low carbon transportation system in the UK look like in 2050?
5. Material efficiency
What is your understanding of the term 'material efficiency'?
Do material efficiency strategies feature in your work?
What potential do you see for material efficiency strategies to reduce emissions from cars?
Why?
Is there anything else you would like to add?

Table 2. Pre-prepared interview questions

Discussion

Two outputs were generated: first, a timeline providing historical context of policies, political developments and focusing events that shape the current UK policy mix (Figure 2), and second, a discussion structured around the MSF of why material efficiency is a limited part of the UK policy agenda to reduce GHG emissions from cars.

Kingdon (2003) cautions that tracking the origins of policies is an exercise in 'infinite regress'. Therefore, Figure 2 begins in 2008, when the UK legally committed to long-term reductions in domestic GHG emissions (CCA, 2008). Figure 2 is not exhaustive but shows important events and policy decisions discussed by interviewees. UK policies are informed by, and aligned with, EU targets on in-use vehicle emissions and a global commitment to address climate change. No policies are explicitly presented as material efficiency solutions. However, since 2011, there has been government support for lightweight design and materials and car clubs, which can lead to more intensive vehicle use. In 2016, material efficiency was a small part of the UK policy mix to reduce GHG emissions from cars. Using the MSF, the sections below examine why it remains a small part of the climate policy agenda.

Problem Stream

In the 'problem stream', public issues are brought to policy-makers' attention by indicators, focusing events and policy feedback. A policy-maker's capacity to focus on a new issue will depend on their existing policy load.

Indicators help with evaluating the magnitude of a public problem and monitoring changes over time. However, the choice of what to measure and how will inform the interpretation of a problem (Kingdon, 2003). The 2008 Climate Change Act and the United Nations (UN) agreements encourage a focus on domestic GHG emissions. In 2014, driving cars was the second largest source of end-user GHG emissions in the UK, accounting for 15% of the total (BEIS, 2016). Data on GHG emissions from producing material embedded in cars is less readily available, which makes it less visible to policy-makers and the wider public. Although the UK government reports the total and per-capita mass of material consumed domestically per annum, there is no detail on the sectoral or end-user of different materials (ONS, 2016) or the GHG emissions arising from their production and processing.

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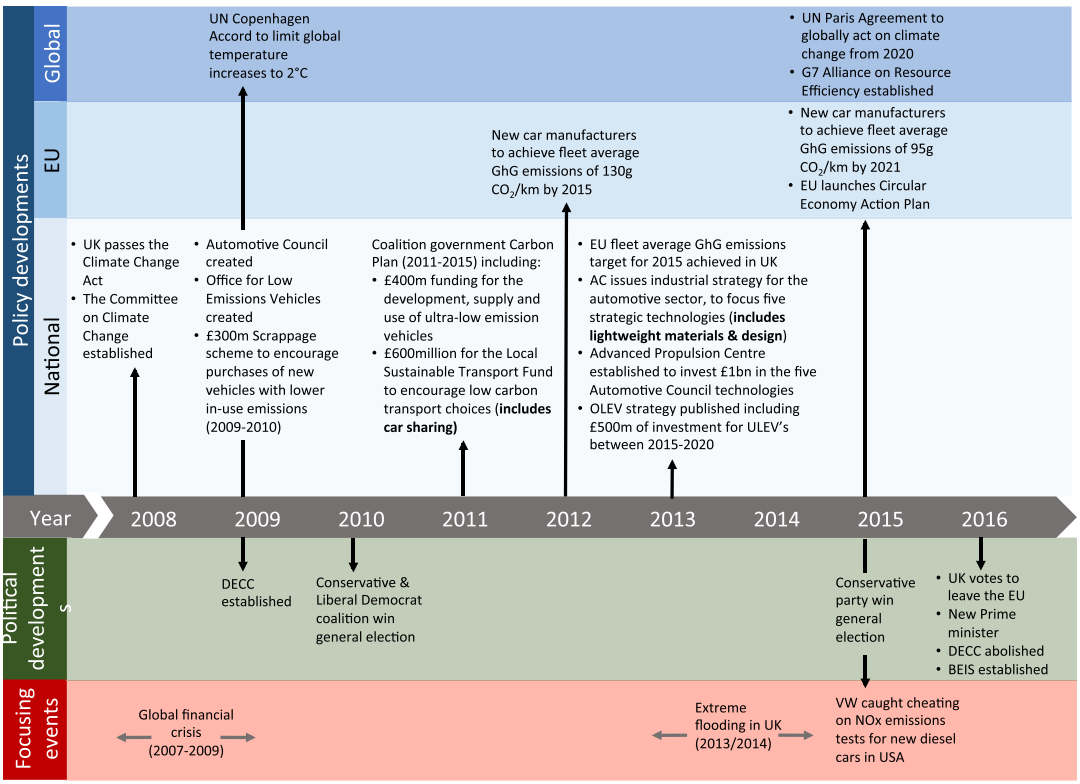

Figure 2. Political and policy developments and focusing events that have shaped the recent UK policy mix to reduce greenhouse gas (GHG) emissions from cars. [Colour figure can be viewed at wileyonlinelibrary.com]

Some studies, for example Serrenho *et al.* (2016), calculate mass flows for individual materials through the UK economy. However, these studies are ad-hoc, creating difficulties with monitoring changes over time.

GHG emissions from material flows could be calculated by estimating emissions associated with individual processes in life-cycle assessments (LCAs). However, interviewees detailed many challenges with LCAs, which limit their appeal within government. These include a lack of standardization which inhibits comparison and may lead to gaming, a lack of public interest in life cycle emissions, difficulties tracing the country of origin of material along the supply chain and challenges with capturing the range of emissions intensities from different manufacturing processes. As a consequence, one interviewee questioned 'how confident would people be [in using LCA data], and how readily understandable would any information be?'. Another suggested 'you would have to allow a wide margin of calculation'. The uncertainty and complexity associated with measuring supply chain manufacturing and end-of-life vehicle emissions may partly explain why the UK has focused on measuring in-use emissions. These calculations are based on fuel sales and are comparatively easy for policy practitioners to measure and monitor.

Even if LCA data were available, increasing the number of indicators and the complexity and subjectivity of their interpretation would increase policy-makers' workload. The MSF explains that policy-makers face temporal, resource and cognitive constraints, limiting the number of problems that can be given attention. Interviewees reported that UK policy-makers already face capacity constraints. The automotive team in the Department for Business, Energy and Industrial Strategy (BEIS) was characterized as 'really small, with a huge remit' as it aims to support growth, investment, employment, productivity and innovation in the sector. Although the Office for Low Emissions Vehicles (OLEV) has an explicit focus on reducing GHG emissions, programmes are multi-modal and include infrastructure. The team in the Treasury working on climate change also covers energy, environment and agriculture. Due to this existing workload, one public sector interviewee simply stated that material efficiency was 'not a priority'. Another emphasized 'there are so many issues to address before then'. Instead, action is taken for 'issue-specific things, [not limited to GHG emissions], that industries have raised or problems we discover'. Materials policy is therefore ad-hoc. Furthermore, no single team has complete oversight of materials throughout

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the life cycle of a product. Policy-makers appear to work in sector or thematic silos. As shown in Table 2, BEIS focuses on GHG emissions from materials and vehicle production, the Department for Transport (DfT) and OLEV focus on reducing in-use vehicle emissions and the waste team at the Department for Environment, Food & Rural Affairs (Defra) oversees policies on the treatment of vehicles at end-of-life. These institutional arrangements may constrain policy-makers' understanding of the full life cycle GHG emissions arising from inefficient material use and the potential solutions that could address this.

In the MSF, focusing events, originally conceived as periods of crisis or disaster, either reinforce attention on existing problems or highlight new ones. For example, the 2007–2009 financial crisis highlighted the procyclicality of UK car sales and led to the 2009 scrappage scheme (Figure 2). More recently, Volkswagen (VW) were fined $14.7 billion for interfering with in-use nitrogen oxides emissions tests in the United States for a range of new diesel cars. Interviews revealed the 'VW scandal' has reinforced the policy focus on in-use, rather than whole life cycle emissions, as there may be similar manufacturer discrepancies with fuel consumption and CO_2 emissions tests (Transport & Environment, 2013). One government interviewee explained that it was challenging enough to monitor car emissions as they are currently framed, stating 'you've seen the problem with measuring in-use emissions ... now imagine the gaming that could go on [with life cycle emissions]'. Progress with existing policies is another source of feedback for governments monitoring a problem. Figure 2 shows that the UK met its 2015 EU target for in-use GHG emissions for new cars in 2013. This signals that UK policies are working successfully and offers little motivation to expand the problem definition to consider life cycle GHG emissions at present.

Indicators, focusing events and policy feedback mean that inefficient material use is only perceived as a problem in so far as it increases domestic in-use vehicle emissions. There appears to be a lack of capacity, interest and certainty around global life cycle vehicle emissions, including those that are attributable to materials.

Policy Stream

In the 'policy stream', potential solutions are debated by a community of individuals inside and outside government. Policy-makers are more likely to pay attention to a solution when there is community consensus, solutions are technically feasible to implement and they align with their values. Figure 3 shows there are numerous material efficiency improvements that could be introduced at different scales, timing and through different types of innovation.

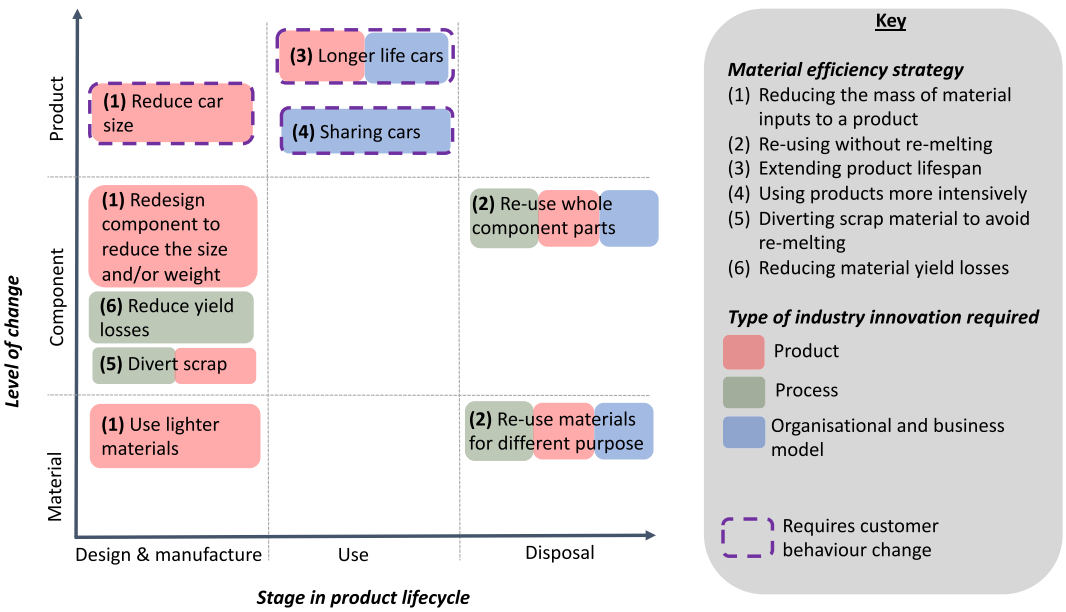

Figure 3. Technical options for implementing material efficiency improvements (adapted from Allwood and Cullen, 2012). [Colour figure can be viewed at wileyonlinelibrary.com]

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Perhaps due to this variety of options, there was no consensus among interviewees on how to define material efficiency. A lack of common understanding and low levels of awareness of material efficiency solutions may mean they are evaluated inconsistently among policy-makers. Some limited their definition to vehicle design and manufacture, i.e. 'being more efficient in the manufacture and use of materials' or 'minimising the amount of inputs you need to produce a thing'. One-third of interviewees understood 'materials' to mean all resources. For one this included 'emissions and embedded water'. Three interviewees professed low levels of awareness. One said 'it's probably the first time I've heard [about] it', another's understanding was 'not huge' and a third said they were 'a bit less familiar with it'. Almost all interviewees, however, recognized one or more of the options in Figure 3 featuring in their work. Of these, light-weight materials and component designs were the most recognized. Nine interviewees indicated they have had discussions about these options.

The legislative landscape also influences how policy-makers evaluate material efficiency solutions. The UK's 2008 Climate Change Act frames the problem as excessive domestic GHG emissions only. Solutions will therefore be valued more by policy-makers if they lead to emissions reductions within the UK. This explains government support, since 2009, for lighter vehicles (Figure 2). Holding all other factors constant, lighter vehicles require less fuel to accelerate to given speed and have lower in-use emissions (Nieuwenhuis, 2014). Car clubs have also received government support, for example through the 2011 Local Sustainable Transport Fund. The in-use GHG emissions of car club vehicles are reportedly 30% lower than the UK average (Carplus, 2016) because they are replaced every 12–18 months due to higher usage rates (Cooper *et al.*, 2016).

Interviewees revealed that climate change solutions are valued highly when there are likely economic co-benefits. One explained that the UK's aim is to 'support the technology that gets to zero emissions, and identify the areas where we [the UK] have a [competitive] advantage'. Similarly, the OLEV works to 'relentlessly support wealth-generating economic activity and ensure motoring is environmentally sustainable' (OLEV, 2013). Currently, there is little understanding of the economic co-benefits from material efficiency solutions related to cars. Although efficiency strategies can reportedly save energy, decrease environmental harm, accelerate economic growth and provide jobs (IEA, 2015), there is limited empirical evidence in the UK to support these assertions. For example, using an input/output model, Cooper *et al.* (2016) show an increase in car club membership can deliver a modest increase in short-term domestic employment.

Solutions need to be technically feasible to implement and policy-makers should have some confidence in the scale of policy costs and impacts (HMT, 2011). Some interviewees expressed concerns about the certainty of emissions reductions that could be achieved through material efficiency solutions. In the case of car sharing, for example, one interviewee said that 'until it becomes clear that this is something that can deliver [GHG emissions reductions], we'll have to wait a bit to include it in the modelling'. This is important as the UK government uses models to compare the costs and abatement potential of different mitigation options. There are numerous challenges with modelling material efficiency solutions. Unlike energy efficiency, which has defined theoretical and practical limits for conversion devices (Cullen & Allwood 2010), only a handful of studies exist which outline current best available practices for efficient material use related to cars (see Milford *et al.*, 2013 and Allwood and Cullen, 2012 for examples). It is therefore harder to evaluate current practices and assess the scale of material savings, and GHG emissions reductions, that could be achieved through material efficiency solutions. A second modelling challenge is that there are incomplete data on the location of material flows and GHG emissions along the UK automotive supply chain. It is therefore unclear if emissions reductions from material efficiency improvements should be attributed to domestic or international sources. A final modelling challenge is that there are few real world case studies of material efficiency solutions, so there are little data on the costs of implementation.

There is little consensus among UK policy-makers about how to define material efficiency solutions. There is also uncertainty regarding the GHG emissions reductions that could be achieved through material efficiency solutions, how much they would cost and if they would yield any economic co-benefits.

Politics Stream

The 'politics stream' comprises elements that motivate and give policy-makers the opportunity to consider different public problems and possible solutions. This includes public interest, pressure group campaigns and government turnover.

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Public interest in climate change appears to be declining. Notwithstanding the extreme flooding in 2013/2014 (Figure 2), around two-thirds of the British population were reported to be '*fairly*' or 'very concerned' about climate change in 2015, down from 80% in the mid-2000s (Capstick *et al.*, 2015). Giddens (2009) argues that the intangible, delayed and invisible impacts of GHG emissions means climate change often becomes a back-of-the-mind issue. Against a backdrop of decreasing public concern, there appears to be little public recognition of how inefficient material use contributes to the problem of climate change, as materials are embedded, and therefore hidden, in products. The authors could find no evidence of public messaging or campaigns that might encourage the UK public to consider how more efficient use of materials could help reduce GHG emissions and help tackle climate change.

There was also concern among interviewees that some material efficiency solutions might be viewed as politically unpopular. In a discussion around vehicle downsizing, to reduce weight and in-use emissions, one interviewee remarked, 'I don't think, from talking to politicians that there's any interest because it's perceived as being "too interventionist".' Instead, a 'hero story', in which a clever technology, such as electric vehicles, may be more politically appealing (Janda and Topouzi, 2015). Similarly, blaming large corporations may be a more attractive political narrative than forcing individuals to consider their personal culpability to the problem of climate change (Parag and Eyre, 2010).

Climate change is a long-term problem, requiring long-term solutions. However, politics is full of short-term distractions. As shown in Figure 2, 2008–2016 was an eventful political period in the UK comprising three governments, four Prime Ministers and a vote to leave the EU. Resource efficiency, including materials, appears to be an issue with declining priority. In 2010, both the Labour Party and Conservatives referenced resource efficiency initiatives in their election manifestos. However, in 2015 only the Liberal Democrats and Green Party referenced resource efficiency. No manifesto referred to specific resources, sectors or supply chains, indicating that the political rhetoric around resource efficiency during elections is high level and non-technical.

At the time of writing, much political and public attention is being given to the UK's departure from the EU, the so-called 'Brexit'. As Figure 2 shows, the UK policy mix to reduce GHG emissions from cars is guided by EU legislation and it is unclear what Brexit will mean for the short-term UK climate change policy agenda. In the long term, the 2008 Climate Change Act should ensure that policy efforts continue. However, the influence of the EU on UK policy-making is far-reaching and not limited to climate change. Existing policies will need to be revisited, requiring significant government and political resources. One interviewee explained that 'Post-Brexit, everything has been reorganised' and suggested it unlikely that the policy agenda would be expanded to include material efficiency as 'we've got somewhat bigger problems to deal with'.

In 2016, there appears to be decreased public concern around climate change and less political interest in resource efficiency. In the short term, attention will be focused on the UK's departure from the EU.

Entrepreneurship and Policy Windows

In the MSF, the three streams are coupled together during policy 'windows'. Policy entrepreneurs, both within and outside of government, are individuals engaged with coupling the three streams.

Aside from a community of academics, the authors could find no dedicated community of entrepreneurs promoting material efficiency improvements as a solution to reducing life cycle GHG emissions from cars. However, some entrepreneurship was identified for individual material efficiency strategies or modes of implementation, as outlined in Figure 3. For example, Carplus, a not-for-profit, environmental transport NGO, collaborates with internal government entrepreneurs from Transport for London (TFL) and Local Authorities to support the expansion of car sharing, which increases the intensity with which a vehicle is used. These organizations emphasize a broad range of benefits not limited to reduced GHG emissions including: reduced congestion, improved air quality, access to mobility and reduced demand for parking (TFL, 2015). Other organizations, including the Waste & Resources Action Programme (WRAP) and the Ellen MacArthur Foundation, subsume materials efficiency into a bigger set of solutions to achieve resource efficiency and the circular economy. A circular economy keeps resources in use for as long as possible to minimize waste and the need for extraction from primary sources. In a 2015 action plan, the European Commission (2015) suggests that a circular economy can: increase competitiveness, mitigate resource scarcity and price volatility, create jobs, save energy and avoid the depletion of finite resources. Lower CO_2 emissions are

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presented only as a 'wider benefit'. With this framing, there is a risk that material efficiency improvements are overlooked by policy practitioners as a solution for reducing GHG emissions.

In the MSF, external entrepreneurs can more readily promote their preferred solutions if they have access to policy-makers. Interviews revealed that the Automotive Council (AC) is an important forum for shaping the policy agenda related to cars in the UK. The Council aims to enhance dialogue and strengthen cooperation between senior representatives in UK government and the automotive sector. One interviewee remarked that through the AC, the industry 'agreed on a direction and then aligned that with government'. Other interviewees characterized communication in AC as 'honest', 'open', 'exemplar', 'refreshing' and 'joined-up'. As shown in Figure 2, of all the material efficiency solutions available, in 2013 only 'lightweight design and materials' were included in the AC's strategy for the sector, which was accompanied by a pot of up to £1 billion of innovation funding. External entrepreneurs operating outside the AC, for example from the NGO and academic community, would have relatively less access to policy-makers, which can limit their effectiveness. One interviewee also described them as 'scattered'. Policy entrepreneurs promoting material efficiency solutions outside of the AC may therefore need to purposefully 'venue shop' (Baumgartner and Jones, 1993) to find alternative forums where they could have the most impact with like-minded entrepreneurs within government. Returning to the example of car sharing, this solution is likely to be of most interest to local governments given the anticipated local benefits on parking, congestion and air quality.

Entrepreneurs are often instrumental in identifying and supporting the expansion of a policy window, which facilitates coupling of the three streams. These windows may be anticipated or unanticipated and entrepreneurs need to be mindful of timely opportunities to raise awareness of a problem and a set of solutions. As shown in Figure 2, EU targets and UK policies are focused on reducing in-use GHG emissions from cars and are often announced years in advance, which creates policy lock-in. However, progress in reducing in-use GHG emissions may encourage more policy discourse around material efficiency solutions because the relative contribution of manufacturing and end-of-life GHG emissions would increase over time. One interviewee engaged with climate policy entrepreneurship explained that although they 'definitely anticipate this [change in relative emissions across the life cycle of a car]', there 'isn't a policy forum to lobby on that now'.

Conclusions

This paper applies the MSF to provide new insights on why material efficiency solutions are a small part of the climate policy agenda to reduce GHG emissions from cars in the UK. It shows that the legislative landscape, policy indicators and the recent VW 'scandal' mean inefficient material use is currently only perceived as a problem by policy-makers in so far as it increases in-use vehicle emissions. The focus on in-use emissions favours some material efficiency solutions, including lightweight design and more intensive use of vehicles via car clubs. The appeal of other material efficiency solutions is further limited by the absence of data and modelling evidence on potential emissions savings, technical feasibility, costs of implementation and potential economic co-benefits. Policy-makers appear to have little spare capacity to consider GHG emissions associated with inefficient material use. The Brexit process may create further capacity constraints, as many public problems and policies which are guided by EU legislation will need to be reviewed. A small community of policy entrepreneurs are promoting some material efficiency solutions but they focus on different public problems, which may limit their effectiveness.

Despite these challenges, material efficiency solutions could become a larger part of the UK policy mix in the future, particularly if in-use vehicle GHG emissions fall to zero. Although the timing of this is unclear, action could be taken now by researchers and entrepreneurs inside and outside of government to ensure material efficiency solutions are sufficiently developed to be included in a future climate policy agenda. Further data are needed on material and emissions flows and reduction potential along the automotive supply chain. Researchers should also collate evidence from real-world and modelling case studies on the potential barriers, costs and impacts of implementing material efficiency initiatives at the sector, supply chain, regional and national level. This would facilitate a comparison with other solutions to reduce GHG emissions and provide a better understanding of the industry and market conditions in which material efficiency initiatives might be preferable.

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Policy entrepreneurs should utilize this information and could collaborate with other entrepreneurs who promote resource efficiency and circular economy solutions. Although the motivation might be different, redefining solutions, linking them to broader issues and sharing ownership can help expand their appeal (Pralle, 2009). There may also be transferable insights from climate policy agendas abroad. The EEA (2016) outlines numerous national and sub-national material efficiency policies in the EU. Understanding what contributed to these relatively favourable political and policy conditions would help inform UK entrepreneurship around material efficiency. The problem of climate change is too significant for material efficiency solutions to remain underexplored by policy-makers in the UK and the rest of the world.

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