The role of policy entrepreneurs and the problem brokers in coupling industry trajectories and multiple streams in multiple windows of opportunity

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Abstract
In this paper, we present an initial analysis of work that seeks to understand, through a novel combination of concepts, the process that are driving the UKs decarbonisation strategy for the automotive sector, specifically cars and the car industry. For this research we draw on grounded theory. We undertake extensive fieldwork interviews and documentary analyses that allow us to explore, in fine-grained detail, the interlinkages in a context where policymakers seek to create a new market (cars with zero tailpipe emissions), but where the technology and investment must come from the private sector, indeed from several related industries within the automotive sector. Moreover, those private sector actors have considerable self-interest in the shape of that policy. We draw upon, notably, the multiple streams framework, the multi-level perspective, policy entrepreneurs, problem brokers, and multiple distinct types of window of opportunity, to understand how technology, market and policy factors have worked jointly to put the UK automotive industry on a specific trajectory. We find this has come about through the interplay of different groups of actors operating across fields of specialism – technology, market and policy – with different actors operating in different windows, to achieve the ultimate goal of a functioning market for electric vehicles.

Key words: Policy entrepreneurs, Problem brokers, Technology innovators, Multiple streams framework, Multiple windows of opportunity, Technology stream, Automotive industry

1. Introduction

Over the period 2017-2020, the UK Government released five decarbonisation strategy documents relating to mobility in the sustainability transition. These documents show a recent shift in policy from "low" emissions vehicles to "zero" emissions vehicles, a move which has already had a significant impact on the automotive industry. Despite the significance of this, a number of issues remain underexplored regarding the role of policy entrepreneurs (PE) in this process.

First, including Problem Brokers (PB) is important as they can frame problems in the problem stream that can open a policy window of opportunity (WoO), so how can we define and distinguish between PEs and problem brokers (PB) in the sustainability transition? Second, do only PEs join streams together in a WoO? If PBs can, we need to distinguish clearly and carefully, both theoretically and empirically, between PEs and PBs. Third, in this research, we distinguish between three types of windows: policy, technological, and market. The first type is the familiar window from the multiple streams framework (MSF), which opens in the problem or politics stream, whereas the other two open in industry trajectories. Thus, what are the possible links between PEs, PBs and the multiple types of WoO, and are different actors only able to open certain types of window? These are our three research questions.

Grounded Theory is used to construct conceptually-dense theory about the role of PEs and PBs in coupling streams in multiple WoOs, in the context of the UKs electric vehicle transition. Forty-eight participants were interviewed, from government organisations, and the automotive and related industries. We also analysed minutes, presentations and reports from the 15 steering group meetings of the Electric Vehicle Energy Taskforce (EVET), over 2018-2020. The EVET is the main organisation in the UK bringing together policymakers, carmakers and energy companies, to accelerate, but also influence the shape of, sustainability transitions in the automotive industry.

We find that working together, PEs and PBs are successful, both at the local and the national level. PBs frame problems and open policy WoOs in the problem stream. In addition, PBs mobilise expert opinion at industry-specific events and conferences and couple industry trajectories in multiple industries with the problem stream, in the technological WoO. Technological WoOs allow carmakers to develop technical solutions to problems, which can then be used by PEs in policy proposals, while coupling policy, problem and politics streams in the policy WoO. The subsequent policy change leads to change in industries' trajectories opening the market WoO.

The examples of PEs at the local level in the UK include mayors of towns and cities; at the national level, they are senior managers of the government's high profile groups. PBs include policy and business development managers; and the managers of external and government affairs with carmakers and trade associations.

These findings introduce a clearer conception of agency around policy entrepreneurs, in conjunction with problem brokers, around the problem and policy streams and industry trajectories, in a context where the development of policies and markets, through technological innovations, are mutually dependent and mutually reinforcing.

In what follows, we start with a discussion of the methodology, before exploring in detail the literature that allows us to piece together our analytical framework. In so doing, in the next section we identify with reference to the interview data the key concepts that emerged from this engagement with stakeholders, consistent with grounded theory. Sections 3 and 4 thus explore in detail the literature underpinning our chosen concepts, justifying their inclusion in the analysis. Section 5 presents a visual representation of the framework, the Multi-Level Governance and Strategy model (MLGS). We seek answers to our research questions in Sections 6 and 7. Section 8 concludes.

2. Methodology

One of the most widely used methods that provide a systematic approach to constructing conceptually dense theory using qualitative data is grounded theory (Denzin, 1994; Timonen et al., 2018). As the research is particularly interested in the participants' action/interaction strategies, the use of well-described theoretical/coding paradigms focused on this aspect of the phenomenon is especially important. In this regard, the Strauss and Corbin (1998) coding approach will be applied. The present study uses a constructivist interpretation of the grounded theory (GT) approach, whilst applying Strauss and Corbin's (1998) coding paradigm to facilitate the coding process (Charmaz, 2006).

The research draws on multiple sources of interview and archival data. Interview data include 30 semi-structured elite interviews and 18 comments from senior managers and specialists of the government, high profile groups, carmakers, consulting organisations, academia, transport planning organisations, government funding organisations, automotive fuel and energy supply companies, infrastructure companies and digital sector organisations. Forty participants are related to the automotive industry in terms of work background, education, work and research tasks. Thirty-eight participants have senior managerial positions and are involved in sustainable transitions in the UK through the development of policies, strategies, research, equipment and consulting services. Eight participants outside the government or industry participated in the study on the issues linked to the development in the related industries. A list of participants is presented in Appendix 1.

Archival data were obtained via a Freedom of Information Request and include minutes, presentations and reports from the steering group meetings of the EV Energy Taskforce convened by The Low Carbon Vehicle Partnership. This is the main organisation in the UK automotive industry bringing together carmakers and energy companies to make proposals to the government to accelerate sustainability transitions in the UK in the sphere of low emission vehicles.

3. Defining policy entrepreneurs and problem brokers in the sustainability transition

In Kingdon's (1984, 2014, pp. 115, 122) work policy entrepreneurs (PEs) are defined as individuals who are ready to spend their "resources - time, energy, reputation, and sometimes money - in the hope of a future return" for future policies of which they approve. They are responsible not only for "prompting important people to pay attention but also for coupling solutions to problems and for coupling both problems and solutions to politics" (Kingdon, 2014, p. 20).

This definition was later clarified by Roberts and King (1991, p. 152), who distinguished four types of public entrepreneurs: political entrepreneurs (holders of elected leadership positions in government), executive entrepreneurs (holders of appointed leadership positions in government), bureaucratic entrepreneurs (holders of formal, non-leadership government positions), and policy entrepreneurs. The last "work from outside the formal governmental system to introduce, translate, and implement innovative ideas into public sector practice" (Roberts & King, 1991, p. 152). Such definitions make it possible to more accurately identify PEs among other actors in the policy process therefore, further analysis will draw on the typology of public entrepreneurs proposed by Roberts & King (1991). According to Roberts & King (1991, p. 147) ""public entrepreneurship" is the process of "introducing innovation - the generation, translation, and implementation of new ideas - into the public sector". Policy entrepreneurship is therefore part of this process.

Following Roberts & King (1991), studies have analysed the activities of all four types of public entrepreneur. Political entrepreneurs have been associated with elected Presidents (Angervil, 2021), Members of Parliament (Herweg et al., 2017), Mayors (Maltby, 2021), Senators (Walker, 1974, 1977) and local prosecutors (Brintnall, 1979). As this suggests, the specific roles of political entrepreneurs are highly dependent on the structure of the political system in any given context. Executive entrepreneurs include heads of government public bureaus (FBI), government agencies (Disabled Persons Transport Advisory Committee), public bodies (British Transport Police Authority) and the government's High-profile groups (Office for Zero Emission Vehicles). Non-executive roles include staff members of Senate committees (Price, 1971); and administrators (Murphy, 1971) refer to bureaucratic entrepreneurs. Possible roles of policy entrepreneurs include "policy analyst; an educator or author; president of a non-profit organization; an academic; head of a lobby group; and an executive director of a public affairs think tank" (Roberts & King, 1991, p. 155).

The concept of problem brokers further refines policy entrepreneurs. Policy entrepreneurs can act as problem brokers (Eckersley & Lakoma, 2021), but problem brokers refrain from acting as policy entrepreneurs (Angervil, 2021; Knaggård, 2015). The problem broker "makes suggestions that something needs to be done", whereas policy entrepreneurs "make suggestions for particular policies" (Knaggård, 2015, p. 453). Policy brokers work within the problem stream (Knaggård, 2015), whereas policy entrepreneurs work within the policy stream (Kingdon, 2014). In addition, it is worth noting that policy entrepreneurs develop policy alternatives and have the power to implement policies (Eckersley & Lakoma, 2021; Knaggård, 2015).Problem brokers operate by connecting *values*, *emotions* and *knowledge* to frame a condition as a problem (Baumgartner & Jones, 2010; Kingdon, 2014; Wildavsky, 1979). *Values* can tell us what is at stake and needs to be protected (Knaggård, 2015). *Emotions* cause fear of the problem, sympathy for those affected by the problem, and anger towards those who are responsible for the problem (Loseke, 2017), which give the appearance of the urgency of this problem (Buzan et al., 1998; Zahariadis, 2003). *Knowledge* of the problem can be divided into scientific, professional, bureaucratic or local condition *knowledge.* Noteworthy professional knowledge may include knowledge about problems in a specific industry or local area, bureaucratic knowledge can be associated with knowledge of problems with measured indicators (Kingdon, 2014). Scientific knowledge has the highest value in making persuasive framings (Knaggård, 2015, p. 456), and those scientists with the greatest chance of strengthening the validity of their frame are those with careers in, and/or knowledge of, policy systems (Kingdon, 2014).

Litfin (1994) formulated the specific concept of *knowledge brokers*, that he associated mainly with scientists. The main difference between knowledge brokers and problem brokers is that the latter use knowledge, values and emotions to frame the problems, whereas knowledge brokers frame only knowledge in order to be understandable in the political world (Zohlnhöfer & Rüb, 2016). They supply the concise evidence that is most relevant to understanding the problem (Cairney, 2018) and tend to be neutral toward the problem without partisanship (Pielke Jr, 2004).

In the present research, the following key actors were identified.

Policymaker – Department for Transport (DfT);

Political entrepreneurs in different levels of governance – the Mayor of London at local level of governance, the office of the Prime Minister at the national level of governance (PEN);

Executive entrepreneur (EE) – the Head of the Office for Zero Emission Vehicles (OZEV);

Policy entrepreneur (PE) – the Head of the Electric Vehicle Energy Taskforce (EVET);

Knowledge brokers (scientists framing the problem) - numerous scientists cited in the EVET work packages;

Problem brokers (scientists framing the problem to public and offering the frame to PE, EE, and PEN) – Scientist A contributed to EVET work packages and participated in EVET meetings.

Technological innovator/Problem broker (TI-PB) – CEO/Scientist B, who participated in EVET meetings.

4. Defining technological, policy and market windows of opportunity

Before proceeding to explain the relationship between multiple types of windows of opportunity, it is necessary to define concepts of industry trajectories and the technology stream.

Industry trajectory

The importance of communication between related industries was highlighted by interviews 12, 17, 18, 19, 22, 25, and 27. Technological and strategic actions of stakeholders related to the transformation of the automotive industry were conceptualised under the term industrial trajectories. This concept is not used in the MSF literature, but it is mentioned in the MLP literature, mainly in terms of the historical development of a particular industry (Cooke, 2018; Yolles & Fink, 2013). Also, industry trajectories were associated with the socio-technical dimension of the MLP, such as the socio-technical regime level (Gee & Uyarra, 2013; Karltorp & Sandén, 2012). The list of elements of the socio-technical regime is quite extensive and includes institutional norms (Geels, 2004), incumbent actors and technologies (Holtz et al., 2008). According to Kemp et al. (1998) the regime can be associated with 'the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology'.

According to Geels (2011), regime transformation can occur as a consequence of changes at the macro level, termed the 'socio-technical landscape', which includes "demographical trends, political ideologies, societal values, and macro-economic patterns". The impact of the landscape level on the regime level can destabilise it and open a window of opportunity for the niche technologies which subsequently can change the socio-technical system.

Since this paper is particularly interested in technological windows of opportunity, the industrial trajectory includes the technologies of incumbent actors and niche innovators, making it possible to trace the transition of technologies from the niche level to the level of incumbents.

During the analysis of the data, the participants repeatedly mentioned the development and transformation of the related industries. In the case of the transformation of the automotive industry, the related industries are associated with energy supply and energy storage technologies for vehicles. In the case of hybrid vehicles, fossil fuels and biofuels are the main energy sources and energy storage media to which the fuel industry is linked (Int. 1, 2). In the case of electric vehicles, the source of energy mentioned by interview participants (Int. 18, 22) is renewable energy, and the main storage technology is batteries (Int. 15, 23, 30). The related industries include the renewable energy industry and the battery industry. Based on interview data, in addition to the industry trajectory of the automotive industry, the industry trajectories of the fuel industry and the renewable energy industry, including the battery industry, were also considered. The battery industry trajectory has been merged with the renewable energy industry trajectory to be consistent with the fuel industry trajectory, where the energy source is also the means of energy storage. Indeed, the battery industry is closely linked with renewable energy and has a significant impact on the integration of the latest technologies to the grid (Nair & Garimella, 2010) and on achieving sustainable development goals (Hannan et al., 2021).

Technology stream

In order to understand the impact of technological change on the policy process, the analysis uses the concept of technology stream introduced by Voß (2007) and adapted by Goyal et al., (2021). The technology stream depicts "the context and activities that contribute to technological innovation, such as research, prototype development, patenting and licensing, the establishment of a business venture, market creation, and technology transfer" (Goyal et al., 2021). The likely actors involved in technology development and diffusion are technology constituencies (Goyal et al., 2021; Goyal & Howlett, 2018). Members of technology constituencies can be technologists, manufacturers, suppliers, service providers, users, lobby groups, political actors, and academics who can also be members of epistemic communities in the problem stream, instrument constituencies in the policy stream, and advocacy coalitions in the politics stream (Goyal et al., 2020, 2021). According to Goyal et al. (2020) entrepreneurial activities in the technology stream focused on promoting "a technological solution to a societal "need" or a policy problem" and can be associated with the activities of technology innovators. In addition, a technology innovator can promote the innovation by coupling "a technology narrative with a socio-political agenda" (Goyal et al., 2020; Smith & Raven, 2012). It is noteworthy that the technology stream can be coupled with problem, politics and policy streams and that the activities of technology constituencies can shape technological trajectories (Goyal et al., 2021). In the analysis, we are using the concept of industry trajectory, that includes technological niche innovations as well as incumbent-level technologies. We find that industry trajectories of related industries can be included in the technology stream since the entrepreneurial activities of technology innovators are linked with multiple industry trajectories and multiple technological levels and can be considered as activities within the technology stream.

Technological window of opportunity

Interviewees 15, 17, 19, 22, 24, 25, 26 and 27 talked about windows of opportunity for hybrid and electric vehicles. These windows are associated with the development breakthrough technology that can be used in related industries, standardisation of fuel/energy infrastructure required to specific technology, and decarbonisation of energy supply (Int 25). In the case of the development of the UK electric vehicle infrastructure strategy, the technological window of opportunity (tWoO) was linked with the development of microelectronics and software in the electronics sector, which was subsequently adapted to transport (Int. 17, 19); decarbonisation of electricity resulting from the development of renewable energy; development of communication protocol between electric vehicles and charge stations. In addition, the development of energy storage technologies - batteries, both for renewable energy and for electric vehicles – was of great importance (Int. 23, 15). The connection between these industries has made it possible to talk about the electric car as a possible solution to the problems of CO2 emissions and dependence on fossil fuels (Int. 27). The connection between the battery industry and the automotive industry allowed for the first demonstration fleet of electric vehicles (EVs) to emerge in 2007 (Int. 19, 25). The subsequent decarbonisation of electricity generation has made it possible to reduce emissions at the production stages as well as on the road (Int. 22). The deployment of a network of charging stations as well as standardisation has made electric transport more convenient to use (Int. 25). At the initial stage - 2010 - 2016, the infrastructure was developed by the manufacturers of electric vehicles themselves, such as Nissan and Tesla (Int. 24, 26). The latest tWoO was opened in 2017 where the outcome was the production of cost effective EV using energy dense batteries capable share information with smart charging.

The tWoO opens in related industries such as batteries, renewable energy, digital industry, infrastructure and semiconductors. These windows allow carmakers to produce a demonstration fleet (for example, electric vehicles, flex-fuel vehicles, hybrid vehicles) by decarbonising sources of energy for BEV/HEV, increasing the energy density of batteries, or improving AI technology. Carmakers use these windows to improve characteristics of cars and reduce their cost. Technological windows of opportunity are linked with implemented policies associated with technological development in related industries. Intersections between technological windows (white circle with arrows in Figure 1) indicate intersections of outcomes of the first technological window with causes of opening the second technological window.

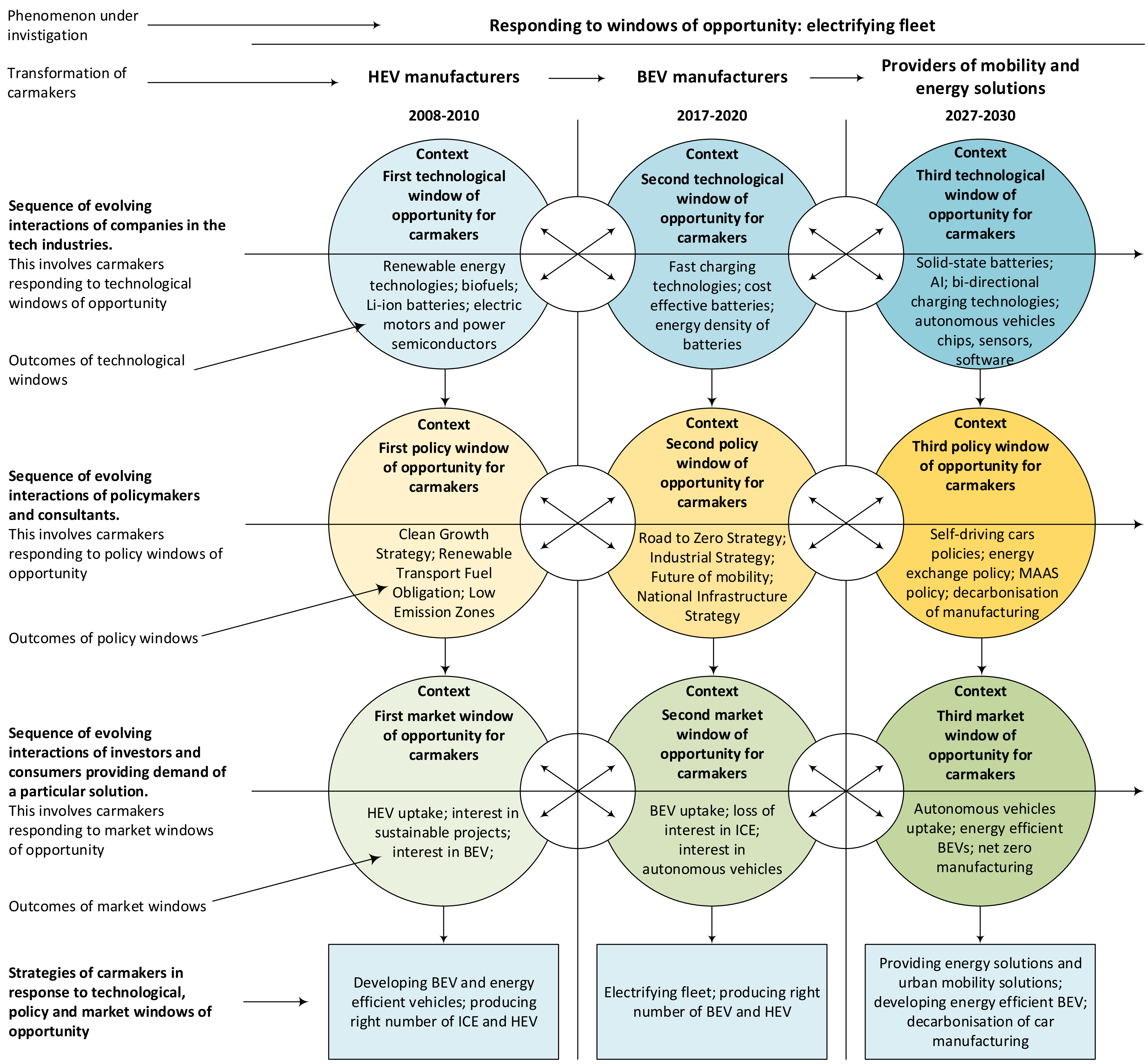

Figure 1 Three stages in the transformation the automotive industry in the UK

For example, if the cost of batteries in the first window was too high (outcome) this will be the cause of reduction of this cost in the second window. Thus, the evolution of technologies is continuing. In Figure 1, technological windows are marked as blue circles.

Figure 1 shows a theoretical framework constructed based on interviews indicating three groups of multiple windows of opportunity leading to transformation of the automotive industry in the UK. The electrification of the fleet takes place in three stages: in the first stage, the first mass market battery electric vehicles (BEV) were introduced (2010), in the second stage BEV became a mainstream technology (2020), and the third stage will be marked by the maturation of the BEV technology and improvements in related technologies such as AI, leading to the further transformation of the industry in 2027 - 2030 (Int. 25, 26, 27). Each of the stages involves the opening of technological (blue circle), policy (orange circle) and market (green circle) windows of opportunity.

Policy window of opportunity

The policy window of opportunity (pWoO) opens by cause of events within the politics stream or problem stream. In the politics stream, such events can be a change in the government or shift in national mood; within the problem stream, these can be the emergence of problems that become visible through focussing events (Kern & Rogge, 2018; Kingdon, 1995). The pWoO allows policy entrepreneurs to advocate policy solutions for the appropriate pWoO in order to be selected by policymakers, whilst policy entrepreneurs are not involved in the opening of the window (Ackrill & Kay, 2011; Kingdon, 1995). A pWoO which opens in the problem stream can be missed if there is no appropriate and well developed policy solution being offered (Kern & Rogge, 2018). If a pWoO is opened in the politics stream, then a solution can be selected first and only then the problem identified (Kern & Rogge, 2018; Zahariadis, 2014).

Maltby (2021) and Collantes and Sperling (2008) identified a pWoO which was opened in the problem stream and has a link to air pollution. The reason for opening a pWoO was the combination of the two focusing events of the air pollution death rate and dieselgate scandal, which were both highlighted by mass media and drew the attention of the public to air pollution (Maltby, 2021). Cohen and Naor (2013, 2017) and Leung et al. (2018) associated the opening of a pWoO with energy security in the problem stream, with an increase in oil prices as the focusing event. The subsequent decline in oil prices closed the window of opportunity (Leung et al., 2018).

Based on contemporary research focusing on transformation of mobility systems it is possible to conclude that decarbonisation of the automotive industry is associated with focusing events such as increased deaths from air pollution and oil and gas crises. Policy solutions such as the introduction of low-carbon zones are developed by policy entrepreneurs and pushed to policymakers, which subsequently lead to policy change and destabilisation at the regime level. There is no direct indication in the MSF literature that carmakers are involved in policy changes, however Wikström, Eriksson, and Hansson (2016) state that test drives have an impact on public opinion, which could lead to the assumption that carmakers may act as problem brokers.

The policy window of opportunity (pWoO) in the automotive industry opened after the tWoO was opened, and the demonstration fleet was produced. The pWoO led to policy change in the automotive industry and ultimately enabled the demonstration fleet to become a niche market product. In Figure 1, it is marked as an orange circle. Policy windows open due to the emergence of problems or requests from the public for example, in connection with environmental issues. Policymakers release policies for which the presence of a technological solution to the problem is important. This solution is related to the demonstration fleet developed after the technological window of opportunity was opened. Intersections between policy windows indicate intersections of outcomes of the first pWoO, which opens the second pWoO. For example, if the implementation of policy that promoting of clean and energy-efficient road transport led to increasing numbers of vehicles and CO2 emissions, this will be the cause of opening a second pWoO where the Road to Zero strategy will be implemented.

Market window of opportunity

Ning, Sutherland and Fu (2017), Wei et al. (2020), and Lema, Fu and Rabellotti (2020) talk about the important role of the government in the emergence of a green market. Wei et al. (2020) frame this idea using the concept an institution-led market, that was partly confirmed by this research. In the institution-led market, the government is concerned not only with an institutional/policy WoO, which refers to legislation, state procurement, resource provision, and administrative control, but also a market WoO, when the government uses mechanisms such as demand creation, resource allocation and regulation of market orders (Wei et al., 2020). The authors conclude that an institution-led market has a positive effect on the probability of newcomers becoming leaders, in the case of changes in the market and transitions to alternative technologies.

The link of government with a market window of opportunity is supported by empirical evidence. For example, the government creates conditions for increasing the demand for BEV through infrastructure development, plug-in grants, or feed-in tariffs, to reduce the cost of ownership and create condition for supply of BEV through ZEV credits or a zero-emissions credit pool. At the same time, it is worth mentioning that findings in the socio-technical transition literature identify three distinct government (policy) approaches hands-off, enabling facilitator, and interventionist director. In the *hands-off* approach, firms do not experience tightly regulated markets; when acting as an *enabling facilitator*, the government becomes more involved in the functioning of the economic system; in the case of an *interventionist director* approach, the government directs innovation through public investment (Schmidt, 2002). According to Wesseling (2016), Kanger et al. (2019) and Sovacool et al. (2019) the regulatory environments for electric vehicles between 2008-2014 in the UK can be classified as is a *hands-off*. We can add to this statement that starting from 2017, after the publication Industrial Strategy, the government's approach can be classified as interventionist director when the government directed innovation in the way of industrial policy. In 2018, the government even convened the Electric Vehicle Energy Taskforce which one of the key objectives was to bring together people from the automotive industry and energy sector and make proposals to the government. Later in 2019, a new Prime Minister takes the office, whose role can be characterised as a political entrepreneur who accelerated the transition to EVs.

Finding in interview and FOI data shows that after tWoO and pWoO open a market window of opportunity (mWoO) which allows a niche product to become mainstream. For example, in 2020 in the UK was opened to battery electric vehicles (BEV). The mWoO is linked with the demand for the new technology and the interest of investors and customers. In Figure 1 these windows are marked as green circles. When the market window of opportunity opens, the demand for a technological solution increases and infrastructure becomes standardised. Intersections between market windows (white circle with arrows in Figure 1) indicate intersections of outcomes of the first market window with causes of opening the second market window. For example, in 2010, a market window of opportunity opened for HEV. Uptake of hybrid electric vehicles (HEV) showed that it is possible to electrify vehicles; they can be a mainstream market and they can be cost-effective. Investors and customers were more interested in sustainable technologies and BEV, which along with second tWoO and second pWoO led to the opening of the second market window of opportunity. In 2020, 9% of new vehicle sales in the UK were BEV, making it a mainstream technology. That year BEV entered the socio-technical regime level. There are currently no major carmakers who do not produce BEV. The outcome of the second market window of opportunity will be associated with uptake of BEV and growing interest in related technologies, for example, autonomous vehicles (AV). This will be the reason for opening the third market window of opportunity in 2027.

5. MLGS

In order to take a comprehensive look at what is going on in the auto industry, we developed the Multi-level governance and strategy (MLGS) model: Figure 2. MLGS syntheses the multiple streams framework, multilevel perspective framework, multi-level governance theory and multiple windows of opportunity identified through grounded theory. MLGS can be used as a tool in strategic planning and at the agenda setting and evaluation stages of policymaking.

In the MLGS model the window sees coupling not only of the problems, policies, politics streams, but also industry level trajectories. Perpendicular to the streams and industry trajectories described above are technological windows of opportunity (pink field), policy windows of opportunity (blue field) and market windows of opportunity (yellow field) identified in the interviews. Industries associated with power supply and vehicle manufacturing, selected in accordance with interview data, are the renewable energy industry, fuel industry and automotive industry. Each of the trajectories includes information about the policies related to the industry, as well as the strategic and technological actions of key industry stakeholders. Information related to policies is located at the governance level, which in turn is divided into global, EU level, national and local levels. Information related to the actions of stakeholders is located at the incumbents' level, which includes strategic actions and technological actions of incumbent actors. Niche innovations are located at the market niche level.

Policies and politics streams refer only to the governance level of industries' trajectories and correspond to MSF logic. The problem stream is divided into two parts, one part includes focusing events and is linked with the governance level of industries trajectories. The second part includes the actions of problem brokers and is linked to the incumbents' level and market niche level of industry trajectories. This arises from the analysis of the interviews and FOI data, which indicated that BEV technology innovators acted as problem brokers, framing environmental problems to the public and policymakers, and working to get the latter to accept these frames.

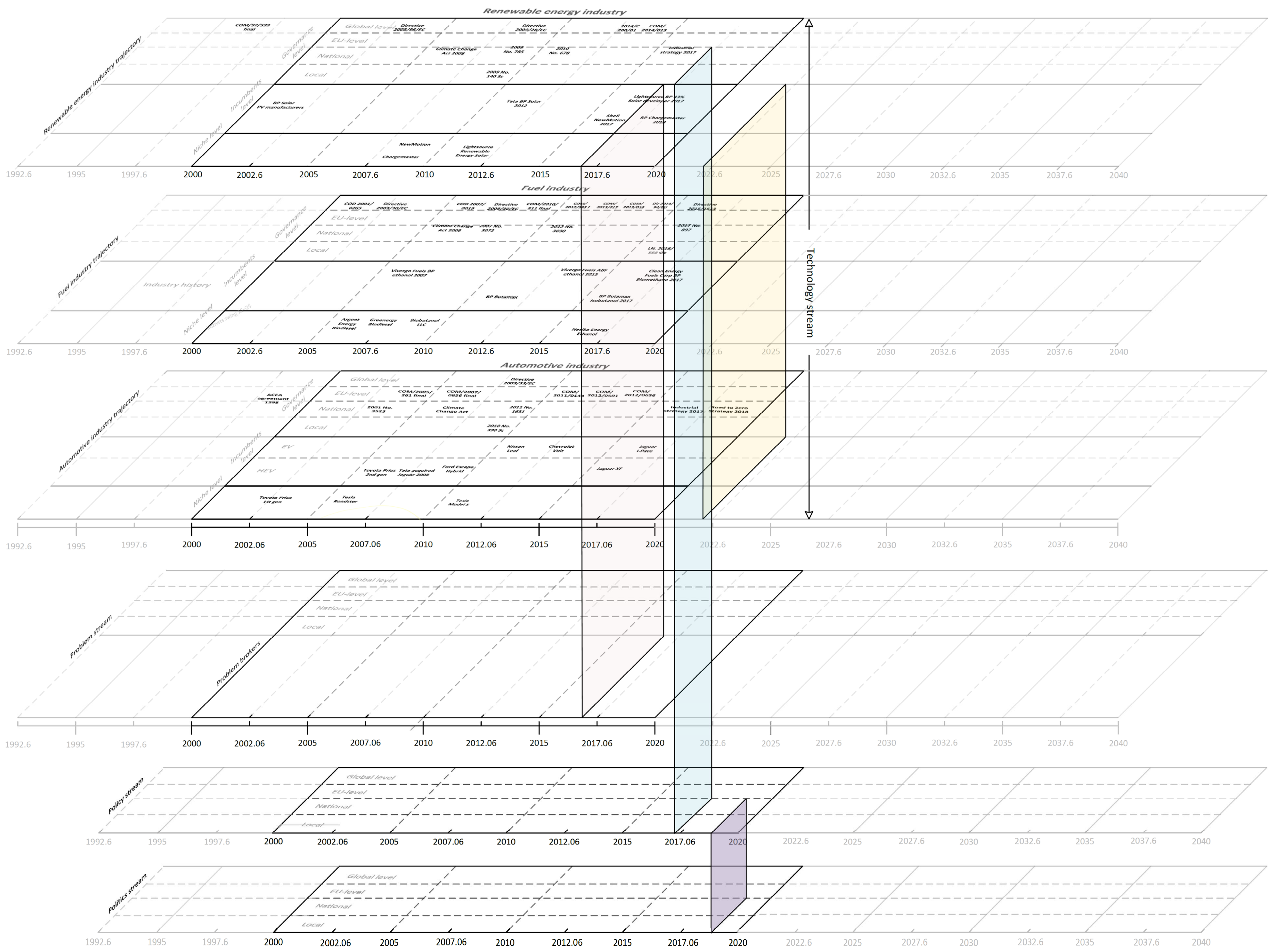

Figure 2 Isometry of MLGS model

6. Do only PEs couple streams in a WoO?

There are different opinions on whether only policy entrepreneurs can couple the streams. One group of studies that has a broader view sees problem brokers as playing an important role. Knaggård (2015, p. 451) states that policy entrepreneurs work together with problem brokers whose objective is to “frame conditions as public problems and work to make policymakers accept these frames”. One of the most recent studies focusing on the decarbonisation of the automotive industry in the UK using the MSF was carried out by Maltby (2021). According to Maltby (2021), NGOs and scientific experts were involved in framing conditions, wherein the mayor of London acted as both policy entrepreneur and problem broker.

The finding of Maltby (2021) is in line with Wikström, Eriksson and Hansson (2016) who found policy entrepreneurs acting as problem brokers engaging with local authorities. They show that policy entrepreneurs accelerated the implementation of Plug-in Hybrid Electric Vehicles (PHEV) by raising the issue on the political agenda of local authorities, where policy entrepreneurs have the position of expert public officials or being a high-ranking local politician. The roles of policy entrepreneurs identified by Wikström, Eriksson and Hansson (2016) and Maltby (2021) are most suitable for the strategy of politicising the issue and mobilising public opinion, discussed by Roberts and King (1991), Hysing (2009) and Goyal, Howlett and Chindarkar (2020). From the foregoing, policy entrepreneurs who act as problem brokers are seen as taking an active role in decarbonising the automotive industry using a bottom-up approach, mobilising public opinion and politicising environmental problems which trigger the policy change.

PEs routinely act as problem brokers. Indeed, identifying an issue as a problem is a key role assigned to PEs in their acting as a PE. Given the earlier definitions of, and distinctions between, PEs and PBs, however, PEs then go on to propose/promote particular policy solutions. Knaggård (2015), Maltby (2021), Eckersley & Lakoma (2021) and Wikström, Eriksson and Hansson (2016) are writing specifically about PEs acting as PBs. Based on the empirical data we elaborated PB concept a little bit further. We found that PB can work with technology innovators (TI) who couple problem stream with technology stream under tWoO. Noteworthy that TI can act both as TI and PB focusing on R&D within technology stream and framing the problem within problem stream. The PB role can be thought of as one specific subset of activities that the PE or TI undertakes, and it remains strictly a PB role only if all the MSF actor do is problem brokerage. However, PB play an important role in policy change as their actions can facilitate opening tWoO and pWoO which can then be used by PE and IT.

The second group of studies bring the bricoleur into the MSF to connect all three streams (problem, politics and policy), or act within the stream and partially connect the streams. Deruelle (2016) found that the bricoleur who frames conditions as a problem can also couple the streams. The difference with the PE is that for the bricoleur "the choice of a particular outcome is less important than the process goal" (2016, p. 43).

A third perspective comes from Goyal et al. (2020). WoO can be exploited not only by policy entrepreneurs but also by problem brokers and political entrepreneurs who can couple problem, policy, and politics streams when a WoO is open. Other types of entrepreneur, such as technology innovators, process brokers, and programme champions, are less significant in couplings the streams, "but are likely to be important for policy formulation, implementation, and "success."" (Goyal et al., 2020, p. 59).

From the foregoing, we thus see one view, that problem brokers can work with policy entrepreneurs to couple streams through problem identification. A second view sees a role for bricoleurs, but their sight is set on the end goal rather than the specific means of getting there. A third view sees other actors being able to couple streams, with yet more actors having potentially important roles in terms of providing information or input at key points in the coupling and policymaking process. In sum, this discussion reflects the idea that a distinction can and perhaps should be drawn between policy entrepreneurs as individuals, and policy entrepreneurship as a process, "allowing us to isolate different facets of entrepreneurial activity" (Ackrill & Kay, 2011, p. 74).

Based on the interview data, we find that partial connection of streams can occur depending on the type of window of opportunity that was opened. Further, in addition to policy entrepreneurs, streams can be connected by other actors depending on the stream in which the actor works. These findings are discussed in the next section.

7. What are the possible links between PEs, PBs and the multiple types of WoO?

This case is associated with the second group of WoO discussed in Section 4 (Figure 1). In the following discussion, we identify multiple actors working jointly to effect change. As such, we also offer initial speculation as to the nature of this collaborative effort (*an aspect of the research we would particularly welcome your thoughts on*). Advocacy coalitions (AC) are groups of people "who share a particular belief system – i.e., a set of basic values, causal assumptions, and problem perceptions and who show a non – trivial degree of coordinated activity over time" (Sabatier, 1988, p. 139). Members of advocacy coalitions can be "political parties, politicians, political appointees, and interest groups, amongst other stakeholders" (Goyal et al., 2020, p. 52). Each coalition operates "against an opposing coalition consisting of other people who advocate for different policy directions" (Weible & Ingold, 2018, p. 326). They can use such activities and strategies as "politicising the issue; mobilising public opinion; exploiting decision - making procedures; negotiating, bargaining, and side payments; controlling information flow; manipulating problem severity or salience" (Goyal et al., 2020, p. 54).

Epistemic communities, the second form of alliance, are associated with problem brokers and entrepreneurial activities in the problem stream. They can be seen as a "subset of an advocacy coalition, particularly by reference to the various decision-making habitats occupied by scientific experts under the auspices of one or more coalitions" (Weible & Ingold, 2018, p. 328). In this regard, by operating within an advocacy coalition, they are not facing an 'other' directly, whereas advocacy coalitions are in tension over a particular policy sub-system. That said, with ideas being an important part of the advocacy coalition framework, epistemic communities can play an important role in shaping, maintaining or changing the ideas binding an advocacy coalition together.

Another form of entrepreneurship is associated with technology innovators who "foster technological innovation and promote its diffusion amongst citizens, businesses, and governments" (Goyal & Howlett, 2018, p. 6). Technology innovators are likely to emerge from a technology constituency comprising technology developers, users, lobbyists, political actors, and civil society organisations (Goyal et al., 2020; Goyal & Howlett, 2018). Their entrepreneurial activities are associated with technology stream and involve such activities as "Research and development; technological invention; nurturing, shielding, and empowering novel technologies; tying a technology narrative with a socio-political agenda" (Goyal et al., 2020, p. 54).

Policy entrepreneurs come from instrument constituency actors whose background can be "businesses, consulting, think tanks, public administration, academia, and civil society and develop policy expertise through involvement in the "lab" and the "field" (Goyal et al., 2020, p. 51; Voß & Simons, 2018). They are active within the policy stream and include such strategies as "Sharing (new and reliable) knowledge about alternatives; constructing models of best practice; using "shadow networks" to develop ideas; initiating experiments or pilot projects; leveraging conditions of funding; persuasive framing; using high valence; manipulating policy ownership or the salience and valence of its memory; venue shopping" (Goyal et al., 2020, p. 54).

In the interviews and archival data, with the development of the UK electric vehicle infrastructure (EVI) strategy, it was found that technology innovators, problem brokers, policy entrepreneurs, and political entrepreneurs formed an advocacy coalition. Each of these participants plays a specific role during the opening of a certain window of opportunity. The second AC were linked with Hydrogen technologies and stakeholders associated with the traditional motor fuel industry. The high cost of hydrogen technologies, the inefficiency of energy conversion, and the low level of technology readiness reduced the number of pro-hydrogen policymakers. This led to the change in the power dynamics that empowered EV focused AC to have the influence that in turn led to the EVI Strategy.

There is another actor - interest group (IG) which is necessary to give definition before the analysis. In Kingdon's original (1984) work, interest groups act within the politics stream, however, Rozbicka & Spohr (2016) developed the concept stating that interest groups are crucial actors in the problem and policy streams as well. They focus on blocking or adapting proposals that are on the government's agenda, but they are not inclined to set the agenda themselves (Kingdon, 2014). In addition, they are not responsible for opening a window of opportunity as they focus on the actions described above that should be visible to the broader public (Kingdon, 2014). Gunn (2017) and Zeilinger (2021) stated that an IG can be outside the government system. In contrast with an advocacy coalition, an interest group will typically be a group with formal membership, led by an organisation that seeks to influence specific or general policy issues (Wright, 1996).Kingdon (2014, p. 47) includes "business and industry, professional, labour, public interest groups, and governmental officials as lobbyists" as constituting interest groups. Interest groups studied in the literature include teacher unions (Angervil, 2021), or farmers' groups (Joshi & Acharya, 2005)

Analysing the interview and FOI data we find that the problem broker and the technological innovator can be the same individual whose entrepreneurial activities are carried out within industry trajectories (which can be grouped into a technology stream). These individuals can frame the problems and couple multiple industry trajectories with a problem stream when the technological WoO is open. The output of coupling industry trajectories with the problem stream is the development of a prototype/demonstration fleet offering a technological solution to the problem. This technological solution could later be included in the policy package. In Figure 2 tWoO is depicted as the first window (pink colour) linking the problem stream with the niche and incumbent levels of industry trajectories. The inclusion of a particular technology in a policy package is associated with policy entrepreneurs (Head of EVET) and executive entrepreneurs (Head of OZEV) who couple the technology stream and problem stream with policy stream in the policy WoO. In Figure 2 pWoO is shown as the blue window linking local and national governance levels in industry trajectories. The political entrepreneur was responsible for coupling the political stream with the policy stream when the political WoO opened after the resignation of Teresa May (pink window in Figure 2). In this way all four streams (technological, problem, policy and politics) were coupled (with some lag in time), which led to the policy solution reaching the top of the agenda of policymakers (DfT), that led to the release of the UK electric vehicle infrastructure strategy. With this policy change towards EVs, the market WoO was opened, making EV a mainstream technology (yellow window in Figure 2). Interest groups such as SMMT tried to sell their solution to DfT but it was not accepted, however they had more success with Department for Business, Energy & Industrial Strategy (BEIS) which released the UK Hydrogen Strategy in 2021 and delayed the complete ban of ICE and ULEV until 2035. It was a compromise solution for all actors (policy entrepreneurs, executive entrepreneurs, political entrepreneurs, problem brokers, technological innovators, interest groups and policymakers). The empirical data contribute to a four-streams version of MSF research (Goyal et al., 2021). In addition, these findings can further develop the work of Zahariadis (2003) and Herweg et al. (2015), that has adapted the MSF to decision making stages beyond agenda-setting.

We find that advocacy coalitions play an important role in the technology stream by linking industry trajectories in related industries with problem stream in the first instance and then the problem with politics and policy streams. The actors who can be involved in the process of linking industry trajectories with problem stream are associated with technology innovators who simultaneously can act as problem brokers (PB). Participant OPMNVU56 (Int 25) worked as a head of consulting and engineering organisation and was involved in development of technological solutions for decarbonisation of the automotive industry in the UK. He also participated in renewable energy focused conferences and workshops framing the problem to the public and professionals. From one side this helped to build acceptance of the problem frame among industry professionals. From the other side it facilitated collaboration between the energy sector and automotive industry, linking renewable energy, fuel and automotive industry trajectories. During the interview, OPMNVU56 mentioned that the mWoO for ICE/EV opened when infrastructure was standardised and this collaboration between energy/fuel suppliers and auto industry helped to become the auto solution's mainstream technology in the market.

Another important fact that OPMNVU56 also communicated with political entrepreneurs on the national level (PEN), executive entrepreneur (EE), and policy entrepreneur (PE) fostering the frame reach the top level of the policymakers (DfT) agenda. To sum up, it is possible to say that TI-PB plays important role in policy change however, it should be noted that their actions are most effective when TI-PB, PEN, EE and PE act as an advocacy coalition.

8. Conclusion

Analysing interview data, archival data and secondary materials there were found answers on three research questions.

First, how can we define and distinguish between PEs and problem brokers (PB) in the sustainability transition?

In the empirical data it was found that PB role associated only with problem brokerage. However, PB play an important role in policy change as their actions facilitate opening tWoO and pWoO which then can be used by PE and IT. PB can work with technology innovators (TI) who couple problem stream with technology stream under tWoO. Noteworthy that TI can act both as TI and PB focusing on R&D within technology stream and framing the problem within problem stream. PEs routinely act as problem brokers identifying an issue as a problem and then propose/promote particular policy solutions to the policymakers.

Second, do only PEs join streams together in a WoO?

Based on the interview data, it was found that partial connection of streams can occur depending on the type of window of opportunity that was opened. It has also been found that, apart from policy entrepreneurs, streams can be connected by other actors depending on the stream in which the actor works. For example, technology innovators who work as problem brokers can frame the problems and couple multiple industry trajectories with a problem stream when technological WoO is open. The output of coupling industries trajectories with problem stream is the development of a prototype/demonstration fleet of technological solution to the problem. This technological solution could later be included in the policy package. The inclusion of a particular technology in a policy package is associated with policy entrepreneurs and executive entrepreneurs who couple technology stream with policy stream in policy WoO. Political entrepreneur was responsible in coupling political stream with policy stream when political WoO is open.

Third, what are the possible links between PEs, PBs and the multiple types of WoO, and are different actors only able to open certain types of windows?

Technological WoO and policy window of opportunity (pWoO) opens by cause of events within industry trajectory for tWoO or the politics stream or problem stream for pWoO, wherein problem brokers facilitate in opening tWoO and pWoO by framing the problem. Following this TI-PB, PE, EE and PEN can partly couple streams when particular WoO is open. Together TI-PB, PEN, EE and PE acting as an advocacy coalition led to the policy solution reaching the top of agenda of policymakers (DfT), which was eventually accepted by DfT and UK electric vehicle infrastructure strategy was released.

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Appendix 1 List of participants

Table 1 List of participants in the pilot study

Int. No	Data collect. stage	Industry	Position classifier	Unique identifier	Position name
10	Pilot Study	Consulting in auto industry (C)	Specialist	JLSNVI63	Technical Specialist
9	Pilot Study	Transport planning (TP)	Specialist	RBVSHF25	Transport Planner at government organisation
8	Pilot Study	Research funding (Fn)	Manager	OVNUGJ89	Regional Manager at government research funding organisation
7	Pilot Study	Automotive (A)	Specialist	UVIOSF78	Product Specialist of a carmaker
6	Pilot Study	EV infrastructure (I)	Manager	MNDFGE56	Project Manager at electric vehicle infrastructure company
5	Pilot Study	Biotech (B)	Manager	DAVIES19	Business Development Manager at engineering company (brewing and biotech)
4	Pilot Study	Automotive (A)	Specialist	IONVDH14	Engineer at multinational engineering company
3	Pilot Study	Academia (R)	Specialist	LFENVI49	Researcher, Civil Engineering
2	Pilot Study	Oil and Gas (F)	Senior manager	CONSUL18	Senior Manager at Oil and Gas company
1	Pilot Study	Academia (R)	Head	KYPROU14	Vice-Dean at a University

Table 2 List of participants in the second round of interviews

Int. No	Data collect. stage	Industry	Position classifier	Unique identifier	Position name
30	Second round	Battery recycling (BR)	Specialist	IDFNBS88	Engineer at battery recycling company
29	Second round	Automotive (A)	Manager	NLFONC09	Manager, carmaker
28	Second round	Research funding (Fn)	Manager	IKFNHF93	Manager, government research funding organisation in auto industry
27	Second round	Policymaker (P)	Head	QJFCLR25	Head of Government Office
26	Second round	Automotive (A)	Senior manager	CMPSHD01	External and Government Affairs Manager, carmaker
25	Second round	Automotive (A)	CEO	OPMNVU56	CEO of engineering company in auto industry, consulting company

Int. No	Data collect. stage	Industry	Position classifier	Unique identifier	Position name
24	Second round	EV infrastructure (I)	Senior manager	DSCPST61	Policy Director in EV infrastructure company
23	Second round	Battery (Li)	Head	YMPFNK30	Head of department in battery cell manufacturing company
22	Second round	Energy (E)	Head	BRKTCH95	Head of department in energy engineering company
21	Second round	Transport planning (TP)	Manager	KLDFSN93	Decarbonisation Programme Manager at government transport planning organisation
20	Second round	Transport planning (TP)	Senior manager	SPFKVS69	Chair of the Sustainable Transport Panel at government transport planning organisation
19	Second round	Consulting in auto industry (C)	CEO	NCJFWO03	CEO of strategic planning and management consulting company in auto industry
18	Second round	Consulting in auto industry (C)	CEO	ODJMNV53	Co-founder vehicles, renewable energy and project management consulting company
17	Second round	Consulting in auto industry (C)	Head	RGDTAI25	Head of innovation hub for technology companies
16	Second round	EV infrastructure (I)	Senior manager	JNSLVM20	Senior Director European Policy at electric vehicle infrastructure company
15	Second round	Battery (Li)	Manager	TSIVKF28	Account Manager within the Battery Materials business
14	Second round	Academia (R)	Senior manager	CCSLKJ32	Senior Research Associate at a University
13	Second round	Consulting in auto industry (C)	Specialist	200520AB	Sustainability consultant
12	Second round	Consulting in auto industry (C)	Specialist	UWORKP34	Industrial waste and sustainability consultant
11	Second round	Academia (R)	Specialist	OPDNYF55	Researcher, Green hydrogen production for maritime transport