SUSTAINABLE MOTORING, RENEWABLE ENERGY AND RENEWABLE FUELS: THE ROLE OF THE AUTOMOTIVE INDUSTRY

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This thesis is dedicated to my mother, Alfiya Arslangulova.

Abstract

This study aimed to develop a theory, using a grounded theory approach, that can explain the role of technology and individuals in the shift of the policy agenda from low emission goals to zero-emission goals, as well as the impact of the shift in the agenda on the automotive industry in the UK, between 2017-2020.

The research draws on 18 comments, 30 semi-structured elite interviews, and archival documents from the Electric Vehicle Energy Taskforce (EVET). The EVET is convened by The Low Carbon Vehicle Partnership (now the Zero Mobility Partnership) and 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. No other studies have been identified that have used such data to analyse agenda setting and EV transition processes in the UK.

Based on the analysis, a theoretical framework has been created that brings technology transitions into the policy process and introduces the concepts of multiple windows of opportunity, as well as multi-level streams and industry trajectories. The theoretical framework developed can facilitate an analysis of many policy processes that deal with industry-specific problems, of which the shift from low emission to zero emission technologies is just one. Using the case of decarbonisation of the automotive industry in the UK, the relationship between technological, policy and market windows of opportunity in related industries have been identified, as well as their relationship with the agenda setting process. The interrelationships between these concepts were visualised using an interactive 3D modelling technique. Analysis of the theoretical literature using the concept of windows of opportunity has revealed the novelty of this approach, which can be further applied to analyse agenda setting and sustainability transition processes in other industries and regions.

The constructed theory clarifies the role of the shift of policy agenda to net zero in the EV transition processes in the UK. It highlights the important role of individuals putting pressure from the landscape level on the socio-technical regime. The sequence of opening and closing windows of opportunity is clarified, as well as the types of windows involved in the transition process. In addition, future scenarios of EV transition in the UK are provided.

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List of Abbreviations

Abbreviation	Meaning
ACF	Advocacy Coalitions Framework
AEV	Automated and Electric Vehicles
BEAMA	British Electrotechnical and Allied Manufacturers' Association
BEIS	Department for Business, Energy & Industrial Strategy
BEV	Battery Electric Vehicles
BSI	The British Standards Institution
CO2	Carbon Dioxide
CPO	Charge Point Operator
DC	Discourse Coalitions
Defra	Department for Environment, Food & Rural Affairs
DESNZ	Department for Energy Security & Net Zero
DfT	Department for Transport
DNO	Distribution System Operator
EHV	Extra High Voltage
ENA	Energy Network Association
ESC	Energy Systems Catapult
EU	The European Union
EV	Electric Vehicle
EVET	Electric Vehicle Energy Taskforce
EVSE	Electric Vehicle Supply Equipment Trade Association
FCEV	Fuel Cell Electric Vehicles
FOI	Data obtained via a Freedom of Information request
GB	Great Britain
GHG	Geenhouse Gas Emissions
GT	Grounded Theory
HEV	Hybrid Electric Vehicles
HM	Her Majesty
HMT	His Majesty's Treasury
HV	High Voltage
ICE	Internal Combustion Engine
LV	Low Voltage
MaaS	Mobility-as-a-Service
MLG	Multi-Level Governance
MLST	Multi-Level Streams and Trajectories
MLP	Multi-Level Perspective
MLP	Multi-Level Perspective
MSF	Multiple-Streams Framework
MtCO2e	Metric Tons of Carbon Dioxide Equivalent
MV	Medium Voltage
mWoO	Market Window of Opportunity
NOx	Nitrogen Oxides
NPV	Net Present Value
OLEV	Office for Low Emission Vehicles
ORCS	On-Street Residential Chargepoint Scheme
PB	Problem Brokers

Abbreviation	Meaning
pbWoO	Problem Window of Opportunity
PE	Policy Entrepreneur
PET	Punctuated Equilibrium Theory
PFT	Policy Feedback Theory
PHEV	Plug-in Hybrid Electric Vehicles
plWoO	Political Window of Opportunity
PM	Prime Minister
pWoO	Policy Window of Opportunity
pWoO-1	The first Policy Window of Opportunity opened in 2016
pWoO-2	The second Policy Window of Opportunity opened in 2018
RACI	Responsible, Accountable, Consulted, Informed classification
RE	Renewable Energy
SG	Steering Group
SMMT	Society of Motor Manufacturers and Traders
SNM	Strategic Niche Management
STT	Socio-Technical Transitions
TEM	Transport Energy Model
TI	Technology Innovators
TIS	Technological Innovation Systems
TM	Transition Management
TP	Tipping Point
tWoO-1	The first Technological Window of Opportunity opened in 2010
tWoO-2	The second Technological Window of Opportunity opened in 2016
tWoOs	Technological Window of Opportunity
UK	The United Kingdom
ULEV	Ultra-Low Emission Vehicles
WoO	Windows of Opportunity
WP	Work Package
WP1	Work Package 1
WP2	Work Package 2
WP3	Work Package 3
WP4	Work Package 4
ZEV	Zero-Emission Vehicle

Chapter 1 Introduction

This chapter introduces the research, justifies its necessity, and set the stages for the following chapters. It includes ten sections. Section 1.1 "Study Background and Context" outlines the context of the phenomenon and introduce the theoretical framework that underpins this study. Section 1.2 "Problem Statement" identifies the gaps in the body of knowledge that forms the basis for the research objectives. Section 1.3 "Overview of the Methodology" provides an overview of the grounded theory approach used in the research. Section 1.4 "Research Aim and Research Questions" lays out what the research intends to achieve, the specific steps that will be taken, and the research questions that will be answered. Section 1.5 "Scope of the Research" sets the research boundaries. Section 1.6 "Significance of the Study" highlights the importance of the research and the contribution it makes. Section 1.7 "Limitations" provides information on the boundaries of the study, delineating what can and cannot be inferred. Section 1.8 "Personal Motivation" connects the researcher to the research and contextualises the interpretation of data. Section 1.9 "Overview of the Study" outlines the structure of the thesis. Section 1.10 "Summary" condense the key points of Chapter 1.

1.1 Study Background and Context

The automotive industry plays an important role in the UK economy. It accounted for 10.9% of total UK exports in 2021, valued at £32 billion, of which £2.6 billion were related to petrol and diesel engine exports (Society of Motor Manufacturers and Traders, 2022). The automotive sector is also a large labour market, employing about 0.8 million people in 2021 (Society of Motor Manufacturers and Traders, 2022). There were in 2022 a total of 33.1 million private vehicles registered in the UK (DfT, 2022a). In 2021, there were 1.7 million new personal vehicles registered (DfT, 2022d), making the UK car market the third largest in Europe after Germany and France (European Automotive Manufacturers Association, 2022). Among the newly registered vehicles in 2021, 190 thousand (11.2%) were battery electric vehicles (BEV), 264 thousand (15.5%) hybrid electric vehicles (HEV), 114 thousand (6.7%) plug-in hybrid electric vehicles (PHEV), with the remaining 1.4 million (66.6%) vehicles being petrol or diesel (DfT, 2022d).

Despite the growth in sales of hybrid and electric vehicles, the transport sector remains one of the largest sources of air pollutants, accounting for about 26% (109 $MtCO_2e$) of total CO_2 emissions in the UK in 2021 (BEIS, 2023). The largest contributor to emissions in the transport sector is road transport (DESNZ, 2023). Although the car market is very important to the economy, the Government is taking measures to reduce CO2 emissions from it. Over the period 2017 to 2019, the UK government released five strategies related to the decarbonisation of the transport sector: The Clean Growth Strategy (BEIS, 2017), the Transport Investment Strategy (DfT, 2017), Industrial Strategy (HM Government, 2017), the Road to Zero Strategy (DfT and OLEV, 2018), and the Future of Mobility: Urban Strategy (DfT, 2019). 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.

To facilitate the transition from low-carbon emission technology to zero emissions, the government, in 2018, convened the collaboration platform – the Electric Vehicle Energy Taskforce (EVET); (see (BEAMA, n.d.). One of the key objectives of EVET is to bring together people from the automotive industry and energy sectors to make "a comprehensive set of proposals to Government and industry to ensure the electricity network is ready for the mass take-up of electric vehicles" (Zemo, 2023a). The work of EVET is supported and led by senior representatives of bodies such as the Low Carbon Vehicle Partnership (LowCVP; now the Zero Mobility Partnership, ZEMO) and the Energy Systems Catapult (Energy Systems Catapult, n.d.). Their activity is intended not only to accelerate but also to influence the shape of, sustainability transitions in the automotive industry in the UK.

Policymakers seek to create a significant, sustainable new market (cars with zero tailpipe emissions) via policy incentives, where the basic technology exists (e.g. batteries), but where investment in technological development must come from the private sector, indeed from several related industries within the automotive ecosystem. Moreover, these private sector actors have considerable self-interest in the shape of that policy. A policymaker may aim to reduce CO2 emissions, while a carmaker may pursue the goal of increasing market share. This conflict of interest can slow down the achievement of sustainability goals, especially if carmakers are resistant to change or policymakers are not able to adopt policies that incentivise sustainable practices. Theories that focus on two-way linkages between policy agendas and technology may provide guidance for carmakers, policymakers, and other industry stakeholders to align their strategies with sustainability goals. To date, however, there are no such theories that have been developed using interviews and archival data from one of the key platforms in the EV transition process in the UK - EVET.

Grounded Theory has earned widespread acceptance as a method for constructing conceptually dense theory in qualitative research. There are three approaches to Grounded

Theory: objectivist, constructivist and pragmatist. Using the canonical objectivist approach to GT suggests that a researcher should start without any preconceptions and use a literature review at the end of the study so as not to “import theory” (Glaser and Strauss, 1967, p.227). The constructivist approach is more flexible in terms of the literature review, with the suggestion that using it at the beginning of the research can help to “reveal gaps in extant knowledge and state how your grounded theory answers them” (Charmaz, 2006, p.168). At the end of the study, researchers can then utilise a literature review to “position your study and clarify its contribution” (Charmaz, 2006, p.168).

The pragmatist approach is more demanding of the literature review, but more flexible in terms of the research stages at which it can be used. The GT approach of Bryant (2017), whilst not explicitly referred to as a pragmatist GT approach, has been confirmed as such in correspondence with the author. This approach can include multiple matching stages with the literature, after the initial literature review. The researcher using pragmatist GT should not start research “without any preconceptions” but rather “clarify … motivation and level of experience and familiarity with the context and issues at hand” (Bryant, 2017, p.354). In addition, researchers almost certainly have to decide to carry out research because of familiarity with the topic (Bryant, 2017, p.355). After the pilot study and writing of the initial study, the researcher can return to the literature to make the first matching between the initial theory and existing theories (Bryant, 2017, p.263). In the second round of interviews and writing up the final version of the theory, the second matching with literature takes place, which gives the researcher and reader “a clear picture how and where his main results fit with the previous [studies and] findings” (Bryant, 2017, pp.261, 263).

In the theory constructed in this thesis, there are elements of concepts brought in from the Multiple-Streams Framework (MSF) and Multi-Level Perspective (MLP) framework, as discussed below. The problem statement of this chapter shows that each of these theories has limitations in explaining the role of technology in setting the net zero policy agenda and its impact on the automotive industry in the UK, which is one of the main reasons for developing a novel theory, drawing them together, but also based on the unique primary data collected from EVET. This is therefore data-driven research, where the concept was brought in using the bottom-up approach and reflecting the data collected. This approach is consistent with pragmatist GT, which is one of the fundamental motives to apply this method. More details on the methodology are provided in Chapter 3.

An appropriate framework to study the socio-technical transition required to create a fully functioning EV market is the MLP. This framework relates to the theory of socio-technical transitions (STT) to sustainability (Geels, 2018c) and emphasises the importance of radical innovations in this process, while recognising the complexity of the interaction between political, technological, economic, and social factors. Other key theoretical frameworks in the STT literature include Technological Innovation Systems (TIS), Transition Management (TM), and Strategic Niche Management (SNM); see (Smith, Voß and Grin, 2010; Markard, Raven and Truffer, 2012; El Bilali, 2020). Out of these frameworks, the MLP, has been considered the most appropriate to study the process of transition of EV from the niche market to the mainstream, for several reasons. Compared with the TIS and TM frameworks, the MLP is specifically focused on explaining the transition of technologies, from the technological niche level to the established socio-technical level, by considering the interplay of multiple factors at the meso and macro levels of analysis. On the other hand, TIS and TM approach more explicitly focus on firm strategies and the agency level (Markard and Truffer, 2008; Rotmans and Loorbach, 2009). SNM is the best suited to explain the early stages of innovations, MLP provides a view on destabilising the existing regime level and contextualising SNM (Schot and Geels, 2008). As a result, MLP presents a more comprehensive approach to the study of socio-technical transitions of EVs.

In the MLP literature, the creation of an EV market is linked with the concept of ‘transition pathways’. There are four types of transition pathway in the automotive industry that differ in the scale of transformation: transformation, reconfiguration, substitution, and de-alignment and re-alignment (Geels and Schot, 2007; Mazur et al., 2015; 2018; Marletto, 2019; Kivimaa et al., 2021). First, in the transformation pathway, the basic mobility system stays the same, while incumbent actors adapt to external pressure and modify the direction of innovative activities (Geels and Schot, 2007; Marletto, 2019). Second, in the reconfiguration pathway, niche technologies are initially used to solve local problems and they then replace parts of the mobility system (Geels and Schot, 2007; Kivimaa et al., 2021). Third, with the substitution pathway, disruptive innovation accumulates at the technological niche level and then seizes a window of opportunity in response to exogenous pressure linked with, for example, environmental problems or changes in public preferences, which ultimately leads to the replacement of the current mobility system. Fourth, in the de-alignment and re-alignment pathway, rapid pressure from the landscape level destabilises the mobility system, leaving a space for multiple niche technologies, one of which will take the leading place (Geels, 2011, 2019). At the moment, there is no consensus as to which path the transformation of the automotive sector in the UK will, or could, follow.

The transition to particular technology decarbonisation can be viewed not only from the perspective of changes in technologies and social functions, but also from the perspective of the process of policy agenda setting. This perspective is particularly important for this research as the government plays an important role in directing stakeholders. By analysing the underlying processes of the policy agenda, it is possible to identify influences on policymakers and the EV transition in general.

Some of the key theoretical frameworks in policy studies include the MSF, Advocacy Coalitions Framework (ACF), Policy Feedback Theory (PFT), Punctuated Equilibrium Theory (PET) and Discourse Coalitions (DC); see (Kern and Rogge, 2018). However, for several reasons, the most appropriate in the present research is MSF. First, the low carbon transition in the automotive industry is a complex and ambiguous process, wherein technological progress and developments are inherently uncertain. Out of the aforementioned frameworks, the MSF is best at handling ambiguity and offers particular insight into the factors shaping policy discourse. The MSF utilises the concept of policy entrepreneurship and emphasises the central role of agency and individuals in policy change. This concept can shed light on the role of individual agents in relation to socio-technical systems (Kern and Rogge, 2018) and this was another reason for including the MSF in the research. Moreover, the MSF operates with the concept of windows of opportunity for policy change, which is of particular interest to this study.

Compared to other frameworks, carmakers and policymakers are not competing advocacy coalitions battling over the policy in a way that could account for the stability of the decarbonisation policy over the EV technology that exists. Thus the ACF would not be appropriate for this study. The study is less focused on the feedback of previous policy on new policy and co-evolution of socio-technical systems and policy mix, but rather it emphasises the role of individuals within windows of opportunity for EVs. In this regard, PFT was not the main focus. PET more closely aligns with the research, however, it is not interested in looking at the change in policy against a backdrop of decades of stasis. Moreover, the research is not primarily concerned with the analysis of discourse struggles and the roles of ideas in shaping policy, as well as how policies shape politics and subsequent policymaking. As a result, the ACF, PFT, PET and DC were not considered in the research.

According to recent studies using the MSF, decarbonisation of the automotive industry is associated with focusing events such as increased deaths from air pollution (Kelly and Fussell, 2015; Maltby, 2021) and high oil and gas prices during energy crises (Penna and Geels, 2015; Derwort, Jager and Newig, 2022). Policy solutions such as the introduction of low-carbon zones are developed by policy entrepreneurs and pushed to policymakers (Maltby, 2021), which subsequently leads to policy change and destabilisation at the regime level. Currently, there is no consensus in the MSF literature as to the ultimate goal of policy in creating a market for EVs, nor is there a consensus on whether a new technology or new policy should come first.

The developed theory has a practical contribution in assisting stakeholders to comprehend the process of transition, identifying effective strategies and aligning their strategies with sustainability goals. The practicality and usefulness of the theory underlies the pragmatist philosophy drawn upon in the study. It can be argued that roadmaps can serve these purposes, however they have their limitations that can be overcome by joint application with theoretical frameworks. For instance, theoretical frameworks can provide a foundation for structuring and evaluating roadmaps, as well as identifying critical factors and relationships that impact the success or failure of roadmaps.

With the aim of improving the coordination of activities and resources in complex and uncertain environments (Kostoff and Schaller, 2001), industry roadmaps can indicate possible directions for both technology and policy development (Lee, Mogi and Kim, 2009). According to roadmaps from the Advanced Propulsion Centre (2021c), J.P. Morgan (2018), and Daim et al. (2016), traditional Internal Combustion Engine (ICE) vehicles will account for a large share of new vehicle sales until 2025, then gradually decrease their share to 41-70% in 2030 and further to 0-55%, depending on the region, in 2035. ICE sales will be less prevalent after 2035 in the UK and EU regions (Advanced Propulsion Centre, 2021c) due to policy measures and the end of sales of new petrol and diesel vehicles from this year (HM Government, 2020). The percentage of newly registered BEVs in the UK by 2030 is influenced by geographic area and could reach 60% (UK Government, 2021), 75% (Green Alliance, 2021a) or 55% (Welsh Government, 2018).

One of the disadvantages of roadmaps, as the foregoing demonstrates, is that the evolution of the BEV market can vary significantly across roadmaps. In addition, scenarios can require significant ongoing revision depending on macroeconomic, political or geopolitical factors. According to Lucas (1976), policymakers must take into account the fact that economic agents can change their behaviour depending on policy changes, so mathematical models that use historical data and assume that the behaviour of the agents will be the same in the future can produce results that differ significantly from reality. To avoid the pitfall of the "Lucas Critique", policymakers must consider how agents might respond to a change in policy and how those responses might, in turn, affect the outcome of the policy. Thus, theories that analyse the process of transition to electric vehicles can complement roadmaps and help coordinate the strategies of key stakeholders.

1.2 Problem Statement

Despite the significance of the impact of the recent shift in policy from "low" emissions vehicles to "zero" emissions vehicles on the automotive industry in the UK, a number of theoretical and empirical issues remain underexplored.

Firstly, the relationship between policy agenda, technologies and windows of opportunity within the context of EV transitions in the UK warrant further empirical and theoretical elaboration.

Windows of opportunity (WoO) play one of the central roles in both the MLP and MSF, and can help in the analysis of sustainability transitions and the process of policy agenda setting. According to the MLP, first, the technologies should be created at the technological niche level, then external factors can lead to policy and regime change which opens a window of opportunity for the technological niches (Geels, 2002). Some of the articles that analysed the case of EV transition in the UK include Geels (2018b), Mazur et al. (2018), and Skeete (2019). From analysing these articles, the role of the policy agenda in WoO, as well as the year of opening and closing of windows for the EVs, were not clearly specified and require further investigation. The policy aspect of WoO as well as the opening and closure points of WoO are important as they can help distinguish the stages in the transition to EVs.

The MSF discusses the policy windows of opportunity that can lead to policy change. They can open as a result of political factors such as changes in party ideology or focusing events that draw the attention of the public and policymakers to a specific problem (Kingdon, 1984). Individuals who have an interest in a particular policy outcome can push policy proposals to the government (Ackrill and Kay, 2011). Policy solutions used within windows of opportunity may include specific technologies for the problem (Lipson, 2007). There are a limited number of articles that have examined the case of policy agenda setting in the UK automotive industry, and there is a lack of detail on the reasons and specific years for the opening and closing of policy windows of opportunity for EVs within the MSF context.

Another issue pertains to the need for further investigation into the role of technology in the policy agenda setting process within WoO; and the role of WoO in the shift of policy agendas in favour of a particular technology in the UK automotive industry. This aspect of policy agenda setting was analysed in the small number of studies that focused on other than the UK context, notably Goyal, Howlett and Taeihagh (2021) and Goyal, Howlett and Chindarkar (2020). Goyal, Howlett and Chindarkar (2020) used the concept of the technology stream to explain the role of technology innovations in shaping the policy agenda in the Indian energy sector. The authors hypothesise that disruptive innovation can be a driving force of policy change. For their specific case, the authors conclude that technology innovation was primarily used at the implementation stage. Goyal, Howlett and Taeihagh (2021) analysed the impact of technology change on the EU General Data Protection Regulation and hypothesise that technology can be framed as a solution or a problem and shape the problem stream that, as a consequence, can result in policy change. In this context, we can talk about the role of technology in the policy agenda setting process in the UK indirectly (theoretically) which requires further empirical and theoretical elaboration.

There were no articles identified that analysed the role of technology in the shift of the policy agenda in the UK automotive industry from low emission to zero emission goals, in particular those using archival data or interviews from EVET. EVET is the main platform in the UK bringing together policymakers and industry stakeholders to accelerate EV uptake. Analysing primary data of this nature can refine theories and provide deeper insights into sustainability transitions and the setting of the net zero policy agenda in the UK automotive industry.

The second issue pertains to the limited research on the key stakeholders involved in setting the EV policy agenda in the UK automotive industry between 2017-2020, and their roles in this process. Similar to the previous issue, there is scant research that explores this issue. In the literature that was identified, the following stakeholders were mentioned: policy entrepreneurs such as Friends of the Earth (Carter and Jacobs, 2014); the Waste and Resources Action Programme (WRAP), the Ellen MacArthur Foundation, Carplus, Transport for London (Cooper-Searle, Livesey and Allwood, 2018), and Mayor of London, Sadiq Khan (Maltby, 2021). That said, several issues still require clarification. These articles did not focus on the case of EV transition specifically, but rather on the issues of climate change, material efficiency in the automotive industry, and air quality, respectively. After analysing these articles, the role of carmakers, energy companies and other key stakeholders in the shift of policy agenda to EVs has yet to be clarified. Moreover, the existing research focuses on the period 2005-2016 and does not include the more recent period after the release of the Road to Zero strategy. In addition, much like the previous literature, these studies did not involve an analysis of archival data of the key stakeholders involved in the acceleration of EV transition, such as EVET and LowCVP.

Finally, there is a limited number of studies that conceptualise and theorise the dynamic and two-way linkages between technology and the policy agenda within the context of windows of opportunity for EVs. No articles were identified that focus on this topic using the MSF, or in the UK context, and there are very few that elaborate this relationship in using the cases of other countries. Among them, Werner and Onufrey (2022) used a comparative case study of two pilot projects on the electrification of trucks in Sweden. Derwort, Jager and Newig (2022) used the case of stainability transition in the energy sector of Germany over the period 1970-2019. Kulmer et al. (2022) explore the diffusion of low-carbon technologies such as photovoltaics, residential heat pumps, and electric vehicles over the period 1950-2018 in Austria. Among these studies, none applied the GT approach to scrutinising elite interviews from policymakers and carmakers, or archival data from government-established Taskforces. Such an approach could help in developing relevant and conceptually dense explanations of the linkages between technology, the policy agenda and windows of opportunity for EVs.

1.3 Overview of the Methodology

This section provides a brief overview of the research philosophy, the rationale of the data analysis method and the role of pre-established theories in the research.

This study concerns a real-world problem and aims to offer a practical solution - a theory and theoretical framework that can be used to explain the shift of policy agenda from low emission targets to zero emission targets in the UK automotive industry and its impact on the industry. It suggests that reality is not only objectively recognisable but is created through our experience and interaction with it. Knowledge is temporary and subject to revision in the presence of new evidence and arguments, and is best seen as a tool for achieving specific goals. This view of reality and the nature of knowledge is most suitably addressed via a Pragmatist-cum-Constructivist philosophy, where the ontological and epistemological position is associated with constructivism and pragmatism respectively. According to Martela (2015, p.553), “the quintessential character that makes scientific inquiry pragmatist is that one remains constantly aware of the aims of the inquiry, the practical consequences that the inquiry is hoped to have”.

Qualitative research provides a view of reality from the participants' perspective (Corbin and Strauss, 2015) and can help in the development of the practical and relevant theory of the phenomenon under investigation. Grounded theory is one of the most widely used methods of constructing theory using qualitative data (Denzin, 1994; Timonen, Foley and Conlon, 2018). According to Fendt and Sachs (2007) grounded theory can provide a systematic approach to handling and analysing data for building processual and conceptually dense theory grounded in the data, which corresponds to the aim of this research.

There are three approaches to grounded theory: objectivist, constructivist and pragmatist. Canonical Grounded Theory is widely referred to as the objectivist method where the researcher starts without any preconceptions. In this practice, the research tries to minimise the impact of the subjective interpretation of data while coding. The constructivist approach acknowledges the interpretivist inclination of the theory and the impact of the researcher in collecting and interpreting the data, wherein the literature review can be included at the beginning of the research. It is worth noting that constructivist GT is flexible regarding using the literature review as the researcher can start the research without it.

The pragmatist approach recognises the subjectivity of the data analysis, but it is more demanding regarding the inclusion of the literature. It is possible to engage with it at the beginning of the research while writing the research proposal and the literature chapter. The literature can also be used at the initial stage of theory development after getting the initial GT results, and at the second stage of theory development after the main GT results are produced. The key authors of objectivist GT are Glaser and Strauss (1967), of constructivist GT it is Charmaz (2006), and pragmatist GT it is Bryant (2017). According to Charmas (2006) and Bryant (2017), it is worth mentioning that all three approaches have abductive roots in creating the theory; however only Bryant (2017) links his guidance to GT explicitly with abductive reasoning.

This research uses pragmatist GT for several reasons. First, an extensive literature review was conducted at the beginning of the study, as a result of which the theory built clarifies and includes the concepts from established theories. Secondly, the literature was used at the initial and second stages of theory building after getting the initial and main GT results respectively. It was necessary to situate theoretical codes within the broader context of theoretical knowledge and clarify gaps and inconsistencies in developing theory. In addition, literature was used in the discussion chapter when the theoretical framework was compared with the literature in order to locate the findings within the scientific domain. Thirdly, inferences in this research were made relying on abductive reasoning, trying to find the most plausible explanation of the phenomenon. Finally, the study has an underpinning idea to create knowledge that can be practically useful, thereby demonstrating the real world validity of the propositions made. Based on the theory, an interactive 3D visual representation of the theoretical framework has been built in AutoCAD with the hope of demonstrating its practical application by stakeholders for the phenomenon under investigation.

The elements that are the essence of GT, that distinguish this method from others, are the specifics of data collection and data analysis, itstheory-generating purpose, theoretical sampling approach, theoretical saturation, validation approach, and abductive reasoning. These features of GT are the reason for choosing this method which, in combination, allows the development of a relevant, practical and conceptually dense theory based on the data provided by participants in the research process. These aspects of GT will be discussed in more detail in Chapter 3. Provided here is just a brief explanation of these features.

The data collection and analysis in GT happen simultaneously, but it is also an iterative process (Bryant, 2017, p.349). GT uses an open, focused and theoretical coding approach (Charmaz, 2006) that encourages the development of abstractions to encompass the process of actions and social interactions (Bryant, 2017). "Generating theory is the prime objective of GT" wherein this method can generate both formal and substantive theories (Bryant, 2017, p.349). In the building of grounded theory, the phenomenon grounded in the data can be studied through a theoretical sampling approach, wherein data are collected to see the big picture first and then to enable and dive into the details. Using a camera analogy, the researcher uses multiple lenses first, to "view a broad sweep of the landscape" and then changes lens several times "to bring scenes closer and closer into view" (Charmaz, 2006, p.14). This way, every new participant is selected to clarify questions that arise from previous interviews, until theoretical saturation is reached. This refers to the moment of repetition of the codes (Strauss and Corbin, 1998), "when the researcher(s) can justify their view that there is sufficient data to substantiate their model" (Bryant, 2017, p.350). The theory has to be validated against incoming data during the research and with participants during the research and at the end of the study (Corbin and Strauss, 2015).

Grounded Theory as used in this study finds its roots in pragmatism, which is characterised by abductive reasoning. Thus, the researcher, studying the phenomenon, tries to find the most plausible explanation of the phenomenon. As Strauss and Corbin (1990, p.63) state, "all data is data" thus researchers should be prepared "to collect all types of data in order to ensure … cover the field completely". Based on this, in addition to interviews, descriptive statistics, observations and archival data are also used in the analysis.

Grounded Theory typically answers "What" and "How" types of question, to encompass the process of actions and social interactions (Strauss and Corbin, 1998; Charmaz, 2006; Corbin and Strauss, 2015; Bryant, 2017). At the stage of collecting data, questions such as "What" often determine the key variables in the data and the characteristics of those variables. "How" questions are related to actions and interactions of social processes. These questions are designed to look for the mechanisms that underlie the data and the strategies and tactics associated with the data. In grounded theory, "what" questions are often associated with causal conditions, intervening conditions, and contextual conditions of action-interactions strategies of participants of the phenomenon (Strauss and Corbin, 1998). The "how" types of question are often related to an explanation of the process of acting and interacting within the social process. Subsequently, linking various action or interaction strategies with different causal conditions, intervening conditions, and contextual conditions allows the researcher to develop a conceptually-dense theory describing the phenomenon under investigation. The specifics of the research questions used in grounded theory, as well as how theories are constructed using the Strauss and Corbin (1998) approach, influenced the choice of research questions and the focus of the investigation in the present research.

The constructed theory includes concepts brought in from both the MLP and the MSF, using the bottom-up approach that reflects the data collected. The MLP fits the purpose of the research and provides a view of the process of EV transition from the niche market to the mainstream from a socio-technical perspective. The key feature of the MLP is that it emphasises the importance of radical innovations in destabilising the existing socio-technical regime, while recognising the complexity of the interaction between political, technological, economic, and social factors.

The other aspect of transitions that the research wants to examine is the agenda-setting element of the policy process. One of the options available within the policy science literature to study this process, but also which is particularly useful for contexts of ambiguity, is the MSF. This emphasises the central role of agency and individuals in policy change and is able to shed light on their roles in the process of EV transitions.

Grounded theory can be perceived as being a context-specific approach to qualitative research and its future adaptability is a key indicator of its relevance and quality. The MSF provides a relevant example of this statement. John Kingdon constructed the MSF framework based on 247 interviews exploring agenda-setting in the United States Congress. Over time, the MSF has been adapted and decontextualised for different settings where scholars come up with their own ideas for the theory. Nowadays the MSF is one of the key frameworks in public policy analysis (Weible and Sabatier, 2018). To ensure the future adaptability of the constructed theory, comprehensive and relevant data were used. The validation with participants took place while collecting the data and after theory development. In addition, the theory creation process involves multiple matching stages with the relevant literature after the writing of the initial study and after writing up the final version.

1.4 Research Aim and Research Questions

The aim of the research is to develop a theory, using a grounded theory approach, that can explain the role of technology and individuals in the shift of policy agenda from low emission goals to zero-emission goals, as well as the impact of the shift in the agenda on the automotive industry in the UK between 2017-2020. The theory also seeks to identify the key stakeholders and their roles in setting policy agenda during the considered period. This thesis primarily focuses on exploring and explaining the transition to EVs witnessed in the UK from the EV supply side, by analysing the dynamic and two-way linkages between technology and the policy agenda. The concept of windows of opportunity will be used to explain the policy-technology relationship, developed on the basis of pragmatist GT.

Further, this research addresses three key research problems, which informed the development of three research objectives, and which themselves guide the three research questions. Below are presented the research problem, research objectives and research question relationships that informed this study. These research questions are cumulative with respect to the grounded theory approach and are essential building blocks and steps on the way to grounded theory development.

Research Question 1

Firstly, the relationship between policy agenda, technologies and windows of opportunity within the context of EV transitions in the UK warrant further empirical and theoretical elaboration. Reviewing the literature it was seen that there are a limited number of articles that have examined the case of policy agenda setting in the UK automotive industry, and there is a lack of detail on the reasons and specific year for the opening and closing of policy windows of opportunity for EVs within the MSF context. Similarly, for MLP research focusing on the EV transition in the UK, the year of opening and closing windows for the EVs was not clearly specified either, and thus requires further investigation. Moreover, within the context of windows of opportunity, the role of technology in the policy agenda setting process and the shift of policy agenda in favour of a particular technology in the UK automotive industry was not clear.

This research problem informed the first objective that relates to the analysis of interviews and EVET data and the conceptualisation of the relationship between policy agenda, technologies and windows of opportunity for EVs. The theoretical framework will encompass the overall structure of the phenomenon and facilitates the analysis of the shift of policy agenda from low-emission goals to zero-emission goals, as well as the role of technology in this process. In addition, the constructed framework facilitated the identification of the key stakeholders and their respective roles in setting the EVs policy agenda in the UK automotive industry between 2017-2020. This objective was addressed by RQ1.

RQ1: How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry?

Research Question 2

The second research problem is associated with uncertainty from the theoretical and empirical literature as to who the key stakeholders were in setting the EV policy agenda in the UK automotive industry between 2017-2020 and what their roles were in this process.

This research problem informed the second research objective focuses on identifying the main stakeholders and their roles in setting the EV policy agenda in the UK. The analysis here will be based on primary data within the context of the constructed theoretical framework. In addition, the interrelationship between stakeholders will be explored.

The research question corresponding to this research objective is as follows:

RQ2: Who were the key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020 and what were their roles in this process?

Research Question 3

Finally, there is a limited number of studies that conceptualise and theorise the dynamic and two-way linkages between technology and the policy agenda within the context of windows of opportunity for EVs.

The third objective of the research targets the theorisation of the processes of the EV transition in the UK, from a niche market to the mainstream. This will involve explaining the dynamic and two-way linkages between technology and policy agenda, as well as the roles of key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020. During the theorisation process, the concepts of the theoretical framework will be used, in which windows of opportunity take the central role.

RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK?

1.5 Scope of the Research

This research focuses on the UK automotive industry and, in particular, EVs. The study period covers 2017-2020 when the shift from a low emission policy to zero-emission policy in the UK took place. The main contributors to this study are senior managers in the automotive industry, energy companies, EV infrastructure companies, policymakers, consultants, and academics involved in EVET. The study also included participants who, by education or professional background, are related to the automotive industry in the UK. It primarily concentrates on the role of policymakers, carmakers and related industry stakeholders involved in the shift of policy agenda to net zero, and does not explore aspects of consumers' behaviour. Thus the study aims to explain the process of EV transition from the supply side rather than from the demand side of EVs. As a result of this, the constructed theoretical framework does not operate with the cultural and behavioural elements of the socio-technical regime, such as cultural discourses and user patterns mentioned by Geels (2004) and mainly focuses instead on regulatory and technical aspects of transitions, such as technologies, policies, and infrastructures.

1.6 Significance of the Study

According to Sovacool, Axsen and Sorrell (2018) the most impactful research is both socially useful and improves fundamental understanding. This is linked with research questions that should both advance theory and address relevant social problems that matter to scholars, practitioners and other stakeholders (Sovacool, Axsen and Sorrell, 2018, p.14). In the process of answering research questions, the research will provide methodological, theoretical and empirical contributions.

From a methodological point of view, grounded theory has not been used widely to study the shift of policy agenda to net zero targets in the UK. Applying this method to the policymaking process in the UK context yields important methodological insights regarding the development of substantive GT theories. In addition, this research demonstrates how theorising can be illuminated using an interactive 3D model (defined and discussed in Chapter 4).

The empirical contribution of this study is associated with the collection and analysis of unique data provided by EVET, which informs the development of the theory. Given the limited number of studies focusing on the agenda-setting process in the UK automotive industry, the analysis of primary data provided in the research will extend the understanding of such processes. This includes identifying key stakeholders, their roles, and interrelations in the agenda-setting process in the UK automotive industry. The elite interviews used in the study will reveal their approach to this process in the UK.

From a theoretical perspective, the research proposes a novel theoretical framework that can be used the examine the policy agenda-setting processes related to technology-centric issues, such as the shift from low-emission to zero emission goals. By bringing in the concept of multiple windows of opportunity and industry trajectories, the policy-technology relationship will be further elaborated. More broadly, the theoretical framework and the concept of multiple windows of opportunity used in the study will extend the understanding of stages in the EV transitions in the UK.

From a practical perspective, an interactive 3D visual representation of the theoretical framework constructed in AutoCAD can aid the strategic decision-making of policymakers and carmakers and align their strategies with sustainability goals. In addition, it can be adapted for other studies and applied in other contexts and countries.

1.7 Limitations

There are several limitations to the study primarily associated with the regional and industry specificity of the theory and its subjectivity. Firstly, the theory constructed is regional and industry-specific. This study uses information from UK companies, policymakers, and industry experts; therefore the developed theory largely focuses on the UK context. The interview data were collected from policymakers, academics and experts in the automotive industry, renewable energy industry, fuel industry, battery industry, and charging points industry. Consequently, the theory mainly centres on interactions between these industries. The FOI data was obtained from the Taskforce focused on accelerating the transition of EVs, thus the constructed theory mainly represents the perspective of companies engaged in EV uptake. The interviews predominantly involved middle managers and senior managers, leading the research findings to reflect the decision-making processes mainly from the senior management perspective, with less emphasis on the operational level. Lastly, the study was conducted during the period of 2017 – 2020 and represents the view on the process only from this time period.

The second limitation is associated with the subjectivity of theory. The grounded theory method implies that the researcher is involved in both collecting and interpreting the data, which is itself the participants' interpretation of the phenomenon under investigation. In this way, the theories constructed using grounded theory inevitably have a subjective element. In order to mitigate this impact and ensure the theory is complete, accurate and useful, validation was used at the coding, writing, and theory testing stages. This involves the comparison of concepts with raw data (Strauss and Corbin, 1998, p.161). The research is approached in a transparent manner - direct quotes are given, showing explicitly the process of deriving the conclusions from quotes. After the completion of the theory, it was validated by participants.

Finally, it is worth mentioning that due to time constraints on data collection and data analysis, the sample size of interviews and archival data was limited to 48 interviews and 118 archival documents. The Covid-19 pandemic complicated the fieldwork, as automaker factories and industry conferences for which tickets had been purchased were postponed. This increased the time for getting access to interviewees and increased the data analysis stage. As a result, the number of interviews and archival documents was lower than initially planned, with the focus being narrowed specifically to the EV technology.

1.8 Personal Motivation

The topic of EV transitions in the automotive industry is related to my education and work background. My specialist diploma in international business, which I completed in 2007, was devoted to the sustainability of transport. After graduation, I worked in a research organisation where I continued to study innovation in the transport sector. In 2009 I published a monograph that analysed the energy efficiency of transport and the prospects for electric vehicles. For the next four years, I continued to work on the topic. In 2015, I completed an MBA degree with a thesis focused on the synergetic effect of the development of renewable energy and high-tech industries in resource-rich countries. The automotive industry played a central role in this study. Long-term experience working as a researcher and analyst of innovation in the automotive industry served as personal motivation for choosing this topic of research.

1.9 Overview of the Study

This study consists of 6 chapters outlined below.

Chapter 1 “Introduction” provides information on the research background and context, research problem, research aim and objectives, research significance and limitations. The research problem is related to the lack of theories that can explain the role of technology in the shift of policy agenda from low emission goals to zero-emission goals, and its impact on the automotive industry in the UK over 2017-2020. There are no theories that use interviews and archival data from government-established Taskforces, such as EVET.

Chapter 2 "Literature review", provides a review of the literature that discusses the transition of electric vehicles from a niche market to the mainstream. It also analyses the structural elements of the MLP and MSF, as well as key players and their role in the transition process. In doing so, it was determined that there is uncertainty in the existing MLP and MSF literature as to who the key stakeholders are and what their roles are in the process of agenda setting and the transition to EVs in the UK. There is also no literature that uses interviews with senior managers or the government Taskforce to conceptualise the policy agenda – technology relationship in the UK automotive industry. Based on this literature gap, the rationale for this study was determined.

Chapter 3 "Research philosophy and research methods" explains the ontological and epistemological positions of the research, the reasons for using pragmatist grounded theory, research design, the concept of theoretical saturation, data collection and analysis methods, and the process of theory creation. The theory validation procedure is also explained at the end of the section.

Chapter 4 "Presentation of Findings" includes four main sections. In the first section, the primary data are conceptualised and the structural elements of the theoretical framework described. The second part focuses on identifying the main stakeholders in setting the EVs policy agenda in the UK. This is based on the analysis of primary data in the context of the constructed theoretical framework. Once the main stakeholders are identified, the third part of this chapter provides an analysis of the role of these stakeholders in setting the EV policy agenda in the UK. The fourth part targets the theorisation of the processes of the EV transition in the UK from the niche market to the mainstream market. This involves explaining the dynamic and two-way linkages between technology and the policy agenda, as well as outlining the roles of key stakeholders in setting the EV policy agenda in the UK automotive industry between 2017-2020.

Chapter 5 "Discussion" is structured according to the research questions. The findings of this research will be compared with the literature used in the literature review chapter as well as with new literature relevant to the research. Thus the grounded theory will be situated in relation to the state of the art in the field of knowledge available today.

In Chapter 6 “Conclusions”, research questions will be restated, and a summary of the research findings will be given. It also discusses the implications and contributions of findings, outlines the limitations of the study, and gives recommendations for future research.

1.10 Summary

Over the period 2017 to 2019, the UK government released five strategies related to the decarbonisation of the transport sector: The Clean Growth Strategy (BEIS, 2017), the Transport Investment Strategy (DfT, 2017), the Industrial Strategy (HM Government, 2017), the Road to Zero Strategy (DfT and OLEV, 2018), and the Future of Mobility: Urban Strategy (DfT, 2019). 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.

One of the most appropriate frameworks to study the transition of EVs from the niche market to the mainstream is the MLP framework. The key framework that is best at handling ambiguity and offers a particular insight into the factors shaping policy discourse is the MSF. There are currently very few studies using the MSF to analyse the process of agenda-setting during the transformation of the automotive market in the UK.

Despite the significance of the impact of the recent shift in policy from "low" to "zero" emissions vehicles, a number of issues remain underexplored. Firstly the concept of windows of opportunity (WoO) for EVs warrant extended research. The second issue pertains to the need for further investigation into the role of technology in the policy agenda-setting process and the shift of policy agenda in favour of particular technologies in the UK automotive industry. Thirdly, it is unclear from the theoretical and empirical literature who the key stakeholders were in setting the EV policy agenda in the UK automotive industry between 2017-2020, and what their roles were in this process. Finally, there is a limited number of studies that conceptualise the dynamic and two-way linkages between technology and the policy agenda within the context of windows of opportunity for EVs.

Grounded theory is one of the most widely used methods of constructing theory using qualitative data (Denzin, 1994; Timonen, Foley and Conlon, 2018). According to Fendt and Sachs (2007) grounded theory provides a systematic approach to handling and analysing data for building processual and conceptually dense theory grounded in the data, which corresponds to the aim of this research. This research uses a pragmatist view of GT for several reasons. First, this approach implies the use of literature at the beginning of the study, during theory development, and at the end of the research in the discussion chapter, to situate the research within the existing body of knowledge. Secondly, inferences made with such an approach rely on abductive reasoning, trying to find the most plausible explanation of the phenomenon. Finally, pragmatist GT emphasises the creation of theories that can be practically useful. This is aided by the development of an interactive 3D framework in AutoCAD, that can be used in the follow up demonstrations and investigations.

The aim of the research is to develop a theory, using grounded theory, that can explain the role of technology in the shift of the policy agenda from low emission goals to zero-emission goals, and its impact on the automotive industry in the UK over 2017-2020. The theory also seeks to identify the key stakeholders and their roles in setting policy agenda during this period. This thesis focuses primarily on exploring and explaining the transition to EVs witnessed in the UK from the EV supply side by analysing the dynamic and two-way linkages between technology and policy agenda. The concept of windows of opportunity will be used to explain policy-technology relationships, developed on the basis of pragmatist GT.

The first objective of the research relates to the analysis of interviews and EVET data and the conceptualisation of the relationship between policy agenda, technologies and windows of opportunity for EVs. The second objective focuses on identifying the main stakeholders in setting the EVs policy agenda in the UK. The third objective of this study considers the analysis of the role of these stakeholders in setting the EV policy agenda in the UK. The fourth objective of the research targets the theorisation of the processes of the EV transition in the UK from the niche market to the mainstream market. This will involve explaining the dynamic and two-way linkages between technology and the policy agenda, as well as the roles of key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020.

In order to achieve the research objective the following three research questions are used.

RQ1: How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry?

RQ2: Who were the key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020 and what were their roles in this process?

RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK?

Because the scope of the research focuses primarily on the role of policymakers, carmakers and related industry stakeholders in the shift of the policy agenda, rather than the demand side, the constructed theoretical framework does not operate with the cultural and behavioural elements of socio-technical regime, such as cultural discourses and user patterns mentioned by Geels (2004), but focuses mainly on regulatory and technical aspects of transitions, such as technologies, policies, and infrastructures.

In the process of answering research questions, the research will provide methodological, theoretical and empirical contributions. However, there are several limitations to the study primarily associated with the regional and industry specificity of the theory and its subjectivity.

Chapter 2 Literature Review

The pragmatist approach to GT used in this study suggests using the literature review "to situate the planned research against current knowledge" (Bryant, 2017, p.350). Researchers have to be familiar with the literature "as a result of immersion in the field which is why they are keen to pursue further research" (Bryant, 2017, p.351).

The main research interest of this study is the process of transition of electric vehicles from the niche market to the mainstream market in the UK, from both policy agenda setting and technological change perspectives. The most suitable frameworks to study such a phenomenon are the Multi-Level Perspective and Multiple Streams Framework. The MLP framework was selected due to its comprehensive approach in the analysis of socio-technical transitions of EVs. The MSF is widely recognised as the best framework to handle the ambiguity of policy agenda setting, reflecting the challenge of the transition to EVs.

In reviewing the literature, the structural elements of the above theoretical frameworks will be explained, as well as the key stakeholders and their roles in the studied process. Both theoretical and empirical articles will be used. In most cases, the empirical articles focus on the UK automotive industry. In addition, a review of the UK technological, product, fuel, and policy roadmaps will be provided to explain the technological and policy landscape in the automotive industry in the UK. By doing this the theoretical and empirical basis of knowledge required for this study will be developed, and the research gap will be identified that informs the research questions.

It is important to note that the practicality of the developed theory is underlined by the pragmatist research philosophy. Reviewing the roadmaps will help to understand the structure of the planning tools that the developing theory is aiming to complement, to support the coordination of the strategies of key stakeholders. This is another reason for the inclusion of roadmaps in the literature review.

This chapter has the following structure. In Section 2.1 "Literature Review Method" the specifics of the literature review in grounded theory are explained, and the taxonomy, synthesis method, and literature search method are presented. The literature sample used in the literature review at the beginning of the research is discussed in Section 2.2 "Literature Review Sample". Section 2.3 "Review of Technological, Product, Fuel, and Policy Roadmaps" includes a review of roadmaps, providing milestones in the development of the industry until 2035. Section 2.4 "Changes in Technologies and Social Functions" explains developments in the automotive industry from a socio-technical perspective, by reviewing the MLP literature. Transition pathways, the role of government and carmakers in regime change, and the motivation of incumbent actors were analysed in this section. Section 2.5 “Handling Ambiguity in the Decarbonisation of the Automotive Industry” focuses on the agenda-setting dimension of transitions, by reviewing research on the MSF. This section clarifies the process of agenda setting in the UK, key actors, and their role in this process. Section 2.6 “The Interaction of Actors Across Multiple Levels of Decision-Making” discusses the impact of international, regional, and national policies on carmakers' strategies and interactions across multiple levels of decision-making. Section 2.7 “Identifying Research Gaps” presents research gaps identified in the literature review that will be filled by this study. Section 2.8 “Summary” summarises the chapter.

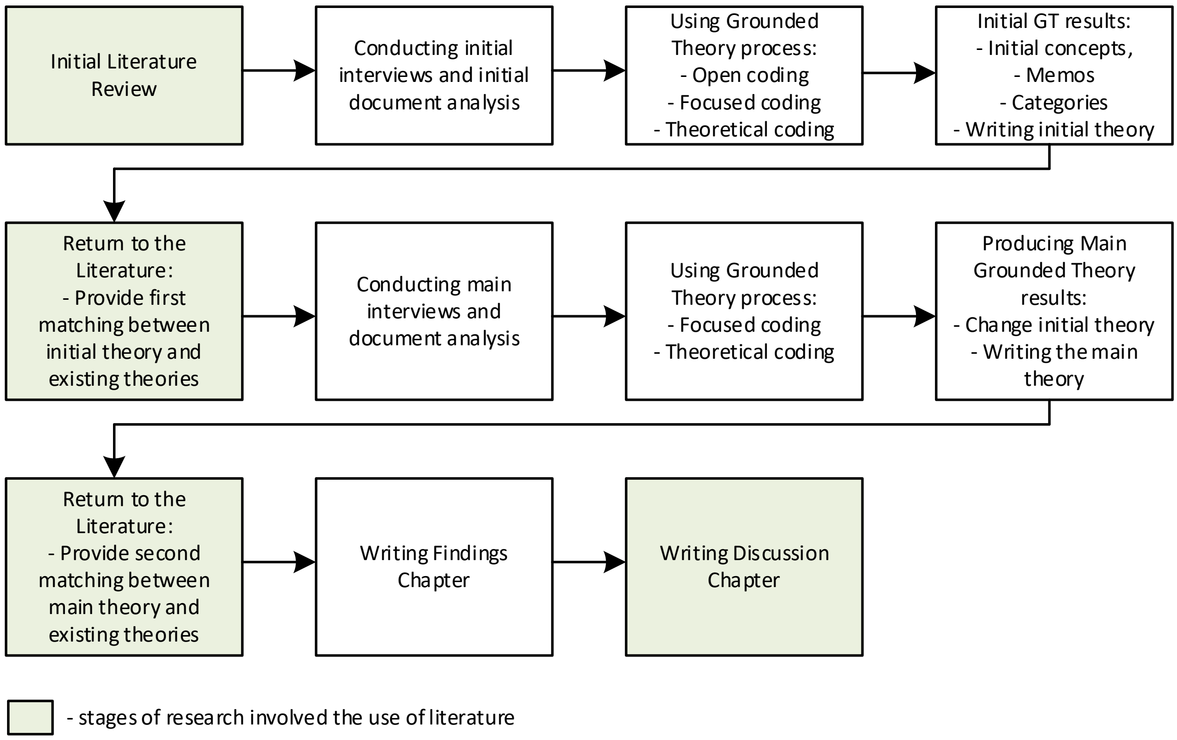
2.1 Literature Review Method

This section describes the nature and role of the literature review in objectivist, constructivist and pragmatist grounded theory research and the process of literature review implemented in this study.

There are three approaches to grounded theory: objectivist, constructivist and pragmatist. The canonical Glaser and Strauss (1967) Grounded Theory approach is widely referred to as the objectivist method, where the researcher starts without any preconceptions. In this practice, the researcher tries to minimise the impact of the subjective interpretation of data while coding and uses a literature review at the end of the study trying not to “import theory” (Glaser and Strauss, 1967, p.227). Reviewing the literature helps the researcher locate their theory in the current knowledge domain. “Once analysis has been completed, it makes sense for researchers to compare their theories to established theories for similarities and differences and to be able to locate their theories within the larger body of professional theoretical knowledge” (Corbin and Strauss, 2015, p.70).

The constructivist approach is more flexible in terms of literature review, which can be used at the beginning of the research to “reveal gaps in extant knowledge and state how your grounded theory answers them” (Charmaz, 2006, p.168). At the end of the study, researchers can utilise a literature review to “position your study and clarify its contribution” (Charmaz, 2006, p.168).

The literature review in pragmatist GT is an integral part of the study. At the initial stage, the literature is used “to indicate familiarity with the existing literature” (Bryant, 2017, p.350) and “to situate the planned research against current knowledge rather than using such material for precise hypotheses" (Bryant, 2017, p.350). It should be noted that "GTM-oriented research does not require a profound and critical literature review at the outset, although a case does need to be made for the potentially innovative contribution of the research proposed" (Bryant, 2017, p.350). At the later stage of theory development and theoretical coding "the researcher(s) need to substantiate their categories and concepts by taking the findings back to the literature" (Bryant, 2017, p.355). In the discussion section in pragmatist GT research, as with objectivist and constructivist GT, scholars need to "locate their work against existing "authoritative" sources" (Bryant, 2017, p.355).



Source: adapted Bryant, 2017

Figure 2.1 Literature review and theory building process

In this study, the literature was engaged at multiple stages. First, the literature was used at the initial stage of writing the research proposal and literature review chapter. Second, it was necessary to go back to the literature at the initial stage of theory building, after getting the initial GT results. The literature was used to situate theoretical codes within the broader context of theoretical knowledge and clarify gaps and inconsistencies in developing theory. Thirdly the literature was used in the second stage of theory development after the main GT results were produced, with a similar goal as the initial theory-building stage. Finally, the literature was applied in the discussion chapter when the theoretical framework was compared with the literature, in order to locate the findings within the scientific domain. A graphical representation of the relationship between theory building and literature used in this research is shown in Figure 2.1.

Taxonomy of the literature review

Cooper's (1988) taxonomy is used to indicate the focus, goal, organisation, perspective, audience and coverage of the literature review. Characteristics of the literature review relevant to this study are marked in green in Table 2.1. Reviewing the literature, the main focus of the review is on (1) research outcomes, research methods, theories, and their applications; (2) goals of the literature review – summation of prior knowledge; (3) organisation of chapter – 'conceptual', where literature relating to the same abstract ideas appear together (Cooper, 1988, p.112); (4) perspective of the literature review – 'espousal of position', where "the reviewer undertakes the task of accumulating and synthesising the literature in the service of demonstrating the value of a particular point of view" (Cooper, 1988, p.110); (5) audience – specialised scholars and the general public; (6) coverage – representative, where the reviewer "presenting works that are representative of many other works in a field" (Cooper, 1988, p.111).

Table 2.1 Taxonomy of the literature review

Characteristics of literature review	Categories			
1 Focus	Research outcomes	Research methods	Theories	Applications
2 Goal	Quantitative data aggregation/ integration	Summarisation of prior knowledge	Criticism	Central issues
3 Organisation of chapter	Historical	Conceptual	Methodological	
4 Perspective	Neutral representation		Espousal of position	
5 Audience	Specialised scholars	General scholars	Practitioners/ politicians	General public
6 Coverage	Exhaustive	Exhaustive and selective	Representative	Central/pivotal

Sources: adapted from Cooper (1988, p.119), Vom Brocke et al. (2009, p.8)

Searching and identifying the literature

At the initial stage of research, it is important to have an initial idea and empirical interests for study, based on background assumptions and disciplinary perspectives (Charmaz, 2006, p.16). This helps to note sensitising concepts (Blumer, 1986, p.148) such as ‘sustainability transitions’, ‘technologocal innovations’, ‘agenda-setting’ and definitive concepts such as ‘electric vehicle’, ‘hybrid vehicles’, ‘automotive industry’, ‘motor fuels’. These concepts are used to set preliminary search questions and select an initial sample of articles.

The procedure of searching and identifying the literature is shown in Figure 2.2. The preliminary sample included 15 articles. In order to add to these articles, adapted snowballing was used (Wohlin, 2014, p.2). The application of the snowballing process added 30 more articles, which were subsequently used to identify the theoretical lenses of interest. A literature search was carried out in the Scopus and Web of Science (WoS) citation databases. Keyword selection and structure of search queries were made using an adaptation of the keyword search strategy of Xie and Miyazaki (2013), firstly by setting a precision criterion, and then selecting keywords meeting the criterion to search in the titles, abstracts, and author keywords (Xie and Miyazaki, 2013, p.28).

After a series of experiments, combinations of keywords, related theoretical lenses, research industries, stakeholders, regional context and combinations of Boolean search operators were clarified. Exclusion criteria for empirical articles include the following: interaction of policymakers and carmakers is not discussed; the main focus of an article is on air, sea or railway transport; the article is not related to innovations, policy or environmental studies; the research does not include a discussion of UK or EU regions. The regional context was not considered with methodological papers or analyses of general tendencies in the automotive industry.

In addition to Xie and Miyazaki’s (2013) search strategy, the CitNetExplorer software was used to search the literature. The software developed by Van Eck and Waltman (2017) allows the creation of a citation network of articles using the WoS and Scopus citation databases or database of downloaded articles. The software divides articles into clusters of mutually cited articles while creating a citation network. Typically, clusters of articles refer to a specific discipline, theoretical lens or research topic. The software also allows us to zoom into the citation network, read annotations of articles and download them. CitNetExplorer was used to identify interdisciplinary literature with multiple links between clusters of literature of interest. Once the network was built, the interdisciplinary articles were selected by reading annotations and applying the exclusion criteria.

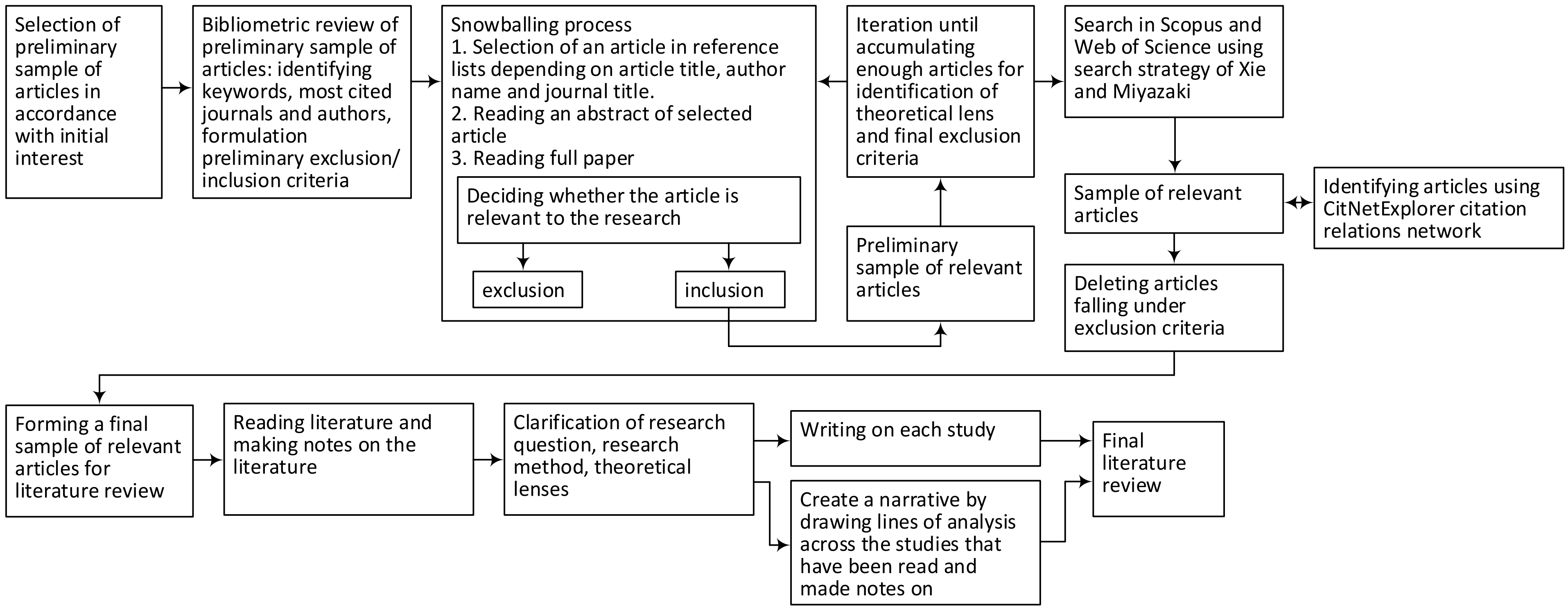


Figure 2.2 Searching and identification of the literature

Synthesis method

This study uses the narrative review synthesis method, which has two stages. The first stage involves identifying, reading, and making notes on the literature. A narrative is then created based on this information, by drawing lines of analysis across the studies that have been read and noted on. The second stage involves writing about each study, which is then added into the final literature review, the writing of which will only draw directly on a part of what has been noted for each paper in Stage 2 (Figure 2.3). The main narrative, drawing on all of the relevant literature, is created with information from a few key references communicated in more detail, without going into the details of each individual article.

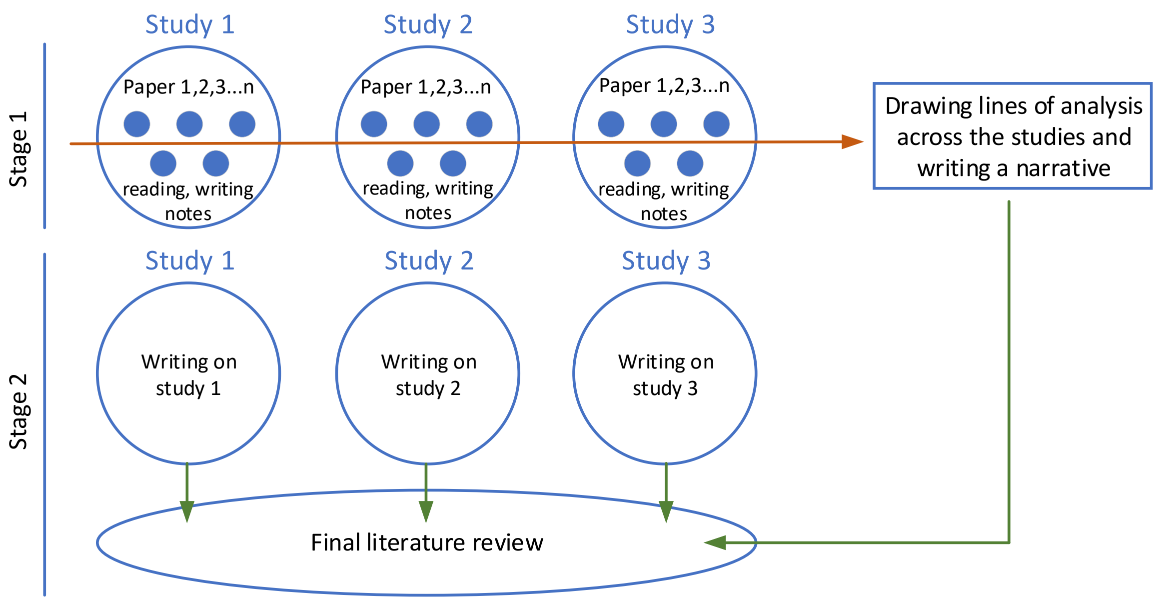


Figure 2.3 Narrative review synthesis method

2.2 Literature Review Sample

A summary of the literature review sample is presented in Table 2.2. Most of the academic journal articles focus on the automotive sector, discuss the UK region, use case study methods, are published between 2007-2022 and use theoretical lenses such as the multi-level perspective, multiple streams framework, and multi-level governance.

Table 2.3 lists representative journals used in the literature review, theoretical lenses discussed in those journals, and the most cited scholars discussing a particular theoretical lens.

Table 2.2 Summary table of the literature review sample

Purpose of article / Categories	Total	Multi-level perspectives	Multi-level governance theory	Multiple streams framework	Co-evolutionary studies	Disruptive innovation theory	Metho-dological papers
Total number of articles	130	42	23	19	26	7	13
Keyword search method	89	31	17	14	15	4	8
LR snowballing	41	11	6	5	11	3	5
Regional context							
UK	44	16	9	7	11	1	0
EU	35	11	13	7	4	0	0
Others or general	38	15	1	5	11	6	0
Industry							
Automotive	33	12	6	5	7	3	0
Renewable Energy (RE)	16	6	5	2	3	0	0
Biofuel (BF)	13	6	3	1	3	0	0
Sustainable motoring	5	3	1	0	1	0	0
Auto + RE	6	3	1	0	1	1	0
Auto + BF	1	1	0	0	0	0	0
Others	43	11	7	11	11	3	0
Article type							
Review	7	3	1	1	0	2	0
Original research	21	5	5	4	6	1	0
Methodological	13	0	0	0	0	0	13
Case study	74	31	16	8	15	4	0
Others	15	3	1	6	5	0	0
Publication time	0						
<2007	16	0	4	0	8	2	2
2007-2015	47	15	8	7	9	2	6
>2015	67	27	11	12	9	3	5
Discussed frameworks, methods or theories							
Multi-level perspective (MLP)	46	38	1	2	5	0	0
Multi-level governance (MLG)	26	1	22	3	0	0	0
Multiple streams framework (MSF)	14	0	0	14	0	0	0
Co-evolutionary analysis (CE)	18	0	0	0	18	0	0
Disruptive innovations	9	2	0	0	0	7	0
MSF + MLP + MLG	1	1	0	0	0	0	0
CE + MLP + MSF	1	0	0	0	1	0	0

Purpose of article / Categories	Total	Multi-level perspectives	Multi-level governance theory	Multiple streams framework	Co-evolutionary studies	Disruptive innovation theory	Metho-dological papers
CE + MLP + MLG	1	0	0	0	1	0	0
CE + MLP	1	0	0	0	1	0	0
Research methods and philosophy	13	0	0	0	0	0	13

Table 2.3 Representative journals and authors

MLP	**MLG**	**MSF**	**CE**
Journals			
Energy Research and Social Science	Energy Research & Social Science	Journal of European Public Policy	Energy Research and Social Science
Energy Policy	Energy Policy	Energy Policy	Research Policy
Environmental Innovation and Societal Transitions	Environmental Innovation and Societal Transitions	Policy Studies Journal	Environmental Innovation and Societal Transitions
Technological Forecasting and Social Change	Environment and Planning C: Politics and Space	Environment and Planning C: Government and Policy	Technological Forecasting and Social Change
Global Environmental Change	Innovation – The European Journal of Social Science Research	Global Environmental Change	Organization Science
Journal of Cleaner Production	Journal of Cleaner Production	Public Policy and Administration	Regional Studies
Transportation Research Part A and D	Environmental Politics	Environmental Politics	Structural Change and Economic Dynamics
Research Policy	Politics	European Journal of Political Research	Progress in Planning
Authors			
Frank Geels	Lisbet Hooghe and Gary Marks	John Kingdon	Richard Nelson
Rob Raven	Harriet Bulkeley	Michael Howlett	Marc Dijk
Bernhard Truffer	Peter Eckersley	Robert Ackrill	Aleh Cherp
Karoline Rogge	Iain Docherty	Nissim Cohen	Philip Cooke
Benjamin Sovacool	Adrian Smith	Steffen Brunner	Carla De Laurentis
Georg Holtz	Sam Hampton	Philip Catney	Frank Geels
Florian Kern	Greg Marsden	Neomi Frisch Aviram	Nick von Tunzelmann
Paula Kivimaa	William Maloney	James Palmer	Duncan Edmondson
Hansen Teis	Andy Pike	Reimut Zohlnhöfer	Arie Lewin

Note: CE - co-evolutionary literature (co-evolution of institutions and technologies); LR – literature review

Figure 2.4 shows the citation network of articles of interest that were cited more than 10 times. The citation network was constructed in CitNetExplorer. The green cluster refers to MLP articles, lilac to MSF, and blue to multi-level governance (MLG). The core publications in the scientific disciplines of interest for this study include the publications of authors such as Frank Geels, John Kingdon, Gary Marks, and Liesbet Hooghe. Figure 2.5 represents the citation relations network of the literature review sample. This network displays articles that have been cited 3 times or more.

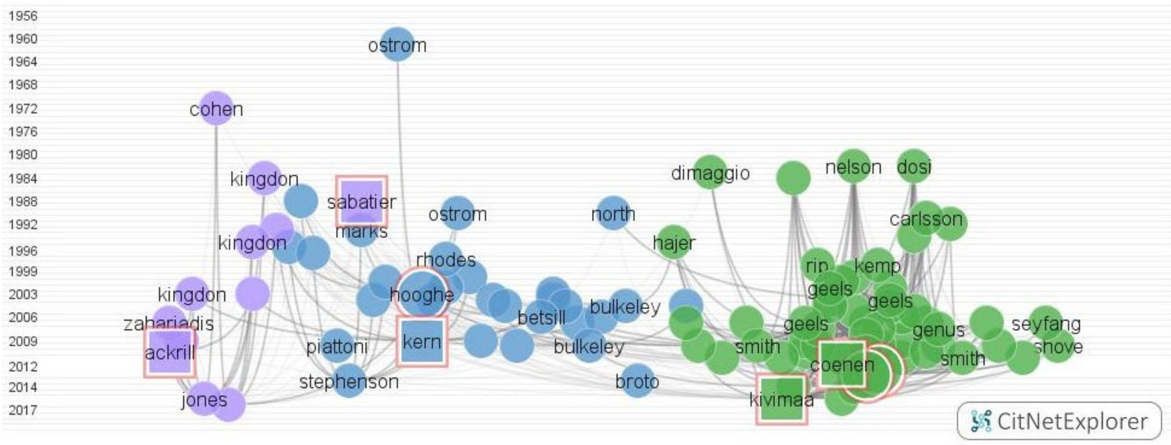


Figure 2.4 Citation relations network of the most cited authors

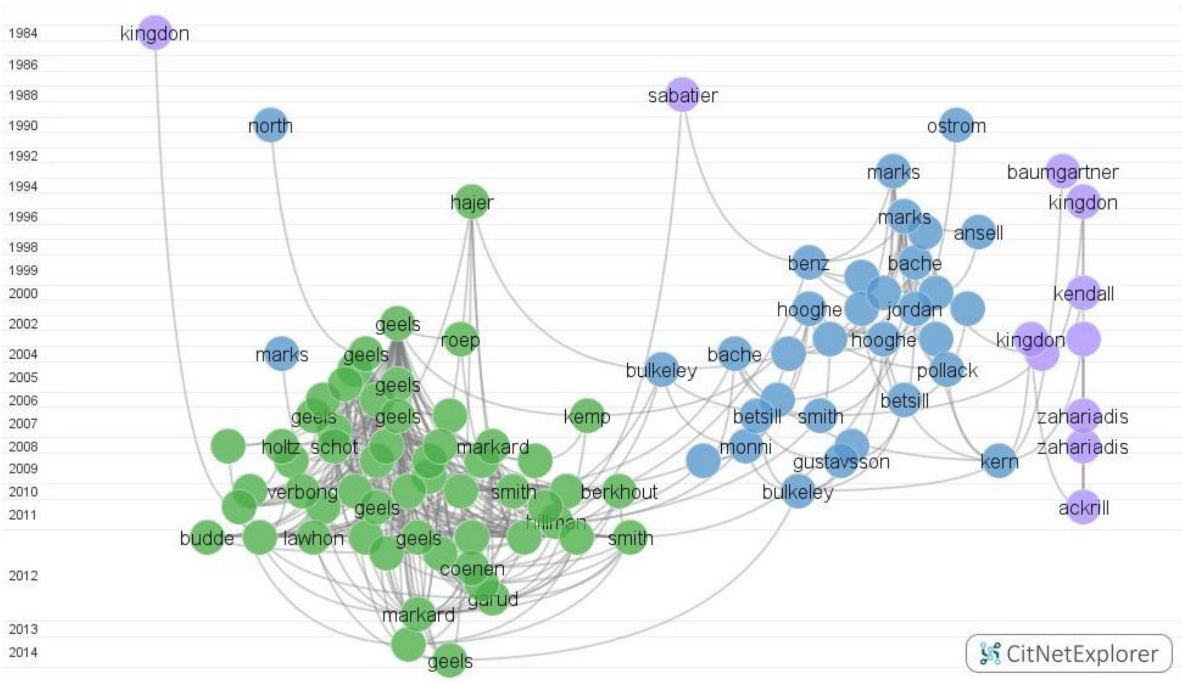


Figure 2.5 Citation relations network of the final literature sample

Figure 2.6 shows the co-occurrence network of keywords in the literature review sample, built using VOSviewer software. The network is based on an analysis of the relatedness of keywords in the documents in which they occur together. Of the 401 keywords in 130 articles, 306 keywords are linked, wherein 27 appear in at least three articles. The colour displays clusters of keywords related to the theoretical lens indicated below. For example: red shows keywords related to socio-technical transitions, purple – multi-level governance, yellow – multiple streams framework, green – machine learning. Keywords in grey appear in different contexts. Some of the largest numbers of connections have keywords such as: multi-level perspective, multi-level governance, and multiple streams framework, which are the main theoretical lenses in the literature. This co-occurrence analysis indicates the interdisciplinarity of the research.

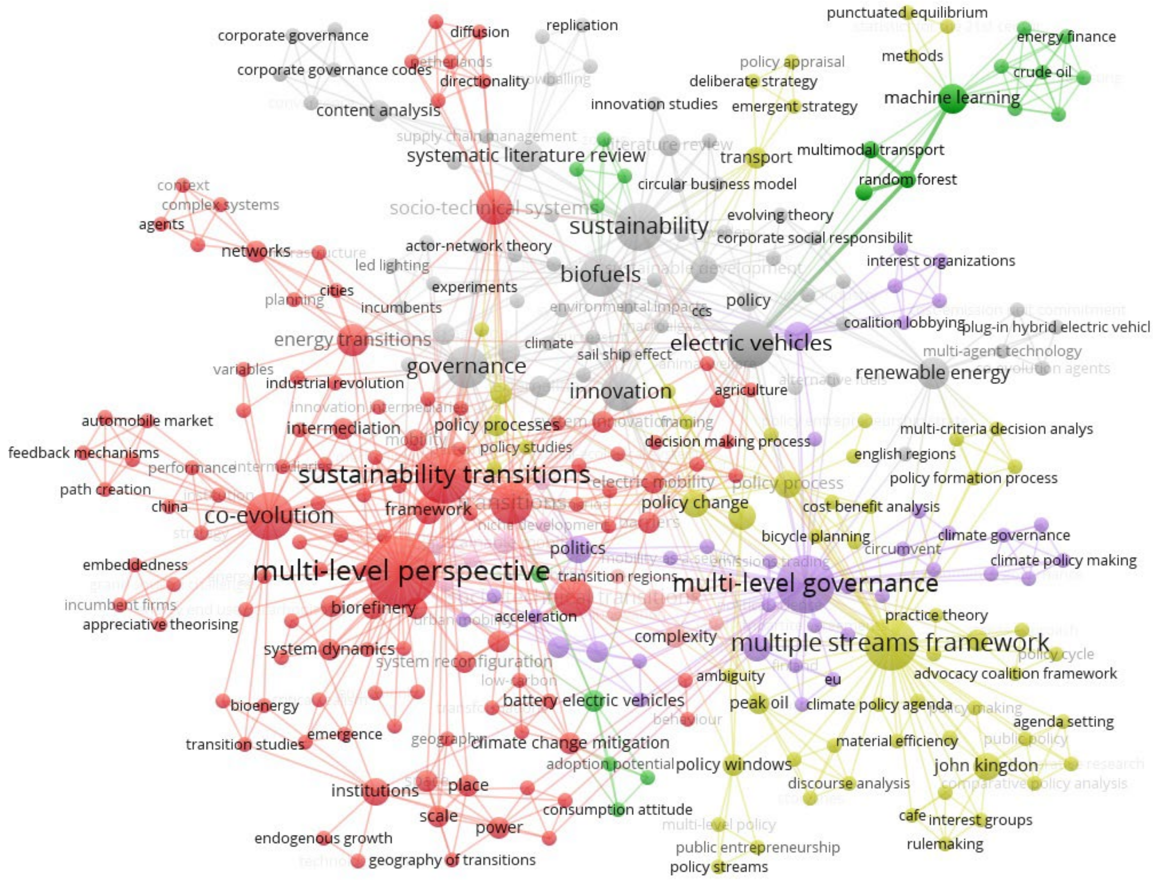


Figure 2.6 Co-occurrence network of keywords

2.3 Review of Technological, Product, Fuel, and Policy Roadmaps

Roadmaps are used in industry, government and academia as decision aids to improve coordination of activities and resources in complex and uncertain environments (Kostoff and Schaller, 2001). They can indicate possible directions for technology and policy development in specific industries or sectors (Lee, Mogi and Kim, 2009).

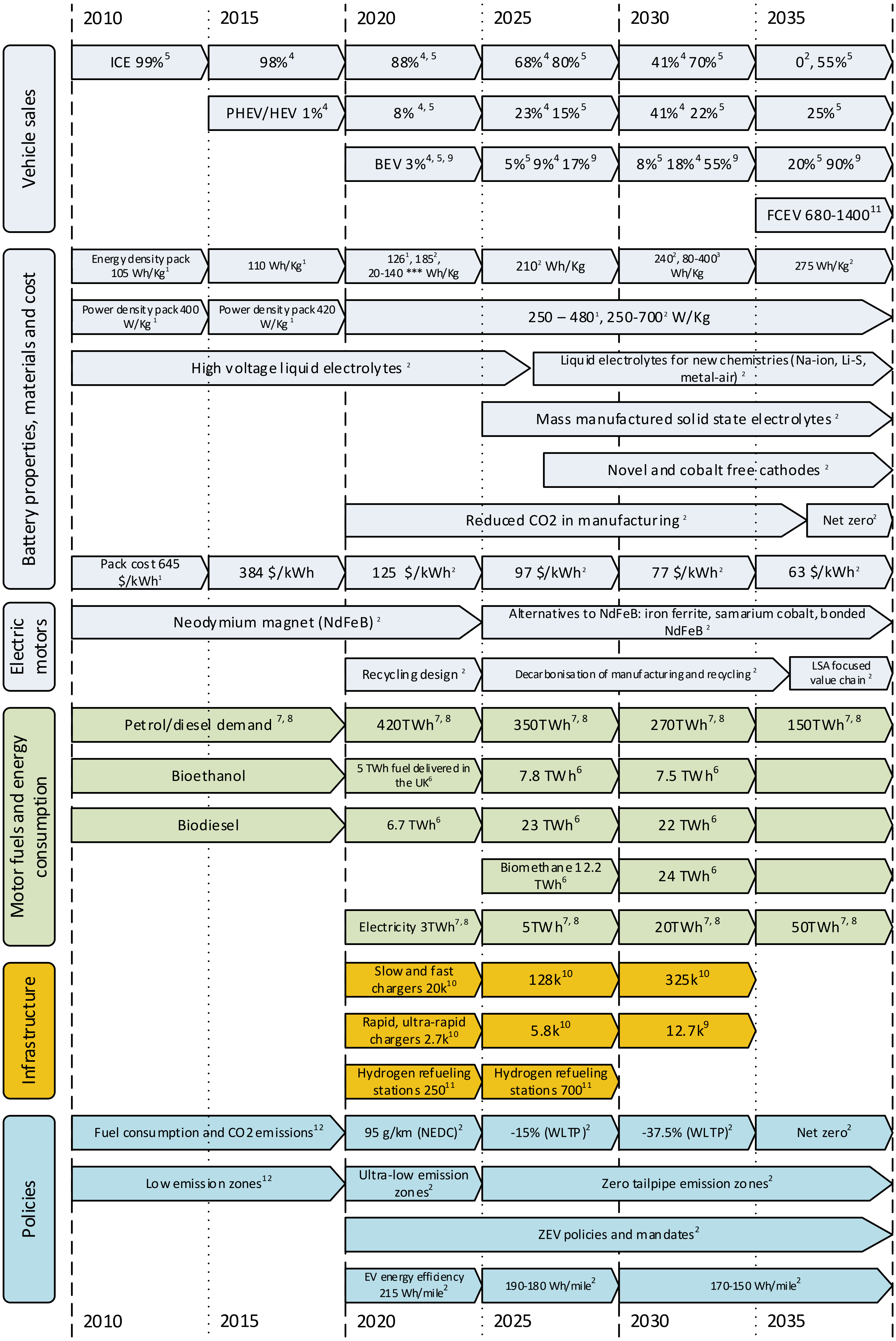
In this subsection, the automotive industry's technological, product, fuel, and policy roadmaps are reviewed. In total 13 roadmaps are used. Eight of the roadmaps focused on the UK (roadmaps no 2, 6, 7, 8, 9, 10, 11, 12 in Figure 2.7), 5 roadmaps on the EU (1, 3, 5, 6), and 2 roadmaps on the global level (4, 5). Such a review helped in understanding the technological and policy landscape in the automotive industry and the possible future trends. The roadmaps analysed are developed by both government organisations and private companies. Figure 2.7 shows a comparison of the results. Superscript numbers indicate the publisher of the particular roadmap. The elements of roadmaps are grouped into 6 categories: vehicle sales, battery parameters, electric motors, motor fuels and energy consumption, infrastructure, and policies.

According to the Advanced Propulsion Centre (2021c), J.P. Morgan (2018), and Daim et al. (2016) roadmaps, traditional ICE vehicles will account for a large share of new vehicle sales until 2025, then gradually decrease their share to 41-70% in 2030 and further to 0-55%, depending on the region, in 2035. ICE sales will be less prevalent after 2035 in the UK and EU regions compared with the international market (Advanced Propulsion Centre, 2021c).

The ban on the sale of plug-in cars will come into effect in 2035 in the UK, so most of the cars sold will be electric vehicles. PHEV have a gasoline mode and are classed as ultra-low-emission vehicles, whereas BEV use only electricity and are classified as zero emission vehicles. The Welsh Government (2018) expects electric vehicles on the road to account for 17% of new vehicle sales in 2025, 55% in 2030, and 90% in 2035. The share of hydrogen private cars will remain negligible in the 2020-2040 period. The first cost-competitive private FCEV will start to take a niche by the early 2040s (Advanced Propulsion Centre, 2021c).

Currently, the energy storage system of an electric vehicle is the most expensive element of this type of transport. Between 2010 and 2020, the cost of batteries dropped by 80%, from \$645 to \$125 per kilowatt. According to forecasts, the cost of batteries will continue to fall and is expected to be \$63 per kilowatt in 2035. Batteries are the main source of CO2 emissions during the manufacturing of electric vehicles, from cathodes, electrolyte and lithium (Aichberger and Jungmeier, 2020).

According to the Advanced Propulsion Centre (2021b), CO2 emissions are also expected to fall over time, reaching net zero after 2035. It is also assumed that starting from 2025, solid-state will be mass-produced. This technology potentially increases safety, simplifies the procedure for recycling batteries and also has a higher energy density compared to Li-ion batteries with liquid electrolyte (Yu et al., 2017). Reducing the amount of cobalt used in the cathodes will help to lower the cost of batteries, as well as reduce CO2 emissions during production. The new cobalt-free cathodes are expected to enter production after 2025.



Sources: 1 - (Fraunhofer Institute for Systems and Innovation Research, 2013); 2- (Advanced Propulsion Centre, 2021a; 2021b; 2021c); 3 - (Eurobat, 2020); 4 - (J.P. Morgan, 2018); 5 - (Daim et al., 2016); 6 - (Renewable Energy Association, 2019); 7 - (House of Commons Library, 2021); 8 - (National Grid ESO, 2020); 9 - (Welsh Government, 2018); 10 - (Nicholas and Lutsey, 2020); 11 - (Cluzel and Hope-Morley, 2015); 12 - (DfT and OLEV, 2018). 1, 3, 5 ,6, global 4, 5

Figure 2.7 Comparison of roadmaps

One of the most expensive elements of electric motors is the neodymium magnet, which is used in the rotor (Łebkowski, 2018). Neodymium is a rare earth element that is difficult to produce and is supplied mainly from China, making it difficult to diversify the supply chain. Until 2025, this element will be widely used in transport, in parallel with improving production standards to facilitate the reuse of these magnets. However, from 2025, carmakers are expected to switch to alternative materials such as iron ferrite, samarium cobalt, and bonded neodymium (Advanced Propulsion Centre, 2021a).

Gasoline and diesel consumption in the UK is expected to gradually decline from 420 TWh in 2020 to 150 TWh in 2035 (National Grid ESO, 2020; House of Commons Library, 2021). The continued presence of ICEs on the road is expected to maintain relatively high consumption of motor fuel by 2035, despite the complete ban on ICE sales. According to the Renewable Energy Association (2019), consumption of bioethanol and biodiesel will increase from 5 TWh and 6.7 TWh respectively in 2020 to 7.8 TWh and 23 TWh in 2025. No further increases in the consumption of bioethanol and biodiesel are expected from 2025 to 2030. Consumption of biomethane, however, is expected to double, from 12.2TWh in 2025 to 24TWh in 2030. Electricity consumption in transport is forecast to increase from about 3TWh in 2020 to 30TWh in 2035 and 50TWh in 2035 as the number of electric vehicles continues to grow.

The growth of electric vehicles on the road is linked to the development of charging infrastructure. Charging stations are divided into slow, fast, and rapid types. The largest part of public stations relates to fast and rapid stations, with slow charging stations associated with home charging (Welsh Government, 2018). The technology of swapping batteries is also known, but its implementation in the UK is currently not included in roadmaps. It is estimated that between 2020 and 2035 the number of slow and fast chargers in the UK will increase from 20,000 to 325,000, while rapid and ultra-rapid chargers will increase from 2,700 to 12,700 (Nicholas and Lutsey, 2020). The number of hydrogen refuelling stations will also increase during this period, however, only on a small scale from 250 units in 2020 to about 700 units in 2030 (Cluzel and Hope-Morley, 2015).

The decarbonisation policies included in the roadmaps can be divided into four groups. Policies regulating CO2 emissions and fuel consumption (1), low emission zones (2), ZEV credits and mandates stimulating BEV consumption (3) and policies stimulating the energy efficiency of electric vehicles (4). Policies regulating CO2 emissions and fuel consumption have been in use for over 30 years and will continue to tighten CO2 emission levels for ICE vehicles. It is expected that broader ZEV mandates and fiscal incentives stimulating net-zero will be released from 2035. In 2009, the low emission zone was introduced in London, in 2019 the ultra-low emission zone law came into effect, and expanded geographically. Starting from 2018, low emission zones are being introduced in other cities in the UK. It is assumed that starting from 2025, zero tailpipe emission zones will come into effect. ZEV credits have been used in the US and EU since 2012 and 2019, respectively. It is to be expected that a similar mandate will also be adopted in the UK. Finally, with the growing popularity of electric vehicles, policies will be adopted to regulate the energy efficiency of electric vehicles.

These policy roadmaps, therefore, predict a significant increase in the share of electric vehicles in the automotive market. This will be associated with the development of the charging station infrastructure, the improvement of batteries and electric motors and a decrease in their cost. The share of hydrogen cars will be negligible. Biofuels consumption will continue to grow until 2025, but then the growth will slow down due to a decrease in the sales of ICE vehicles. Environmental standards will be tightened further. Zero tailpipe-emission zones are expected to be introduced from 2025.

One of the disadvantages of roadmaps is that they are constructed based on historical data and assume that the stakeholders will behave in a similar way in the future. According to Lucas (1976) policymakers must take into account the notion that economic agents can change their behaviour depending on policy changes, so mathematical models that use historical data and expect that the behaviour of the agents will be the same in the future can produce results that differ significantly from reality. Instead, policymakers must consider how agents might respond to a change in policy and how those responses might affect the outcome of the policy. Thereby, theories that analyse the process of EV market uptake can complement roadmaps and help coordinate the strategies of key stakeholders. For instance, theoretical frameworks can identify critical factors and relationships that impact the success or failure of roadmaps and provide a foundation for structuring and evaluating the plan. The next sections provided a review of the key frameworks for this study that represent the socio-technical and policy agenda setting dimensions of EV transitions in the UK.

2.4 Changes in Technologies and Social Functions

Decarbonisation of the automotive industry involves changes in technologies and social functions (European Environment Agency, 2018). These changes are conceptualised in the theory of socio-technical transitions (STT) to sustainability (Geels, 2018c). The study of socio-technical transitions is one of the mainstream directions in the scientific literature and most of the articles analysing the change in the automotive industry in the UK are linked with this. There are a large number of theoretical frameworks for the analysis of sustainability transitions, such as technological innovation systems (TIS), transition management (TM), strategic niche management (SNM), and the social practice approach (SPA), however, the most widely accepted framework is the multi-level perspective (Smith, Voß and Grin, 2010; Markard, Raven and Truffer, 2012; El Bilali, 2020). Below we present the current views on the socio-technical transition in the UK automotive industry, using the multi-level perspective (MLP).

2.4.1 Structural Elements of the MLP

This section discusses analytical levels used in MLP as well as the nature of windows of opportunity allowing the transition of technologies from the niche market.

2.4.1.1 Analytical levels of the MLP

The MLP emphasises the importance of radical innovations. It considers transitions as interactions between three levels: ***niche***-innovations – radical innovations; socio-technical ***regimes*** – established practices and rules; and socio-technical ***landscape*** - wider context influencing niche-innovations and socio-technical regimes dynamics (Rip and Kemp, 1998; Geels, 2011).

The first level of the MLP is referred to as niche-innovations and is associated mainly with radical innovations. These emerge through pioneering activities by, for example, entrepreneurs or start-ups (Kemp, Schot and Hoogma, 1998). Geels (2019) distinguishes four groups of radical niche-innovations in mobility systems in the UK: radical technical innovation – BEV, HEV/PHEV, FCEV, FFV; grassroot and social innovation – carsharing, shift to bicycles, buses, tele-conferencing; business model innovation – mobility services, carsharing; and infrastructural innovation – compact cities, tram, light-rail, metro.

The second level is related to socio-technical regimes. These include established practices and rules that stabilise the existing system and shape the actions of incumbent actors (Geels, 2011; Fuenfschilling and Truffer, 2016). Mobility systems are stabilised by the alignment of technologies, policies, user patterns, infrastructures, and cultural discourses (Geels et al., 2017). The incumbent actors in the system are the companies, engineers, users, policymakers, the wider public, and other stakeholders with special interests who improve and maintain the system (Geels, 2019). The mobility system in the UK consists of multiple socio-technical regimes: auto-mobility, rail, bus, and cycling regimes (Geels, 2018b).

In addition to socio-technical regimes, the MLP literature also distinguishes socio-technical systems, which are interrelated. The main difference between socio-technical systems and socio-technical regimes is that socio-technical systems include “tangible elements needed [to] fulfil societal functions” wherein socio-technical regimes comprise “rules … that guide and orient activities of actors and social groups” (Geels, 2005, p.449). Examples of tangible elements of societal functions: road infrastructure – light, signs; fuel infrastructure – oil companies, petrol stations; maintenance and distribution – repair shops, dealers; production system – car manufacturers, suppliers; regulation and policies – parking fees, emission standards; culture and symbolic meaning – individuality, freedom; automobile – vehicle/artefact (powertrain, drivetrain, transmission, control system); market and user practices - mobility patterns, drivers preferences (Geels, 2005). Examples of rules of socio-technical regime comprise “legally binding contracts, cognitive routines, core capabilities and competences, lifestyles and user practices, favourable institutional arrangements and regulations” (Geels, 2005, p.450). Jointly the socio-technical regime and socio-technical systems guide the activities of incumbent actors (Geels, 2005).

The niche level and regime level are influenced by external factors that can be divided into two groups, slow changing developments, and external shocks. Slow changing developments include demography, geopolitics, macroeconomics, cultural changes, and societal concerns (Geels, 2019). External shocks include, for example, wars, financial crises, accidents, and oil price shocks (Geels, 2019). The level including external factors is labelled the socio-technical landscape (Geels and Schot, 2007).

2.4.1.2 Windows of Opportunity

In the MLP literature, the window of opportunity for niche technologies is associated with pressure from the macro level on the socio-technical regime level, coming from various factors. Geels (2011, p.29) termed the macro level as the 'socio-technical landscape,' wherein factors that can exert pressure include changes in "demographic trends, political ideologies, societal values, and macro-economic patterns." In the UK context, landscape developments that put pressure on the transport regime from 1990 to 2016 include a shift to neoliberal ideology that shaped British politics, "public and political concerns over climate change," "the diffusion of Information and Communication Technologies," the 2008 financial-economic crisis that led to a decline in overall mobility, and an increase in oil prices that raised the running cost of cars. The article considered transport regime change from a broader perspective and included such types of personal mobility as auto-mobility, trains, buses, and cycling (Geels, 2018b, p.90). Niche technologies include electric cars, biofuels, teleworking, and compact cities. The impact of the landscape level on the regime level can destabilise it and open a window of opportunity for niche technologies, which can subsequently change the socio-technical system. "Niche-innovations gradually build up internal momentum (through learning processes, price/performance improvements, and support from powerful groups)" and take advantage of windows of opportunity (Geels, 2018b, p.86).

2.4.2 Key Stakeholders in Socio-Technical Transitions

It is possible to distinguish two broad groups of stakeholders in the MLP literature: incumbent actors, and niche innovators. This section provides the main characteristics of incumbent and niche level actors and gives examples from the MLP literature.

2.4.2.1 Incumbent Actors

Incumbent actors maintain the existing socio-technical system and improve it incrementally. Their actions are guided by a set of rules and institutions established by a socio-technical regime (Geels, 2018a, p.2). These actors have no influence over the landscape level but rather the opposite; the broader context influences the socio-technical regime and regime actors (Geels, 2018a). In the pursuit of strategic reorientation, the incumbent actors can be involved in technological niche innovations and be a part of this level (Geels, 2018a). By using strategic reorientation they can accelerate the diffusion of innovation. In other cases, they can delay or resist innovations (Geels, 2018a).

The groups of incumbent actors correspond to the elements of a socio-technical system and include public authorities – for example, the European Commission, National Ministers; members of the research network - universities, technical institutes; members of the financial network - venture capital suppliers, insurance firms; suppliers - material suppliers, component suppliers, machine suppliers; user groups – individuals and companies that use the specific technology on a day to day basis, customers, carsharing providers, delivery companies; members of producer networks – for example, carmakers; societal groups – NGOs, labour groups, professional associations (Geels, 2002).

2.4.2.2 Niche Innovators

Niche innovators are involved in creating radical innovations (Geels, 2002), that are significantly different from the current socio-technical regime technologies (Geels, 2018b). Such technologies can be BEV, FCEV or biofuels (Geels, 2018b). The term 'niche actors' is associated with entrepreneurs, start-ups, spinoffs (Geels, 2018b), engineers and innovators (Christensen, 2013; Geels, 2018a). Radical innovations at the niche level have the potential to change society and are aiming to be used at the regime level (Geels, 2011) or substitute the regime technology and reconfigure the socio-technical system (Geels, 2018a).

The MLP highlights that "transitions occur when new technologies align with broader ongoing processes such as political struggles, societal debates, and strategic games" rather than "being caused by (heroic) innovators conquering the world" (Geels, 2018a, p.225). Niche innovators try to gain momentum when the innovation becomes broadly accepted, the alignment in the design stabilises the configuration of innovation (Geels, 2011), and there is support from niche advocates (Kern et al., 2015; Raven et al., 2016). The niche innovators work to expand their network, which may include powerful actors. If the enlarged network includes powerful actors that may "convey legitimacy and resources to niche-innovations" (Geels, 2011, p.28). The niche innovators are aware of the regime structure and work to change it (Geels, 2011, pp.37–38). It is worth mentioning that in some cases, incumbent actors can be responsible for the creation of radical innovations, however in most cases, they do not emerge within a socio-technical regime (Geels, 2011, pp.37–38).

2.4.3 Roles of Key Stakeholders in Socio-technical Transitions

2.4.3.1 Role of Carmakers in Regime Change

Carmakers are one of the key stakeholder groups responsible for the transition in the automotive industry and in most cases relate to incumbent level actors. There are three views in the literature on the role of carmakers in regime change. The first group of papers finds that there are tensions between niche-innovations and the regime level and carmakers tend to compete with niche technologies such as BEV. The second group of scholars argue that carmakers voluntarily develop low-emission technologies and are actively involved in regime change. The third literature indicates that incumbents absorb some of the innovations by reconfiguring the mobility system to fit their needs.

Analysing the works of Nykvist and Whitmarsh (2008), Cohen (2012), Dijk, Orsato and Kemp (2013) and Dijk, Wells and Kemp (2016), incumbents are found to stick to the business-as-usual model, thus transitions have a disturbance effect on them. In this way, incumbents are more interested in technologies with a lower disruption level (Nykvist and Whitmarsh, 2008; Cohen, 2012; Dijk, Wells and Kemp, 2016). Dijk, Orsato and Kemp (2013) and Hammond and Pearson (2013) argue that before 2005, car mobility was locked into ICE technologies. Carmakers invested in ICE related innovations, while hybrid technologies allowed the carmakers to innovate without moving away from their core competence (Dijk, Orsato and Kemp, 2013; Hammond and Pearson, 2013). Between 2005 and 2010, a new electric mobility trajectory emerged, in which carmakers began to follow and include BEV into their portfolio. According to Dijk, Wells and Kemp (2016) EV is a disruptive technology, used by non-incumbent entrepreneurs to get first-mover advantage. Incumbents introduced BEV at a much slower pace and for them, this technology is competing (Dijk, Wells and Kemp, 2016).

Another group of authors argues that incumbents participate directly in regime change, by developing innovative technologies such as BEV, HEV, FCEV, or autonomous vehicles (Bohnsack, Kolk and Pinkse, 2015; Skeete, 2018). Bohnsack, Kolk and Pinkse (2015) found that there is a fit between policy requirements and firm capabilities. Technology-forcing regulations that direct the industry innovation trajectory towards more radical emission reduction technologies are only effective if companies have already made the first steps in the development of the required technologies (Bergek et al., 2014; Bohnsack, Kolk and Pinkse, 2015). Otherwise, companies resist radical innovation by using lobbying competencies.

A low-emission vehicles (LEV) trajectory emerged in 1997 when carmakers launched LEV technologies on a large scale (Bohnsack, Kolk and Pinkse, 2015). Carmakers initially experimented with HEV, BEV and PHEV in 1997, then over 1998-2005 they became more focused on HEV and FCEV, and in 2006-2010 they locked out FCEV and focused mainly on HEV, BEV and PHEV (Bohnsack, Kolk and Pinkse, 2015). Carmakers who voluntarily developed low-emission vehicle technology before policymakers began to impose technology-forcing standards, followed socio-technical regime change and were involved in the process. Skeete (2018) found that carmakers are aware of the possible disruption for the automotive industry and prepared for it by developing and integrating innovations into the vehicles, which contradicts Christensen's (2006) classic disruptive innovation theory.

The third group of scientists concludes that incumbents absorb some of the innovations by reconfiguring the system to fit their needs (Mazur et al., 2015; Geels, 2018b; Moradi and Vagnoni, 2018). Mazur (2015), analysing niche-regime interaction in the UK automotive industry, came to the conclusion that they have a form of symbiosis. Innovative SMEs are not able to replace incumbents, thus they supply symbiotic niche innovations such as powertrain components to large carmakers at the regime level. Moradi and Vagnoni (2018) found that, in addition to government support, one of the main drivers of niche innovations is support by incumbent regime actors and powerful emerging core actors.

Geels (2018b) focused on the role of incumbents in regime change in multiple adjacent industries. According to Geels (2018b), hybrid forms of innovation such as biofuels and hybrid electric vehicles have emerged due to the adaptation of symbiotic innovations by the regime actors. Thanks to this adaptation, there is an improvement in the existing regime which may lead to a linkage between adjacent industries. For example, the shift to BEV created symbiotic linkages between electricity and auto-mobility regimes (Geels, 2018b). Carmakers prefer decarbonising the system this way, rather than through rail since, in spite of the fact that BEV are radical, they do not change the role of auto-mobility in mobility systems (Geels, 2018b). Thus, for regime change and its linkage with regimes in adjacent industries, incremental regime improvement is necessary.

2.4.3.2 The Role of Government in the Functioning of the Automotive Market

The second key stakeholder is the government, which is associated with incumbent level actors. The MLP literature distinguishes three government (policy) approaches in the functioning of the market: 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 environment for electric vehicles in the UK is a *hands-off* approach from the government.

2.4.3.3 The Motivation of Incumbent Actors for Regime Change

The motivations for sustainable transitions for incumbent actors, from the point of view of the MLP literature, are discussed below. Decarbonisation of the mobility system involves changes in the rules of socio-technical regimes and is linked with internal regime dynamics and multi-regime interactions (Geels, 2018b). Some of the motivating factors of the environmental considerations of incumbent actors such as carmakers, consumers, and policymakers in the mobility systems are profits, accessibility, congestion, safety, convenience, affordability, and air quality (Geels, 2018b).

According to Mazur (2015), policymakers are motivated by the desire to increase the competitiveness of the automotive industry, develop and preserve it. Geels (Geels, 2018b, p.99) states that policymakers are “motivated by the hope of creating ‘green growth’ potential for the UK car industry”. Hussaini and Scholz (2017) argued that there are two sets of factors motivating policymakers in the UK to change socio-technical regime - landscape pressure and legally binding commitments under international treaties or EU emissions regulations. Landscape pressures include such problems as global average temperature anomalies and fluctuation of fossil fuel prices due to an imbalance of supply and demand (Hussaini and Scholz, 2017). Legally binding commitments comprise international treaties such as the Kyoto Protocol, and EU emissions regulation, for example, renewable energy directives or fuel quality directives. The EU is the largest export market for the UK, accounting for 53% of car exports (Society of Motor Manufacturers and Traders, 2020c). After Brexit, carmakers still need to meet EU standards and the pressure of this level is still having an impact on the UK automotive sector (Society of Motor Manufacturers and Traders, 2020b).

2.4.4 The Process of Socio-Technical Transitions

The path of development or evolution in the analytical levels of MLP is related to the concept of ‘trajectory’. For example, Geels (2018b) used this concept to explain the path of development in niche-innovations and landscape levels, Dijk, Orsato and Kemp (2013) analysed the emergence of the trajectory of the niche technology - electric mobility, Turnheim et al. (2015) mentioned regime trajectories, while Yolles and Fink (2013) and Cooke (2018) used this term to explain the historical development of a particular industry. In the subsequent section, we will discuss the process of transition in detail.

2.4.4.1 Phases of Socio-Technical Transitions

Socio-technical transitions take several decades and can be divided into four phases: experimentation, stabilisation, diffusion/disruption, and institutionalisation (Geels, 2019). At the stage of experimentation, innovators clarify the techno-economic performance of radical innovations, their socio-cultural acceptance, and political feasibility (Kemp, Schot and Hoogma, 1998). This stage includes experiments in laboratories and the creation of demonstration projects (Geels and Raven, 2006).

At the stage of stabilisation, innovations find a market niche, a dominant design is determined, a reliable flow of resources appears, and product cost and performance are improved (Geels, 2019). At this stage, innovations are supported by intermediaries such as innovation agencies, as well as influential actors who share the vision for these products (Geels, 2019; Kivimaa et al., 2019). In addition, a positive view of the social groups is important, as opposition groups can make it difficult to legitimise innovation (Geels, 2019).

In the diffusion/disruption stage, "the radical innovation diffuses into mainstream markets" (Geels, 2019, p.192). There are two reasons for this. Firstly, the productivity of innovation improves, there are economies of scale, complementary technologies are developed, and more influential actors support innovation (Geels, 2019). Secondly, due to the development at the landscape level, pressure appears at the regime level, destabilising the regime, and a window of opportunity opens (Geels, 2018b). This phase is characterised by tensions between niche level and regime level. This is manifested in the form of economic competition with existing technology, business competition between newcomers and incumbents, political conflicts between political actors and interest groups with different interests (Meadowcroft, 2009; Christensen, 2013; Geels, 2019). Finally, there can be struggles between different social groups with different visions regarding a given innovation (Roberts and Geels, 2018).

The institutionalisation stage involves replacing the old socio-technical system and changing regulatory programmes, user behaviour, professional standards, visions of normalcy, and technical capabilities (Geels, 2019).

2.4.4.2 Transition Pathways

Geels and Schot (2007) differentiate four pathways in transition processes: technological substitution, regime transformation, regime reconfiguration, and de-alignment and re-alignment. The *substitution pathway* implies the replacement of the regime with niche innovations as a consequence of the destabilisation of the regime level by the landscape level (Geels and Schot, 2007). In this case, innovations are well developed when opening a window of opportunity (Geels, 2011). In the *transformation pathways*, niche-innovations are not well-developed and cannot take advantage of landscape pressure (Geels and Schot, 2007). The pressure from the landscape level increases gradually allowing the incumbent actors to reorient innovation activities (Geels, 2011).

A distinctive feature of *regime reconfiguration* pathways is that incumbent actors adopt symbiotic innovations developed at the niche-innovation level (Geels, 2011; 2019). The adopted innovations can lead to further technical changes and changes in user practice, which lead to a substantial change in the socio-technical system (Geels and Schot, 2007). In the *de-alignment and re-alignment* pathway, the rapid pressure of the landscape level destabilises the regime level, leaving space for multiple niche technologies, one of which takes the place of the regime (Geels, 2011; 2019). On this path, niche technologies are not sufficiently developed, wherein incumbent actors do not defend the socio-technical regime. Due to the lack of stable guiding principles, user preferences, regulations, and developed niche innovation, a situation of uncertainty arises. After a period of parallel development of several innovations, one of them fills the vacuum created and the system re-aligns (Geels and Schot, 2007).

2.4.4.3 Transition Pathways in the UK Automotive Industry

The socio-technical regime is dominated by ICE in the UK, with the sector employing about 0.7 million people and producing 0.9 million vehicles per year (Mazur et al., 2015; Society of Motor Manufacturers and Traders, 2020a; 2021b). The UK government aims to achieve net zero GHG by 2050, with all new cars sold in the UK from 2035 to be zero emissions (HM Government, 2020). Therefore, it is clear that CO2 reduction is a key focus of UK road transport policy (Mazur et al., 2015). The vision of the government is that local manufacturers can be part of the new regime by bringing low-carbon technologies to the market. The government's objectives are to reduce CO2 emissions, support the local auto industry, introduce ULEV and BEV, develop EV infrastructure, and create new jobs associated with green technologies (HM Government, 2017; 2020; DfT and OLEV, 2018). These initiatives will make ULEV and BEV technologies the new regime (Mazur et al., 2015).

There is no consensus in the MLP literature on which transition pathway the automotive sector in the UK is following. Mazur et al. (2015, 2018) and Geels (2018b) believe that a reconfiguration pathway is taking place. According to Mazur (2015), this conclusion follows from the foregoing. Firstly, the government is going to support both local producers and existing companies; the transitions should not replace incumbents with new players. The current regime is stable, and scenarios of substitution or de-alignment and re-alignment are unlikely. The government is going to support local producers; in this case transitions should not follow a transformation pathway when incumbents reorient innovation activities. There are currently many innovative niche companies in the UK such as Millbrook, Ricardo, Zytek, Astheimer, and major players have partnerships with them. In this regard, the transitions follow the reconfiguration pathway when incumbents adapt symbiotic innovations that lead to changes in the socio-technical system.

Upham, Kivimaa and Virkamäki (2013) analysed path dependence in transport policy and concluded that the policy vision of transport system innovation focuses on the technological substitution of motor vehicle technology through the electrification of transport, whereby path dependence is associated with the stickiness of institutions to decisions made in the past. Gould, Wehrmeyer and Leach (2016) believe that the automotive industry in the UK is following a transformation pathway first. Then technological substitution happens, as innovations are initially adapted by incumbents, but then they replace the existing regime. Hussaini and Scholz (2017) found that the auto industry is currently pursuing a transformation pathway as the regime adapts technologies such as biofuels, hybrid cars, and electric vehicles. However, this pathway will not be enough to achieve a low carbon road system in the UK. In this regard, the sequence of pathways will follow - transformation - substitution - de-alignment/re-alignment.

Skeete (2019) argues that the transition pathway in the UK follows the creative accumulation pathway. This is due to the fact that policymakers and industry stakeholders have a similar vision. The government links niche innovators with incumbents through development centres such as the Advanced Propulsion Centre (APC) or Transport Systems Catapult (TSC). The accumulated knowledge and experience of incumbents allow them to reconfigure and develop solutions to problems much faster.

2.4.4.4 Forms of Multi-Regime Interactions in the Mobility System

Exogenous factors can influence multiple socio-technical regime levels, creating interactions between them. During the transformation of the mobility system, the interaction between multiple mobility regimes can take the forms of competition, symbiosis, or integration (Geels, 2018b). C*ompetition* between regimes could lead to a shift from cars to trains; *symbiosis* involves creating a link between electricity and auto-mobility regimes while shifting towards BEV; whilst *integration* can involve bus, train, and cycling regimes joining into intermodal transport systems, including the integration of payments and schedules (Raven and Verbong, 2007; Geels, 2018b).

Summarising the MLP literature, we see that decarbonisation of the transport sector has a significant impact on stakeholders, both at the technological niche level and regime level, and includes a change in the socio-technical regime. There is no definite opinion among scientists about which transition pathway has been followed or should be followed by sustainability transitions in the UK, and there is also no agreement on the impact of incumbents on the niche actors and interactions that carmakers have with policymakers.

2.5 Handling Ambiguity in the Decarbonisation of the Automotive Industry

The decarbonisation of the automotive industry can be viewed not only from the perspective of changes in technologies and social functions, but also from the perspective of technological development and policy change. One of the key frameworks at handling ambiguity in the process of policy agenda setting is the multiple streams framework. A review of multiple streams framework literature is provided in this section.

Kern and Rogge (2018) argue that transition scholars need to pay more attention to policy process theories. Some of the key theoretical frameworks in the policy studies include the advocacy coalitions framework (ACF), multiple streams framework (MSF), punctuated equilibrium theory (PET), discourse coalitions (DC) and policy feedback theory (PFT) (Kern and Rogge, 2018).

The low carbon transition in mobility systems is a complex and ambiguous process, wherein technological progress and developments are inherently uncertain. It is unclear what the causes are of policy change, how different actors respond to the opportunities whose time has come, how policymakers and carmakers interact, and whether efforts to decarbonise are successful or not. Which policy process framework is the most appropriate to answer such questions? Carmakers and policymakers were not competing advocacy coalitions battling over the policy in a way that could account for the stability of the decarbonisation policy over such a long time, thus ACF would not be appropriate for this study. PET is closer, however, the research is not interested in looking at the change in policy against a backdrop of decades of stasis. The research is not focused on discourse struggles and the roles of ideas in shaping policy, nor how policies shape politics and subsequent policymaking, therefore the literature on DC and PFT are also not included in the literature review.

Of the five key frameworks, the MSF is best at handling ambiguity in policy processes and can help in exploring the details of the change process itself and the key actors (Ackrill, Kay and Zahariadis, 2013). It can complement STT research and help in understanding political decision-making (Elzen et al., 2011; Geels, 2018a). The policy entrepreneurship concept used in the MSF emphasises the central role of agency, which can shed light on the role of individual agents in relation to socio-technical systems (Kern and Rogge, 2018). The MSF demonstrates how political factors and public opinion can open a policy window of opportunity for reforms from a political dimension (Derwort, Jager and Newig, 2022). Using both the MSF and MLP makes it clear that policy change "is the product of a larger trajectory of path-dependence that emerges from the interplay of socio-technical and political dynamics" (Derwort, Jager and Newig, 2022, p.671).

The MSF has controversies, for example, it has been criticised for its lack of testable hypotheses and the claim that the problem, politics and policy/solution elements of policy system have independent dynamics (Robinson and Eller, 2010; Elzen et al., 2011; Kern and Rogge, 2018). It also tends to focus on a single policy issue, limiting its focus on how socio-technical systems can influence subsequent policy-making (Kern and Rogge, 2018; Roberts and Geels, 2019). Since the review of the MSF literature complements our understanding of the EV transition in the UK in terms of the process of agenda-setting, the role of policy entrepreneurs in the decarbonisation of the industry, and the process of policy window of opportunity opens, the MSF limitations discussed above are not significant for this research.

2.5.1 Structural Elements of the MSF

The MSF is John Kingdon's adaptation of the garbage can model that was developed by Cohen, March and Olsen (1972) as an explanatory framework for the agenda setting the stage of policymaking in the presence of ambiguity of information (Ackrill, Kay and Zahariadis, 2013; Zahariadis, 2016). It was constructed based on 247 interviews with members of the US Congress and people outside the government (Kingdon, 2014). Later it was adapted by scholars for analysis of policy change in different contexts and regions. The five structural elements of the canonical MSF are the problem stream, policy stream, politics stream, windows of opportunity and policy entrepreneurs. Policy entrepreneurs will be discussed in Section 4.4.2 "Policy Entrepreneurs". By applying the framework to the different contexts, other elements will be added such as industry trajectories, technological and market windows of opportunity.

According to Herweg (2016), for agenda change to happen, three conditions have to be satisfied. First, the three streams – problem, policy, and politics – must be ripe when the policy window of opportunity is open. The second is that the window of opportunity must be open in the problem stream or politics stream; and third, the policy entrepreneur must be successful in coupling the streams when the window of opportunity is open. Below is a more detailed explanation of the building blocks of the MSF and the processes they can explain.

2.5.1.1 Problem Stream

"The problem stream contains perceptions of public problems that should be addressed by the government" (Kern and Rogge, 2018) and which "policy makers and citizens want to be addressed" (Zahariadis, 2014, p.32). The problem stream is ripe if two conditions are met. First, one of the following mechanisms draws attention to the problem: indicators (for example, statistics of oil dependence), focusing events, and feedback from previous policy programs (Herweg, 2016). Second, after drawing attention to the problem, the problem should be interpreted as being problematic.

Reviewing the literature, two main problems leading to the transformation of the automotive industry were identified: air pollution and energy security. The following paragraph discusses the reason for associating these problems with the problems stream, as well as focusing events drawing attention to them.

Focusing events draw the attention of the public and the government to the problem. They can be crises, disasters, or a powerful symbol that catches on (Kingdon, 2014). In addition, focusing events may have a link with the personal experience of a policymaker (Kingdon, 2014). One of the main problems that has led to the transformation of the automotive industry is air pollution. The focusing events that brought attention to this problem are the publication of statistics of premature deaths associated with air pollution in London and the UK in 2015 – 2016 (Kelly and Fussell, 2015; Maltby, 2021). The number of deaths due to air pollution reached 9,400 and 40,000 at the local and national levels respectively, which served as a strong signal to the public and government. Another focusing event that put attention on emissions, in particular on vehicles, was the dieselgate scandal which showed a gap between real emissions and official figures (Brand, 2016). In the wake of the dieselgate scandal, the government's approach to diesel vehicles has gradually changed. Health costs highlighted the urgency of the problem and were used by problem brokers to frame the problem and increase the awareness of policymakers.

The second problem leading to the transformation of the automotive industry is energy security (Penna and Geels, 2015; Leung et al., 2018). The dependence of European countries' transport systems on fossil fuels and the threat of resource scarcity is one of the most important topics on the political agenda (Berlo, Wagner and Heenen, 2017; Derwort, Jager and Newig, 2022). This problem is one of the reasons for the development of renewable energy and biofuels in Europe (Derwort, Jager and Newig, 2022). E-mobility can reduce dependence on fossil fuels as well as reduce environmental impacts, which is used by policy entrepreneurs to justify their approach to personal mobility (Cohen and Naor, 2013). The focusing events that draw attention to the problem of energy security are crises with countries supplying energy resources and the volatility of oil prices (Penna and Geels, 2015; Derwort, Jager and Newig, 2022).

2.5.1.2 Policy Stream

The policy stream comprises policy ideas/solutions which specialists try out in a variety of ways – "bill introductions, speeches, testimony, papers, and conversation" (Kingdon, 2014, p.19) and which are selected by an "environment of technical feasibility, value congruence, budgetary implications and political support" (Ackrill, Kay and Zahariadis, 2013, pp.879–880). Lipson (2007) also states that solutions can take the form of technologies.

The policy ideas and policy proposals are developed by policymakers, bureaucrats, lobby groups, analysts, academics and experts in policy communities, for example in think tanks (Zahariadis, 2014; Kern and Rogge, 2018). Members of policy communities share a common concern in a single policy area (Kingdon, 2014; Derwort, Jager and Newig, 2022). The ideas have a greater chance of adoption if they meet criteria such as budgetary workability, technical feasibility, and public acceptability (Kingdon, 2014; Jegen and Philion, 2018).

The ripeness of the policy stream is associated with the fact of having at least one technically feasible policy idea which at the same time is discussed by the policy community (Herweg, 2016, p.21). It is worth noting that the stream can be ripe before or at the time of the opening of the policy window of opportunity.

2.5.1.3 Politics Stream

The politics stream consists of the public mood, financial institutions' mood, pressure group campaigns, election results, partisan or ideological distributions in Parliament (Kingdon, 2014). Changes in the politics stream can create an environment that is conducive to agenda-change (Ackrill and Kay, 2011, p.72). Such changes include changes in governments or legislatures, changes in interest group campaigns, and public debate (Kern and Rogge, 2018). Majorities for proposals in the politics stream are sought by means of bargaining and power (Herweg et al., 2017; Derwort, Jager and Newig, 2022). In the case of the government supporting the policy problem the political stream can be seen as ripe for coupling (Herweg, 2016).

The politics stream can be divided into local and national levels, providing varying degrees of impact on the local and national levels of policy making. According to Maltby (2021), the political consensus on emission reductions differs at the national level and in London. At the national level, it is limited due to disagreements between government departments and the limited presence of environmental issues on the political agenda of the Conservative Party, compared with opposition parties (Maltby, 2021). There is greater political consensus at the local level, as majority parties discuss environmental issues with broad coverage in the national and local media (Maltby, 2021).

Public opinion awareness regarding environmental issues also differs at the national and local levels. For example, public concerns regarding air quality decreased from 45% to 40% between 2019 and 2021 at the national level, but only from 74% to 73% in London, at the same time as sales of diesel vehicles decreased by 70% (Society of Motor Manufacturers and Traders, 2021a; YouGov, 2021). In London, public opinion is more inclined towards decarbonisation as a result of the actions of Labour Mayor Sadiq Khan, who is acting as a policy entrepreneur and problem broker simultaneously (Maltby, 2021).

2.5.1.4 Technology Stream

In order to understand the impact of technological change on the policy process, the present analysis uses the concept of the technology stream (Voß, 2007; Goyal, Howlett and Taeihagh, 2021). The technology stream depicts "the context and activities that contribute to technology innovation, such as research, prototype development, patenting and licensing, the establishment of a business venture, market creation, and technology transfer" (Goyal, Howlett and Taeihagh, 2021). The likely actors involved in technology development and diffusion are technology constituencies (Goyal and Howlett, 2018; Goyal, Howlett and Taeihagh, 2021). 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, Howlett and Chindarkar, 2020; Goyal, Howlett and Taeihagh, 2021). According to Goyal et al. (2020), entrepreneurial activities in the technology stream focus on promoting "a technological solution to a societal "need" or a policy problem" and can be associated with the activities of technology innovators. The main activity of technology innovators in the technology stream is R&D (Goyal, Howlett and Chindarkar, 2020), but also shielding, nurturing, and empowering innovations (Raven et al., 2016). In addition, a technology innovator can promote the innovation by coupling "a technology narrative with a socio-political agenda" (Smith and Raven, 2012; Goyal, Howlett and Chindarkar, 2020). 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, Howlett and Taeihagh, 2021).

2.5.1.5 Problem Window of Opportunity

The problem window of opportunity opens in the problem stream and triggers the search for possible solutions to the problem (Zahariadis, 1996). "A "problem window" can open when an indicator worsens substantially [for example unemployment rate or emissions level] or when a crisis or feedback focuses attention on a specific problem" (Herweg, Zahariadis and Zohlnhöfer, 2022, p.208), wherein the problem stream includes the conditions "that can turn into problems, which the political system then may have to deal with" (Herweg, Zahariadis and Zohlnhöfer, 2022, p.207).

2.5.1.6 Policy Window of Opportunity

According to Kingdon (2014, pp.168–169) pWoO open in three cases due to the change in the political stream (change of administration, shift in national mood), as a result of new problem "captures the attention of governmental officials" or as a consequence of crisis/focusing event that that draws attention to a particular problem. The policy entrepreneur can use this opportunity and couple problem, policy and politics stream (Kingdon, 2014, pp.165–166). This can happen if "problem is recognized, a solution is available, the political climate makes the time right for change, and the constraints do not prohibit action" (Kingdon, 2014, p.88). The policy entrepreneur can use this opportunity to push their pet proposal or push attention to their special problems to the government (Kingdon, 2014, p.165).

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

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).

2.5.2 Key Actors of the Agenda Setting Process

2.5.2.1 Policy Entrepreneurs

Advocates of solutions are called policy entrepreneurs (PE) – influential individuals who participate in policy processes by investing their resources in pushing their proposals or problems, prompting important people to pay attention, coupling solutions to problems and coupling both problems and solutions to politics (Ackrill, Kay and Zahariadis, 2013; Kingdon, 2014). They couple policy proposals, problems and politics streams when a window of opportunity opens (Kingdon, 2014). A policy window opens in the politics or problem streams and "constitute triggers that delimit and/or help frame the way issues are debated" (Ackrill, Kay and Zahariadis, 2013, p.873). According to Ackrill and Kay (2011), the window can be held open due to institutional ambiguity and endogenous spillovers which enable active policy entrepreneurship to lead to policy reform. This duration of the open window complements Natali's (2004) width of the open policy window.

The MSF proposes PEs act according to their judgment and because no one controls the linkage between individual inputs and policy outputs, randomness and ambiguity are part of much policy-making (Ackrill, Kay and Zahariadis, 2013). Ambiguity is controlled by the PE through the logic of political manipulation (Zahariadis, 2014; Zohlnhöfer and Rüb, 2016) and the application of PE strategies to promote their solutions (Frisch-Aviram et al., 2019; Johannesson and Qvist, 2020). Originally, PE strategies were seen as being exogenous to the policymaking process, however, Ackrill and Kay (2011) show that they can be endogenous.

2.5.2.2 Political Entrepreneurs, Executive Entrepreneurs, and Bureaucratic Entrepreneurs

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 group of actors "work from outside the formal governmental system to introduce, translate, and implement innovative ideas into public sector practice" (Roberts and 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 entrepreneurs. 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), referred to as 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 and King, 1991, p.155).

2.5.2.3 Problem Brokers and Knowledge Brokers

The concept of problem brokers further refines policy entrepreneurs. Policy entrepreneurs can act as problem brokers (Eckersley and Lakoma, 2021), but problem brokers refrain from acting as policy entrepreneurs (Knaggård, 2015; Angervil, 2021). 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 (Knaggård, 2015; Eckersley and Lakoma, 2021). Problem brokers operate by connecting *values*, *emotions* and *knowledge* to frame a condition as a problem (Wildavsky, 1979; Baumgartner and Jones, 2010; Kingdon, 2014). *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*, which 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 and 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).

2.5.2.4 Bricoleurs

Deruelle (2016) brings the bricoleur concept into the MSF. Bricoleurs are individuals or groups who are active in both the problem and the policy stream and actively participate in opening a problem window (Deruelle, 2016). They select elements of ideas in the policy stream which the policymakers are ripe to and couple problem and policy streams by formulating a bespoke solution that fits the existing problem (Deruelle, 2016). Coupling the streams happens in an oblique way: “rather than a solution being joined to a new problem, a bespoke solution is created to accommodate the definition of the problem” (Deruelle, 2016, p.50). In contrast with policy entrepreneurs, who are inherently driven by an outcome goal and selecting policy ideas having a clear preference on how to solve the problem, the bricoleurs take responsibility for finding a solution (Deruelle, 2016). They are the problem-solving driven agent, have a process goal and create policy solutions by recombining policy ideas (Deruelle, 2016). “The micro-foundations of the bricolage are that preferences regarding solutions are secondary; the issue of problem solving is at the core of this type of agency” (Deruelle, 2016, p.61). “Unlike the problem broker, the bricoleur's agency is not only a matter of creating meaning in the problem stream: she[/he] finds the imperative for policy change and consequentially engages on a search for solutions” (Deruelle, 2016). In the case of transformation of the UK automotive industry, groups of individuals within the Department for Transport can work as bricoleurs, however this hypothesis needs further investigation. Examples of bricoleurs can be researchers who provide advice to ministry officials (Blum, 2018) or government institutions such as the European Commission (Deruelle, 2016) whose role is to draw up proposals and implement government decisions.

2.5.2.5 Technology Innovators

Technology innovators work within the technology stream and are responsible for R&D projects, technological inventions, “nurturing, shielding, and empowering novel technologies” (Goyal, Howlett and Chindarkar, 2020, p.54), as well as linking the technology narrative with the socio-political agenda (Smith and Raven, 2012). The inclusion of technology in policy solutions can be associated with technology innovators, but also with other actors in the policy process (Goyal, Howlett and Chindarkar, 2020). Technology innovators have inherent technological, social and political knowledge (Goyal, Howlett and Chindarkar, 2020). One example of such an actor in the literature is the CEO of a car manufacturing company who has been involved in promoting electric vehicles in Israel through collaborations with bureaucrats, politicians and lobbyists (Cohen and Naor, 2013). In this case, the electric car was presented as a technological solution to the problem of reducing the oil dependence of the country (Cohen and Naor, 2017). Technology innovators belong to a group of technology constituencies that are responsible for accelerating the diffusion of technological innovation among citizens, businesses, and government (Goyal and Howlett, 2018). Also, members of this group are technology users, lobbyists, political actors, and civil society (Goyal, Howlett and Chindarkar, 2020).

2.5.3 The roles of Key Actors in Agenda Setting in the UK

2.5.3.1 The Role of Policy Entrepreneurs in the Decarbonisation of the Automotive Industry in the UK

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). Maltby (2021) uses the case of policymakers' responses to the problem of air quality in the UK, at the national and local levels. The author finds that at the national level, there is less agreement on the appropriate policy response to the problem compared with the local level, specifically in London (Maltby, 2021). In the capital, Mayor Sadiq Khan acted as a policy entrepreneur, coupling the problem of air pollution to the policy solution – Ultra Low Emission Zones, which were introduced in April 2019 and scheduled to be expanded in October 2021 (Maltby, 2021). In addition, the mayor mandated that all taxicabs and single-decker buses must be zero emission, from 2017 and 2020 respectively (Maltby, 2021). NGOs and scientific experts were involved in this process of framing the problem, wherein the Mayor of London acted as both policy entrepreneur and problem broker.

The finding of Maltby (2021) is in line with Monios (2016), Wikström, Eriksson and Hansson (2016) and Demeulenaere (2019), who have found policy entrepreneurs engaging with local authorities. For example, Wikström, Eriksson and Hansson (2016) show that policy entrepreneurs accelerated the implementation of PHEV by raising the issue on the political agenda of local authorities, wherein policy entrepreneurs have the position of public official experts or being a high-ranking local politician. In addition, policy entrepreneurs engaged with the local community and promoted PHEV through test drives (Wikström, Eriksson and Hansson, 2016; Demeulenaere, 2019). Some have done this in order to ensure the acceptance of the technology and increase its demand (Wikström, Eriksson and Hansson, 2016). Thus policy entrepreneurs/experts are key actors in transferring policies and ideas in the transport sector from the bottom-up perspective (Monios, (2016).

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). Upham, Kivimaa and Virkamäki (2013), by using interviews for the analysis of path dependence in UK transport policy, show how policy entrepreneurs were able to catalyse policy change through the introduction of new ideas related to smart mobility. This approach is closest to the prime mover in the reform process approach mentioned by Goldfinch and Hart (2003) and Goyal, Howlett and Chindarkar (2020). From the foregoing, policy entrepreneurs 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.

2.5.3.2 Do Only Policy Entrepreneurs Couple Streams in the Windows of Opportunity?

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". 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 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 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.

The second group of studies bring the bricoleur into the MSF to connect all three streams, 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). Windows of Opportunity (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 entrepreneurs, 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, Howlett and Chindarkar, 2020, p.59).

From the foregoing, one view is 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).

2.5.3.3 Collaborative Efforts in Policy Change

In the following discussion, multiple actors are identified as working jointly to effect change. As such, initial speculation is also offered as to the nature of this collaborative effort. 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, Howlett and Chindarkar, 2020, p.52). Each coalition operates "against an opposing coalition consisting of other people who advocate for different policy directions" (Weible and 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, Howlett and Chindarkar, 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 and 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 and 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 and Howlett, 2018; Goyal, Howlett and Chindarkar, 2020). Their entrepreneurial activities are associated with the 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, Howlett and Chindarkar, 2020, p.54).

Policy entrepreneurs can 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" (Voß and Simons, 2018; Goyal, Howlett and Chindarkar, 2020, p.51). They are active within the policy stream and their strategies can include "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, Howlett and Chindarkar, 2020, p.54).

Summarising the MSF literature, 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. Ackrill and Kay (2011) have shown that the window can be held open by a PE due to institutional ambiguity and endogenous spillovers. However, there are topics that require further clarification such as: the role of technologies in agenda setting in the UK, the relationship between technological innovations in multiple industries, policy problems, and policy proposals; the role played by multiple windows of opportunity in the evolution of the EV market. In addition, it is not clear when the window of opportunity closed in the automotive industry in the UK.

2.6 The Interaction of Actors Across Multiple Levels of Decision-Making

A review of the MLP and MSF literatures indicates the interplay of actors at supranational, national, regional, and local levels. The most widely accepted concept focusing on the interaction of actors at different levels of decision-making is multi-level governance (MLG) (Bache, Bartle and Flinders, 2016). MLG recognises that modern societies comprise multiple actors, partly competing and partly cooperating, who cannot be managed using just a top-down approach (Willke, 2007; Hoffmann, Weyer and Longen, 2017). Confirmation of that can be found in the MSF literature. For example, there are different reactions to the air quality problem at national and local levels (Maltby, 2021) wherein PEs use bottom-up activities for policy change (Monios, 2016; Wikström, Eriksson and Hansson, 2016; Maltby, 2021). There are examples of MLG in action. According to Ehnert et al. (2018) MLG can help in studying sustainability transitions as it allows scholars to explore the impact of institutional structures at different levels of governance and capture both the agency of societal actors and state actors. In this study, a review of the MLG literature will help to analyse the transitions in the automotive industry in terms of the interaction of actors in both vertical and horizontal directions across international, European, national, and local levels.

2.6.1 Impact of International and EU Policy on Firm Strategies

Bohnsack, Kolk and Pinkse (2015), analysing the impact of international policy developments on firm innovation strategies in the EU, found that decarbonisation policies have diffused vertically between levels of government as well as horizontally between countries. This diffusion has impacted both firm strategies and low-emission vehicles' (LEV) trajectories. The Kyoto Protocol was one of the main reasons for the emergence of national programmes related to sustainable mobility in the 1990s in the EU (Bohnsack, Kolk and Pinkse, 2015; Hoffmann, Weyer and Longen, 2017). These programmes tightened fuel-efficiency regulations, as CO2 emissions correlate with fuel consumption (Dijk, Orsato and Kemp, 2013). The European Commission is a key actor in the decarbonisation of the automotive industry, however, their actions have not impacted carmakers significantly, as the regime level remains stable (Hoffmann, Weyer and Longen, 2017). The main reason for this is that the main policy instrument - emissions trading schemes - did not have a direct impact on carmakers and the EU pursued the goal of incremental changes as it was necessary to accommodate both policy requirements and firm capabilities (Pilkington, 1998; Bohnsack, Kolk and Pinkse, 2015). During this period, there was a trend towards decentralisation of traffic development plans in the UK, but at the local level, there was a lack of economic and political resources to promote sustainable mobility, which stabilised the regime in the UK (Dudley and Chatterjee, 2012; Hoffmann, Weyer and Longen, 2017).

According to Pinkse, Bohnsack and Kolk (2014) one of the most significant bottom-up policy diffusion impacts that destabilised the industry and triggered low-emission vehicles was the implementation of the Zero-Emission Vehicle programme in 1990 in the US. There are two reasons for the horizontal spread of this policy across countries at the global level. Firstly, decarbonisation policies in the automotive industry target a strategically important industry (Bohnsack, Kolk and Pinkse, 2015). National governments implement similar programmes to ensure that local industries develop the necessary competencies to compete in other regions and avoid competitive lag (Porter and der Linde, 1995). Secondly, policymakers act in a problem-oriented way, and if decarbonisation policies can solve a problem, they can adopt policies from abroad (Busch and Jörgens, 2005). In Europe, trade encourages policy transfer, so that cars are subject to the same rules in the country of manufacture and the countries of export (Society of Motor Manufacturers and Traders, 2020b).

Since the mid-2000s, the EU has intensified efforts to regulate the transport sector and transform towards sustainable mobility, but this has not yet led to significant regime changes (Dijk and Kemp, 2012; Hoffmann, Weyer and Longen, 2017). Until 2008, the EU followed the politics of incremental change without exerting significant pressure on the regime level (Bohnsack, Kolk and Pinkse, 2015). Implementing incremental policies such as Directive 2009/28 (promotion of the use of renewable energy), Directive 2009/30/EC (specification of petrol and diesel fuels) and Directive 2009/33/EC (energy-efficient road transport) allowed carmakers to develop energy-efficient petrol and diesel vehicles without embarking on radical innovations such as BEV or FCEV.

The UK was one of the first EU countries to implement more radical policies at the local level, notably with the London congestion charge in 2003. This suggests a link from the EU to the local, bypassing the national level. In 2008, the UK government was the first EU member state to legally commit to meeting the Kyoto Protocol CO2 reduction targets, through the Climate Change Act (Hoffmann, Weyer and Longen, 2017). This opened a market to the companies preparing for an LCV trajectory. For example, Volvo initiated its hybrid bus project in London, the success of which led to similar projects in Paris, Gothenburg and Stockholm, showing that horizontal linkages can also occur at the local level (Sushandoyo and Magnusson, 2014; Bohnsack, Kolk and Pinkse, 2015). London, Paris, Gothenburg and Stockholm became a part of the Covenant of Mayors (CoM) in 2009, 2008, 2008 and 2008 respectively (Covenant of Mayors, 2021). The Covenant of Mayors (CoM) is a cross-national organisation that brings together actors from lower levels of government within an MLG framework. The environment and sustainability are high up the CoM agenda, therefore the success of a sustainable project in one location has led to the horizontal transfer of similar projects to other locations at the same level, providing further opportunities for LEV companies.

After 2008, European politics began to destabilise the regime level. At this time, EU members began to implement incentives for LEV, and binding EU targets for CO2 emissions were established. Since 2008, despite the fact that the UK was the first country to implement radical policies at the local level, the UK government has acted in an ambivalent manner at the national level, supporting the regime, for example through a scrappage scheme, while challenging it by publishing the Climate Change Act (Hoffmann, Weyer and Longen, 2017). The lack of UK climate policy at the national level is also mentioned in the MLP literature. "The four greatest contributors to emission reductions [auto-mobility, train, bus and cycling regimes] … happened mostly without dedicated UK climate policies" (Geels, 2018b, p.99), but rather have been driven mainly by European policies (Geels, 2018b). Mazur et al. (2015) found that in 2015 the UK government recognised the problem and solutions and started putting pressure on incumbent actors. As well as in the previous period, this was due to the commitment of the UK to the European Energy and Climate Policy Package. Some of the policy solutions included the Plug-in vehicle grant, Ultra-low Emission Vehicles (ULEV) exemption from Vehicle Excise Duty and Company Car Tax, and funding for recharging stations.

Since 2002, in both the EU and the UK, the industry has followed the path of hybridisation technologies (Hoogma et al., 2002; Wells and Nieuwenhuis, 2012). More recently, however, there has been a noticeable shift in UK government policy from "low" emissions vehicles to "zero" emissions vehicles, with more radical policies passed at the national level, such as the Road to Zero (DfT and OLEV, 2018) and the Ten Point Plan for a Green Industrial Revolution (HM Government, 2020). These events can serve as signals that the government has a policy prioritisation 'greening the car' (Argyriou and Barry, 2021) and indicate the emergence of a zero emission trajectory in the UK automotive industry.

2.6.2 Coherence Between Policy Sectors in the UK

Ehnert et al. (2018) state that after the election of the Conservative Party in 2015, hard power - the power of command and incentives - was concentrated in the central government, reducing the room for sustainability transition initiatives for local actors. The power of the central government is further enhanced by the centralisation of fiscal politics, giving the Treasury tremendous influence over local and national governments, controlling incomes and expenditures (Ehnert et al., 2018).

More broadly, the structure of local government in the UK is complex and includes three categories: national governments (UK, Scotland, Wales and Northern Ireland), national or regional transport bodies (such as Transport for the North, Transport for Wales) and local authorities (including unitary councils, county councils, city councils, boroughs) (Gov.uk, 2021; Marsden and Anable, 2021). Marsden and Anable (2021) found that there is a gap between means for budgets at different levels of government in order to deliver the Paris agreement, for example, local budgets for decarbonising transport are too limited. Lower-tier authorities have greater difficulty in taking more comprehensive or quick action than upper-tier governments, mainly due to potential costs and significant resource dependence on national governments (Marsden et al., 2014). The ambition of governments is also constrained by conflicts with economic growth goals and difficulties in aligning the goals of the multitude of public and private organisations that need to act (Marsden et al., 2014). Due to the difference in the alignment of policy competencies and distribution of emissions, currently, there is no budgetary, accounting, and policy coherence across policy sectors in the UK. This creates obstacles in decarbonisation of the transport sector (Marsden and Anable, 2021).

2.6.3 Coupling of Policy Stream and Problem Stream at National and Local Levels

The MSF also distinguishes different interplay between streams at the national and local levels. For example, from the transport planning perspective, coupling the policy stream with the problem stream is incomplete at the national level. Argyriou and Barry (2021) argue that the government limits bus-based transportation transition prospects, protecting a 'business as usual' future for road transport. This causes tension between the influential policy broker Clean Earth and the government. Since 2015 the government has repeatedly lost in the courts to Clean Earth for non-compliance with the solutions offered by the broker (Maltby, 2021). These solutions included: "traffic planning and management; congestion pricing; differentiated parking fees; establishing low emission zones; other economic incentives" (Maltby, 2021, p.7). The difficulty of linking policy solutions with environmental problems at the national level was also attested to by Carter and Jacobs (2014), who analysed the transformation of the UK climate change and energy policy between 2006 and 2010 and noted disagreement on the basis of cost and emissions targets between the Department for Environment, Food & Rural Affairs (DEFRA), the Treasury, and the Department for Trade and Industry (DTI).

In contrast, at the local level, policy solutions such as congestion pricing and establishing low-emission zones have been coupled with the problem of air quality and adopted by policymakers (Maltby, 2021). Clean air zone proposals are in place in London, Glasgow, Bath, Birmingham and are expected in Manchester, Aberdeen, Dundee, Edinburgh, Newcastle, Sheffield in 2022 (Green Alliance, 2021b). However, there is more than one way to improve air quality. For example, the Nottingham approach has focused on establishing the Workplace Parking Levy (Nottingham City Council, 2021). The funds are then used to improve public transport, which decarbonises transportation, discourages car-use and thus improves air quality.

Summing up, international policies have a significant impact on the decarbonisation of the automotive industry and the strategies of carmakers. The decarbonisation policies diffuse vertically between levels of government as well as horizontally between countries and cities/regions in different countries, opening up markets for LEV-prepared carmakers. In Europe, trade encourages policy transfer, with cars subject to the same rules in the country of manufacture and the countries of export. One of the examples of how MLG can work is through links between the EU and local levels, such as London, bypassing the national level, during the implementation of the London congestion charge in 2003. Another example of MLG in action is the horizontal expansion of sustainable projects at the local level among the members of cross-national organisations, for example, the Covenant of Mayors. Horizontal expansion of sustainability projects provides enhanced opportunities for LEV companies. Only more recently have governments at both the EU and the UK levels begun to implement radical policies that destabilise the socio-technical regime level. There are signals for the emergence of a zero emission trajectory in the automotive industry. However, despite the commitment to achieve net zero by 2040 in the UK, due to differences in the alignment of policy competencies there is an inconsistency between policy sectors that creates problems for the decarbonisation of the automotive industry.

2.7 Identifying Research Gaps

In GT research, the literature review is used to situate the planned research with current knowledge (Bryant, 2017), guide the initial research questions and interview questions, and situate the research findings (Corbin and Strauss, 2015). The literature review above has identified three research gaps, discussed below.

Among the many articles discussed in this chapter, only nine used interviews with industry professionals to analyse the interactions of stakeholders in the automotive industry in the UK. Of these articles, four relate to socio-technical transitions - Upham, Kivimaa and Virkamäki (2013), Moradi and Vagnoni (2018), and Skeete (2018; 2019); two papers are linked with multilevel governance - Marsden et al. (2014), Hoffmann, and Weyer and Longen (2017); and three are associated with the multiple stream framework - Collantes and Sperling (2008), Wikström, Eriksson and Hansson (2016), and Maltby (2021). No articles were found that use interviews with senior managers from the government, high profile groups, participants of the EVET, as well as archival data from the EVET.

Given the limited number of articles that draw on stakeholder interviews and EVET data, there is no theoretical framework, derived from participants of sustainability transitions in the UK, that can explain the agenda-setting process during the time of EV transitions in the UK. Such framework could shed light on the stakeholders' interpretation of this process, supported by archival data.

One of the most widely used methods of constructing theory using interview data is grounded theory (Denzin, 1994; Timonen, Foley and Conlon, 2018). According to Fendt and Sachs (2007) grounded theory can provide a systematic approach to handling and analysing data for building processual and conceptually dense theory grounded in the data. No articles have been found that use the grounded theory method to explain developments in the automotive industry in the UK. Thus the first gap is related to the significantly smaller number of articles using interview data, let alone EVET data, on the EV transitions from the niche market to the mainstream market in the UK that can explain the process from stakeholders' perspectives.

Scholars' opinions regarding the shift of policy agenda and the transitional pathways of sustainability transitions in the UK automotive industry and the role of carmakers in regime change and policy change are divided. Differing opinions regarding this issue also mean that there is a lack of clarity on who are the key stakeholders in the transition process and what are their roles.

Finally, there are very few MSF articles using the case of the automotive industry in the UK. This raises questions regarding the role of technologies in agenda setting in the UK, the relationship between technological innovations in multiple industries, policy problems, policy proposals and the role played by multiple windows of opportunity in the evolution of the EV market.

These research gaps can be filled by answering three cumulative research questions.

RQ1: How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry?

RQ2: Who were the key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020 and what were their roles in this process?

RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK?

These research questions are cumulative with respect to the grounded theory approach and are essential building blocks and steps on the way to grounded theory development.

2.8 Summary

The main research interest of this study is the process of transition of electric vehicles from the niche market to the mainstream market in the UK, from policy agenda setting and technological change perspectives. Below is a summary of views in the secondary materials on the topic of interest that deepens understanding of the phenomenon under investigation. It also outlines research gaps identified in the literature which clarify the research topic and research questions.

Milestones in the development of the industry and the whereabouts of tomorrow's markets (consequences of actions/interactions of stakeholders)

Analysing automotive industry roadmaps, it has been found that traditional ICE vehicles will account for a large share of sales until 2025, then gradually decrease their share to 0-55% in

2035, depending on the region (Daim et al., 2016; J.P. Morgan, 2018; Advanced Propulsion Centre, 2021c). The most expensive part of BEV, which generates most of the CO2 in production, is energy storage systems. New cobalt-free cathodes are expected to enter production after 2025, reducing the cost of batteries. At this time solid batteries will be mass-produced. It is assumed that CO2 emissions in the battery production process will be reduced over time, reaching net zero after 2035 (Advanced Propulsion Centre, 2021b). Another expensive element of BEV is electric motors. From 2025, carmakers are expected to switch from neodymium magnets to alternative materials such as iron ferrite, samarium cobalt, and bonded neodymium (Advanced Propulsion Centre, 2021a). This will allow for further cost reductions.

Gasoline and diesel consumption in the UK is expected to gradually decline from 420 TWh in 2020 to 150 TWh in 2035 (National Grid ESO, 2020; House of Commons Library, 2021). Consumption of biofuels will grow until 2025, but then growth will slow down due to a decrease in the sales of ICE. Consumption of electricity in the next decade will increase sharply. The growth of charging stations will also continue. It is estimated that between 2020 and 2035 the number of slow and fast chargers in the UK will increase from 20,000 to 325,000 charging stations, while rapid and ultra-rapid chargers will increase from 2,700 to 12,700 (Nicholas and Lutsey, 2020). The development of hydrogen refuelling stations will be on a much smaller scale, from 250 units in 2020 to about 700 units in 2030 (Cluzel and Hope-Morley, 2015). Policies regulating CO2 emissions and fuel consumption will continue to tighten. It is expected that broader ZEV mandates and fiscal incentives stimulating the transition to net-zero will be released from 2035. It is also assumed that due to the growing popularity of electric vehicles, policy will be adopted to regulate the energy efficiency of electric vehicles.

Changes in technologies, policies, and social functions (context)

Currently, the automotive industry is undergoing a transformation and a shift to a zero emission vehicle trajectory. Decarbonisation of the automotive industry involves changes in technologies, social functions, and policies (European Environment Agency, 2018). This leads to the destabilisation of the socio-technical level and interaction between multiple mobility regimes and technological niche levels. This interaction can take the forms of competition, symbiosis, or integration (Geels, 2018b).

Analysis of government strategy and type of transition pathways (context)

The opinion of scientists regarding the transition pathways followed by sustainability transitions in the UK can be divided into 4 groups. Mazur et al. (2015; 2018) and Geels (2018b) believe that transitions in the automotive industry follow the reconfiguration pathway. Upham, Kivimaa and Virkamäki (2013) conclude that technological substitution is taking place. Gould, Wehrmeyer and Leach (2016) believe that the automotive industry in the UK is following a transformation pathway first and then technological substitution happens. Hussaini and Scholz (2017) argue that the industry is currently pursuing a transformation pathway, however, the sequence of pathways will be transformation - substitution - de-alignment/re-alignment. Skeete (2019) argues that the transition pathway in the UK follows the creative accumulation pathway.

The role of carmakers in regime change (causal conditions)

There is no consensus in the literature on the role of carmakers in regime change. The first group of papers finds that there are tensions between niche-innovations and the regime level and carmakers tend to compete with niche technologies such as BEV. The second group of scholars argues that carmakers have voluntarily developed low-emission technologies and are actively involved in regime change. The third literature indicates that incumbents absorb some of the innovations by reconfiguring the mobility system to fit their needs.

Factors that drive technology and policy in a certain direction (causal conditions)

The factors that drive technology and policy in a certain direction are the actions of the incumbent actors, policymakers, the pressure of the socio-technical landscape level, horizontal and vertical policy diffusion, and the actions of policy entrepreneurs. The motivating factors for incumbents are profits, accessibility, congestion, safety, convenience, affordability, and air quality (Geels, 2018b). Policymakers drive technology and policy in a certain direction by the desire to increase the competitiveness of the automotive industry, to develop and preserve it (Mazur et al., 2015). In addition, the development of technology and policy is exerted by landscape pressure arising from such problems as global average temperature anomalies and fluctuations in fossil fuel prices (Hussaini and Scholz, 2017). Vertical or horizontal policy diffusion and legally binding commitments under international treaties or EU emissions regulations can destabilise the regime level.

The Kyoto Protocol was one of the main reasons for the emergence of national programmes related to sustainable mobility in the 1990s in the EU, which is associated with top-down policy diffusion (Bohnsack, Kolk and Pinkse, 2015; Hoffmann, Weyer and Longen, 2017).

One of the most significant bottom-up impacts destabilising the industry and driving the trajectory of low-emission vehicles was the implementation of the Zero-Emission Vehicle programme in 1990 in the US (Pinkse, Bohnsack and Kolk, 2014). National governments are implementing similar programmes in their countries to ensure that local businesses develop the necessary competencies to compete in other regions and avoid competitive lag. Another important factor that can drive technology and policy in a certain direction is the activities of policy entrepreneurs. Policy entrepreneurs are able to advance their policy solutions to policymakers, which can lead to policy change.

Diagnosis of the reasons for the implementation of decarbonisation policies in the industry (causal conditions)

One of the main problems leading to the transformation of the automotive industry is air pollution. The focusing events that brought attention to this problem are statistics of premature deaths associated with air pollution in London and the UK in 2015 – 2016 (Kelly and Fussell, 2015; Maltby, 2021). Another focusing event that brought attention to emissions, in particular on vehicles, was the dieselgate scandal, which showed a gap between real emissions and official figures (Brand, 2016). In addition to air pollution, the second problem leading to the transformation of the automotive industry is energy security (Penna and Geels, 2015; Leung et al., 2018). The focusing events that draw attention to the problem of energy security are crises with countries supplying energy resources and volatility of oil prices (Penna and Geels, 2015; Derwort, Jager and Newig, 2022).

Identification of policy entrepreneurs and their strategies in the automotive and related industries (actions)

Policy entrepreneurs play an active role in decarbonising the automotive industry and they have been shown to be most successful at the local level in the UK (Demeulenaere, 2019; Maltby, 2021). In the UK capital, Mayor Sadiq Khan acted as a policy entrepreneur, having coupled the problem of air pollution to the policy solution – Ultra Low Emission Zones, which were introduced in April 2019 and expanded in October 2021 (Maltby, 2021).

Policy entrepreneurs work alongside problem brokers. They both frame conditions as public problems and work to make policymakers accept these frames (Knaggård, 2015, p.453). The difference between brokers and policy entrepreneurs is that the latter develop policy alternatives and have the power to implement policies whereas problem brokers formulate and explain the problem to the public and makes suggestions that something needs to be done (Knaggård, 2015; Eckersley and Lakoma, 2021). Policy entrepreneurs engage not only with local authorities but also with local communities, for example, when promoting PHEV through test drives (Wikström, Eriksson and Hansson, 2016; Demeulenaere, 2019). Policy entrepreneurs' approaches in the UK are most suitable for the strategy of politicising the issue and mobilising public opinion (Roberts and King, 1991).

Identification of a time when a policy window of opportunity opened and closed (context)

A policy window of opportunity opens as a result 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, such events can be the emergence of problems that become visible through focussing events (Kingdon, 1995; Kern and Rogge, 2018). Windows of opportunity open with the emergence of a problem and a focusing event on that problem. For example, the air pollution problem in the UK and the publication of air pollution death rates, and the dieselgate scandal in 2015, opened a policy window of opportunity for implementing and expanding Ultra Low Emission Zones (Maltby, 2021). Cohen and Naor (2013; 2017) and Leung et al. (2018) associate the opening of a pWoO with energy security, wherein an increase in oil prices is related to the focusing event. The window of opportunity closes as the problems of air pollution and energy security become less acute.

Analysis of the governance structure in the automotive and related industries (context)

The structure of local government in the UK is complex and includes three categories: national government - UK, Scotland, Wales and Northern Ireland; national or regional transport bodies - Transport for the North, Transport for Wales; local authorities (including unitary councils, county councils, city councils, boroughs) (Gov.uk, 2021; Marsden and Anable, 2021). Stakeholders influencing decarbonisation policy in the automotive industry in the UK are the Department for Transport, Department for Business Energy and Industrial Strategy, HM Treasury, Department for Environment, Food & Rural Affairs, high profile government groups such as the Office for Zero Emission Vehicles, think tanks, trade associations and carmakers.

The research gaps

The literature review has identified three research gaps. The first gap is related to the significantly smaller number of articles using interview data and EVET data than other data sources, which has limited clarity over the EV transition process from stakeholders' perspectives. Secondly, the key stakeholders and their roles require further clarification. This follows from the fact that there is a lack of clarity in the MLP literature regarding the transition pathway the UK automotive industry has followed. In addition, there are a very low number of MSF studies focusing on this topic: the key stakeholders and their roles require investigation. Finally, due to the very small MSF literature, the role of technologies in agenda setting in the UK is not clear, nor are the relationship between technological innovations in multiple industries, policy problems, policy proposals and the role played by multiple windows of opportunity in the evolution of the EV market. In addition, it is not clear when the window of opportunity closed in the automotive industry in the UK, or if this event has even taken place.

Chapter 3 Research Philosophy and Research Methods

This chapter provides information on the research philosophy, research design, and the rationale for using the grounded theory approach, as well as data collection techniques and data analysis procedures inherent to it. The sampling approach, stages of data collection, list of participants and types of archival data used in the study are then explained. This section concludes with a discussion of the theory-validation process.

3.1 Research Philosophy

This section discusses the ontological and epistemological foundations of the research.

3.1.1 Ontology

Ontology is a philosophical science that deals with the nature of reality and how the world operates (Gray, 2004, p.16; Saunders, Lewis and Thornhill, 2007, p.108). In essence, does reality exist and we merely observe it, or do we help to create reality through our observation? This study admits that transitions from ICEs to EVs depend on interactions between groups within the industry (major carmakers, technological niche companies) and interactions between groups from different industries (renewable energy companies, fuel companies), who act in the context of, and who respond in different ways to, rules created by policymakers. Respondents are not automata. Groups have agency in their actions which they express in different ways. If this were not the case, then the answers to the research questions would be straightforward to establish. The exploration of RQ1-RQ3 is based on the assumption of the central role of agency by individuals in the EV transition process. This perspective suggests that the reality of the EV transition process is socially constructed.

At the same time, it is worth admitting that there are objects that exist independently of observers and which can be studied by methods used in natural science (Grix, 2010, p.86; Bryant, 2017, p.340). Along with decision making, there are economic factors and physics laid behind the development of technology, which are also important components of groups' responses. However, of these three this study is focused primarily on the processes associated with the actions of people. We proceed from the fact that the strategies of companies and policymakers are created by people whose actions do not lend themselves easily to mathematical modelling. Although the specifications of new technologies are based on the laws of physics, and the profitability of companies can be calculated by quantitative methods, the final decisions are made by people. Policymakers can support or create barriers to the advancement of new companies or technologies. Senior managers of companies, in turn, can invest or sell divisions dealing with certain innovations. Thus, the reality is constructed by individuals, so the constructivist position is the most appropriate for this research.

This position is consistent with the pragmatist GT approach adopted below. For example, Bryant (2017, p.56) states the following “my own position might be summarized as Pragmatist-cum-Constructivist, although even this is couched in ironist terms— that is, it is entirely contingent”. The following section discusses the interplay between interpretivism, which is typical for constructivist research, pragmatism, and positivism, which are all relevant to this study.

3.1.2 Epistemology

Epistemology is a philosophical science that is concerned with the acquisition of knowledge and what knowledge is acceptable and legitimate (Gray, 2004, p.16; Saunders, Lewis and Thornhill, 2007, p.116). How do we know what we know about the process of EV transitions? On the one hand, there is an element of objectivity in an understanding of this process, for example, by analysing government statistics or by reviewing the decarbonisation policies that represent this reality. From this perspective, a positivist epistemological position is appropriate where such analyses explain the reality in the most accurate manner.

On the other hand, knowledge is also gained from the process of "parsing" interviews when the words of participants are deconstructed and reassembled to draw a conclusion on the phenomenon. By changing the context, the number of participants, or by including a different selection of people, interpretations can be different. Context dependency and subjectivity are inherent to the interpretivist epistemological position and stand in contrast with positivism.

With this study drawing on both positivist and interpretivist epistemologies, we are drawing on pragmatist epistemology. In this study, descriptive statistics, policies, archival data and interviews are all acceptable forms of acceptable knowledge in answering the research questions.

Another argument that allows for the adoption of pragmatism epistemology in this research is its aim. This is a theory building study that is bringing in unique data that have not previously been analysed. This approach views knowledge as a tool that is "fallible and contingent" (Bryant, 2017, p.340), which can be modified in light of new developments and experiences. By analysing these data the current understanding of the EV transition can be modified and improved.

3.2 Role of Theory

The role of theory is different across the various interpretation of GT. This section explains the role of theory for the selected approach to GT and how abductive reasoning fits within this.

3.2.1 Preconception

There are three widely recognised approaches to GT: objectivist (Glaser and Strauss, 1967; Strauss and Corbin, 1998), constructivist (Charmaz, 2006) and pragmatist (Bryant, 2017). Each of these approaches has different views regarding preconceptions. The idea of entering into the research without any preconception is typical for objectivist GT. "The whole purpose of doing a grounded theory is to develop a theoretical explanatory framework" (Corbin and Strauss, 2015, p.70) wherein authors should not "import theory" (Glaser and Strauss, 1967, p.227). However, research proposals setting out doctoral projects are expected to include an extensive literature review to identify the research gaps. Avoiding preconceptions under such circumstances is rather difficult. Later versions of GT are more flexible regarding the use of preconceptions, which is especially relevant for pragmatist GT. According to Bryant (2017, p.150) "[w]e are able to gain an understanding of what is happening and so develop new insights precisely because of our preconception" from a literature review. In this way "innovative insights arise precisely from someone seeing things differently, based on a different set of preconceptions, and not because they have no preconceptions" (Bryant, 2017, p.150).

Reviewing pre-established theory was an important part of the initial stage of this research, with the purpose of finding the research gap and "to situate the planned research against current knowledge rather than using such material for developing hypotheses" (Bryant, 2017, p.108). The pre-established theories were also used to identify inconsistencies in theories after theoretical coding; and at the end of the research when comparing the results of the study with the empirical and theoretical literature. "Once analysis has been completed, it makes sense for researchers to compare their theories to established theories for similarities and differences and to be able to locate their theories within the larger body of professional theoretical knowledge" (Corbin and Strauss, 2015, p.70). In order for the theory to be practically useful for industry practitioners and academics, the study strives not to substitute well-known concepts with new ones. Rather, a novel view of the phenomenon can be represented using familiar terminology where possible. Thus, preconceptions and the pre-established theory play an important role in this study. This approach contradicts the canonical objectivist approach of grounded theory developed by Glaser and Strauss (1967).

3.2.2 Abductive Reasoning

According to Bryant (2017) "GTM needs to be understood as a Pragmatist method" (Bryant, 2017, p.xiii) where the "abductive aspect of GTM is highly significant" (Bryant, 2017, p.350). Abduction is a type of reasoning where the researcher tries to find the most plausible explanation of the observed data and phenomenon (Charmaz, 2006). It is at the core of all versions of GT. Abduction is not mentioned explicitly in the canonical version of GT, but this term is used explicitly in constructivist and pragmatist methodological sources.

This study uses abductive reasoning at four stages: when collecting the data, analysing, theorising and validating the theory. At the stage of collection of data, interviews, archival data and secondary data are used to explain the phenomenon. As Strauss and Corbin (1990, p.63) state, "all data is data" thus researchers should be prepared "to collect all types of data in order to ensure … cover the field completely". The process of data collection continues until theoretical saturation is reached. Theoretical saturation refers to the moment of repetition of the codes (Strauss and Corbin, 1998), "when the researcher(s) can justify their view that there is sufficient data to substantiate their model" (Bryant, 2017, p.350). The inclusion of different types of data and collection of the data until theoretical saturation contributes to finding the most plausible explanations of the phenomenon.

The data collection and analysis in GT happen simultaneously, in an iterative process (Bryant, 2017, p.349). As new data are included the constant comparison and refinement of codes are taking place to ensure the codes adequately explain the phenomena. Moreover, the three stages of coding, open coding, focused and theoretical coding (Charmaz, 2006) further refine the codes and links between them.

"The general idea of abduction is to select a hypothesis that explains a particular segment or set of data better than any other candidate hypotheses" (Thornberg, 2012, p.247). Theory in GT is constructed by linking selective/theoretical codes with concepts and their dimensions. This includes two stages in theory: development creation of the initial theory and final theory writing. In pragmatist GT, at both of these stages can the theory and concepts be matched with literature that ultimately can help to interpret the result of the study (Bryant, 2017). This is intended to refine the theory such that it can explain the phenomenon better than others. At the final stage of the research, the theory is validated by the participants (Corbin and Strauss, 2015) confirming or further refining the explanation of the phenomenon. Abduction is this appropriate for this study.

3.3 Nature of Research and Research Design

3.3.1 Nature of Research

According to Gray (2004) and Yin (2018) there are three types of research design: exploratory, descriptive, and explanatory – each of which should be reflected in the design of the research questions. Descriptive studies answer "who" and "where" questions, explanatory studies typically have "how" and "why" questions and exploratory studies focus on "what" type of questions (Saunders, Lewis and Thornhill, 2007, pp.133–134; Yin, 2018, p.8).

Grounded Theory typically answers "What" and "How" types of questions, to encompass the process of actions and social interactions (Strauss and Corbin, 1998; Charmaz, 2006; Corbin and Strauss, 2015; Bryant, 2017). For example, 'How do women with pregnancies complicated by chronic illness manage their pregnancies?' (Corbin and Strauss, 2015, p.56), 'What was the Vietnam War experience like for persons who served in Vietnam during the war?' (Corbin and Strauss, 2015, p.214). These questions may be considered too general and nonspecific in quantitative investigations, but they are "perfectly good for conducting a qualitative research study" (Corbin and Strauss, 2015, p.56).

This research mainly focuses on "what" questions, consistent with conducting exploratory research. Research studies that have a "what" question can be divided into two types. The goal of the first type of "what" question is to "develop pertinent hypothesis and propositions for further research" (Yin, 2018, p.10). The second category of "what" question is "a form of how many, how much, or to what extent line of inquiry" (Yin, 2018, p.10). According to Corbin and Strauss (2015, p.55), research questions in qualitative studies and grounded theory specifically are exploratory in nature and "aim at hypothesis generating rather than hypothesis testing". The research questions in this study relate to the first type of "what" questions and are going to develop hypotheses and propositions explaining the transitions in the automotive industry. These can then be tested under different contexts in further research.

3.3.2 Research Design

This study uses interview data, archival data, secondary qualitative materials, and secondary quantitative data. Interview data were collected from semi-structured elite interviews and comments with 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. The archival data were obtained using a Freedom of Information Request (FOI) and include minutes, presentations and reports from the steering group meetings of the EV Energy Taskforce. Secondary qualitative materials mean journal articles, books, companies' strategies, professional reports, policy papers and newspapers. Secondary quantitative data include statistical data requested from the Department for Transport and downloaded from open sources of the Office for National Statistics and the Department for Business, Energy & Industrial Strategy.

This study uses qualitative data analysis procedures inherent to grounded theory. The research design is shown in Figure 3.1.

A literature review is an integral part of this pragmatist GT study. At the beginning of the research, the literature review facilitates identification of the research gap and selection of research methods. It also helps in preparing interview questions for the pilot study. The development of theory involves two stages: the development of the initial theory and the development of the main theory. In both stages, the matching with existing theories took place after obtaining the initial and main GT results, respectively, to situate theoretical codes and identify gaps and inconsistencies in developing theory. Additionally, the literature was used in the discussion chapter, below, when the final theory and theoretical framework were compared with the larger body of professional theoretical knowledge (Corbin and Strauss, 2015; Bryant, 2017). This involved identifying similarities and differences in research findings with empirical and theoretical works, and discussion of how the novel theory can fill the gaps identified in the literature review.

Throughout the study, when reviewing the literature the greatest attention was paid to theoretical and empirical work associated with the multi-level perspective framework and the multiple streams framework. The selection of the MLP is justified by the fact that it is specifically focused on explaining the transition of technologies, from the technological niche level to the established socio-technical level, by considering the interplay of multiple factors at the meso and macro-levels of analysis; and representing the most comprehensive view to study socio-technical transitions required to create a fully functioning EV market.

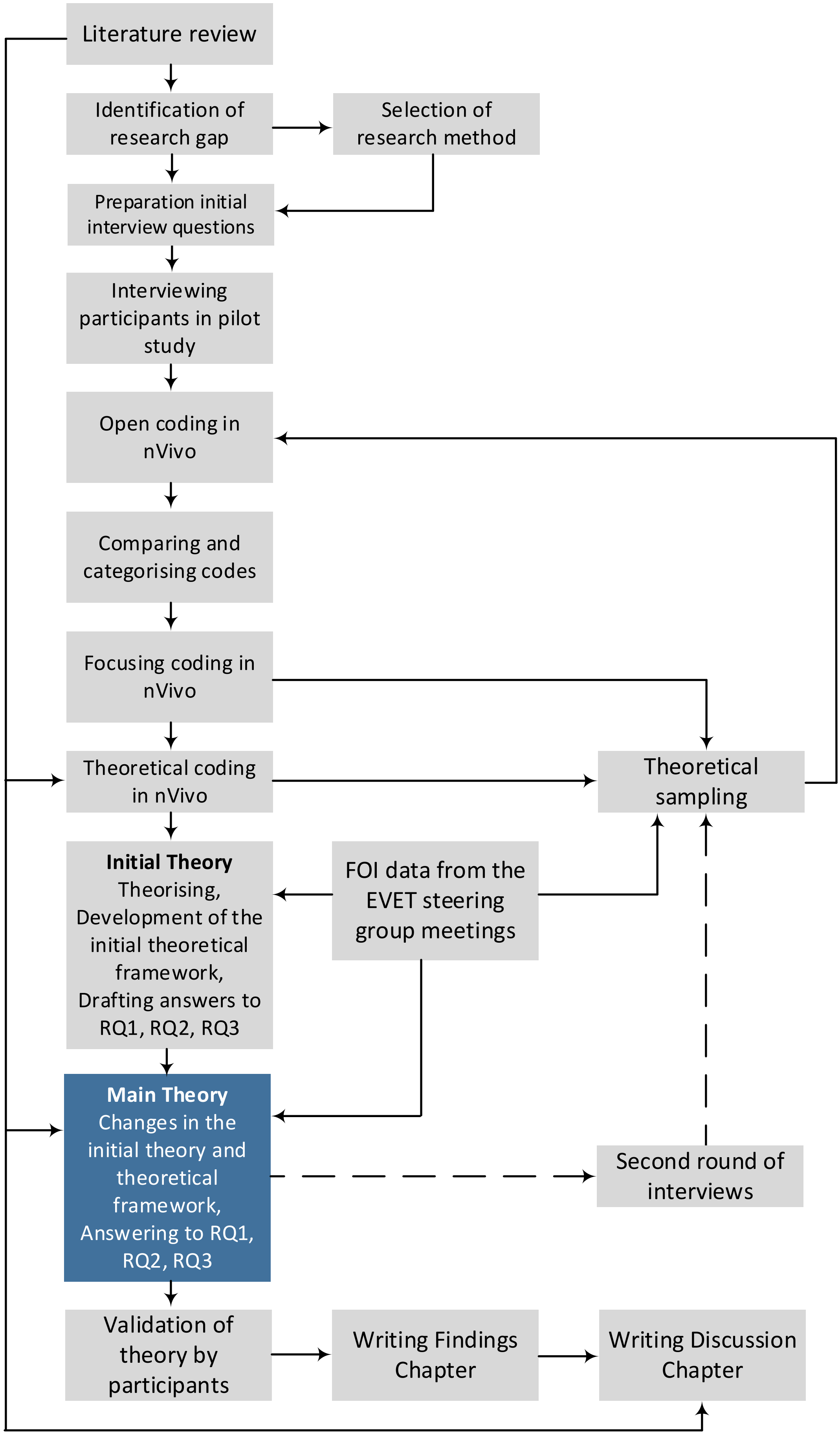


Figure 3.1 Research design

The MSF was chosen as it is best at handling ambiguity in the policy process and offers particular insight into the factors shaping policy discourse. In combination, these theoretical lenses cover political, technological, social and strategic aspects of decarbonisation of the automotive industry and can be used to analyse intersections with developments in multiple related industries at multiple-levels of decision making.

The initial industries chosen were the fuel and biofuel industries, whose experts were subsequently interviewed first, based on the literature review and discussion with the supervisory team. Later this list of industries was expanded by relying on the GT sampling approach, named theoretical sampling. Theoretical sampling is associated with the search for information to clarify properties and dimension categories for building a theory (Charmaz, 2006, p.96). Each subsequent interview answered the questions that arose in the previous interview until theoretical saturation and repetition of the codes obtained from the data was reached (Corbin and Strauss, 2015).

Data collection was divided into two stages: the pilot study and the second round of interviews. During the pilot study, the methods for data collection and analysis were tested, to establish that the use of the chosen research tools could achieve a satisfactory result (Gray, 2004, p.106). The pilot study involved 10 interviews. The second round of interviews included 20 interviews and 18 comments. The proportion of 10 to 38 allowed us to generate 70 initial concepts, 10 memos and 10 categories, as well as construct a draft theoretical framework to validate the research method. According to Bryant (2017, p.263), this number of concepts, memos and categories are sufficient for the initial GT results. Data collection continued until achieving the data saturation required to construct the final version of the theoretical framework and answer the research questions.

With the interviews and comments, the average duration of interviews was 40 minutes, while short commentaries were 5-10 minutes long. The study also used archival data received on the basis of a freedom of information (FOI) request, from The Low Carbon Vehicle Partnership which convenes the EV Energy Taskforce (LowCVP, 2020a). Archival data include 118 documents from 15 steering group meetings that took place between 11 June 2018 and 2 June 2020 and include minutes, presentations, agendas, work packages, reports, and supplementary materials. The Low Carbon Vehicle Partnership is an organisation that facilitates dialogue between policymakers, carmakers and energy companies with the aim of transforming the transport sector. On 18 February 2021, the Low Carbon Vehicle Partnership was relaunched as Zemo Partnership. Archival data were used to clarify interview data, select interview participants, choose interview questions, and develop theory.

Bryant and Charmaz's (2007) coding approach adopted in this study includes three steps of coding: open coding, focused coding, and theoretical coding. In the first phase of coding the data were broken down into smaller parts moving from incident to incident in the analysis. The tentative categories of codes were also parsed. At the focusing coding stage, some tentative categories were left, mainly focused on the categories of most interest. The data collection continued at this stage adding new focusing categories and clarifying the properties and dimensions of old categories. In the final stage of coding, the theoretical coding relationship between categories were built, to which the theoretical codes were then assigned. The continuation of data collection can clarify theoretical codes, their properties and dimensions. By explaining relationships between theoretical codes as well as properties and dimensions, the theory was created and represented visually in a theoretical framework. In the process of creating a theory and theoretical framework, the research questions were answered.

Following Corbin and Strauss (2015), the theory was validated by participants at the final stage of research. The participants were asked to read the theory and comment on whether the theory and theoretical framework was understandable to them. Feedback was received via email as textual information. A total of 6 responses were obtained. All of the participants welcomed the developed theory and answers to the questions, which made it possible to clarify the RQs.

3.4 Data Collection Techniques

This section discusses the sampling technique, data collection technique, stages of data collection used, the number of participants at each stage of data collection, and the types of archival data and their role in the study.

3.4.1 Theoretical Sampling

The selection of participants was carried out utilising the approach defined in the early version of the grounded theory of Gauss and Strauss (Glaser and Strauss, 1967) - theoretical sampling, with participants selected to clarify properties and dimensions of categories. This approach is key to building grounded theory and is used in all three interpretations of the method.

Data analysis was carried out in parallel with data collection, each new interview clarified the issues that arose during the previous interview. Interviews were conducted with senior managers, managers and specialists from the automotive industry, government organisations, independent research organisations, academia, oil and gas industry, biofuel industry, renewable energy industry, EV infrastructure industry, and battery industry. The participants can be conditionally divided into those who were directly involved in the creation of decarbonisation policies - policymakers, those who responded to these policies – and key industry stakeholders and those who analysed this interaction – research organisations, academia, consulting.

Interviewed experts relate to the automotive industry in terms of work background, education, work and research tasks. They are in senior managerial positions or specialists who are involved in sustainable transitions in the UK through the development of policies, strategies, research, equipment and consulting services. Participants from outside the government and the automotive industry took a part in the study as it was needed to clarify issues related to developments in related industries.

Carmakers in the transition from ICEs to EVs are interacting with the vehicle powering industries. This study was therefore also interested in the opinion of managers working in the energy sector, and industries such as the oil and gas industry, biofuel industry, renewable energy industry, and EV infrastructure industry. In the process of collecting data, it was determined that during the shift, in addition to the energy sector, the battery industry also plays an important role. In collecting data, attention was paid to whether these are really different industries and whether there is a merger of different industries. Therefore, the interview with managers from this industry was of great interest. Academics, members of independent organisations and consulting companies are also taking part in the transformation of the transport sector, some of whom were involved in consultations with government organisations. The opinion of these experts clarified the causal conditions and significantly contributed to the generation of theory.

Data collection was carried out until data saturation was reached, allowing the research questions to be answered.

3.4.2 Semi-Structured Interviews

A semi-structured interview is the most suitable interview technique for this research, as it assumes that there is a specific topic for discussion, so participants do not talk about just anything, but the topic is especially interesting to discuss, while at the same time allowing flexibility. Using semi-structured interviews there is no need to adhere to a specific order for questions, and there is also the opportunity to ask follow up questions to expand understanding of the topic (Gray, 2004, p.216; Saunders, Lewis and Thornhill, 2007, p.312). Following the code of ethics the interview schedule was sent to the participants before the interview. During the interview, additional follow up questions were asked as required by the answers provided. In some cases, contingent on the unexpected answers of the participants, deviation from the original plan took place. These deviations were not disadvantageous but, on the contrary, were very effective in terms of generating concepts of the theory.

According to Dworkin (2012, p.1319) adequate number of participants for qualitative research using interview methods is 5-50 people. This study involves 30 elite semi-structured interviews and 18 comments with managers and specialists from industries of interest. The roles of participants are indicated in Table 3.1, Table 3.2, and Table 3.3.

3.4.3 Stages of Data Collection

The interview data were collected in two stages: the pilot study stage and the second round of interviews. The pilot study did not expose any major problems with the interview instrument and the data collected were able to make a significant contribution to the overall data collection of the project.

In collecting interview data, networking at conferences, webinars, workshops and industrial events played a significant role. The pilot study was conducted from March to August 2019. Networking was carried out at the event presented in Appendix 1 “List of Networking Events”, in total, 4 events were attended during the pilot study. Personal contacts and contacts of supervisors were also used.

The second round of interviews was conducted from March 2020 to February 2021. During this period, 20 interviews were collected with the participants shown in Table 3.2. Networking was carried out at conferences, seminars, workshops and webinars. Due to covid all of the events were conducted online which significantly complicated the networking process. A list of events is presented in Appendix 1 “List of Networking Events”. During the second round of interviews, 24 events were visited. Access to some of the events was paid for and was purchased using a Seedcorn grant awarded by Nottingham Business School, which was awarded in February 2020. In total the study involved participation in 28 industry-specific, out of which 6 were LowCVP events.

3.4.4 List of Participants

3.4.4.1 Pilot Study

The list of participants in the pilot study is presented in Table 3.1. Those interviewed constituted a representative cross-section of the roles targeted for the project as a whole. Five of the participants held managerial positions: 1 interview was conducted with a respondent having a head position, 1 senior manager, 3 managers and 5 specialists. Two participants have a doctoral degree, and 1 is a professor. Among 10 experts interviewed, 2 worked in the automotive industry, 1 in the oil and gas industry, 1 in the biofuel industry, 1 in the electric vehicle (EV) charging infrastructure industry, 2 in government organisations, 1 in an independent research organisation, and 2 in academia. Five interviews were conducted in person, the rest by phone or Skype.

The key interview topics covered were: strategic directions of carmakers and fuel companies, challenges and opportunities of traditional carmakers during sustainability transitions, perspective innovative projects in the UK, global and local strategies of carmakers, links between technological responses of carmakers and fuel companies, challenges for implementation industrial strategy. The pilot study showed the viability of the research design in answering the research questions.

3.4.4.2 The Second Round of Interviews

The list of participants in the second round of interviews is shown in Table 3.2 The majority of respondents are in managerial positions: 3 CEOs, 4 Heads, 5 Senior managers, 4 Managers and 4 Specialists. One of the participants has the title of Professor, and 3 participants have Doctoral qualifications.

Among 20 experts interviewed, 5 worked in consulting in the automotive industry, 3 worked in car manufacturing, 2 in government transport planning organisations, 2 in the battery industry, 2 in EV charging infrastructure industry, 2 in academia, 1 in government research funding organisation in the transport sector, 1 in the energy sector, 1 in the government department, 1 in battery recycling.

All 20 interviews were conducted by Skype or Teams. Six interviewees participated in the EV Energy Taskforce. In addition, during the second round of interviews, comments were taken from the experts listed in Table 3.3. Participants were asked their consent to include answers in research in accordance with the code of ethics.

Table 3.1 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 3.2 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
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

Table 3.3 List of participants gave a comment for research

No	Code	Position
18	COM18	Consulting in auto
17	COM17	Digital industry
16	COM16	EV infrastructure
15	COM15	Automotive
14	COM14	Government research funding in transport
13	COM13	Battery recycling
12	COM12	Academia
11	COM11	Energy
10	COM10	Energy
9	COM9	Consulting in auto industry
8	COM8	Consulting in auto industry
7	COM7	Fuel
6	COM6	Business consulting
5	COM5	Local authority
4	COM4	Local authority
3	COM3	Government transport planning organisation
2	COM2	Local authority
1	COM1	CEO, carmaker

3.4.5 Archival Data

The archive data from the EV Energy Taskforce steering group meetings were requested to deepen understanding of interviews. The complete list of documents is presented in Appendix 2 “List of FOI Data”.

The archival data were used to clarify the interviews, but also in selecting the participants, while coding, memo writing, and theory building. During the reviewing of interviews, the terminology or specific context of the concepts the participants mentioned sometimes required further clarification. This was especially true for the interviews with the members of the EVET steering group. Reviewing the archival data helped to clarify the meaning of the participants' words. Moreover, subsequently new participants were interviewed to clarify the documents. Based on the analysis of FOI data some of the focused and theoretical codes were reframed and rewritten. This analysis also contributed to the novel concepts to be derived, which were included in the memos and consequently in the theory. Finally, the inclusion of the archival data contributed greatly to making connections between concepts and selective codes in theory building.

3.4.6 Ethical Considerations

Data collection was carried out in accordance with the policy of the relevant College Research Ethics Committee at Nottingham Trent University (NTU) and the Research Ethics

Code of the Social Research Association. The NTU committee reviewed and gave a favourable opinion on the ethics application for this research. The materials are handled in a manner consistent with the General Data Protection Regulation and Data Protection Act 2018. The Participant-Information Sheet, Consent Form and sample of Interview Schedules are presented in Appendix 3.

3.5 Data Analysis Procedure

This section explains the rationale for using grounded theory, the type of grounded theory used, the coding procedure, and the nature of theory in grounded theory research.

3.5.1 The Rationale for Choosing the Grounded Theory Method

At the stage of the literature review, 27 methods of analysing and synthesising knowledge were found. Of these methods, grounded theory was chosen in connection with the essence inherent to it which will be discussed below.

The elements that are the essence of GT that distinguish this method from others are the theory generating purpose, theoretical sampling approach, theoretical saturation, specifics of data analysis procedures, validation approach and abductive reasoning. The combination of these features in GT allows for the development of a relevant, practical and conceptually dense theory based on the data provided by participants in the process under investigation.

Grounded theory is one of the most widely used methods of constructing theory using interview data (Denzin, 1994; Timonen, Foley and Conlon, 2018). According to Fendt and Sachs (2007) grounded theory can provide a systematic approach to handling and analysing data for building processual and conceptually dense theory grounded in the data. GT research presents a view of reality from the participants' perspective (Corbin and Strauss, 2015) and can help in the development of relevant and useful theory (Bryant, 2017) of the phenomenon under investigation. This is a flexible method that does not constrain our imaginations, allowing the use of different paradigms for data analysis, wherein each offers guidance for systematic data collection (Locke, 2001; Charmaz, 2006).

In building grounded theory, the process of EV transitions grounded in the data is studied using a theoretical sampling approach, that is, the data collection which starts from the big picture and then begins to delve into the details. The participants are selected that way to clarify properties and dimensions of theoretical concepts (Glaser and Strauss, 1967), with the goal of finding all sorts of variety between them, their contexts and relationships between the concepts. This way each new participant is selected to clarify questions that arise from previous interviews, until theoretical saturation is reached. Using this method, all possible aspects of EV transitions in the UK can be found, and what is noteworthy from the direct participants of the process.

Theoretical saturation refers to the moment of repetition of the categories (Strauss and Corbin, 1998), "when the researcher(s) can justify their view that there is sufficient data to substantiate their model" (Bryant, 2017, p.350). It is worth noting that saturation should be reached in terms of the generation of new groups of codes, called categories, as it is quite difficult to reach saturation of codes when no new codes can be generated. This helps to avoid collecting unnecessary data, which aligns with the pragmatist view of knowledge as instruments that should be useful, and not necessarily to be worrisome and accurate (Bryant, 2017). By reaching this point it is possible to be confident that there is enough data to adequately explain the phenomenon. On the basis of theoretical saturation, it ias then possible to validate the theory.

Data analysis in GT is carried out in parallel with data collection when each new interview clarifies the issues that arose during the previous interview (Bryant, 2017, p.349). As new data are included, the constant comparison and refinement of codes take place to ensure these codes adequately explain the phenomena. This increases the validity of the research and reduces bias, as the researcher can adjust the analysis according to incoming data. From another perspective, data analysis can identify a gap and guide the data collection process, which reduces ambiguities in the developed theory. While coding, the researcher remains open to developing new concepts and new theories, paying particular attention to emerging concepts that do not have adequate theoretical references in the existing literature (Gioia, Corley and Hamilton, 2012, pp.20, 26). Since data analysis and data collection occur simultaneously while following changes in the industry, the process of transitions over time can be traced, clarifying aspects of the phenomenon.

In GT the validation takes place while collecting the data, coding, writing and after the theory development. While data collection and coding validation occurred through constant comparison of incoming data with new codes. During the writing stage, theory validation against secondary materials was used in order to locate the developed theory among existing knowledge. The final theory is validated by participants to ensure that the theory is understandable and reflects the primary data. Validation by participants reflects pragmatist idea of the usefulness of knowledge.

By using various types of data, the researcher can provide the most relevant explanation of the phenomenon, which can then be validated by participants. On the basis of these six essentials of the GT method, it is possible to create a relevant and useful theory, which is the rationale for the selection of this method.

3.5.2 Types of Grounded Theory Methods

Grounded theory can be divided into two generations: the first generation associated with Glaser and Strauss's (1967) canonical work on grounded theory, and the second generation of authors who interpreted and adapted the original work (Birks and Mills, 2015). The canonical version is widely referred to as an objectivist grounded theory approach, whilst the second generation can be related to Strauss and Corbin's (1990) interpretation of objectivist GT, constructivist GT (Charmaz, 2006) and pragmatist GT (Bryant, 2017). The pragmatist GT approach set out by Bryant (2017), whilst not explicitly referred to there as a pragmatist GT approach, has been confirmed as such in correspondence with the author.

Abduction is at the core of all versions of grounded theory and refers to the process of finding the most plausible explanation of the observed data and phenomenon (Charmaz, 2006). The main differences between the three versions of GT are the role of the researcher in interpreting the data, the role of literature review and the type of coding procedure used. The main differences in the role of literature review in the GT research are discussed in Chapter 2. The following provides information regarding the role of the researcher in interpreting the data and coding procedures.

Strauss and Corbin's (1998) version is more rigorous in terms of the role of research in interpreting the data, where the research should try to be as objective as possible to explain objective reality and minimise the researcher's subjective interpretation of the data when coding and theorising (Birks and Mills, 2015, p.15). The Constructivist GT approach (Charmaz, 2006) and pragmatist GT approach (Bryant, 2017) acknowledge the interpretivist inclination of the theory and the impact of the researcher in collecting and interpreting the data. Such different views on the role of research influence the way data is coded.

In the original work, little emphasis was placed on describing the coding process, suggesting that the reader should know what to do (Birks and Mills, 2015, p.10). This led to different interpretations of this process and, as a consequence, differences in research philosophies. Strauss and Corbin's (1990) grounded theory method implies a systematic process of coding which has three steps: open coding, axial coding, and selective coding. In addition, it suggests using Strauss and Corbin's (1990) coding paradigm during axial coding. The main elements of the Strauss and Corbin (1998) paradigm are phenomenon, contexts, conditions, actions/interactions, and consequences. The coding procedure involves open, axial and selective coding wherein, at the selective coding stage, the researcher should determine the central/core category to which all other codes must be related, while grouped according to the coding paradigm. The Strauss and Corbin (1998) paradigm is not one of a kind and the researcher can develop his own suitable for a particular study paradigm. For example, Glaser (1978) offer 18 families of theoretical paradigms in order to help the researcher integrate categories for theory building (Locke, 2001).

The intperretation of Charmaz (2006) and Bryant (2017) allows us to use various coding paradigms, or not use them at all. For example, situational maps introduced by Clarke (2005) can be applied to facilitate theory development. Bryant (2017) and Charmaz (2006) recognise that coding parading can limit the researcher's vision (Charmaz, 2006) and forced the data (Bryant, 2017). The categories of codes should be driven by data and “emerge in the ongoing process of data analysis” (Bryant, 2017, p.226). As this research aims to create a relevant theory that can be used by industry practitioners and as a consequence can have a very different coding structure compared with Strauss and Corbin’s (1998) parading, Charmaz’s (2006) and Bryant’s (2017) coding approach is the most suitable for this study. Charmaz’s (2006) and Bryant’s (2017) approach includes four steps: initial coding, focused coding, axial coding (may not be used) and theoretical coding which will be discussed in the following sections.

3.5.3 The Rationale for Choosing Pragmatist GT

This research uses a pragmatist approach to GT for several reasons. First, pragmatist epistemology is closest to the study, where the main idea is to create knowledge that can be practically useful and adaptable to different contexts. Based on the theory, an interactive 3D visual representation of the theoretical framework was built in AutoCAD with the hope of demonstrating its practical application by stakeholders for the phenomenon under investigation. Secondly, the literature was used at the initial and second stages of theory building after getting the initial and main GT results, respectively. It was necessary to situate theoretical codes within the broader context of theoretical knowledge and clarify gaps and inconsistencies in developing theory. In addition, literature has been used in the discussion chapter when the theoretical framework was compared with the literature in order to locate the findings within the scientific domain. Such an approach is consistent with pragmatist GT. Fourth, the inference was made relying on abductive reasoning, trying to find the most plausible explanation of the phenomenon. As a consequence, multiple sources of data are used and multiple verification stages are included. Finally, the coding procedure does not involve using coding paradigms as this can force the data. In this regard, Charmaz’s (2006) and Bryant's (2017) coding approach is the most appropriate for this study and in line with pragmatist GT.

3.5.4 Coding Procedure

This section defines the coding terminology and the coding procedure used in this study.

The core elements of the coding procedure are codes, categories, and concepts. The activities associated with these elements include coding, categorising, and conceptualising which correspond to the three types of coding in GT: open coding, focused coding and theoretical coding.

This study uses Bryant and Charmaz's (2007) coding hierarchy and coding approach when researchers move from a low level of abstractions – codes – to a higher level of abstractions – categories – and further to concepts.

3.5.4.1 Open coding

The codes are the product of the early stages of the data breakdown and serve as a starting point for abstraction (Bryant, 2017). Coding is the process of creating codes that emerge from the data (Charmaz, 2006; Bryant, 2017). Coding can be conducted abductively "against previously prepared coding grids" (Bryant, 2017, p.124). The process of coding is associated with the open/initial coding stage of GT. During the open coding stage, the researcher prepares initial groups of codes or tentative categories that can be described in terms of themes or patterns originating from interview transcripts as well as from documents or other sources (Bryant, 2017).

According to Saldana (2016) initial coding/open coding of interview transcripts can employ in-vivo coding or process coding. It is permissible to use word-by-word, line-by-line, sentence-by-sentence, incident-by-incident, and paragraph-by-paragraph coding practices. In the study there was no need to name each line of transcriptions or carry out word-by-word analysis, so the coding was carried out from incident to incident. The gerund was used for coding process-related categories and codes; for structural-related categories and codes, nouns were used. The process-related categories and codes include actions or interactions of stakeholders, structural-related categories refer to context, intervening conditions, and causal conditions. This is consistent with the GT method (Saldana, 2016; Bryant, 2017).

3.5.4.2 Focused Coding

Codes should be grouped into categories for related data. This process started with open coding and continued with focused coding. The categories can naturally emerge from the data or can be actively created by a researcher (Charmaz, 2006; Bryant, 2017). The process of creating categories may be referred to as categorising. Categorising involves selecting the codes that have common themes into categories (Charmaz, 2006). While categorising, the research tries to define the properties of the category and its dimensions or conditions under which this category exists. For example, the category "entrepreneurship" can have properties - the type of entrepreneurship activity (technological innovating, problem brokering, policy entrepreneurship) and dimension – the condition under which this category exists (industry trajectory, problem stream, policy stream). The most significant categories from a theoretical perspective can become a concept of a theory (Charmaz, 2006).

The categorisation process is associated with the focusing coding stage of GT. At this stage, the researcher can leave some tentative categories from the open coding stage "for a later study" (Bryant, 2017, p.127) and focus on the most of interest. The data collection is continued at this stage and is associated with theoretical sampling (Bryant and Charmaz, 2007). The names of categories can be changed, and the codes derived from the new data can be called focused codes (Bryant, 2017). The aim of this stage is to further clarify the properties and dimensions of selected/focused categories by including more focused codes in them.

3.5.4.3 Theoretical Coding

In further theoretical elaboration, the researcher can transform categories into theoretical objects – concepts (Bryant and Charmaz, 2007; Bryant, 2017). The creation of concepts from the categories is associated with the conceptualisation process where the researcher builds a relationship between categories (Bryant, 2017). During conceptualisation, some categories from the previous stage can be set aside (Bryant, 2017). Elaborated concepts can be renamed and assigned theoretical codes. "Theoretical codes specify possible relationships between categories you have developed in your focused coding" (Charmaz, 2006, p.63). The process of data collection can continue at this stage, wherein the codes are derived from incoming data called theoretical codes. The purpose of data collection at this stage is to fill in the gaps in the properties and dimensions of categories and the relationship between categories underlining the concepts. In addition, the data collection at this stage can test the fact that no further details can be added to categories. The point where no new categories and relationships between categories can be identified is called theoretical saturation (Charmaz, 2006; Bryant, 2017). Theoretical saturation may not be reached but this is what "grounded theorists aim for-or should aim for, according to the canons" (Charmaz, 2006, p.114).

An important point worth mentioning is that one must exercise caution when using the concepts with established meanings from the literature, as they can limit the interpretation of the data (Strauss and Corbin, 1998, p.115). The constructed theory includes concepts brought in from both the MLP and the MSF, using the bottom-up approach that reflects the data collected. This approach is in-line with the pragmatist GT.

3.5.5 The Nature of Theory

The creation of theory and the creation of a theoretical framework are interrelated processes in the objectivist, constructivist and pragmatist approaches to GT. The basis of the theory is forming "theoretical codes that enable the conceptual integration of the core and related concepts to produce hypotheses that account for relationships between the concepts thereby explaining the latent pattern of social behaviour" (Holton, 2007, p.254). According to Corbin and Strauss (2015, p.80) "theory denotes to a set of well-developed categories (themes, concepts) that are systematically developed in terms of their properties and dimensions and interrelated through statements of relationship to form a theoretical framework that explains something about a phenomenon".

"The whole purpose of doing a grounded theory is to develop a theoretical explanatory framework" (Corbin and Strauss, 2015, p.70). That itself has a purpose, to "explicate conceptual logic and direction(s); engage leading ideas; acknowledge prior theoretical works; position new grounded theory in relation to previous theories; explain the significance of original concepts of the research; fit your immediate writing task and readers" (Charmaz, 2006, p.169). Strauss and Corbin (1998, p.15) stated that the framework can also be used to "predict phenomena".

From a pragmatist perspective the theoretical insight of GT, which includes grand theory, theoretical framework or analytical model, must be seen as instrumental and provisional and should be modifiable "in the light of later developments and experiences" (Bryant, 2017, p.345). These GT insights can be judged in terms of the differences they make to people's practical understanding of the phenomenon and actions (Bryant, 2017, p.343).

The process of theory and theoretical framework created in this research follows the methodological literature. The data were analysed using the step-by-step approach to explaining the theoretical framework. In doing so, firstly, the major blocks – concepts of the framework – were explained and how they were derived. In addition, the roles of actors and their actions-interactions strategies were explicated. To support the arguments, citations from archival data and interviews were provided. The explanation eventually led to an overarching summary and narrative description of the theoretical framework.

3.5.6 Theory Building Process

"In a grounded theory study you put your sensitizing concepts and theoretical codes to work in the theoretical framework" (Charmaz, 2006, p.169). Theoretical codes are building blocks of theoretical framework that can explain the phenomenon under investigation. Theorising process involves explaining the relationships between codes, categories, subcategories, and theoretical codes, using diagrams, memos and computer software (Strauss and Corbin, 1998) to help in the analysis and interpretation of the data. The final theory mainly operates with the theoretical codes that are built upon the initial analyses of open codes. The relationship between the theoretical codes can take different forms including causal, correlational, conditional, complementary or temporal (Bryant and Charmaz, 2007). Theoretical codes can be assigned to various aspects of the data, including the actors involved in the phenomenon, their actions and the context of these actions. While theorising, the researcher can answer the questions such as: How are the theoretical codes related? Why are they related? Who is involved in a process, and where and when does it occur? (Whetten, 1989). In addition to exampling the relationships between theoretical codes, the theory can articulate the boundaries of theoretical codes (properties and dimensions) and articulate the range of situation (scope of the theory) when such a relationship between theoretical codes is applicable (Weber, 2003).

The data was analysed using the step-by-step approach. Firstly, the major blocks – concepts of the framework were explained and how they were derived. Second, the notion of actors and their roles in the EV transition process were explicated. To support the arguments, citations from interviews, archival data and secondary data were provided. The explanation eventually led to an overarching summary and narrative description of the theoretical framework, clarifying the process of the EV transition from a niche market to a fully functioning mainstream market.

3.6 Validity in the Research

This section discusses the notion of reliability and credibility in the qualitative study, the process of validation of theoretical findings.

3.6.1 Reliability, Credibility and Validity in Qualitative Studies

Reliability refers to the extent to which data collection procedures or data analysis techniques will produce the same results in other cases if similar observations are made by other researchers (Saunders, Lewis and Thornhill, 2007, p.149).

During the analysis of the methodological literature of grounded theory, the concept of reliability was not encountered, in contrast with the concepts of credibility and validity. There are several reasons for this.

The results of data collection and analysis in GT are very context dependent, therefore the studied processes operating in one context may not work in another. As a result, the findings will differ from case to case. In addition, while the research tries to minimise the impact of the subjective interpretation of data while coding, eliminating this impact is barely possible. Thus, there is an inherent interpretative and subjective element in GT. According to Charmaz (2014, p.354) the researcher in the interpretive study will "seek to learn specific meanings in the context of their production without expectation of generalizability and such context distinguishes their approach" (Charmaz, 2014, p.354).

Readers studying GT theory must agree that the developed theory provides one possible explanation for the phenomenon (Strauss and Corbin, 1998). This opinion is shared by Charmaz (2006), who argues that the quality of research is based on "rich, substantial, and relevant data" (Charmaz, 2006, p.60), while one of the main aims of interpretive theories is to "conceptualize the studied phenomenon to understand it in abstract terms; articulate theoretical claims pertaining to scope, depth, power and relevance; acknowledge subjectivity in theorizing and hence the role of negotiation, dialogue, understanding; offer an imaginative interpretation" (Charmaz, 2006, p.127).

In the last work of Corbin and Strauss (2015, p.365), the authors state that in qualitative research it would be most correct to talk about credibility and validity rather than reliability, wherein "credibility indicates that findings are trustworthy and believable in that they reflect participants', researchers', and readers' experiences with phenomena, but at the same time, the explanation the theory provides is only one of many possible "plausible" interpretations from data" (Corbin and Strauss, 2015, p.365). Following thsi statement, the credibility of the theory in this study was achieved by selecting experts directly involved in EV transitions in the UK as well as by using the archival EVET - the key platform responsible for the acceleration of EV transitions.

Validity refers to the fact the codes and the findings accurately represent the data and the possible explanation of the reality being studied. This aspect of GT is discussed in the next section.

3.6.2 Validation of Theoretical Findings

"Validity is concerned with whether the findings are really about what they appear to be about" (Saunders, Lewis and Thornhill, 2007, p.150). From Strauss and Corbin's (1998, p.159) point of view, validation is concerned with checking how well abstractions fits the raw data and checking whether something has been omitted in the theoretical scheme. The process of validating a theory includes comparing it with raw data or presenting it to participants to find out their reactions (Strauss and Corbin, 1998, p.161). Validation refers to the intelligibility and usability of the research result by those who participated in the research (Bryant, 2017, p.102). In order for the theory in the present research to be complete, accurate and useful, validation took place at the coding, writing, and theory testing stages.

The impact of the researcher on the research is significant at the coding stage, as the assigned labels to concepts and categories are an interpretation of the data provided by the researcher. The validation at this stage is achieved by the following. First, since the process of collecting and analysing data took place in parallel, this allowed comparing abstract concepts, categories, and their relationships against the incoming interview data in order to check how well the abstractions fit them and whether there was something missing (Strauss and Corbin, 1998, pp.89, 159). Secondly, abstractions were checked for correspondence from incident to incident (Strauss and Corbin, 1998, p.135). By comparing abstract concepts with new data or with each other, we can validate them and correct them if they do not match.

After theory writing, validation of theory against secondary materials was used in order to locate developed theory among existing knowledge. The answers to the research questions were also validated using secondary materials. According to Strauss and Corbin (1998, pp.51, 52), at the theory writing stage, literature can be used to confirm findings or to illustrate gaps in the literature.

Theoretical findings, categories and hypotheses generated as a result of the analysis are preliminary and should be validated in subsequent interviews (Strauss and Corbin, 1998, p.46). The theoretical findings include an analytical model, a theory of the transition from ICEs to EVs, and answers to research questions. The theoretical framework was presented and validated at conferences and symposiums. The preliminary theory and answers to the research questions were tested and validated during the second round of interviews. The final theory and answers to the questions were validated at the last stage when sending textual information to research participants. Participants were asked to check the clarity of the theory and answers, as well as the consistency of the data they shared. Feedback was received in textual form and represented in the data analysis chapter.

3.6.3 Verification

The verification concept is not commonly used in GT research. Instead, validation is applied.

"Verification refers to aspects such as conformity to standards and legal requirements, and other forms of "conventional wisdom" (Bryant, 2017, p.102). Gray (2004, p.407) stated that verification is "drawing the implications from a set of empirical conclusions to theory". Charmaz (2006, p.149) argued that "checking hunches and confirming ideas, in my view, does not equal verification" and "rather than contributing verified knowledge, I see grounded theorists as offering plausible accounts".

GT researchers do not use positivist canons such as "significance, theory-observation compatibility, generalizability, consistency, reproducibility, precision, and verification" (Strauss and Corbin, 1998, p.266), but focus more on theory generation (Glaser and Strauss, 1967, p.10), study evaluation (Strauss and Corbin, 1998, p.268), and categorical saturation (Goulding, 2002, p.44) depending on the type of grounded theory used. What all versions of GT have in common is that the participants and data should be related to the phenomenon under investigation (credible), the theory must be accurate to the original data (valid) and must be one of the plausible explanations for the phenomenon.

In the study rather than checking the theory meets specific standards or requirements (verification), the theory is validated by checking whether it is close to the data and can meet the intended purpose of explaining the EV transition. This is done through participants' feedback.

3.6.4 Triangulation

According to Locke (2001) triangulation in grounded theory refers to the collection of data from multiple sources such as interviews, and archival data, related to the phenomenon under study. In the original work of Glaser and Strauss (1967, p.65) this procedure refers to 'slices of data' since the term 'triangulation' was not used at that time (Jick, 1979; Locke, 2001). In Strauss and Corbin's (1998, p.44) work, triangulation refers to the process of using different methods and approaches to collect data in order to obtain different meanings and interpretations of events, actions/interactions and objects, and to use these variations in the constructed theory. "Triangulation involves the combination of different interpretations of different types of data towards a more correct representation of what is going on" (Bryant and Charmaz, 2007, p.443). Triangulation can increase the internal validity of the theory by triangulating participants' perspectives and triangulating data sources (Bryant and Charmaz, 2007, p.505). Such sources can be archival data or secondary materials that help to deepen the understanding of interview data, facilitating theory development.

This study employs triangulation in three ways. Firstly, triangulation is used in the collection of archival, statistical and secondary materials to gain a deeper understanding of the interview data, as well as acquaintance with other opinions regarding the analysed event. Secondly, triangulation is used when comparing, literature with in-vivo codes associated with well-known scientific terms, in order to confirm the meaning of an in-vivo code. As a result, it is possible to compare the participants' perspective on a term with what is said in literature and in case of a coincidence then give a code corresponding scientific term. If what is said in the literature differs from what the participant says on this term, then an abstract code is assigned which is different from the scientific literature. For example, if the participant mentioned salami tactics and mostly talked about lobbying rather than time manipulation, then the event would be assigned the code 'lobbying' rather than 'using salami tactics'. Thirdly triangulation is associated with the literature matching that takes place during initial and final theory development stages.

3.7 Summary

This research is based on the position of constructivism, seeing reality as socially constructed. Epistemology refers to pragmatism, whereby abductive reasoning is used in theory building and answering the research questions. The underpinning idea of the study is to create knowledge that can be practically useful, thereby confirming the reality of the propositions made in it.

The research approach of this study is grounded theory. The rationale for using GT is related to its essential elements that distinguish this method from alternatives. These are the theory generating purpose, theoretical sampling approach, theoretical saturation, specifics of data analysis procedures, validation approach and abductive reasoning. The combination of these features in GT allows for the development of a relevant, practical and conceptually dense theory based on the data provided by participants in the process under investigation.

Out of three types of GT, objectivist, constructivist and pragmatist, the research employs pragmatist GT. This is bceause a pragmatist epistemology is best-suited to this study, the preconceptions and literature review play an important role in theory development, abduction reasoning implemented in data collection, coding, theory building and validation stages, the coding procedure reflects the pragmatist GT.

The research is influenced by preconceptions and pre-established theory. Reviewing existing theories helped at the initial stage of the research with the purpose of finding the research gap and locating the planned research against current knowledge. The pre-established theories were also used during theory development to identify the gaps and inconsistencies in theoretical codes. This approach contradicts the canonical objectivist approach of GT developed by Glaser and Strauss (1967), however, it is consistent with the pragmatist interpretation (Bryant, 2017) applied in this research.

Abductive reasoning was implemented in four stages of the study: while collecting the data, analysing the data, theorising and validating the theory. This is associated with providing the most plausible explanation of the observed data and phenomenon, using multiple sources of data, which is constantly refined and finally validated by participants.

The main method for collecting qualitative data is semi-structured interviews. The pilot study includes 10 interviews whilst the second round of interviews comprises 20 interviews and 18 comments. In total, the opinions of 48 experts were included. In addition, using an FOI request 118 documents were requested from 15 EVET steering group meetings held between June 2018 and June 2020. These documents significantly contribute to theory development during theoretical sampling, coding, and theorising.

The selection of participants was carried out in accordance with an essential element of GT - theoretical sampling. The theoretical sampling approach suggests the inclusion of participants to clarify the properties and dimensions of categories, based on which the theory is developed. Data collection was carried out until the moment of repetition of the categories, allowing the researcher to substantiate the theory. It is noteworthy that the data analysis was performed in parallel with data collection, wherein each new interview clarified the issues that arose during the previous interview.

This study uses Bryant and Charmaz's (2007) coding hierarchy and coding approach, moving from a low level of abstractions – codes – to a higher level of abstraction – categories – and further up to concepts. The process of theory and theoretical framework follows the guidelines in the methodological literature. The data were analysed using the step-by-step approach to explaining the theoretical framework. In doing so, firstly, the major blocks –

concepts of the framework were explained and how they were derived. In addition, the roles of actors and their actions-interactions strategies were explicated. The study also provided citations from archival data and interviews as supporting evidence for the arguments. The explanation eventually led to an overarching summary and narrative description of the theoretical framework.

The concepts of reliability and verification are not used in GT where it is more correct to talk about the credibility and validity of the research. The credibility of the study was achieved by selecting experts directly involved in EV transitions in the UK as well as by using archival EVET data. Validity refers to the fact the codes and findings accurately represent the data and the reality being studied. Validation took place at the coding, writing, and theory testing stages. While data collection and coding validation occurred through constant comparison of incoming data with new codes. During the writing stage, theory validation against secondary materials was used to locate the developed theory among existing knowledge. The final theory was validated by participants to ensure that the theory is understandable and reflects the primary data. Validation by participants aligns with the pragmatist notion of the usefulness of knowledge.

The next chapter focuses on the analysis of the data using the GT approach where the concepts and their relationships will be explained that ultimately leading to the description of the theoretical framework.

Chapter 4 Presentation of Findings

This chapter introduces findings from two empirical data collection phases and describes the theory that has been developed using the grounded theory approach. According to Corbin and Strauss (2015, p.70), “the whole purpose of doing a grounded theory is to develop a theoretical explanatory framework”. As outlined in Chapter 1, the aim of the research is to develop a theory that can explain the process of EV transition from the supply side in the UK. This is achieved by creating a theoretical framework that encompasses the overall structure of the phenomenon and facilitates identifying the key stakeholders and their respective roles in the EV transitions from the niche market to the mainstream. The research questions derived for this project are:

RQ1: How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry?

RQ2: Who were the key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020 and what were their roles in this process?

RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK?

The presentation of research findings is broken down into seven parts. Section 4.1 “Presentation of Findings in Grounded Theory Research” clarifies the process of presenting findings in grounded theory research. Section 4.2 “Electric Vehicle Energy Taskforce” outline the main objectives and the key stakeholders in the organisation whose archival data were used in theory building. Section 4.3 “Structural Elements of the Theoretical Framework” explains the structural elements of the constructed theoretical framework and the context under which the EV transitions take place. Section 4.4 “Key Stakeholders and Their Roles in the EV Transition” describes the nature of key stakeholders involved in the agenda setting process and their roles. Section 4.5 “The Process of the EV Transition” explain the EV transition process in the UK. Section 4.6 “Theory Validation” presents the results of the theory validation stage of the research. Section 4.7 “Summary” summarise findings.

4.1 Presentation of Findings in Grounded Theory Research

In grounded theory research, the presentation of findings and the process of theorisation are closely related. This involves explaining the relationships between codes, categories, subcategories, and theoretical codes, using diagrams and research memos. Theoretical codes are building blocks of the theoretical framework. Explanation of the relationship between theoretical codes ultimately leads to the construction of a theoretical framework that can explain the phenomenon under investigation.

During the coding stage, 1621 open codes were created. These were grouped into 64 focused codes and 22 theoretical codes. The theoretical codes correspond to the titles of the third level subsections of this chapter. The coding was carried out in NVivo. A hierarchy of codes, code grid and NVivo codes are provided in Appendix 4 "Hierarchy of Codes and Coding Grids" and Appendix 5 "NVivo Codes".

The theorising process begins with an explanation of theoretical codes related to the structural elements of the theoretical framework. These codes correspond to the third level subsections of Section 4.3 "Structural Elements of the Theoretical Framework". While explaining theoretical codes the relationship between these codes and the concepts they comprise will be clarified. For example, while explaining theoretical code – 'automotive industry trajectory' it will be described how concepts such as 'governance level', 'incumbent level' and 'technological level' are related to theoretical code and each other. During the theorisation, the discussions will be supported by quotes from interviews, archival data and secondary materials. In addition, visualisations of the relationship between theoretical codes and their corresponding concepts will be provided.

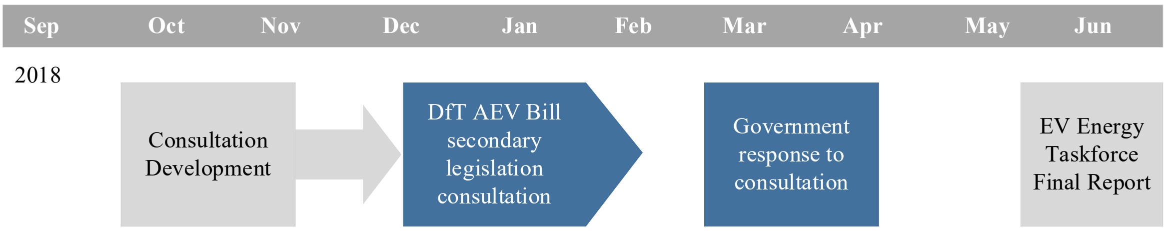
Following the explanation of the structural elements of the theoretical framework in Sections 4.3.1 - 4.3.3, the complete overarching framework will be explicated in Section 4.3.4 "Multi-level Streams and Trajectories Framework" linking theoretical codes and concepts in Section 4.3. Section 4.4 "Key Stakeholders and Their Roles in the EV Transition" will include an explanation of theoretical codes related to the key stakeholders involved in agenda setting and transition to EVs. Section 4.5 "The Process of the EV Transition" will links theoretical codes from Section 4.3 and Section 4.4 together, finalising the theorisation process. Following step-by-step through Sections 4.3 - 4.5 the theory grounded in the data will be explained. This process of theorising corresponds to the theorisation stages outlined by Whetten (1989), Strauss and Corbin (1998), Weber (2003), Charmaz (2006) and Bryant and Charmaz (2007). In detail, the theorising process is discussed in Sections 3.5.4 - 3.5.6.

4.2 Electric Vehicle Energy Taskforce

The constructed theoretical framework was developed primarily based on the analysis of FOI data requested from the Electric Vehicle Energy Taskforce (EVET), as well as interviews with EVET members. This section outlines the main objectives of this organisation and key stakeholders.

EVET brings together stakeholders from the energy supply, energy storage and automotive industry, to provide recommendations to the government to facilitate the transition to EVs. As indicated in UK Parliament and FOI data, the EVET provided 21 proposals to the government over the period 2018–2020 (UK Parliament, 2020a).

By analysis of the FOI data, it was also clarified that EVET "assist in the development of a consultation to inform the development of secondary legislation following the introduction of the Automated and Electric Vehicles Act (AEV), and maximising stakeholder engagement" (FOI 16 cf). The AEV includes, for example, The Electric Vehicles (Smart Charge Points) Regulations (HM Government, 2021). In addition, EVET recommendations were included in the UK electric vehicle infrastructure strategy (DfT, 2022b). The first iteration of EVET consultation development is indicated in Figure 4.1.



Source: adapted FOI 16 cf

Figure 4.1 EVET AEV consultations

The key members of the EVET Steering Group include:

- EVET Chair - CEO of Energy Systems Catapult (ESC)
- EVET Secretariat – Senior Manager of Low Carbon Vehicle Partnership (LowCVP)
- Office for Low Emission Vehicles (OLEV)
- Department for Business, Energy & Industrial Strategy (BEIS)
- HM Treasury
- Energy UK
- Energy Network Association
- British Electrotechnical and Allied Manufacturers' Association (BEAMA)
- Automotive Council UK
- Society of Motor Manufacturers and Traders (SMMT)
- Electric Vehicle Supply Equipment Trade Association (EVSE)
- National Grid

- Ofgem
- TechUK
- University of Leeds

During work package (WP) meetings the policy ideas were generated by members of each WP, which included industry stakeholders experienced in WP topics (FOI 55). Between 2018 and 2020 EVET concentrated on the development of four WPs. Each WP focused on a specific topic:

- WP1 targeted a common strategic understanding of the requirements of the energy system to support mass EV uptake (FOI 103) identifying trigger and tipping points of EV transitions and providing policy proposals that can change commercial or business models of stakeholders (FOI 67);
- WP2 put emphasis on EV users' engagement with smart charging and energy services (FOI 103). This WP involved analysis of customer journey-use cases and giving recommendations on enhancing the EV customer experience (general public, electricity customers and EV users) (FOI 67);
- The aim of WP3 was to achieve a common strategic understanding of the functional requirements of smart chargers to support mass EV uptake and market and technical innovation (FOI 105);
- WP4 prioritised data accessibility for decision-making in the EV, infrastructure and energy value chain; and to address how EV-related data can be accessed and utilised, to ensure that the electricity system is able to facilitate the mass-deployment of EVs (FOI 106). This involves analysing information decision-making use cases and providing policy proposals relating to data and information accessibility and interoperability.

The roles of stakeholders within each WP were WP leaders, WP sponsors and WP organisations/volunteers. The policy ideas are generated during WP debates between the members of WP (FOI 55). WP Leaders were responsible for organising WP meetings, drafting outputs and communicating with Steering Group members.

The following WP Leaders were established:

- WP1 – Energy Systems Catapult;
- WP2 – Energy UK;
- WP3 – BEAMA;
- WP4 – Energy Networks Association.

The WP Leaders were supported by WP Sponsors:

- WP2 – University of Leeds;
- WP3 – Automotive Council UK;
- WP3 – SMMT.

The WP Sponsors representing the Steering Group (FOI 55) have industry-specific knowledge and provide research and consultancy support. As we can see WP Leaders and WP Sponsors are members of the Steering Group.

In addition, each WP was staffed by volunteers from EVET stakeholder organisations which include energy companies, carmakers, consulting organisations, engineering companies, and financial organisations. The list of participants of each WP is quite broad and depicted in Appendix 6 "List of EVET Stakeholders". According to EVET Reports (FOI 110) over 350 organisations input to the WPs. However, reviewing the documents, it was possible to identify only 108.

4.3 Structural Elements of the Theoretical Framework

The theoretical framework developed and presented in this chapter is named the Multi-Level Streams and Trajectories (MLST) framework. It has been designed to be capable of explaining the complex agenda-setting processes related to technology-centric issues, such as the decarbonisation of transport, and technology-centric policies like the Road to Zero Strategy or the Electric Vehicles (Smart Charge Points) Regulation. The MLST unifies the Multiple Streams Framework, Multi-Level Perspective and Multi-Level Governance into a single framework. It has then been visualised using 3D AutoCAD, allowing for components and layers to be turned on/off during the presentation of results. On the one hand, such a pluralist approach to policy analysis reflects the comprehensive strategy used by the participants of the policy process. On the other, the collective utility of the lenses can help to overcome the limited focus of the individual lenses and provide a more nuanced understanding of complex phenomena (Van der Heijden, 2013).

Central to the framework and visualisation within the model are windows of opportunity (WoO), drawing on their key roles in both the MLP and MSF. In the MLP literature, windows of opportunity are associated with the process of transitioning technologies from the technological niche level to the incumbent level. The MSF literature considers the concept of policy windows of opportunity (pWoO) within the context of policy change. MLST adopts these as building blocks but also introduces new types of window of opportunity: technological windows of opportunity (tWoO), and market windows of opportunity (mWoO). Together, tWoO, pWoO and mWoO enable a comprehensive analysis of the dynamic and two-way linkages between technology and policy in the development of a new EV market.

Following the abductive research process, theoretical codes comprising the MLST were derived both deductively and inductively. The deductive theoretical codes were linked with the MSF, MLG and MLP, while the inductive theoretical codes came out of the analysis of the interviews and archival data. The deductive theoretical codes include such codes as problem, policy, and politics streams, governance levels, incumbent level and technological niche levels. Inductive theoretical codes supplement deductive codes and expose the novel relationship between them. Examples of inductive theoretical codes include automotive, energy supply, energy storage trajectories, technological and market windows of opportunity. Both deductive and inductive theoretical codes consist of lower-level focused codes that were identified inductively and serve to clarify characteristics of theoretical codes. This approach is in line with Pragmatist GT, as described earlier.

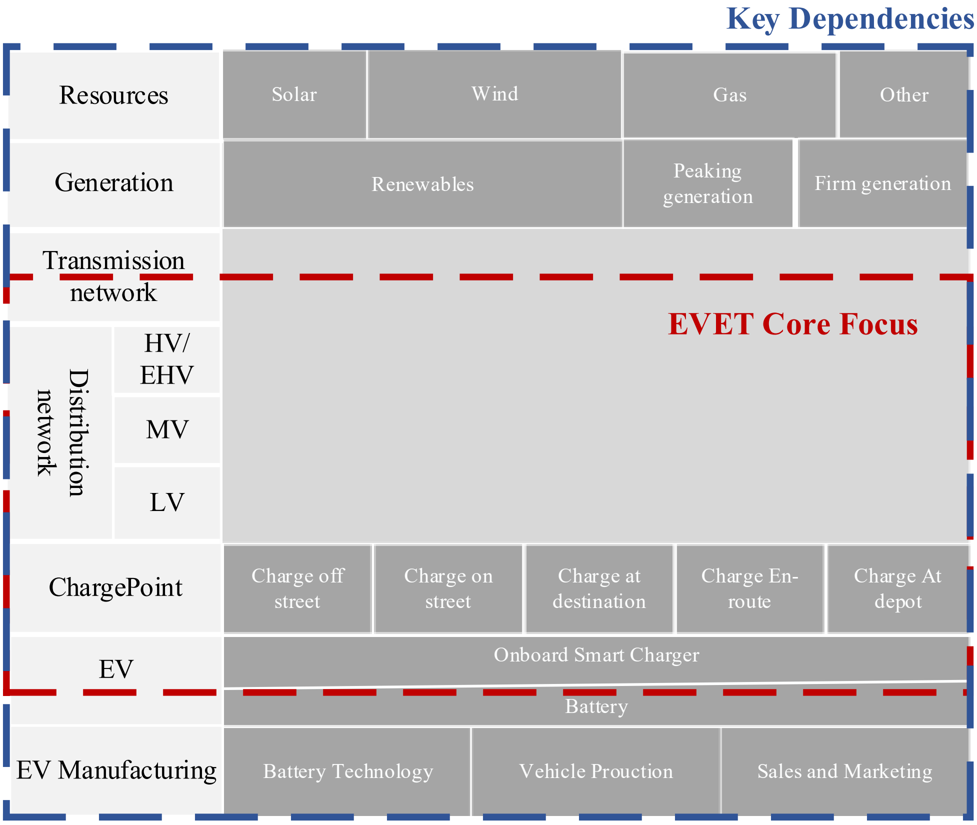
The constructed theoretical framework consists of six layers: automotive industry trajectory, energy supply trajectory, energy storage trajectory, and each of the problem, policy and politics streams. The automotive industry trajectory, energy supply trajectory, and energy storage trajectory refer to industry layers; the problem, policy and politics streams refer to MSF layers. The six layers of the MLST model are analysed in detail in Sections 4.3.1 “Industry Trajectories”, 4.3.2 “Streams”, and 4.3.3 “Windows of Opportunity”. The model as a whole is then explained in 4.3.4 “Multi-level Streams and Trajectories Framework” and shown in Figure 4.18 and Figure 4.19.

4.3.1 Industry Trajectories

The code ‘trajectory’ was included in the research deductively, but it was confirmed and further developed inductively.

The term ‘trajectory’ is mentioned in MLP and co-evolutionary studies in different contexts. For instance, Geels (2018b) used the term to explain the changes in niche-innovations and landscape levels, while Dijk, Orsato and Kemp (2013) analysed the emergence of the trajectory of the niche technology - electric mobility. Turnheim et al. (2015) discussed the dynamics of the regime trajectories, while Yolles and Fink (2013) and Cooke (2018) use this term to explain the historical development in the industry of interest. The concept of ‘trajectory’ in this study is used to explain the development over time in the energy supply, energy storage and automotive industry layers of the MLST.

The term 'trajectory' emphasises the dynamic in the industries. The selection of specific industries is based on the analysis of FOI data and Interviews. FOI 60 includes the discussion of Steering Group members regarding the scope of EVET recommendations and its effect on the dependent industries. The framework they discussed at their meetings is shown in Figure 4.2. As we can see it includes resources, generation, transmission network, charge point, EV and EV manufacturing, wherein EV breaks down into battery and on-board smart charger sublevels. These elements were grouped into energy supply trajectory - resources, generation, transmission network, charge point; automotive trajectory – EV; and EV manufacturing and energy storage trajectory – battery. The battery industry was placed on a separate trajectory to reflect the well-to-wheel processes discussed in FOI data and interviews.



Note: voltage of charge points - High Voltage (HV), Extra High Voltage (EHV), Medium Voltage (MV) Low Voltage (LV)

Source: adapted FOI 60; LowCVP, OLEV, ESC

Figure 4.2 Physical layer EVET framework

4.3.1.1 Automotive Industry Trajectory

The automotive industry trajectory (Figure 4.3) includes three levels: governance level (blue area), incumbent level (green area) and technological niche level (pink area) that were identified in interviews. The *governance level* code includes policies that were mentioned by participants, identified in FOI data and clarified at the literature review matching stage. The list of policies identified during the analysis is included in Appendix 7 "Industry Trajectory Policies" (Table 1) and shown in Figure 4.3. These are the parameters within which actors of the ICE-EV transitions operate. Policies and announcements of the government intentions included in the *governance level* are one of the main drivers of technological changes and have shaped the development of the automotive industry trajectory.

> "I think then what's driven the sustainability transitions has been particularly public policy. Not even public policy measures, because the UK government hasn't announced any measures, all they've done is announced an intention" (Int. 26).

In Figure 4.3, the governance level is split into international, EU, national and local levels, which is reflecting the concept of multi-level governance that was developed by Marks (1992) and Hooghe (1996).

Governance Level

One of the factors that drives the EV transition in the UK is international treaties and international regulations. There is no world government that has the direct authority to regulate national industry trajectories. Nevertheless, international agreements have an impact on national industries. For example, they can set goals for reducing CO2 emissions and encourage national governments to implement national decarbonisation programmes. As a consequence, policy diffusion can take place where decarbonisation programmes spread out across countries. The national governments implement similar programmes to ensure that local industries develop the necessary competencies to compete in other regions and avoid competitive lag (Porter and der Linde, 1995). Thus, policies at the international level can influence national industry trajectories. This was confirmed in an interview with a Senior Manager from the automotive industry. The international treaties stimulated the UK government to set environmental targets to reduce CO2 emissions which then leads to the adoption of decarbonisation policies in the UK automotive industry.

> "I think that would be my main thought that it is definitely a transition that has been driven by international action and regulation by governments but that's not the only element that you need to make it work" (Int.26).

Apart from the international level, the EU level has an impact on the trajectory, the subsequent exit from the EU notwithstanding. Examples of policy documents mentioned in

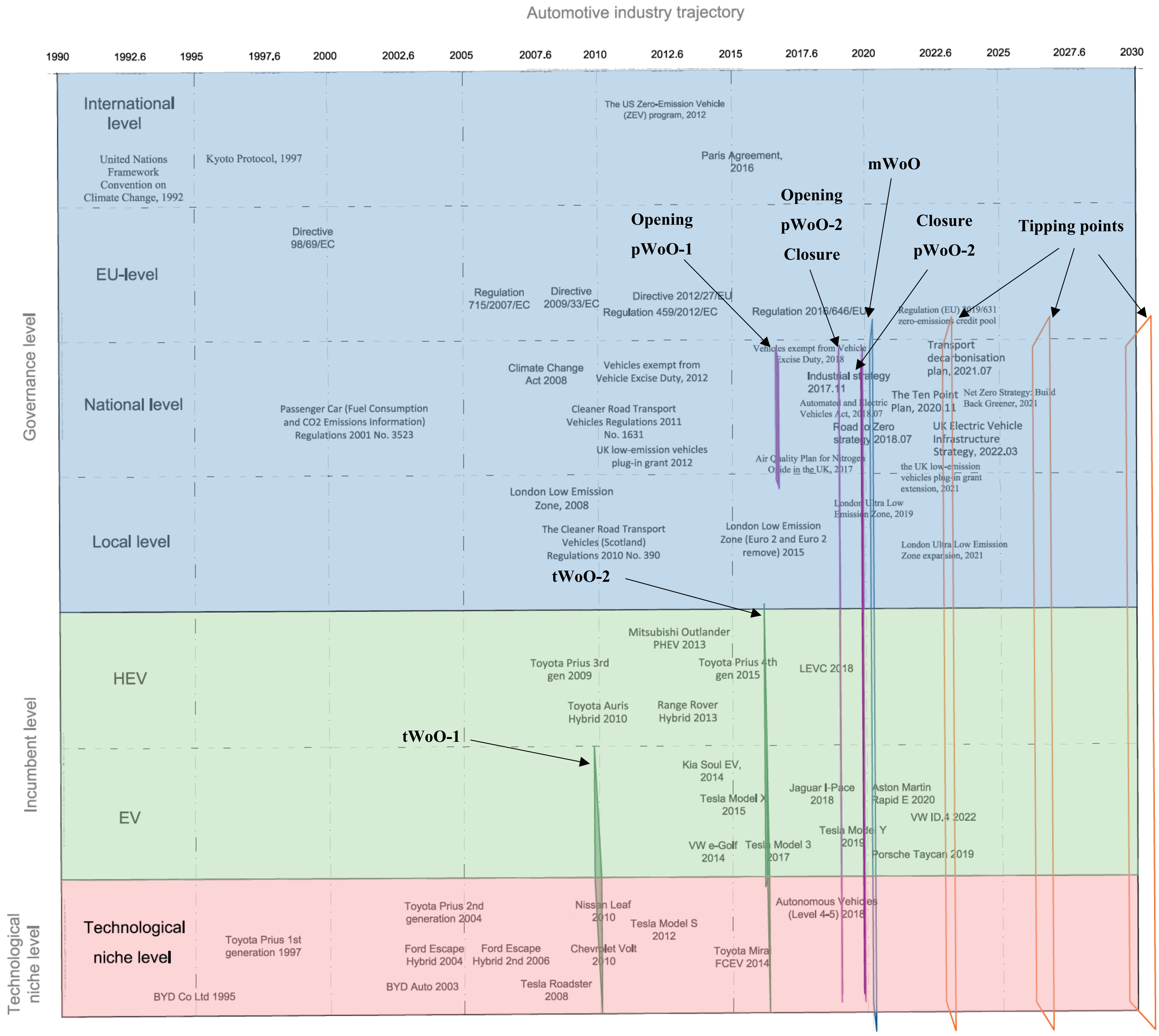
FOI data and interviews that are specifically related to The European Union include Regulation (EU) 2019/631 (Int.12), Directive 2001/116/EC (FOI 33, FOI 74), Directive 2009/72/EC (FOI 74), Directive 2014/94/EU (FOI 105), Directive 2012/27/EU (FOI 38, FOI 81, FOI 104, FOI 105), Regulation 715/2007/EC, Directive 2009/33/EC, Regulation 459/2012/EC, Regulation 2016/646/EU, and Regulation (EU) 2019/631. These policy papers focus on aspects of sustainability transitions such as emission standards, the performance of cars, renewable energy and energy efficiency. Over 55% of UK car exports go to the EU (Society of Motor Manufacturers and Traders, 2022), so EU standards will have a significant impact on the automotive industry and EV transitions in the UK.

> "Apart from that law [Renewable Transport Fuel Obligation], I also feel that the European standard for emissions also impacted on auto industries in the UK because if you want to produce a vehicle and you want to sell that vehicle in the EU, then you must ensure that your vehicle meets this standard set out by the EU. That has a lot of influence in what vehicle manufacturers do" (Int.12).

On the national level, the release of the Road to Zero strategy was one of the main factors that drive the EV transitions. It was the first policy to explicitly identify BEV as the primary technological solution to the decarbonisation of the automotive industry. That was mentioned not only in the Road to Zero strategy by also confirmed by the Head of OLEV during an interview (Int.27).

Local policies play an important role in the transition to EV and can trigger the sustainability process on the national level. One of the most important local policies triggering EV transition processes in the UK was the Low Emission Zone (LEZ) in London which was introduced for the first time in 2008. LEZ required vehicles to meet Euro 4 emissions standards to avoid paying charges. The further implementation of the Low Emission Zone in London made owning ICEs unprofitable, which was also an incentive for increasing demand for BEV and Ultra-Low Emission Vehicles (ULEV). Buyers anticipated that their ICE investment could be discounted as zones expand or tighten, making a significant impact in favour of hybrid vehicles. The more recent Ultra Low Emission Zone (ULEZ) sets even tighter emission standards where the cars need to meet Euro 6 emissions standards. *LEZ* and *ULEZ* as codes are included on the local governance level MLST.

> "What's led to that kind of shift? I think, certainly in the UK, it started with the announcement by the UK government that it was going to be ending sales of diesel vehicles by 2040, coupled with public concern over air quality, and then air quality measures being put in place in London [London emission zone] and in other cities, and that led to a dramatic and sustained collapse in demand for diesel" (Int.26).



Note: technological windows of opportunity (tWoO-1, tWoO-2), policy windows of opportunity (pWoO-1, pWoO-2), market window of opportunity (mWoO) and Tipping Points will be distributed in Section 4.3.3

Figure 4.3 Automotive industry trajectory, top view

Incumbent Level

The incumbent level of trajectories represents the evolution of mainstream technologies and services of incumbent level actors – the actors who produce mainstream products. The technological niche level signifies technological development in technological niche markets where technological niche innovators operate. The transition of a niche technology or service to the incumbent level can be associated with the process of the shift from a small niche level market to a fully functioning sustainable, and competitive market. This may be evident as an increase in market share and adoption of niche technologies or services by incumbent actors.

It is important to mention at this point that the MLST does not operate with the cultural and behavioural elements of the socio-technical regime, such as cultural discourses and user patterns mentioned by Geels (2004). Instead, it focuses mainly on regulatory and technical aspects of transitions such as technologies, policies, and infrastructures. In this regard, the shift of technology from the niche level to the incumbent level can be associated with a shift from a niche market to a sustainable and competitive mainstream market. With such an approach the technology after the shift to the incumbent level/mainstream market can move back to the niche level/niche market in the case of disruption.

The incumbent level is split into two subsections (Figure 4.3). The first subsection/subcategory is related to HEV technology. In total 18 participants out of 48 mentioned hybrids in the interviews and have a positive view on their perspective by 2030. Participants' views on the prospects of various technological options up to 2030 are shown in Appendix 8 "Participants' Views on the Prospects of Vehicle Technologies up to 2030". The fact that HEV is a fully functioning established market accounting for 162 thousand (8.5%) of newly registered vehicles in 2021 allows us to say that this is a mainstream technology rather than a niche market technology (Society of Motor Manufacturers and Traders, 2021c).

The second technology that was included in the incumbent level is EV (Figure 4.3). The shift of EVs to the incumbent level occurred in 2020 when the technology became mainstream. According to the Head of OLEV:

> "I think we're at the moment [December 2020] in another key tipping point where there's more [EV] models available and it's getting all mainstream, last month it was nine percent of new vehicle sales in the UK were full battery electric which is extraordinary" (Int.27).

This statement is confirmed by DfT statistics showing a growth of 184% to the previous year (DfT, 2022c), see Table 4.1.

Table 4.1 Vehicles registered for the first time by vehicle type in Great Britain 2005 to 2021, thousands (k), percentage of the total (%)

Type of Vehicle	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Petrol, k	1544	1061	925	968	1090	1174	1276	1313	1342	1460	1510	987	891	801
Petrol, %	63	53	48	48	49	48	49	49	53	62	66	61	54	50
Diesel, k	894	913	959	1016	1102	1214	1253	1262	1048	736	604	295	188	123
Diesel, %	37	46	50	51	50	50	48	47	42	31	26	18	11	8
HEV, k	5.38	21.80	23.04	24.49	28.74	36.65	44.16	50.88	70.91	86.43	108.4	164.0	257.3	322.7
HEV, %	0.22	1.09	1.21	1.22	1.29	1.50	1.70	1.91	2.83	3.69	4.72	10.1	15.69	20.0
PHEV, k	0	0.02	0.00	0.46	0.67	6.50	17.3	26.3	32.4	41.7	34.6	66.3	112.7	99.0
PHEV, %	0	0	0	0	0	0	0.66	0.99	1.29	1.78	1.51	4.09	6.87	6.14
BEV, k	0.226	0.256	1.20	1.68	2.62	6.66	9.83	10.27	13.69	15.58	37.61	106.7	188.1	263.2
BEV, %	0.01	0.01	0.06	0.08	0.12	0.27	0.38	0.39	0.55	0.67	**1.64**	6.59	11.47	16.3
REV, k	0	0	0.01	0.51	0.39	1.34	1.70	1.90	2.47	2.15	0.25	0.053	0.027	0.068
FCEV, k	0.005	0	0.001	0.007	0	0.006	0.013	0.017	0.035	0.037	0.08	0.059	0.012	0.008
Gas, k	0.528	0.149	0.105	0.073	0.024	0.028	0.042	0.032	0.014	0.096	0.034	0.77	2.31	3.59
Others, k	0.014	0.083	0.008	0.007	0.004	0.002	0.008	0.002	0.003	0.003	0.004	0.006	0.003	0.003
Total	2443	1996	1907	2011	2225	2438	2602	2665	2509	2342	2295	1620	1640	1613

Note: others - new fuel technologies and steam engine; ZEV = FCEV + BEV; number in green indicates the beginning of market uptake by EVs

Source: (DfT, 2023b)

Technological Niche Level

The technological niche level is associated with technological niche markets where technological niche innovators operate. Technological niche innovators do not necessarily need to be small companies or startups focusing on disruptive innovations, these can be legacy carmakers having innovative projects separated from their main business; so-called skunk projects.

An example of niche technology that is currently in the niche market is personal hydrogen vehicles developed by Toyota. According to Department for Transport (2022d), the percentage of *FCEV* out of the total newly registered vehicles in 2021 in the UK was about 0.001%.

> "I don't think people know enough about them to... I know we used to do some fuel cell stuff at work and we sold that part of the business because it wasn't going anywhere" (Int.4)

4.3.1.2 Energy Supply Industry Trajectory

Energy supply trajectory is a theoretical code that encompasses the relationship between policies and technologies in the industries responsible for generating and distributing energies to the various types of vehicles, including HEV and BEV. The importance of energy supply was mentioned in EVET FOI data and was discussed within the context of *tipping* and *trigger points* (FOI 67).

In the context of FOI data, *tipping points* refer to the critical threshold in the electricity system, beyond which an increase in the number of EVs can lead to disruption in the energy supply. This can happen due to excessive energy demand. The *trigger point* is associated with the events signalling the need to take a measure to deal with energy supply issues by adjusting technologies, market structure or regulations. Based on this, it is evident how important the *energy supply trajector*y is for EV transitions (FOI 103).

A graphical representation of the *energy supply trajectory* is given in Figure 4.4. As in the *automotive industry trajectory,* the energy supply trajectory includes three levels: *governance level (blue area), incumbent level (green area)* and *technological niche level (pink area)*.

The first level of the *energy supply trajectory* visualises the code *governance level*. Following the logic *automotive industry trajectory,* the governance level shows policies that were identified in interviews and FOI data and impacted the energy supply trajectory from the different levels of governance. The policies that have shaped the industry at the international level include the legally binding international treaty to limit global warming – the Paris Agreement. From the EU level, this includes policies aimed at increasing the share of renewable energy and improving energy efficiency – Directive 2009/72/EC and Directive 2012/27/EU. On the national level, it was mentioned the policies that encourage the supply of RE, such as the Feed-in Tariffs Order 2010 and its amendments. Strategic policies like the Climate Change Act and Industrial Strategy also play a significant role. In total 16 policies were identified; their codes and policy priorities are shown in Appendix 7 “Industry Trajectory Policies” (Table 3 – 4).

The *incumbent level is* subdivided into the *energy supply subcategory* (having the same code name as the trajectory) and the *EV infrastructure subcategory*, which includes open codes associated with the technologies or services provided by the incumbents supplying energy to the vehicles. These technologies or services add value and generate revenues for the energy supply companies. They form part of the business model and can include, for example, renewable energy technologies, types of smart charging that are serviced, smart charging protocols adapted, or special tariffs. These elements correspond to the physical layer EVET framework shown in Figure 4.2.

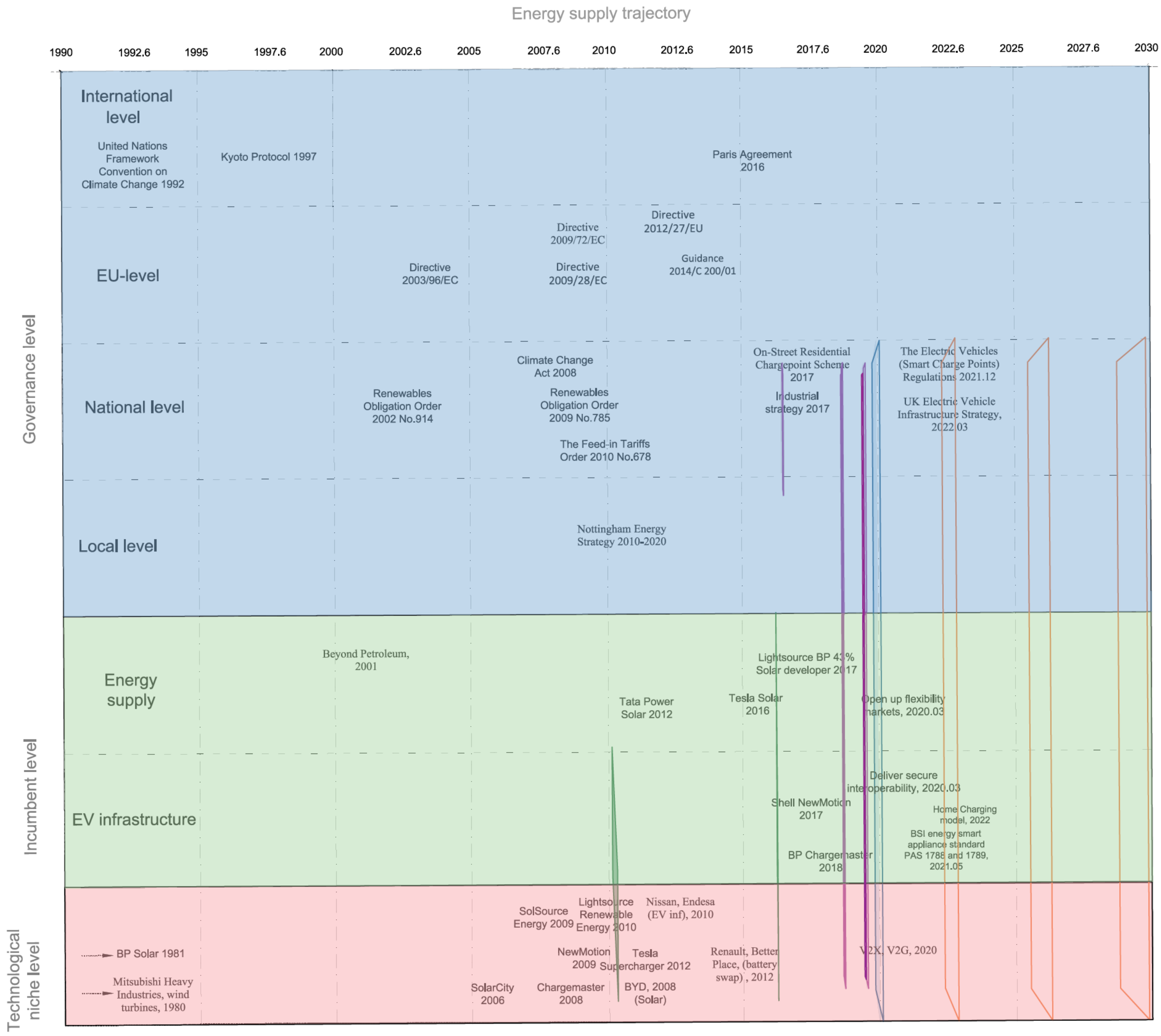


Figure 4.4 Energy supply trajectory, top view

The two niche technologies that were adopted by incumbent actors and now comprise incumbent level are *renewable energy* and *EV charging*.

> "Generally, the strategy of BP was always if you cannot beat let's join and therefore whatever new innovations will develop in the market, they were always there…and it's not a surprise that Chargemaster [EV infrastructure] was a natural step for them to acquire because that is a mood in the market and obviously if the electric vehicles would be one of the part of the automotive industry, certainly BP should have a stake on these things." (Int.2).

Following the release of the Industrial Strategy in 2017, the ICE energy supply companies began to show interest in the EV charging industry. First, Shell acquired NewMotion in 2017, and then BP acquired Chargemaster in 2018. Prior to these acquisitions, NewMotion and Chargemaster were operating at the technological niche level (Figure 4.4). Following such a move the total number of charging points (slow, fast, and rapid charging) began to increase rapidly, growing from 2,283 in 2015 to 9,565 in 2018, a 418% increase (DfT, 2023a). The incumbents do not lose interest in this industry: later in 2020 EDF Energy acquired Pod Point, and Shell invested in Ubitricity in 2021. Nowadays, most of the ICE energy supply incumbents are involved in this business, with more than 19 stakeholders in the UK and a total of over 40,000 EV charging points installed (Zap Zap, 2023). This allows us to say that nowadays charging point technology has shifted to the incumbent level, a move that started in 2017 with the first investments by incumbents (Figure 4.4).

Renewable energy technology reached the incumbent level in 2016. This follows the significant drop in coal generation in the energy balance from 29% in 2014 to 9% in 2016, whilst renewable energy increased from 19% in 2014 to 25% in 2016 (Office for National Statistics, 2022). As with the charging point industry, incumbent actors especially oil and gas companies take an active role in this shift which can transform them into global energy companies in the long term (Int.1).

> "Global publicly traded private companies like Shell, BP, Chevron, etc. they do not own a lot of resources available. Their reserve-to-production ratio is like 10 to 15 years, and they are under constant pressure to find reserves to enable to produce and refine, etc. These companies have started to transform themselves to global energy companies, not only gas but rather energy. Bit by bit they invest in solar, wind and other renewable sources and adapt, buy or even has subsidiaries called 'ventures' which invest is high-risk projects and I think this trend will continue" (Int.1).

4.3.1.3 Energy Storage Industry Trajectory

Within the context of energy storage mediums for vehicles, the participants frequently mentioned *petrol, diesel, synthetic, bioethanol, biodiesel, biogas,* and *hydrogen fuels*. For EVs, the following types of battery technologies were mentioned: *Li-ion*, *sodium-ion* and *solid-state batteries.* These codes are related to two different industries *fuel* and *battery.* However, in the context of cars, they overlap in terms of the function of these specific technologies to store the energy, either chemical or electrical, with subsequent conversion into kinetic energy. Based on this fact the codes discussed above were integrated under the theoretical code *energy storage industry trajectory*. The visual representation of the code is shown in Figure 4.5.

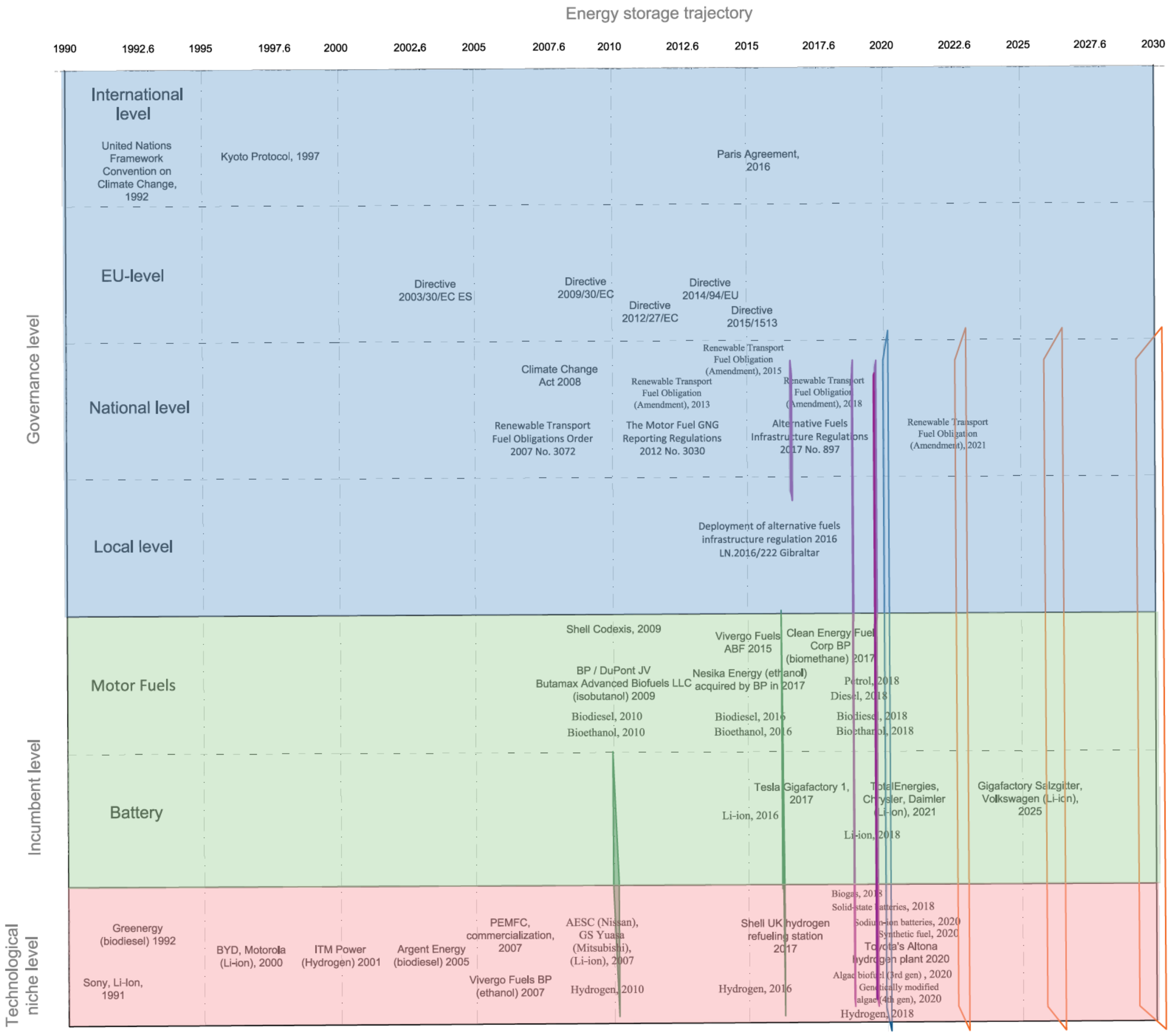


Figure 4.5 Energy storage trajectory, top view

Incumbent Level

One of the most important technological developments that impacted the automotive industry was the advancement of Li-ion batteries. This technology was introduced in 1991 and was widely used in telecommunications and information technology industries. By 2010 when the first mass market-oriented EV was released, this technology reached the incumbent level. The advancement of such technology allowed the production of the first mass-market EV in 2010.

> “A lot of the technology development has been driven by other tech industries. So the fact that batteries have been getting smaller and smaller because of, for example, mobile phones and so on, has led the development in battery ion technology”. (Int.26).

> “I would say that the more recent move [2010] towards electric vehicles has been driven by improvements in battery technology … since 2010, battery prices came down by a factor of

five or six, so that for me is the point at which the policy drivers, which had been in place for a long time, became answerable with the technology that was affordable to the public. Not all of the public at that point in time, but at least some." (Int.25).

The participants' opinions are confirmed by IEA (2022b; 2022a) statistics, where the cost of Li-ion battery cells decreased by a factor of 5.6, from 3382 USD/kWh in 2000 to 601.4 USD/kWh in 2011 (Table 4.2).

Table 4.2 Average price of lithium-ion batteries and share of cathode material cost 2000 to 2021, USD/kWh

	2000	2005	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cathode material	nd	nd	32.6	25.1	29	21.9	12.6	13	29.8	31.6	26.4	21.1	28.7
Other cell cost	3382	1271	601.4	473	440.4	390.5	250.6	207.6	128.8	102	86	83.4	72.3
Pack cost	nd	nd	290	227.9	214.7	194.4	130.2	82	66.9	51.6	48.5	35.9	31

Source: IEA, 2022b; 2022a

Technological Niche Level

The second technology frequently mentioned by participants and potentially used to achieve net-zero targets in the automotive industry in the UK is Fuel Cell Electric Vehicles (FCEV). The energy storage medium for this technology is hydrogen fuel. Currently, there is a lack of demand for FCEV. There were only a few fuel cell vehicles in the UK in 2010. The same tendency continued over the years, for example in 2016 as well as in 2020 only 0.001% out of total personal cars registered for the first time were FCEV. This inevitably affected the consumption of hydrogen fuel.

"I would say 15 years ago [2008], maybe even less, there was this argument about whether we would be hydrogen or batteries. I think that argument's been resolved for passenger EVs" (Int.19).

Currently, hydrogen technologies within the automotive industry context remain on the market niche level. That was anticipated in the documentation provided to MPs in 2010.

"Fuel cell production is unlikely to be cost competitive in the next decade and little infrastructure exists for transporting hydrogen around the UK. Fuel cells may offer the lowest carbon option for larger vehicles such as HGVs in the long term." (UK Parliament, 2010, p.4).

However, recently, the government released its Hydrogen Strategy aiming to increase the usage of such types of fuels (BEIS, 2021). This is seen as a positive development for hydrogen technology and it is anticipated that it will be an important green source of fuel in transport (IBISWorld, 2023). However, it is unlikely that this technology will be used in personal cars; instead the most prominent application would be depot-to-depot transport, for example in heavy-duty vehicles or buses.

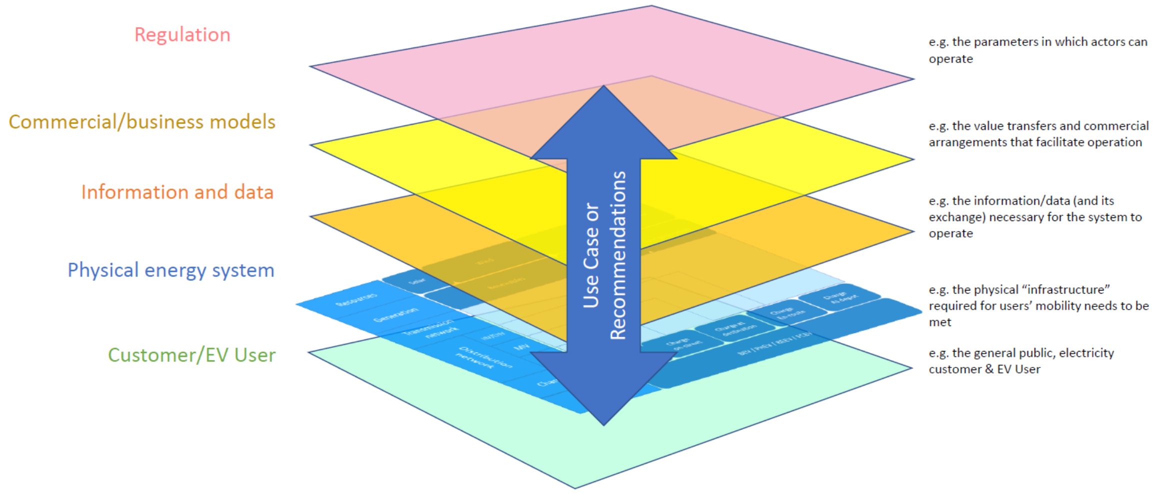
> “Where I can see it [hydrogen vehicles] working, will be where you have depot-to-depot traveling [can work for hydrogen]. So where you have a vehicle that starts off at a depot, travels a long distance to another depot. I can see it working there, because you can then have depot-based refuelling. If you're reliant on refuelling across the whole country, I think that would be really difficult, because of the infrastructure costs … would you then invest in a second zero carbon technology [after investing in EVs infrastructure]?” (Int.26).

As was indicated in this section, technological development in energy storage and energy supply industries is an important aspect of EV transitions which was recognised by the participants of the interview. It was conceptualised as industry trajectories and is one of the main elements of the constructed theoretical framework. In the next section, we will consider the problem, policy and politics aspects of the transitions that were integrated under the code ‘Streams’.

4.3.2 Streams

Problem, policy, and politics streams correspond to structural elements of the MLST. The code ‘streams’, as well as the code ‘trajectory’, was included in the research deductively, but it was confirmed and further developed inductively. In FOI 60 and FOI 67, the members of the Steering Group discussed the EVET framework that was used while developing and synthesis the policy recommendations to the government. The level of EVET framework has common ground with the MSF, both of which were adapted in the MLST.

To mitigate the possible negative effect of tipping points or constraints on the EV transition pathway, the EVET suggests providing policy recommendations to the government [FOI 60]. Analysing EVET data, it was found that the recommendations focus on five elements of the automotive industry ecosystem: regulations (for example, the parameters in which actors can operate), commercial/business models (the value transfers and commercial arrangements that facilitate the operation of companies), information and data (the information/data and its exchange that is necessary for the energy system to operate), physical energy supply (the physical infrastructure required for users’ mobility needs to be met), customers/EV users (the general public, electricity customers and EV user attitudes and preferences); see Figure 4.6.



Source: FOI 60

Figure 4.6 Layers of the EVET Framework

The EVET Framework plays an important role in structuring policy recommendations. Figure 4.7 shows an example of the alignment of policy recommendations discussed in one of the Steering Group meetings with the framework. The colours of rows in Figure 4.7 correspond to the layers of the EVET framework. It is possible to see that problems associated with the *lack of consumer protection* influence the Regulatory layer and Commercial and Business Model layers of the EVET Framework. In response to this problem, EVET recommends "government and relevant regulators launch a review of protections for customer interactions with companies that are not currently regulated" (FOI 67 cf). This recommendation refers to the regulatory layer of EVET (pink colour).

Layer	Today	Problem	Recommendation	Test Case
Consumer & EV User	• Lack of consumer protection.	• Unregulated companies • Lack of clarity of areas of responsibility between market players • Lack of accessible dispute resolution		• Good consumer protection.
Regulatory			1. Government and relevant regulators launch a review of protections for customer interactions with companies that are not currently regulated.	
Commercial / Business Model			2. Define clear responsibilities within market participants and the required cooperation needed to resolve consumer complaints. 3. Require all companies that deal with EV drivers to offer – and inform their customers of the availability of – an accredited Alternative Dispute Resolution process.	

Source: FOI 67 cf

Figure 4.7 Problem - recommendations relationship

According to Zahariadis (2014, p.33) within the MSF context, “the policy stream includes a “primeval soup” of [policy] ideas that compete to win acceptance in policy networks”. The problem stream comprises “various conditions that policymakers and citizens want to be addressed” (Zahariadis, 2014, p.32). The politics stream consists of the public mood, financial institutions' mood, pressure group campaigns, election results, and partisan or ideological distributions in Parliament (Kingdon, 2014).

If we relate the EVET framework with the MSF, the problems of the *lack of consumer protection* from the customer/EV user layer can refer to the problem stream. Policy recommendations to “government and relevant regulators launch a review of protections for customer interactions with companies that are not currently regulated” can be an element of the policy stream.

Moving to the commercial/business models layer it is possible to see that recommendations also have industry-specificity. For example, in Figure 4.7 it was recommended to all companies to inform their customers of “the availability of – an accredited Alternative Dispute Resolution process” (FOI 67 cf). This can be considered an industry-specific recommendation for industry stakeholders.

The MLST adapts these ideas and suggests dividing the streams on governance, incumbent and technological niche levels by the analogy of Industry Trajectories discussed earlier. In this case, the governance level of MLST streams is related to the governance/macro level recommendations/problems/political events while incumbent and technological niche levels of the MLST streams refer to industry-specific/meso and micro level recommendations/problems/political events. The MLST streams and their levels will be discussed in the following sections.

4.3.2.1 Problem Stream

This study sees the problem stream as a timeline, with conditions framed as problems to which policies or technologies on different levels of governance or markets, respectively, are addressed. In addition, the problem stream includes problems preventing the advancement of technologies at the incumbent level, or problems hindering market uptake for the market niche technologies. The visual representation of the problem stream is shown in Figure 4.8.

The problem frames identified during the analysis of interviews and archival data are displayed below. Quotes supporting the analysis will be presented, starting with the local governance level and moving to the national level, EU, and international levels. Furthermore, the quotes supporting the open codes for the incumbent level and technological level will be provided as well as the year assigned to the codes. These years will be used to position the codes on a timeline of the graphical representation of the problem stream.

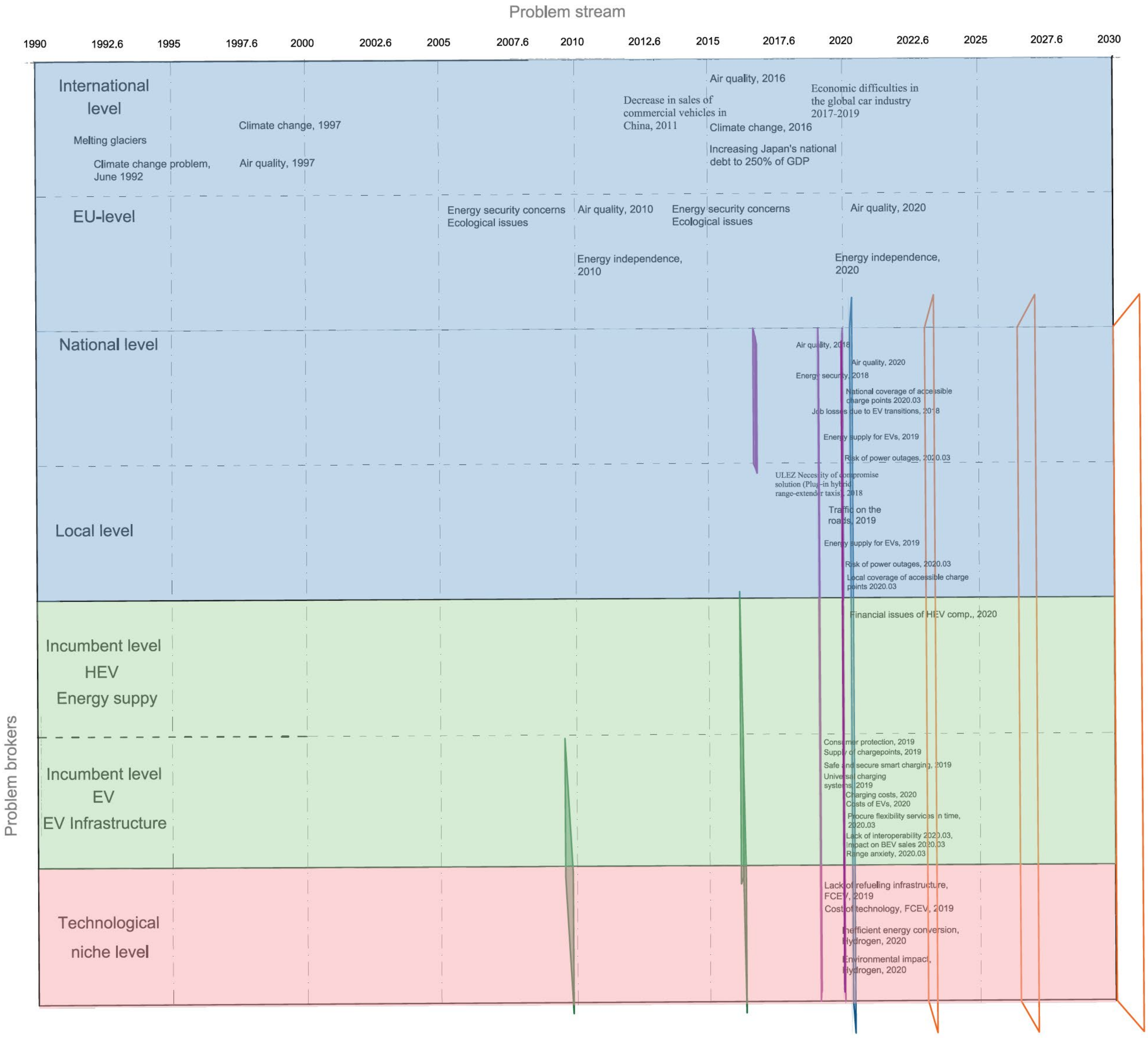


Figure 4.8 Problem stream, top view

It is important to clarify national, incumbent and technological niche level problems. National or local level problems impact the population of a country or local areas and can be, for example, associated with climate change, air quality or energy security issues. Incumbent level and technology niche level problems are technology-specific and predominantly affect the respective industry and industry stakeholders. The incumbent level problems can be, for example, associated with the issues of supply or demand of a specific technology on incumbent or technological niche levels, or the issues related to the development of a specific technology.

During the interviews with UK local authorities, problems associated with traffic in the cities and towns were mentioned multiple times. The code *traffic on the roads* was assigned to the *local level* problem of the *governance level* (subcategory - local level; open code - traffic on the roads; year on timeline - 2019). The year 2019 was selected based on the date of the interview.

> "Sub-optimal response [to decarbonisation policies by the carmakers] would be to portray business as usual as, ever expanding numbers of vehicles on the roads, but driven electrically rather than by fossil fuels, it isn't really gonna solve our problems" (Int.21). Transport planning, Local Authorities

At the *national level,* social problems were framed around *air quality* and *energy security* issues (subcategory - national level; open codes - air quality, energy security; year on the timeline - 2018). In the foreword to the Road to Zero (2018, p.1) strategy, MP Secretary of State for Transport, Rt Hon Chris Grayling stated "as part of that [the government plan to build a high-growth, high-productivity, green economy], our UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations ('the NO2 Plan') and Clean Growth Strategy will cut exposure to air pollutants, reduce greenhouse gas emissions and improve our energy security". These problems were reiterated multiple times throughout the document, clearly indicating the issues the strategy aimed to resolve. This was the reason for their inclusion at the national level of the problem stream. The released date of the Road to Zero strategy was assigned to the problem frame in the problem stream timeline (Figure 4.8).

Moving to the EU level, three interviews with senior managers who have expertise in the EU energy sector were conducted. The open codes associated with *air quality* and *energy independence* were identified (subcategory - EU level; open codes - air quality, energy independence; year – 2010 and 2020). The context of the topics discussed during the interviews were 2010 and 2020, hence the corresponding years of the codes were used in the timeline.

> "Definitely in Europe, the priority of the governments is public health, and especially since the pandemic, but before that [2010], so they start with the public health piece which is improving air quality" (Int.16).

> "One of the key drivers for the European Union at the time [2010] to push for renewables was actually to... A decreased link... The dependency from oil supply and gas supply from non-European suppliers. It was to become more independent from an energy standpoint. Honestly, when they came with the 20% renewable share by 2020, at the time, there was not so much discussion about decarbonisation as such, the concern was more, "We're too much relying on external supplier for our energy." (Int.24)

The interview with the Head of OLEV clarified that the problems, not only at the national level but also at the international level of the stream, are of importance. During the literature matching stage, the information provided during the interview was matched with the information in the international treaties, the Kyoto Protocol and Paris Agreement. Based on this, the open codes *climate change* and *air quality* were added at the international level in the problem stream. The years for the *climate change* and *air quality* codes at the national level were assigned according to the adoption year of the treaties – 1997 and 2016. However, for the *air quality* code at the UK level, the year of the interview was assigned instead.

> "It's been very much driven by not UK but international regulation and that is all off the back of increasing international concern around climate change, but also and it sort of waxes and wanes in terms of what's more important but air quality also very much in the mix" (Int.27)

Stakeholders of EVET were able to address the industry-specific problems relating to EV infrastructure and the energy supply to the government and other members of EVET. The problems are typically framed in the form of questions during the work packages debate or EVET meetings. The problems regarding the advancement of BEV that were identified in archival data were allocated to the technological niche level. The BEV technology was at the technological niche level at that time; and the problems associated with this technology, for example, the problem of demand, primarily impacted the niche level actors. Thus, the problem frames associated with niche technology are associated with the niche level of the problem stream. The problem related to the EV energy supply and distribution were included at the incumbent level. This is linked to the fact that these problems primarily affected actors in the energy sector, most of whom were incumbent actors. These questions were addressed in 2019 and subsequently included in the corresponding year on the timeline of the problem stream. The key problems identified in work packages are shown in Table 4.3.

Table 4.3 Key problems identified in work packages of EVET

Taskforce	WP1	WP2	WP3	WP4
How to prepare the electricity system to facilitate the uptake and exploit the benefits of EVs in an optimal way (at least cost)?	Understand the evolving energy system and how to exploit it	How to ensure consumers see smart charging as a benefit rather than an imposition?	What are the technical requirements for smart charging?	Lack of accessible data
How to ensure consumers have the choice to benefit from and engage with smart charging optimally (at least cost to the electricity system)?	Need to establish a common vision across sectors to deliver an EV-ready grid that decarbonises transport and energy sectors?	How to deliver the benefits of smart charging to consumers?	How to deliver safe and secure smart charging?	How to improve the electricity system operation?
	Where is investment needed, who benefits and how to apportion costs?	How to provide consumer protection?	How to deliver interoperability?	Forecasting future spatial demand for EVs
	How to deliver benefits to the energy system and EV user simultaneously?	How to address consumer concerns?	Technical limitations and opportunities.	Where will network monitoring data come from?
	How to tackle near-term transitional issues for the electricity grid and EV users?	How to deliver the benefits of smart charging or demand-side response to fleets?		Supporting the supply of chargepoints
				Data ownership and access to data

Source: FOI 67

Based on the analysis of FOI data, the problems were grouped into 5 subcategories, which were included in the *EV* incumbent sublevel of the problem stream Figure 4.8. These are *energy supply for EVs*, *safe and secure smart charging*, *supply of chargepoints*, *data interoperability*, and *consumer protection*. An interview with the members of EVET in 2020 revealed two additional subcategories of problem codes associated with *charging costs* and *costs of EVs.* The year 2020 was assigned to these two additional open codes.

> “Two particularly the challenge we have with EVs - the lower running cost higher upfront purchase price” (Int.27).

The problem codes that incumbent actors linked with the advancement of HEVs and ICE types of vehicles are *financial issues* and *job losses due to EV transitions*. Below are two quotes from the expert who was involved in the negotiations with HEV and ICE stakeholders. The timeline of the code is 2020 for *financial issues* and 2018 for *job losses due to EV transitions,* according to the context of topics discussed in the interviews.

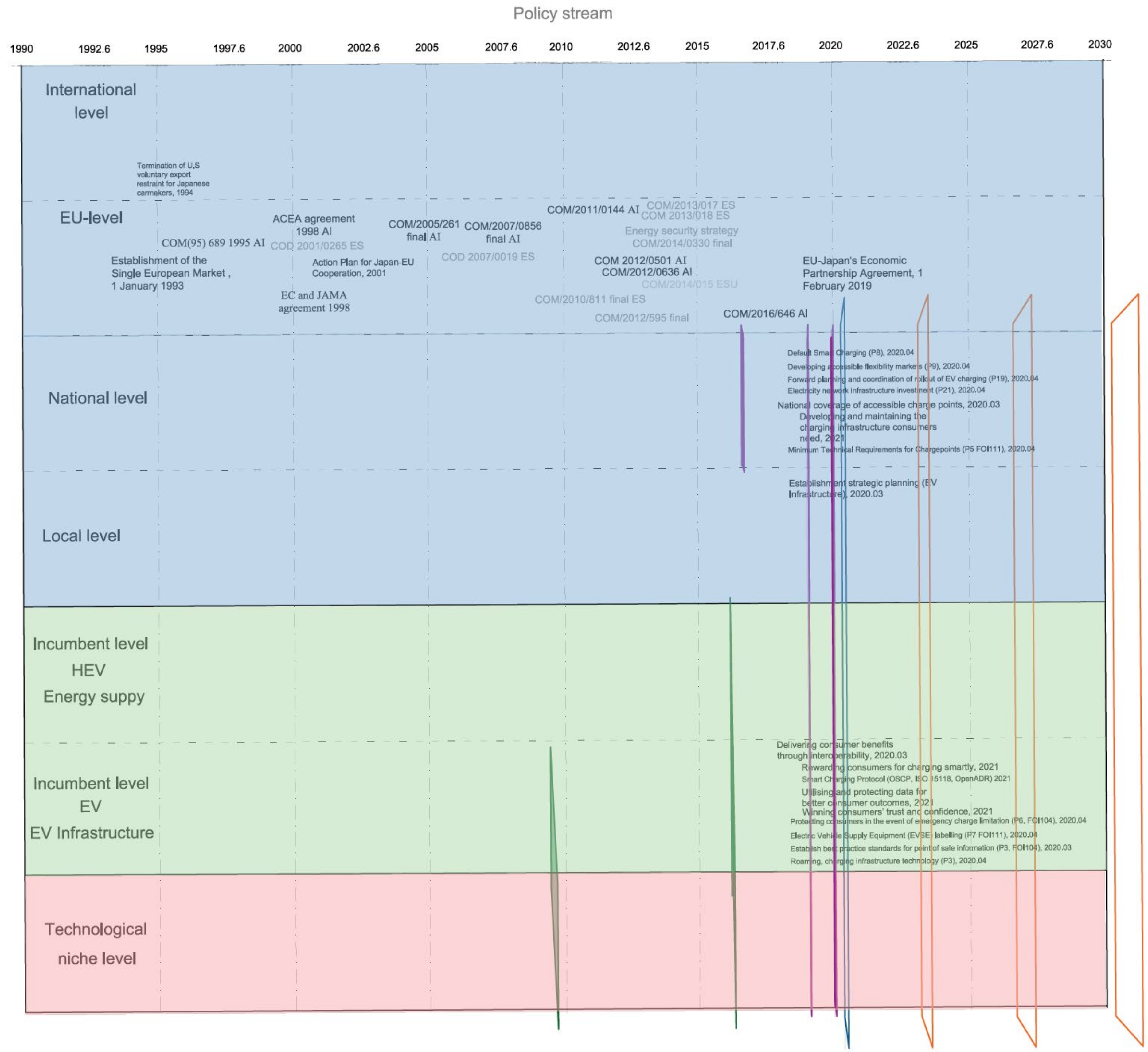
> “I think in June [2020], they [carmakers] were talking about doing a scrappage scheme as part of the pandemic recovery. And when they were talking about the scrappage scheme, they were talking about it being available for all vehicles including diesel " (Int.16).

> “The business department was on the side of the car industry [in 2018], because the car industry makes engines in the UK, and so the business department is involved with ensuring that there are jobs in manufacturing, and so they were supporting the car industry” (Int.16).

The next section will focus on the policy stream, which is directly related to the problems discussed in this section.

4.3.2.2 Policy Stream

A graphical representation of the *policy stream* is shown in Figure 4.9. By analogy with the *problem streams*, as well as the *industry trajectories*, the policy stream is divided into three levels: *governance level, incumbent level*, and *technological niche level*. The governance level of the policy stream is divided into international, EU, national and local sublevels and includes policy ideas in response to the broader environmental problems depicted at sublevels of the governance level of the problem stream. These policy ideas can be adopted and included in the final policy papers. The final policies that include policy ideas of the policy stream are shown in the governance level of the industry trajectories. For example, the Electric Vehicles (Smart Charge Points) Regulations (2021) and the UK infrastructure strategy (2022b) comprise the ideas of roaming and interoperability of the policy stream that was discussed in 2020 at the incumbent level. These policies are depicted in the governance level of the energy supply trajectory in the years 2020 and 2021. The timeline of the policy stream indicates the specific date when the policy idea was identified in the FOI data, interviews, communication, or consultation papers.



Note: at EU-level, communication papers (COM) in grey colour relate to energy supply and energy storage trajectories; black COMs relate to the automotive trajectory

Figure 4.9 Policy stream, top view

The incumbent level and technological niche levels of the policy stream encompass policy ideas in response to technology-related problems included in the incumbent level and technological niche level of the problem stream. The policy ideas (policy proposals) of the incumbent level of the policy stream are industry-focused.

It was also noted that one technology-specific policy idea from the incumbent level can be included in multiple national-level policy proposals of the policy stream. As a result, this idea can be incorporated in one or multiple policy papers depicted in the governance level of industry trajectories. In addition, the situation when multiple policy ideas are included in one or multiple policy papers is possible. This can happen when multiple ideas and different aspects of the broader social problem are included in the consultation paper. This resulted in issuing a national level policy that comprises multiple policy ideas from incumbent and technological niche levels.

Below are provided quotes from the archival data, consultation papers and policy documents supporting the above statement related to the inclusion of a single policy idea in multiple policy papers.

In FOI 20 2018.10.22 stakeholders identified a specific problem of EV transitions, namely access to the energy markets via smart charging points and V2G technology.

> "Work Package 1 should consider the following specific questions: 2. What are the barriers for EVs (in terms of smart charging and V2G) accessing the energy markets? 3. Are changes required to metering/supply arrangements to accommodate new innovative business models associated with EV charging infrastructure, whilst ensuring that consumers' interests are protected?" (FOI 20).

After the closure of the consultations, EVET provides a recommendation to maximise the use of smart charging.

> "The work of the Taskforce has highlighted a complex range of credible options, by various parties in the energy and EV services supply chains, to maximise the use of smart charging technologies for controlling the charge/discharge rate of EVs under various circumstances. These have the potential to benefit both consumers and the electricity system, whilst supporting the transition to EVs." (FOI 103, 2020.03.16).

Afterwards, the smart charging policy idea was included in multiple final policies that addressing to the broader social problem – delivering a net zero target. The first national policy is The Electric Vehicles (Smart Charge Points) Regulations 2021 published 15th December 2021, the second is UK Electric Vehicle Infrastructure Strategy published 25th March 2022.

Both of these papers encourage the installation of smart charging points.

> “3. (1) Subject to paragraph (2), these Regulations apply to charge points (5) which are intended to be used for charging cars, vans or both of them, other than — (a) non-smart cables; (b) public charge points; (c) rapid charge points. 5. (1) A relevant charge point must have smart functionality.” (HM Government, 2021, pp.2, 3).

> “Delivering a reliable, comprehensive public charging network requires a UK-wide approach. These cover electricity network capacity, efficient energy system integration through smart charging, and consumer participation and protection.” (DfT, 2022b, p.31)

Not all EVET ideas were related to the policy papers; some were included in the industry standards. For example, in FOI 87 cf (drafts of proposals 15 and 16) the standardisation issues were addressed to the governments and associated with the standardisation of the digital architecture, charging protocols, and energy management systems for the EV charging infrastructure. They are related to flexibility types of proposals focusing on customers' perceptions of EVs.

> “It is proposed that Government should: Establish a body with industry to coordinate the involvement of industry stakeholders in agreeing the adoption of international and open standards as the basis of EV charging based on the outcome of PAS [Publicly Available Specifications] 1878 [The British Standards Institution (BSI) energy smart appliance standard] and 1879 [BSI energy smart appliance standard].” (FOI 87 cf)

These standards were consequently released in 2021 and include requirements and criteria that an electrical appliance, including smart chargers, needs to meet (BSI, 2021).

Policy ideas at the national and local level are government focused, they are addressed to the government and have a macro scope. Some examples of national level policy ideas include the implementation of default smart charging regulation (Proposal 8 FOI 111) 2020.04; the development of accessible flexibility markets in the UK (Proposal 9 FOI 111) 2020.04; forward planning and coordination of rollout of EV charging (Proposal 19 FOI111) 2020.04; the creation of favourable conditions for electricity network infrastructure investment (Proposal 21 FOI 111) 2020.04; provision of national coverage of accessible charge points (FOI 87), 2020.03 (see Figure 4.9).

Analysing FOI data, 21 proposals were identified that were selected and refined out of questions, recommendations and policy ideas of 108 EVET participants. The proposals are listed in Table 4.4, grouped into five subcategories. These subcategories were included in the visual representation of the policy streams (Figure 4.9) and hierarchy of codes in Appendix 4 “Hierarchy of Codes and Coding Grids” (Table 8).

Table 4.4 EVET policy proposals

Themes & Proposals	**Year**
Theme 1 Delivering consumer benefits through interoperability	
Proposal 1 Review of International Standards	2025
Proposal 2 CPO System Security	
Proposal 3 Roaming	2021
Proposal 4 Smart charging coordination	2021
Proposal 5 Minimum Technical Requirements for Chargepoints	2021
Proposal 6 Emergency Charge Limitation	
Proposal 7 Electric Vehicle Supply Equipment (EVSE) labelling	2021
Theme 2 Rewarding consumers for charging smartly	
Proposal 8 Default Smart Charging	2021
Proposal 9 Developing accessible flexibility markets	2023
Proposal 10 Smart meters	2020
Theme 3 Utilising and protecting data for better consumer outcomes	
Proposal 11 Access to data	2021
Proposal 12 Chargepoint Registration	2021
Proposal 13 Access and privacy framework	
Theme 4 Winning consumers' trust and confidence	
Proposal 14 Body for consumer facing communications	2022
Proposal 15 Independent tailored advice service	2022
Proposal 16 Complaint handling	2021
Proposal 17 Market protections	2021
Proposal 18 Point of sale information	2021
Theme 5 Developing and maintaining the charging infrastructure consumers need	
Proposal 19 Forward planning and coordination of rollout of EV charging	2020
Proposal 20 Effective operation and maintenance Govt support & Sharing Best Practice	2021
Proposal 21 Electricity network infrastructure investment	2021

Source: FOI 111

4.3.2.3 Politics Stream

A graphical representation of the *policy stream* is shown in Figure 4.10. The Politics Stream, like the problem and policy streams, comprises governance, incumbent and technological niche levels that include events indicating the government, public or industry stakeholders' support, or resistance relevant to the policy ideas in response to the problems on the national, local, incumbent or technological niche levels. The events that reflect the government attitude or public perception toward EV transitions, which can influence this process, are shown at the global, EU level, national and local levels of the stream. The events that indicate the attitude of incumbent actors or technological niche actors, influencing EV transitions are portrayed at incumbent and technological niche levels.

The events included on the national level of the politics stream are discussed below. On July 13, 2016, Theresa May became UK Prime Minister. This event was included in the politics stream and had a positive effect on the EV transition. This was evident in the release of decarbonisation policies during PM May's tenure, such as The Clean Growth Strategy (BEIS, 2017), Transport Investment Strategy (DfT, 2017), Industrial Strategy (HM Government, 2017), Road to Zero Strategy (DfT and OLEV, 2018), and the Future of

Mobility: Urban Strategy (DfT, 2019). The support of the PM for EVs is also evident in FOI data.

> "On 1st July [2019] the Prime Minister announced that OLEV will lead a review and develop a vision for a core network of rapid chargepoints along England's key roadways... the Prime Minister welcomed a proposal for a Green Mobility Transition Board which would bring together key sectors to coordinate efforts to speed up the adoption of ultra-low emission vehicles" (FOI 76).

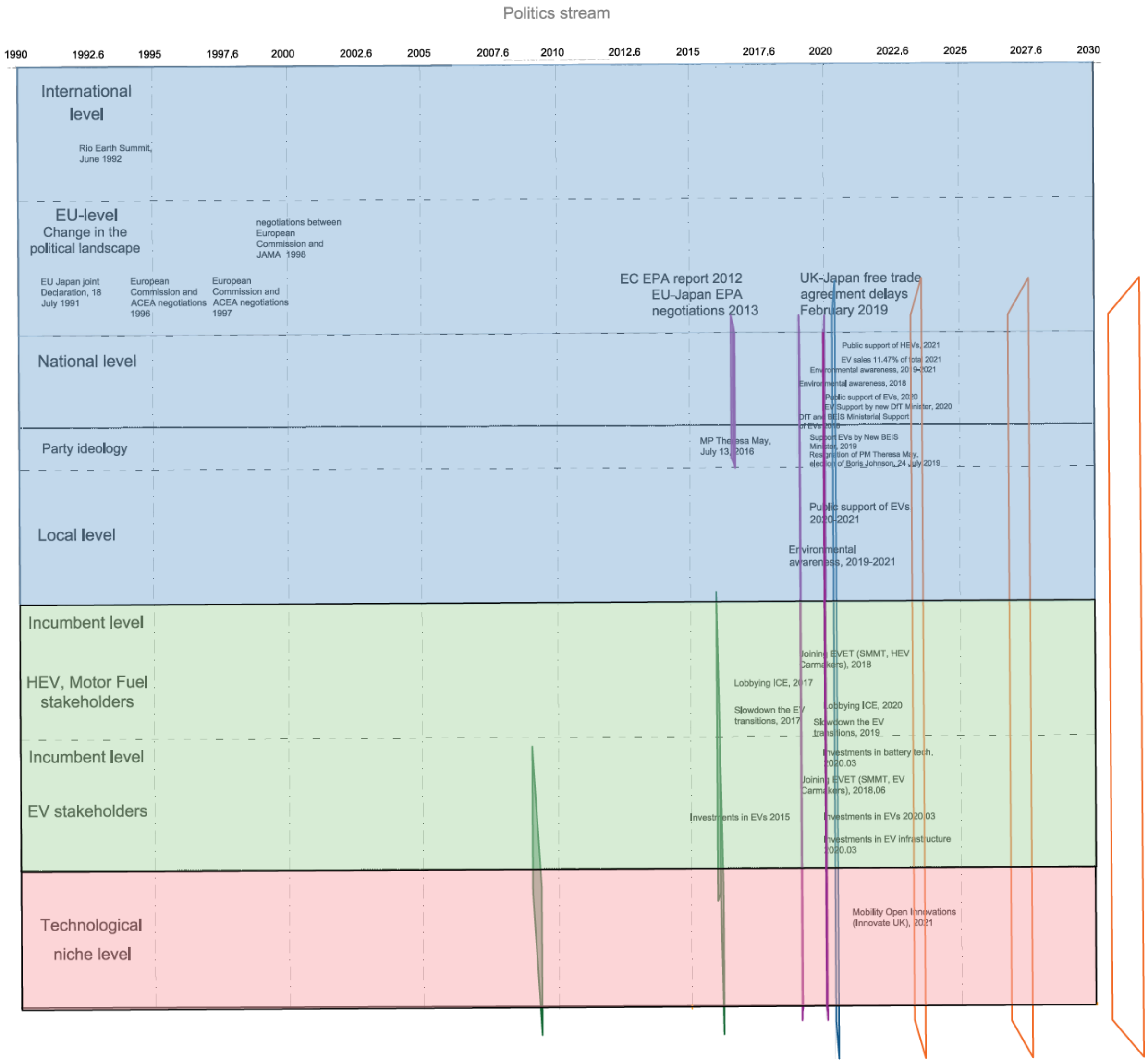


Figure 4.10 Politics stream, top view

The next PM, Boris Johnson, continued to support EVs and was responsible for releasing the Ten Point Plan for a Green Industrial Revolution (HM Government, 2020) mentioned in Int. 27. This policy paper announces the government's plan to phase out petrol and diesel vehicles in 2030 and hybrid vehicles in 2035 and sends a very strong signal to the key industry stakeholders.

Another event demonstrating the positive attitude to the EV transition on the national level indicated in the FOI data was related to the support for the transition by the Minister of State for Transport in 2020 (*DfT Minister Support*). In the Government Perspective section of the minutes of EVET Steering Group meeting of 28 Apr 2020 (FOI 113) the following record was made:

> "It was noted that the new DfT Minister A is very keen on electrification of transport." (FOI 113, 2020.04)

Public opinion shows a tendency to support EV transitions rather than oppose them, especially over the last 5 years. The code that is included on the national and local level of the politics stream is *public support of EVs*. This conclusion was made based on an analysis of the interviews and secondary data.

In 2018, the general public attitude towards the EVET objectives was broadly positive, as indicated by national level surveys. For example, on October 19, 2018, on the question "Currently the government has said it will ban the sale of new petrol and diesel cars after 2040. Some people have suggested that this ban should come into force earlier - which of the following best reflects your view?" 33% of participants (out of 2957 Great Britain adults) answered that new petrol and diesel cars should be banned earlier than 2040, 15% stated that new petrol and diesel cars should be banned from around 2040, 22 % felt there should not be any ban on new petrol or diesel cars, and 25 % did not know (YouGov, 2018a). In a second survey from October 2018, when asked "How concerned, if at all, are you about climate change?" 31% of 4130 participants in Great Britain answered "very concerned"; 43% replied, "somewhat concerned"; 16% "not very concerned", and 7% "not concerned at all" (YouGov, 2018b). The generally positive public attitude towards this EVET topic was further confirmed by personal observations made during the EVET meetings, as I was able to attend six stakeholders' events.

The positive impact of the EV-oriented legacy carmakers investing in BEV was confirmed by their activities in the EVET meetings. In the FOI data three such carmakers were identified as being regularly involved in the meetings and contributing to the policy proposals and consultation papers. Specifically, BMW and Nissan were involved in WP1 and WP2; Tesla in WP1, WP2, and WP4.

The code *joining EVET* includes the motor manufacturing interest group the Society of Motor Manufacturers and Traders (SMMT). SMMT is a trade association for the UK motor industry that "exists to support and promote the interests of the UK automotive industry at home and abroad" (Society of Motor Manufacturers and Traders, 2023). The FOI data indicates that the SMMT was actively involved in the EVET steering meeting and was a sponsor of WP3.

> "Work Package 3 has been led by the BEAMA Limited with sponsorship by the SMMT and the Automotive Council. At the commencement of the project, two groups were established;" (FOI 105, 2020.03.16)

At the moment SMMT is increasingly supportive of EV transitions, confirmed by the last interview with the CEO of SMMT, Mike Hawes.

> "We must accelerate a transition from fossil fuels to decarbonised technologies. OEMs are investing to build the vehicles and we are trying to attract investment in gigafactories, because batteries need to be produced relatively nearby." (Manufacturing Today, 2022).

Among the trade association involved in EVET are the Electric Vehicle Supply Equipment Trade Association (EVSE), British Electrotechnical and Allied Manufacturers' Association, Renewable Energy Consumer Code, Energy Networks Association, Energy UK and TechUK. These stakeholders were engaged in EVET and classified as supporters from industry.

It is worth noting that there were *lobbying ICE* and *slow down the EV transitions* campaigns that were not announced in the press but were regularly mentioned by interviews of different stakeholders: battery producers, academics, carmakers and policymakers. These events were placed on the timeline according to the interview dates in 2019-2020. Below provided some quotes from interviews helping in the understanding of the context of lobbying or slowdown.

> "We could see already that the release of the new policy has been delayed for months by intensive lobbying and not everyone is happy about this" (Int.2).

This section has demonstrated the problem, policy and politics aspects of the transitions identified in the data. The next section will focus on the third building block of the developed framework – windows of opportunity.

4.3.3 Windows of Opportunity

The code 'windows of opportunity', similar to the codes 'trajectories' and 'streams', was included in the research deductively but then refined by the actual data. Both the MLP and MSF literatures use the concept of windows of opportunity. In the MLP literature, the window of opportunity for niche technologies is associated with pressure from the macro level on the socio-technical regime level, due to changes in "demographic trends, political ideologies, societal values, and macro-economic patterns" (Geels, 2011, p.29). The MSF literature sees the policy window of opportunity (pWoO) opens by cause of events within the politics stream or problem stream and can lead to policy change (Kingdon, 1984).

This study offers a unique insight into this strand of literature, distinguishing between multiple windows of opportunity, technological, policy and market, that are opened in industry trajectories or problem streams and can lead to changes in the industries, policy agenda or markets. These concepts will be explained in this section.

4.3.3.1 Technological Windows of Opportunity

The concept of 'technological windows of opportunity' was formulated based on the analysis of interviews conducted with the members of EVET. It is associated with developments in energy storage, automotive and energy supply industries facilitating the shift of EVs to the incumbent level. The development in these industries enables advocates of EVs in the capability of technology to solve environmental problems. Two technological windows were identified, that opened in 2010 and 2016.

The first technological window of opportunity (tWoO-1) related to the production of the first mass market-oriented EV, the Nissan Leaf, and it was opened in the technological niche level of the automotive industry trajectory.

> "In terms of first opening [WoO] I think it was the early 2010s, so the 2010-2011. It really the first time there was a vehicle that potentially more people could buy, it was probably the Nissan Leaf. In about 2014 we started to see it more out there [UK]" (Int.27).

> "What proved the case I think was maybe the Nissan Leaf in the early 2010s, maybe 2011, I think that came out that those are the early pieces of evidence that there could be a mainstream market for EVs" (Int.19).

EV was a niche level technology at that time, as this technology "was not affordable to most of the public" (Int.25). The annual registration of EVs in 2011 and 2012 was 1.2k and 1.68k vehicles respectively (Table 4.1). As it was discussed, in Section 4.3.1.3 Li-ion batteries used in EVs were the mainstream market product in 2010 and their development was one of the most important drivers for EVs. Based on this, tWoO-1 opened in the niche level of the automotive industry trajectory and the first mass market-oriented EV powertrain was coupled with incumbent level technology of the energy storage trajectory – Li-ion batteries. This resulted in the manufacturing of the first mass market-oriented EV – the Nissan Leaf. Visualisation of tWoO-1 is shown in Figure 4.11 and depicted as a green area coupling automotive and energy supply industries.

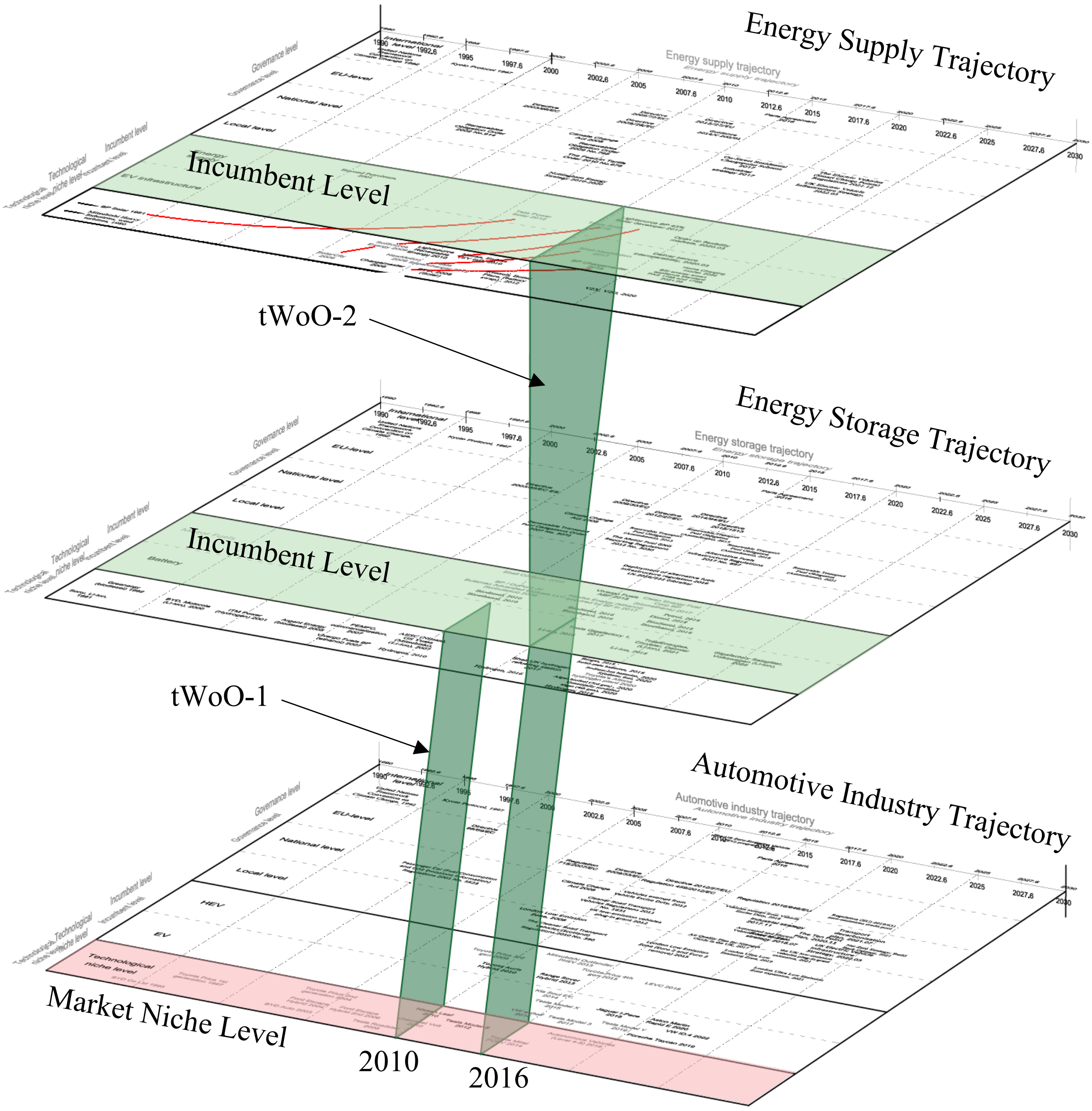


Figure 4.11 MLST perspective view, focus on industry trajectories and tWoO

The second technological window of opportunity (tWoO-2) for EVs was opened in 2016 (Int. 25) in the energy supply trajectory which was mentioned in the interview and confirmed statistically.

> "I would say that window opened properly in about 2014, 2015, that was the point where technology was available that really started to answer a real user need at a price that some of them could afford" (Int.25).

In 2016 the UK generated 47 TWh of energy from wind and solar sources, accounting for 13.7% of total energy generation, while coal contributed 31 TWh or 9% of the total (Table 4.5). Compared with the first tWoO-1, in 2010, wind and solar generated only 10 TWh, or 2.6% of total energy, while coal generated a substantial 108 TWh or 28.2% of the total. By comparing these two years it is possible to say that usage of coal dropped significantly alongside a shift toward cleaner energy sources. In the following year, the share of wind and solar energy continue to increase, reaching 77 TWh in 2022 or 24.9% of total energy generation. This is conceptualised as a shift of renewable energy in 2016 from the niche level to the incumbent level, signifying a considerable decarbonisation of the energy supply for EVs. This made the EVs a viable environmental solution for the air quality problem.

> "The decarbonisation of cars was driven by the decarbonisation of energy because unless energy decarbonised, they cannot make the decarbonised cars." (Int. 22).

By 2016, the cost of battery cells had dropped to 207.6 USD/kWh, from 601.4 USD/kWh in 2011, a decrease by a factor of 2.9 (Table 4.2). This indicated that EVs could become a cost-effective technology affordable to the broader market (Int 17, 21, 25). As a result, the price of EV per range decreased by 60% from 435 USD/km in 2010 to 173 USD/km in 2015, and further to 110 USD/km in 2019 (IEA, 2023). However, as the range of EVs constantly increased, the price of EVs did not decrease as significantly, about 33% from 55,200 USD in 2010 (in 2019 prices) to 36,500 USD in 2015 (in 2019 prices). Then the price of EVs even started to increase, reaching 36,900 USD in 2019 (IEA, 2023) and 37,800 in 2023 (NimbleFins, 2022).

Table 4.5 Electricity generated by fuel 2005 to 2021, TWh

Generator type	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Coal	135	108	108	143	130	100	76	31	23	17	7	5	7
Oil	5	5	3	3	2	2	2	2	2	1	2	2	2
Gas	153	176	146	100	96	101	100	143	137	131	132	111	123
Nuclear	82	62	69	70	71	64	70	72	70	65	56	50	46
Hydro (natural flow)	5	4	6	5	5	6	6	5	6	5	6	7	5
Total wind	3	10	16	20	28	32	40	37	50	57	64	76	65
Onshore wind	nd	7	11	12	17	19	23	21	29	30	32	35	29
Offshore wind	nd	3	5	8	11	13	17	16	21	27	32	41	36
Shoreline wave / tidal	nd	0	0	0	0	0	0	0	0	0	0	0	0
Solar	nd	0	0	1	2	4	8	10	11	13	12	13	12
Bioenergy	10	12	13	15	18	23	29	30	32	35	37	39	40
Other fuels	4	3	3	3	3	4	5	6	5	6	6	7	7
Pumped storage	3	3	3	3	3	3	3	3	3	2	2	2	2
Total all generating companies	398	382	368	364	358	338	339	339	338	333	324	312	309

Note: nd – no data

Source: National statistics, 2022

The percentage of registered EVs out of total vehicles registered in the UK increased from 0.01% in 2011 to 0.39% in 2016. This trend stimulated investment by incumbent actors in this technology. For example, VW launched an EV version of the popular ICE model the VW Golf in 2015, while Kia began producing the fully electric SUV Kia Soul EV. Following the growing popularity of EVs, the number of charging points also increased. Beginning from 2013 this segment showed exponential growth, rising from 913 units in 2013 to 1962 units in 2014, and 4182 units in 2016. After 2015, the growth of charging stations continued, reaching 37055 units in 2023 (Table 4.6).

Table 4.6 Number of public charging devices available since 2013, Units

Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Total Charging Devices	913	1962	2776	4182	5743	8312	12684	18051	23467	31328	37055
Rapid charging or above devices	nd	nd	294	787	979	1463	2154	3168	4403	5755	6887
% change of total charging to the previous year	-	115	41	51	37	45	53	42	30	33	18

Source: (Nissan, 2019; DfT, 2023a)

Despite the positive growth in EV sales, in 2016, it was still at the niche level, accounting for just a fraction of a percent of total vehicle sales. However, RE technologies and Li-ion technologies were on the incumbent level of the trajectories. The shift to cleaner sources of energy in 2016, jointly with decreasing the cost of batteries and the increase of EV infrastructure, allows us to say that in the second tWoO-2 all three trajectories - automotive, energy storage, and energy supply were coupled (Figure 4.11). On the one hand, this demonstrated the efficiency of well-to-wheel processes of EVs; on the other hand, it indicated the market potential of the technology. As EVs were in the niche level, coupling in the automotive industry happened on the niche level, while in energy supply and energy storage it happened on the incumbent levels (Figure 4.11). This facilitated the shift of EVs from the market niche level to the incumbent level, the same level at which the complementary technologies were already located.

The coupling with complementary technologies on the incumbent level does not mean that the focal technology became a mainstream-market product, but rather indicates the first step to becoming such a product. Below, we shall discuss both policy and market windows of opportunity that are important elements of the transition process.

The term WoO suggests that there is a point of opening and closing the window. Within the context of the developed framework, there is a link between the technological niche level and niche market, as well as the incumbent level and mainstream market. Considering the case of decarbonisation of the automotive industry, the opening of tWoO is associated with the shift of technology, that facilitates the decarbonisation of well-to-wheel processes of EVs, from the niche market to the mainstream, as happened, for example, with RE in the UK in 2016. The closure of the tWoO in this case could be related to the shift of RE back to the niche market. This can for example happen if the energy generation from coal significantly surpasses that from RE. In such a case RE would shift back to the niche level, causing a reduction in the effectiveness of well-to-wheel processes for EVs. This will effectively lead to the closure of tWoO-2. As the duration of tWoO can be significant, the moment of opening tWoO can be considered a coupling point between industry trajectories.

4.3.3.2 Policy Windows of Opportunity

According to Kingdon (2014) the policy windows of opportunity (pWoO) can open unpredictably due to changes in politics or problem streams, or be quite predictable, for example, with the scheduled renewal of a government programme. This allows individuals who are interested in a specific policy outcome to push their policy proposals to the government. Zohlnhöfer and Rüb (2016) stated that the pWoO can be deliberately created by policymakers. Both opinions on the involvement of government in the opening of pWoO are in line with this study. It was found that the government was responsible for opening two pWoO, pWoO-1 in July 2016 and pWoO-2 in June 2018. These types of windows will be discussed below.

The first pWoO (pWoO-1) is associated with the work initiated by DfT in response to the problem of "the environmental impact of road vehicles" (DfT, 2018, p.4). The work includes two stages: the first stage focused on the analysis of the "relative environmental performance of different fuels and technologies" within the Transport Energy Model (DfT, 2018, p.4). The second stage involved the creation of a key strategic policy paper – the Road to Zero strategy.

The Transport Energy Model (TEM) allowed "stakeholders from industry, academia, environmental groups and Government, including vehicle manufacturers, fuel suppliers, vehicle and environmental consultancies, environmental lobby groups and other Government Departments" (DfT, 2018, p.5) to contribute to the model. Work on the TEM was important as it informed the government on the environmental impact of various types of vehicle technologies and fuels and underpins the policies set out in the Road to Zero (DfT, 2018). The development of the Road to Zero was led by OLEV and, as with the development of TEM, involved the contribution of industry stakeholders, academia and the government department. The duration of the window was 24 months, which opened at the beginning of work on TEM in July 2016 and closed with the end of work on the Road to Zero strategy in July 2016. This strategic policy set targets for new ZEV registrations to reach up to 70% by 2030, aiming to phase out petrol and diesel vehicles in the UK by 2040. In addition to the problem of the environmental impact of road vehicles, the strategy also dealt with the problem of energy security (DfT and OLEV, 2018). Both of these problems can impact the entire population of a country and thus corresponds to the national level.

Visualisation of pWoO-1 is shown in Figure 4.12 and Figure 4.13. It is possible to see that pWoO-1 coupled the national levels of the problem, policy and politics streams. This related to the fact that this policy was developed at the national level by the Office for Low Emission Vehicles (OLEV, later renamed OZEV) and dealt with national level problems. This strategic policy document set the national targets for ZEV uptake, but importantly, it was not intended to include detailed technology and industry-specific recommendations. These were made afterwards in the policy documents released within or after pWoO-2. Such an approach relates to the salami tactics when a big issue is divided into smaller more manageable parts (Ackrill and Kay, 2011). This tactic was used by LowCVP managers who contributed to the development of the 46-point plan of the Road to Zero. One of these points aimed to launch EVET, focusing on EV energy supply issues, although EVET was initiated before the release of the Road to Zero.

The context of pWoO-2 was the government's prioritisation toward a specific technology – EVs; and the ripeness of the policy stream for a macro/national level policy solution – the Road to Zero. The opening of the pWoO-2 corresponded to the month when the EVET was established within the policy stream in response to the problems at national, incumbent and technological niche levels. At national level, as EVET was announced as a part of Road to Zero (University of Leeds, 2018), it addresses similar problems as Road to Zero - the environmental impact of road vehicles and energy security. At the incumbent level, the energy sector as well as the network of EV charging stations was not ready for mass EV uptake. Another problem is associated with the lack of widespread adoption of EVs which requires industry-specific policy interventions. In addition, there was uncertainty by the government about the problems the incumbent and niche level stakeholders may face during EV uptake, and it was unclear what kind of respective solutions to these problems could be used to address this.

The government used the Taskforce to identify technology-specific policy solutions, such as a smart charging regulation that favours a particular functionality of the energy supply infrastructure, to advance an earlier selected technological solution, such as electric vehicles.

> "It [EVET] was charged to bring forward proposals to ensure that the GB electricity system acts as an enabler of the EV transition and that opportunities to positively engage and deliver benefits to consumers can be realised. The underlying goal is to encourage the growth of EVs without incurring unnecessary costs" (FOI 87 cf).

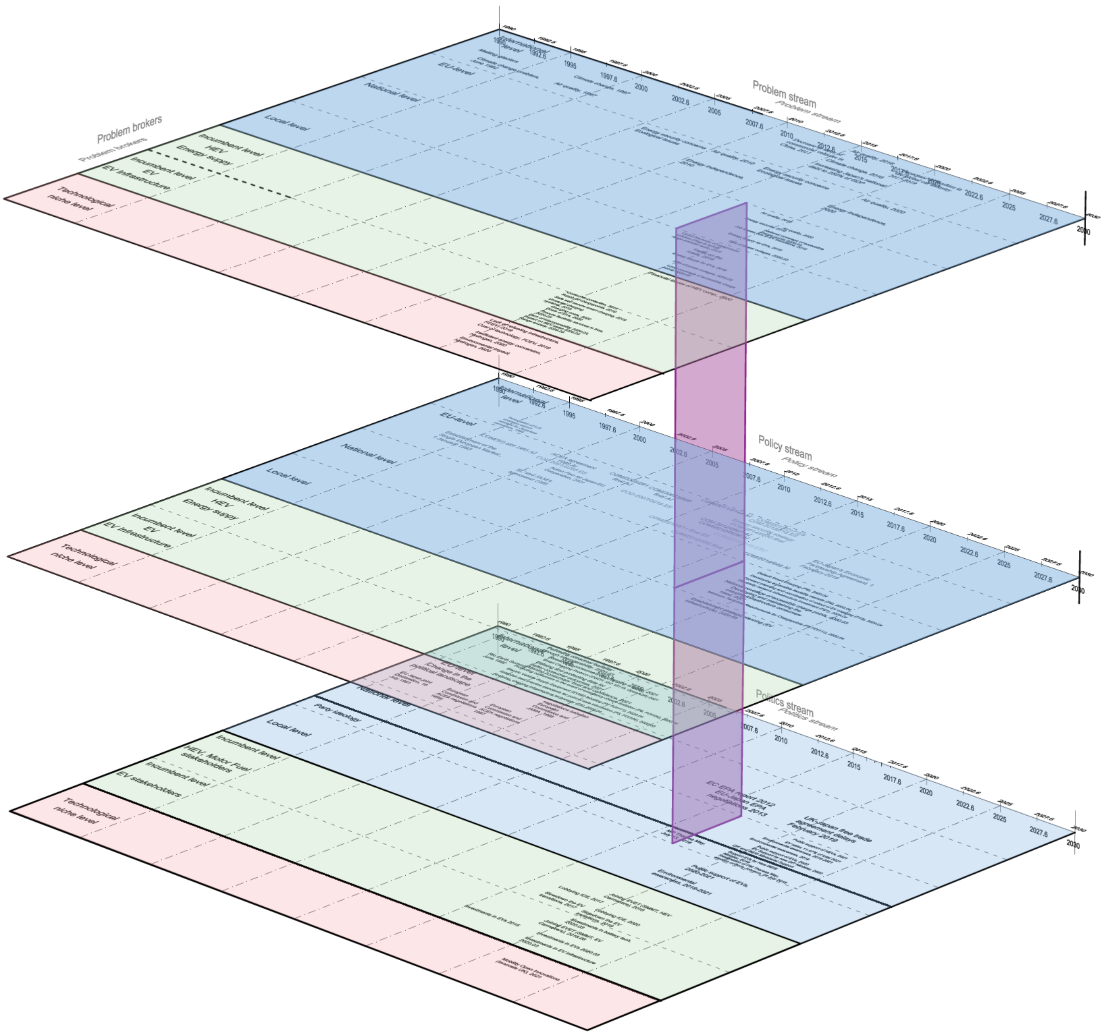


Figure 4.12 Visualisation of pWoO-1

As EVET was established in response to the problem, it was concluded that pWoO was opened in the problem stream embracing national, incumbent and technological niche levels. It was opened by DfT and BEIS and conveyed by OLEV in June 2018.

> "EVET [Electric Vehicle Energy Taskforce] was convened by the Office for Low Emission Vehicles (OLEV) in 2018, at the request of ministers from BEIS and DfT, with the objective of making proposals to Government and Industry on 'how to ensure the GB energy system is ready for and able to best exploit the mass take up of electric vehicles?'" (FOI 107).

In pWoO-2 it can be seen that the governance level and incumbent levels are adjacent (Figure 4.13). This is due to the fact that the EVET documents revealed that industry-specific recommendations addressing the energy supply problems (incumbent level of the problem stream) and focusing on the technological aspects of EV transitions, are included in broader recommendations aimed at solving national level problems. For example, incumbent level recommendations/policy proposals of the policy stream on *using roaming technology in* *charging stations, delivering consumer benefits through interoperability* and *winning consumers' trust and confidence*, were targeted to solve the incumbent level problems in the problem stream such as *lack of interoperability*, *consumer protection*, *safe and secure smart charging*. These incumbent level policy proposals are components of the national level policy proposal to *set default smart charging regulation* (national level of the policy stream) that address to *national coverage of accessible charge points* problem (national level of the problem stream) and more broadly to the *air quality* issue (EU and UK national level of the problem stream).

In EVET data, nine incumbent level recommendations and seven national level recommendations were identified, and are listed in Table 4.7. These address both national and incumbent level problems, listed in Table 4.8. The recommendations and problems included in these tables represent focused codes of the MLST that are depicted in corresponding layers of the policy stream depicted in Figure 4.9. The coding grid is shown in Appendix 4 "Hierarchy of Codes and Coding Grids" (Table 17).

Table 4.7 National and incumbent level recommendations

National level recommendations	**Incumbent level recommendations**
National coverage of accessible charge points, 2020.03 Electricity network infrastructure investment (P21), 2020.04 Forward planning and coordination of rollout of EV charging (P19), 2020.04 Developing accessible flexibility markets (P9), 2020.04 Set minimum technical requirements for chargepoints (P5 FOI111), 2020.04 Set default smart charging regulation (P8), 2020.04 Developing and maintaining the charging infrastructure consumers need, 2021	Use Smart Charging Protocol (OSCP, ISO 15118) 2021 Use roaming technology in charging stations (P3), 2020.04 Establish best practice standards for point of sale information (P3, FOI104), 2020.03 Electric Vehicle Supply Equipment (EVSE) labelling (P7 FOI111), 2020.04 Protecting consumers in the event of emergency charge limitation (P6, FOI104), 2020.04 Winning consumers' trust and confidence, 2021 Utilising and protecting data for better consumer outcomes, 2021 Rewarding consumers for charging smartly, 2021 Delivering consumer benefits through interoperability, 2020.03

Source: FOI 103 (2020.03), FOI 111 (2020.04)

Note: data indicates the data of the document where the policy problem of recommendation was identified

Table 4.8 National and incumbent level problems

National level problems	Incumbent level problems
Air quality, 2018 Energy security, 2018 National coverage of accessible charge points 2020.03 Energy supply for EVs, 2019 Risk of power outages, 2020.03	Consumer protection, 2019 Supply of chargepoints, 2019 Safe and secure smart charging, 2019 Universal charging systems, 2019 Charging costs, 2020 Costs of EVs, 2020 Procure flexibility services in time, 2020.03 Lack of interoperability 2020.03, Impact on BEV sales 2020.03 Range anxiety, 2020.03

Source: FOI 103 (2020.03)

It is noteworthy that to date not all EVET policy proposals have been included in final policies. Analysing the recently released UK EV policies that were mentioned in the EVET documentation and which was informed by EVET, responses to three of the seven national level recommendations were identified. The Electric Vehicles (Smart Charge Points) Regulations (2021) can be associated with two recommendations to *set default smart charging regulations* and *set minimum technical requirements for chargepoints*; the UK Electric Vehicle Infrastructure Strategy (2022b) can be linked with recommendation for *forward planning and coordination of rollout of EV charging*.

It was confirmed that the same incumbent level policy recommendations can be used in multiple national policies. For example, examining the content of The Electric Vehicles (Smart Charge Points) Regulations (2021), it is possible to identify the inclusion of recommendations related to the incumbent level, such as *delivering consumer benefits through interoperability*, *utilising and protecting data for better consumer outcomes,* and in such policy sections as electricity supplier interoperability and security. The UK Electric Vehicle Infrastructure Strategy (2022b) includes such incumbent level recommendations as *delivering consumer benefits through interoperability, utilising and protecting data for better consumer outcomes, winning consumers' trust and confidence and using roaming technology in charging stations.* Thus the recommendations *delivering consumer benefits through interoperability* and *utilising and protecting data for better consumer outcomes* were used in both policy papers.

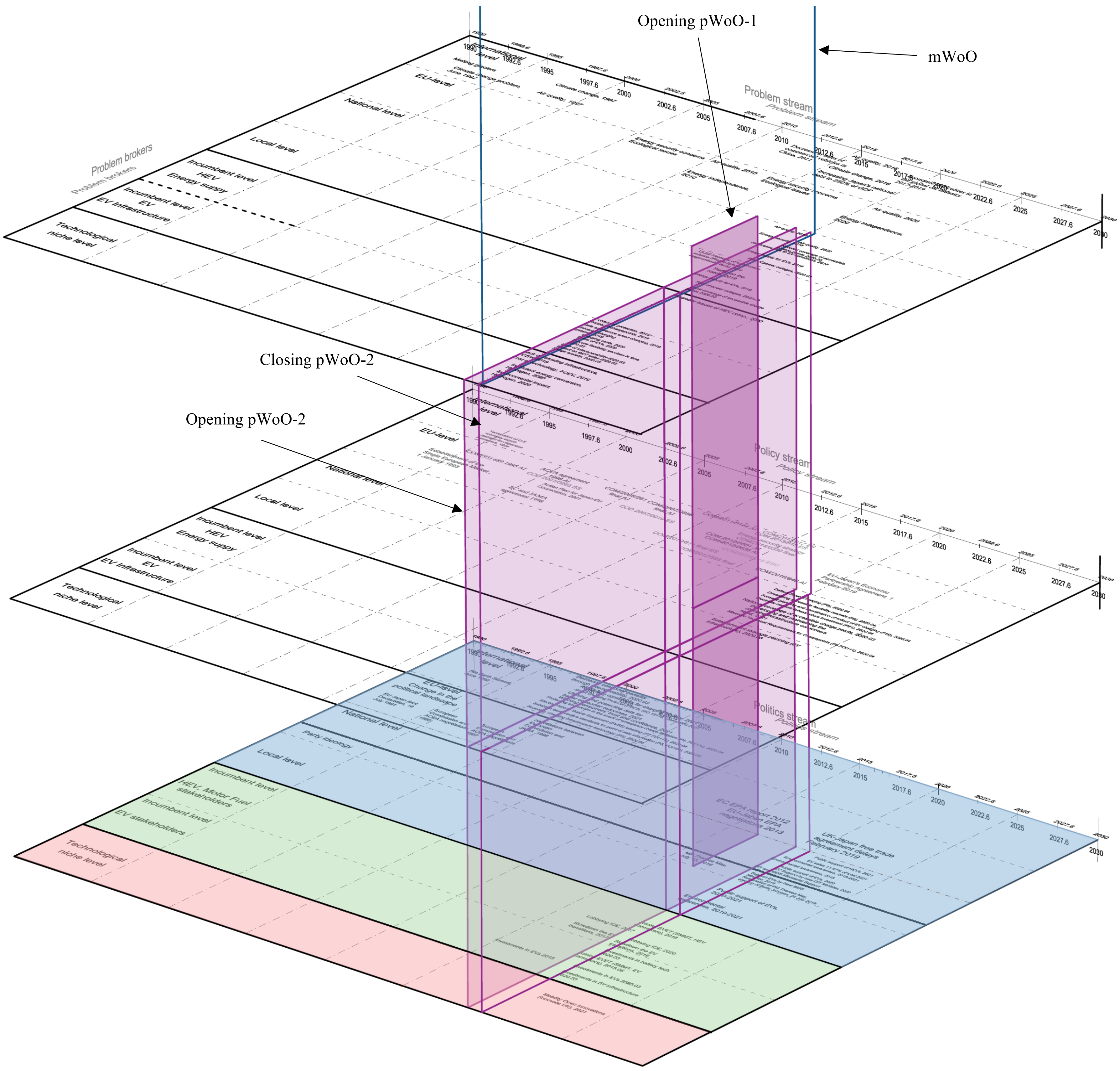


Figure 4.13 pWoO-1, pWoO-2 and mWoO

By adjacency of incumbent level policy WoO with national level policy WoO, the MLST reflects the fact that incumbent level recommendations are parts of the national level recommendations and address the national level problems such as air quality, as was stated in high-level positions that WP1 addresses.

> "[For industry stakeholders] it is important to recognise the changing energy and transport landscape from digitalisation, decentralisation, decarbonisation and democratisation of energy supply and desire for improved local air quality." (FOI 103).

The closure of the pWoO was linked with the completion of all four Taskforce work packages in March 2020. Given these facts, it is possible to conclude that the duration of the pWoO for proposing policy ideas to the government was 21 months (see Figure 4.13), starting in June 2018 and closing in March 2020. The result of pWoO was the development of the final EVET report and presenting of policy proposals to members of the House of Lords and the Secretary of State for Transport.

4.3.3.3 Market Windows of Opportunity

This section provides information regarding the concept of the market window of opportunity that manifested the commencement of EV mass market uptake. The concept of the market window of opportunity was derived inductively based on the interviews with the Head of OLEV (Int.27) and further analysis of EVET data. During Interview 27, *tipping points* were mentioned that can trigger a mass market for BEV uptake. The initial question was "When did the window of opportunity open for the widespread adoption of electrical vehicles?".

> "I think we're at the moment [December 2020] in another key tipping point where there's more [EV] models available and it's getting all mainstream, last month it was nine percent of new vehicle sales in the UK were full battery electric which is extraordinary" (Int.27).

> "Then there should be again another tipping point as we really start to trigger that mass market, but I think that will be in the future so I'm not sure there'd be one point, but I think there's been several interesting bits as we've been going through" (Int.27).

In order to understand the meaning of *tipping points* and their link with windows of opportunity, the FOI data were analysed, and further interviews were conducted. The clarification of *tipping points* was found in the presentation of the EVET framework (FOI 67). Minutes in FOI 64 indicate that the Head of the Government Office participated in the presentation of the tipping points concept (Figure 4.14). The *tipping points* discussed during the FOI meeting have a similar multiple-tipping point approach as discussed during Interview 27.

The tipping points according to EVET data refer to a significant increase in the level of EV penetration:

> "Tipping Point Analysis to identify when significant tipping points might occur in terms of the capability of the electricity system to accommodate increasing levels of EV penetration, and hence when trigger points might be reached in terms of need for a significant change in approach (including from a technology, market or regulatory perspective). This analysis has helped inform the MoSCoW analysis" (FOI 103)

The further analysis of FOI data revealed that EVET uses scenario based planning with 4 tipping points between 2018 – 2030, in 2018, 2022, 2026 and 2030 (Figure 4.14). Each tipping point will involve EVET intervention/pressure and industry stakeholders' and the government's actions to sustain the momentum of EV market uptake.

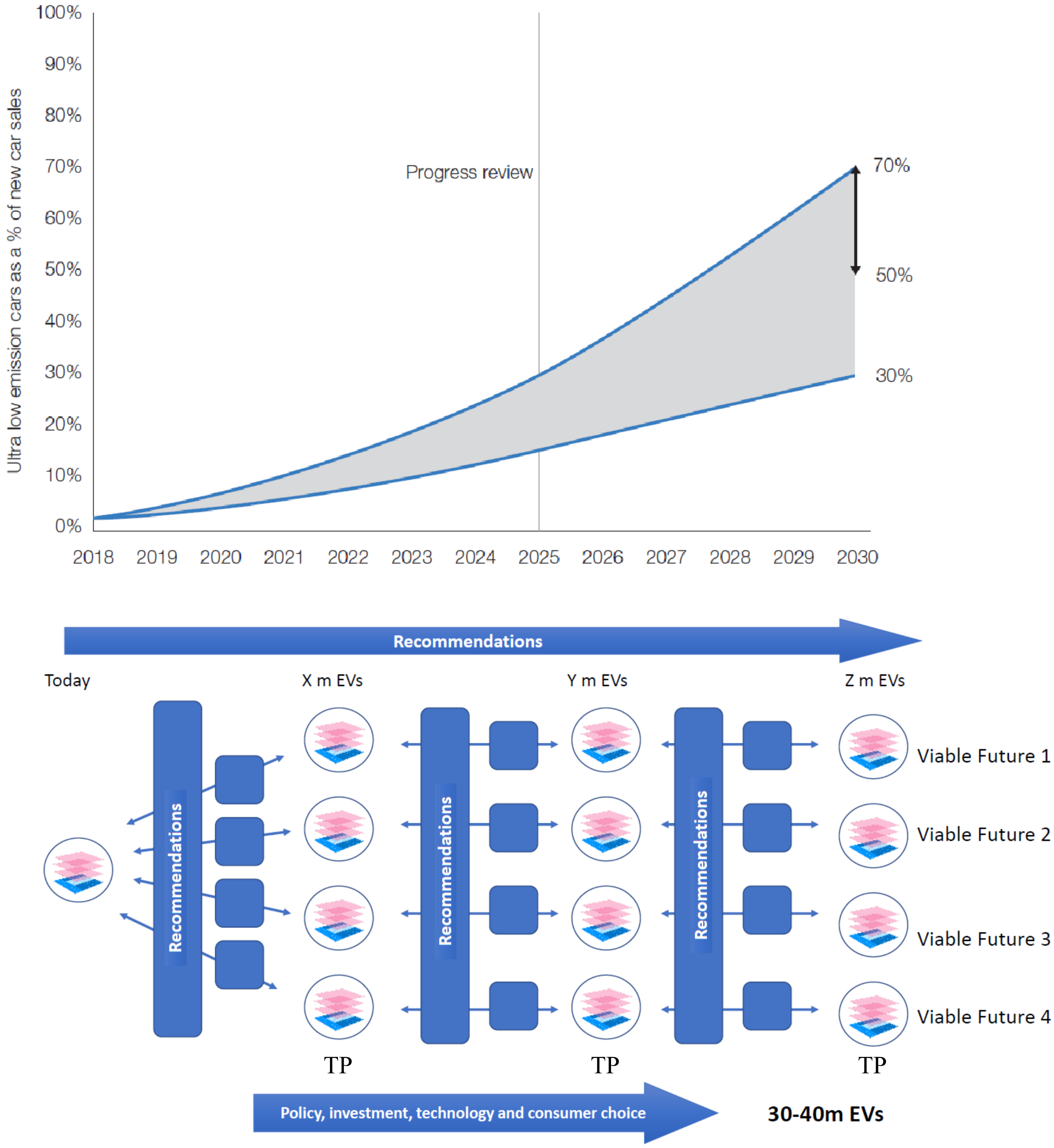
> "EVET's formation has found the value and necessity in collaboration and to build momentum to support the EV transition. However, its proposals only offer a starting point. The Government is strongly recommended to maintain the momentum and cooperative working that has been achieved, through a joint industry forum that is properly resourced and sustainable into the future." (FOI 108)

It is worth noting that the term "intervention" is mentioned frequently in EVET data with respect to recommendations provided to the industry stakeholders and the government (FOI 60 cf, FOI 67 cf).

> "[EVET's Steering Group seek to] determine interventions that would mitigate the constraints … [and] seek to find the common aspects of these [interventions] across the [transition] pathways… low regrets interventions" (FOI 60 cf)

The EVET interventions/pressure associated with trigger points that locate in close proximity to the tipping point and can be reactive or proactive. An example of a *proactive trigger point* related to a situation of successful completion of a program as shown below.

> "The completion of the smart meter programme and the introduction of half-hourly settlement will be a further trigger point for the development of multi-rate tariffs which might help shift demand away from peak times and/or towards times when renewable generation output is high" (FOI 103).



Source: FOI 60 cf, FOI 67 cf; Note: TP – tipping point

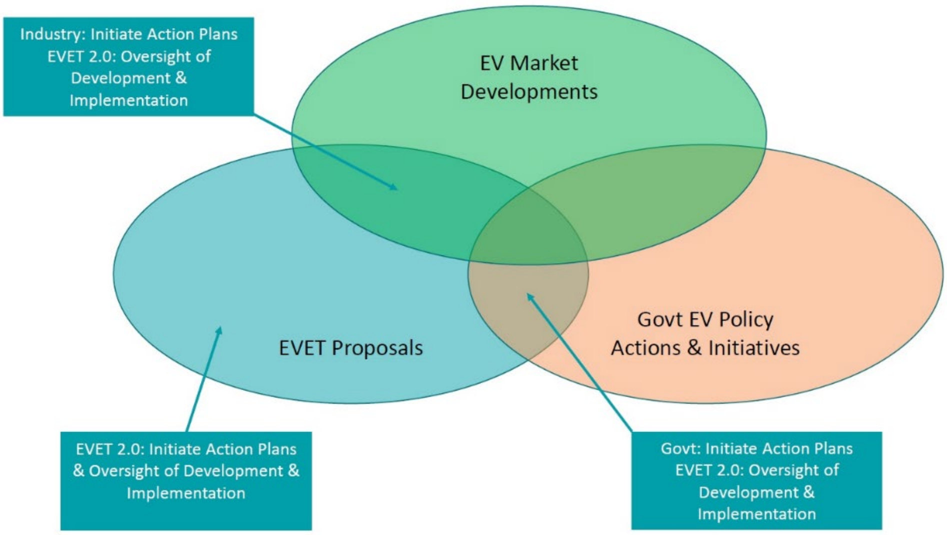
Figure 4.14 Tipping points, 2018-2030

The *reactive trigger points* can be related to, for example, the realisation that the sustainable energy network investment strategy is not optimal at the point when the number of EVs has significantly increased. This will trigger investment in a range of cost-effective (i.e. on an NPV basis) smart technologies (FOI 103). Another example can be linked to the low number of EV sales in the year of the planned tipping point. This can trigger activities to facilitate an increase in the number of sales.

> "Trigger points – [in the] short and medium term expressed as time and % [of EV] sales, [trigger point in the] long term [is expressed] only [in terms of] % [of EV] sales" (FOI 75)

The EVET interventions can push the EV transition to follow one of 4 paths, wherein the percentage of newly registered ULEV out of the total can vary from 5% to 10% in 2022, from 15% to 25% in 2025, and reach 30% to 70% in 2030 (Figure 4.14). The FOI data complement Interview 27, leading to the conclusion that there are multiple tipping points. The sequence of tipping points will contribute to an increase in EV market share from 5%-10% in 2022 to 30%-70% in 2030 with four possible scenarios for EV market uptake (viable future 1-4). The tipping points discussed during Interview 27 and the archival data are linked with innovative studies where such points are associated with "accelerating growth" of innovations and an increase in demand (Whittington et al., 2019, p.325).

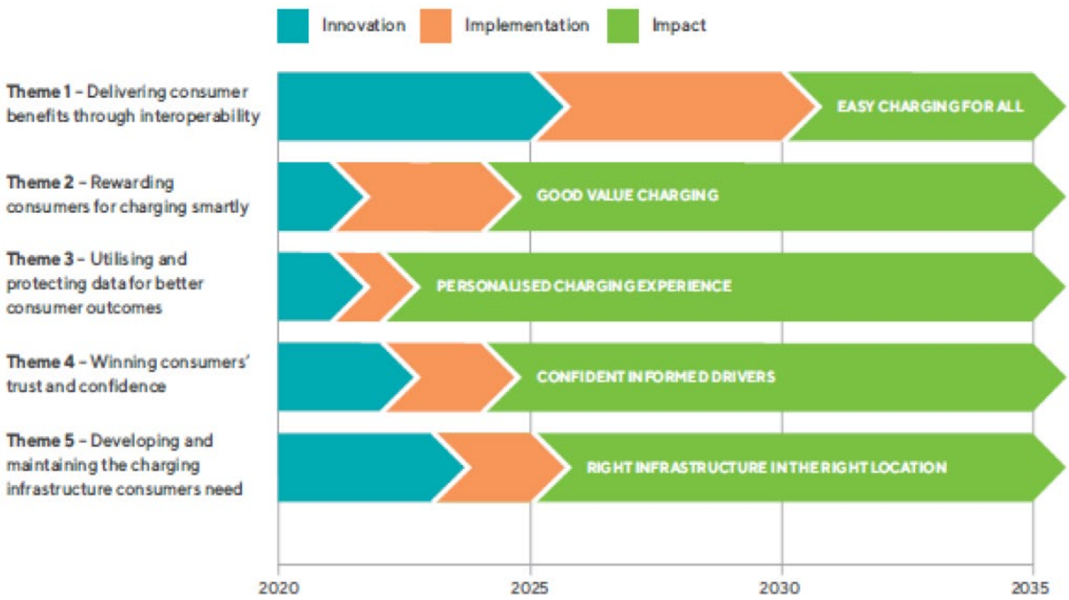
Further scrutinising the EVET data, it was found that EVET operates the concept of EV Market Development in "preparing the GB energy system for the mass take up of electric vehicles" (FOI 107), see Figure 4.15.



Source: FOI 111

Figure 4.15 The relationship between EVET proposals, government policy actions and EV market development

The processes of the development of EVET proposals, the government actions and the development of the EV market are interrelated and there is a sequence between these three processes (Figure 4.16). The first stage - the development of EVET proposals ('innovation' stage in Figure 4.16) - includes identifying the necessity of actions, prioritisation of recommendations/policy proposals and the development of an action plan to deliver the policy measure. The second stage pertains to the government actions or 'implementation' stage in Figure 4.16, this suggests the implementation of policy measures. The third stage implies market development or the 'impact' stage in Figure 4.16. It is expected that the impact will be in multiple elements of the EV ecosystem wherein each of the measures will have different dynamics. For example ‘Theme 3 - Utilising and protecting data for better consumer outcomes’ - has the shortest period of development and implementation, while ‘Theme 1’ will have the longest period before reaching the impact stage. As discussed in Section 4.3.3.2, the recommendation of ‘utilising and protecting data for better consumer outcomes’ was already released in the final policy papers, the UK electric vehicle infrastructure strategy (DfT, 2022b) and The Electric Vehicles (Smart Charge Points) Regulations (HM Government, 2021), currently at the implementation stage. Thus it is possible to say that EVET follows the outlined plan. The level of impact of policy proposals is substantial and it is expected to boost the market share of EVs by up to 70% in 2030 (Figure 4.14). These findings underlie the concept of the market window of opportunity discussed in this section.



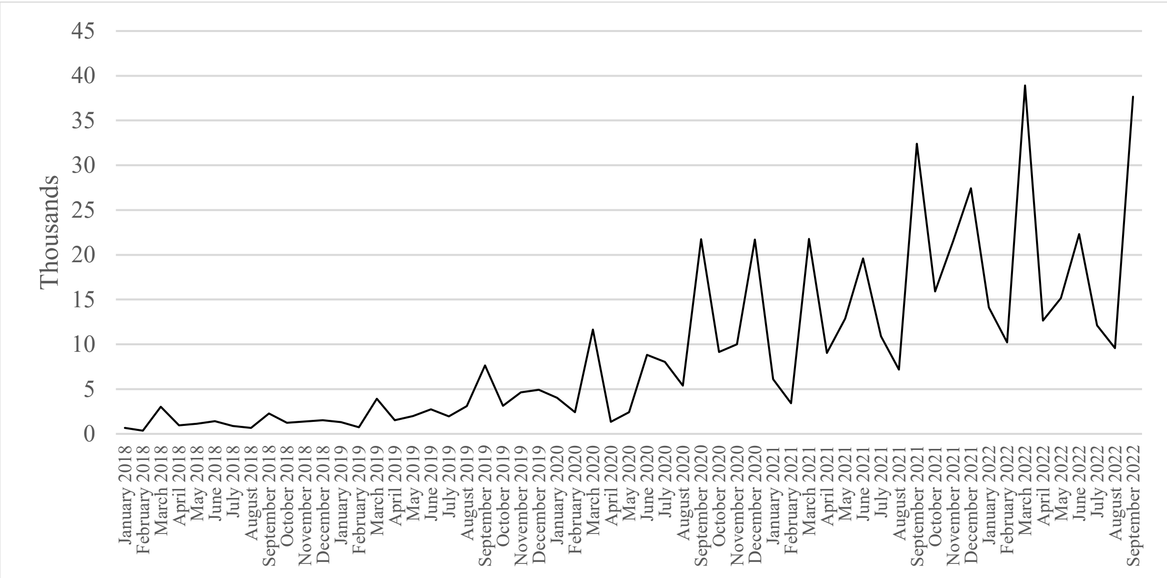
Source: FOI 111

Figure 4.16 Three phases of the EV transition in the UK

Based on the analysis of interviews and EVET data the theoretical code market window of opportunity (mWoO) was bring in into the research. It corresponds to the first tipping point mentioned in Int.27 and is associated with the shift of the focal technology to the incumbent level. This is the point when EV technology became mainstream. The follow up tipping points and EVET interventions will focus on maintaining EV technology uptake, progressively accelerating the transition. The closure of mWoO for EVs can be associated with the shift of EV technology back to the niche level in the event of disruption of EV technology.

At the moment we are witnessing the closure of a mWoO for dedicated petrol and diesel vehicles. The sales of these types of vehicles have been decreasing since 2019 for petrol vehicles, and from 2016 for diesel vehicles. In 2022, the sale of petrol vehicles decreased by 47% compared to 2019 levels, and a significant 79% decrease for diesel vehicles. If this tendency continues, these types of vehicle would eventually pass to the technological niche level where their market share will be marginal. At this point, mWoO for petrol and diesel vehicles will effectively be closed.

To ascertain when the EVs started to become mainstream, interviews, FOI and statistical data were scrutinised. The EV market WoO partly opened in September 2019, as evidenced by a 141% jump in vehicle registrations (highlighted in green Table 4.9). It was partly driven by the start of Tesla Model 3 sales in the third quarter in the UK and the increase of other EV model registrations, except the Nissan Leaf which showed a 27% decline that year. The percentage of EVs out of total UK car registrations was initially relatively small, at 1.64% in 2019 (highlighted in green Table 4.1). The market WoO fully opened in March 2020 (Figure 4.17), coinciding with the closure of pWoO-2. At this point, EV registration significantly increased for the second consecutive year, by 184% in 2020. That was a successful year for all the EV models, with 71% of registrations attributed to models other than Nissan and Tesla (highlighted in green Table 4.9). The percentage of total UK car sales accounted for by EVs increased significantly, to 6.59%, and continued to grow in the following years. At this point, the mWoO was fully opened indicating the significant widespread adoption of EVs and its shift to the incumbent level.



Source: (DfT, 2022c)

Figure 4.17 BEV registered for the first time in Great Britain, Jan 2018 to Sept 2022

Table 4.9 BEV models registration for the first time in Great Britain, 2009 to 2021

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tesla (all models), thousands	0	46	6	0	0	0.691	1.384	2.4	4.569	3.095	12.6	23.8	33.7
Tesla, % change to previous year	-	-	-87	-100	-	69k	100	73	90	-32	**306**	89	42
Nissan Leaf, thousands	0	0	0.635	0.664	1.678	3.717	4.23	3.418	4.761	5.017	3.643	7.494	8.845
Nissan, % change to previous year	-	-	-	5	153	122	14	-19	39	5	**-27**	106	18
Other models, thousands	-	-	-	1.04	0.92	2.29	4.19	4.48	4.37	7.49	21.36	75.41	145.6
Others, % change to previous year	-	-	-	-	-11	149	83	7	-2	71	185	253	93
Other models, % of total EV reg.	-	-	-	61	35	34	43	44	32	48	57	**71**	77
Total EVs models, thousands	0.23	0.26	1.2	1.7	2.6	6.7	9.8	10.3	13.7	15.6	37.6	106.7	188.1
Total EVs, % change to previous year	-	13	370	40	56	154	48	4	33	14	**141**	184	76

Note: green colour indicates statistics mentioned in the text that are related to the partly open and fully open mWoO in 2019 and 2020 respectively

Source: (DfT, 2022d; 2022c)

In Figure 4.18 the market window of opportunity is shown as a blue rectangular area that couples the governance level (national and local sublevels), incumbent level and market niche level of the problem stream and industry trajectories. The coupling of national and local sublevels of the governance level within mWoO signifies the links between the multiple levels of decision making and the market dynamics within the automotive market in the UK. The coupling mWoO of industry trajectories and problem stream underscores the fact the mass take up of EVs may cause problems across multiple levels of the problem streams and impact not only technological and policy development within the automotive industry but also the energy supply and energy storage industries. The problems of the widespread adoption of EVs could be associated with excessive electricity demand and the risk of power outages. This will require the reduction of peak demands and the development of smart charging, which will impact the incumbent level of the energy supply trajectory as incumbent actors will need to response to this problem. An example of a positive effect of mass EV uptake could be the increased demand for batteries. This will positively impact the incumbent level actors of the energy storage industry trajectory, generating an additional revenue stream for them. If the EV market uptake continues, then the discussed earlier three tipping points occurring in 2022, 2026 and 2030 (Figure 4.14) can be associated with the EVET interventions to maintain momentum on the uptake. It is expected that these interventions will progressively accelerate the EV transition (FOI 60 cf, FOI 67 cf). In Figure 4.18 and Figure 4.19 tipping points are depicted as three orange frames followed by mWoO.

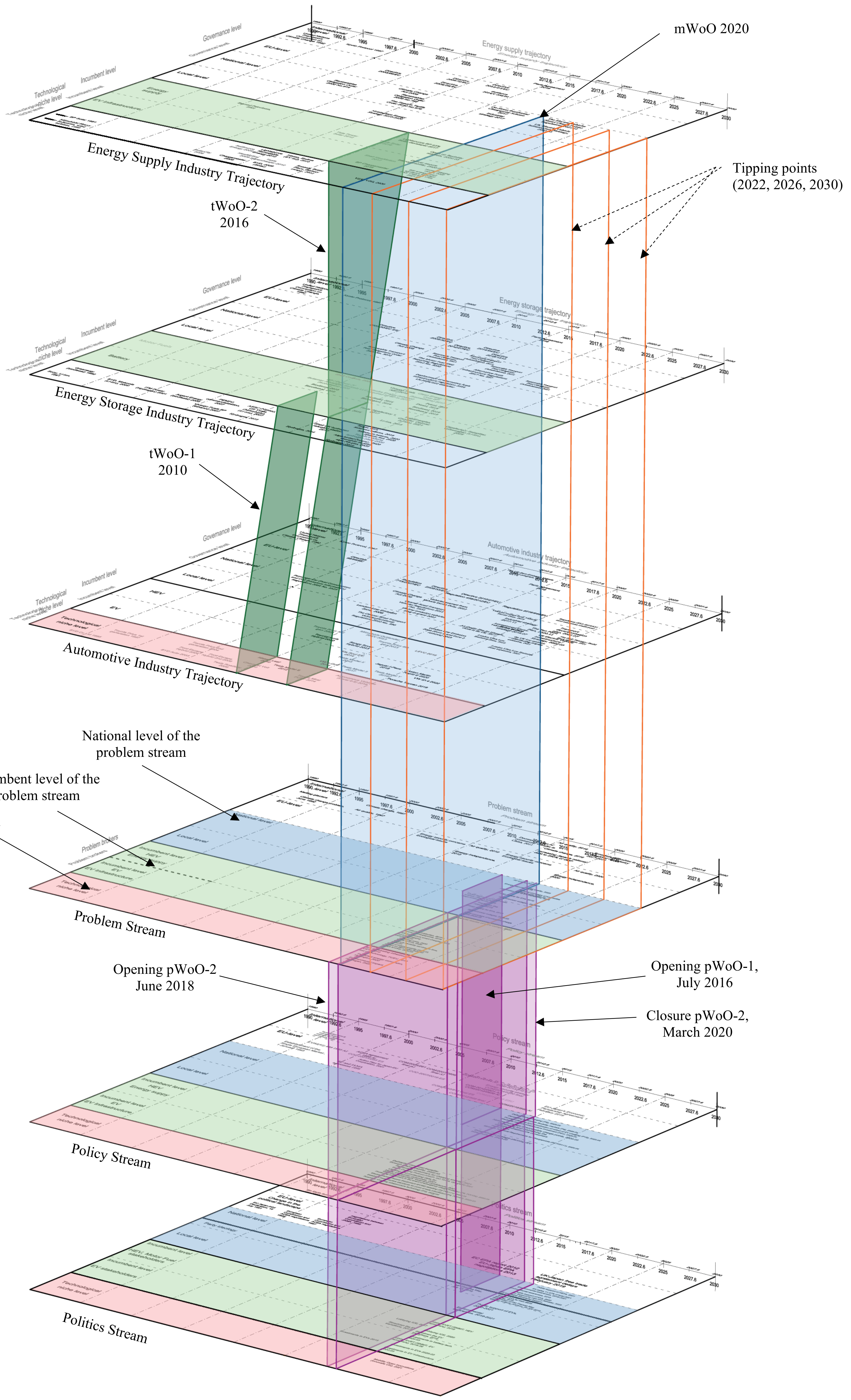


Figure 4.18 Right-side three-point perspective view MLST

4.3.4 Multi-level Streams and Trajectories Framework

Technology is an important element of the agenda setting process related to technology-centric issues, such as the decarbonisation of transport. The advancement of technology and decarbonisation of its well-to-wheel processes can make it a viable technological solution to the environmental problem that has been of concern for many years. This can shift the policy agenda in favour of such a technology which in turn can impact the technology and the developments in industry. Then the advancement or lack of advancement of technology can become a source of problems which again shape the policy agenda process. There are two-way linkages between the technology and policy agenda that can be analysed through the lens of multiple windows of opportunity, conceptualised within the MLST framework. Thus the development in the industry trajectories influences the policy agenda, while the inverse is also true.

The right-side three-point perspective of the MLST is shown in Figure 4.18, and the multiview projection of the MLST can be assessed in Figure 4.19. The top three trajectories relate to energy supply, energy storage and automotive industry trajectories. These are followed by three streams: problem stream, policy stream and politics stream. Industry trajectories reflect the evolution of technology within the elements of the EV ecosystem required for the EV to become a mainstream market product. The streams contextualise the agenda setting process underlying the policy change in industry trajectories. Both industry trajectories and streams are subdivided into governance, incumbent and technological niche levels. The governance level reflects the multi-level governance decision making processes influencing the policy agenda, while incumbent and technological niche levels pertain to the industry-specific processes impacting the process. The streams are coupled with tWoO, pWoO and mWoO. The sequential opening of the windows results in a shift of the focal technology from the niche level to the incumbent level. This shift is influenced by the shift of agenda from the low-emission goals to the zero-emission goals.

In the case under investigation, there was a sequence of windows of opportunity before the technology was paired with a policy solution. The first opened technological windows of opportunity (green vertical areas Figure 4.18 and Figure 4.19) that coupled niche level technology (pink level within automotive trajectory) with incumbent levels technologies (green areas within energy supply and energy storage trajectories). This coupling facilitates the use of technology as a solution to environmental problems. First, the battery industry trajectory was coupled with the automotive industry trajectory within tWoO-1 in 2010, allowing the production of the first commercially viable mass market-oriented EV – the

Nissan Leaf. At the time, the niche level technology mass market-oriented EV powertrain was coupled with incumbent level technology: Li-ion batteries. It is worth noting at this point that tWoOs in the case of EV transitions are cumulative and sequential, and were not decoupled after being coupled. The coupled technologies complement EV technology nowadays.

The second technological window (tWoO-2) coupled energy supply and automotive industry trajectories in 2016. This happened with the shift of RE technology to the incumbent level, when energy generation from RE (mainly wind and solar) surpassed energy generation from coal, decarbonising EV energy supply significantly. In addition, the EV infrastructure network continues to be built up in the UK by incumbent and niche level actors. Within tWoO-2, the link between energy storage and automotive industries was reinforced as battery technologies used in the cars continued to improve in terms of energy density, reliability, and cost efficiency. After tWoO-2, national level environmental questions became answerable by EV technology.

There was a series of policy WoO, with the first pWoO-1 at the national level opening between July 2016 – July 2018 (24 months) while the Transport Energy Model (TEM) was developed and work on the Road to Zero took place. The LowCVP managers used the EV technology in the TEM to shift the agenda from low emission targets to zero emission targets. That was possible due to the coupling of the EV technology with energy supply and energy storage trajectories signifying the effectiveness of well-to-wheel processes of EVs.

In Figure 4.18 and Figure 4.19, pWoO-1 is indicated as a purple vertical area coupling streams on the national level (blue horizontal areas within the streams). The work on the TEM was important as it informed the government on the environmental impact of various types of vehicle technologies and fuels. This resulted in the release of the Road to Zero strategy, when the government shift away from being technologically neutral and focused on EVs. This strategic policy set targets for ZEV uptake up to 70% by 2030 and phase-out petrol and diesel vehicles by 2040. During pWoO-1 the EV technology was paired with the policy solution, the Road-to-Zero. The pWoO-1 was closed one month after the opening of the second policy WoO.

The second policy WoO (pWoO-2) was opened at the national, incumbent and technological niche levels of the problem stream (purple vertical area in Figure 4.18 and Figure 4.19) and was associated with unpreparedness of the energy supply and EV infrastructure for the mass market uptake of EVs. In addition, the lack of widespread adoption of this niche technology - EVs was itself a problem - which required EVET interventions to create favourable conditions within the automotive and energy supply industries. The government set up a Taskforce within the policy stream to accelerate the EV transition and provide policy solutions for the incumbent level problems that incumbent actors may experience during the EV transitions in the UK. The pWoO-2 remained open for a period of 21 months while the work on Taskforce packages continued, from June 2018 until March 2020. As e result of pWoO-2, some of the ideas of EVET were included in Electric Vehicles (Smart Charge Points) Regulations (2021) and the UK infrastructure strategy (2022b).

The release of the Road to Zero strategy and subsequent initiation of EVET ended the government's stance of technological neutrality and indicated the shift in policy agenda from low emissions to zero emission goals. This provides policy support for transitions and sent a strong signal to the industry stakeholders. Other factors in support of EVs were the public's growing awareness of the environmental problem and industry stakeholders' support, which was reflected in the politics stream and underlies pWoOs. The sequential opening of tWoOs and pWoOs ultimately leads to the opening of mWoO signalling the shift of EV to the incumbent level.

The EV market WoO was partly opened in September 2019, within pWoO-2. In that year the percentage of change in the EVs registered for the first time increased sharply, by 141%. It was partly linked with the start of Tesla Model 3 sales in the third quarter of 2019. However, compared to the total number of cars registered in the UK, the share of EVs was still relatively small at 1.64%. The EV market demonstrated substantial growth in 2020 wherein EVs accounted for 6.6% of total registered cars. This occurred alongside diversification of the EV model range registered. The registration of most EV models increased simultaneously, including Nissan (Table 4.9). In the following year, the EV market share continued to increase. Given this, it was concluded that mWoO was fully opened in March 2020 (blue vertical area Figure 4.18 and Figure 4.19), in proximity to the closure of pWoO-2. This signified the shift of EVs to the incumbent level, wherein EVs became a mainstream market product.

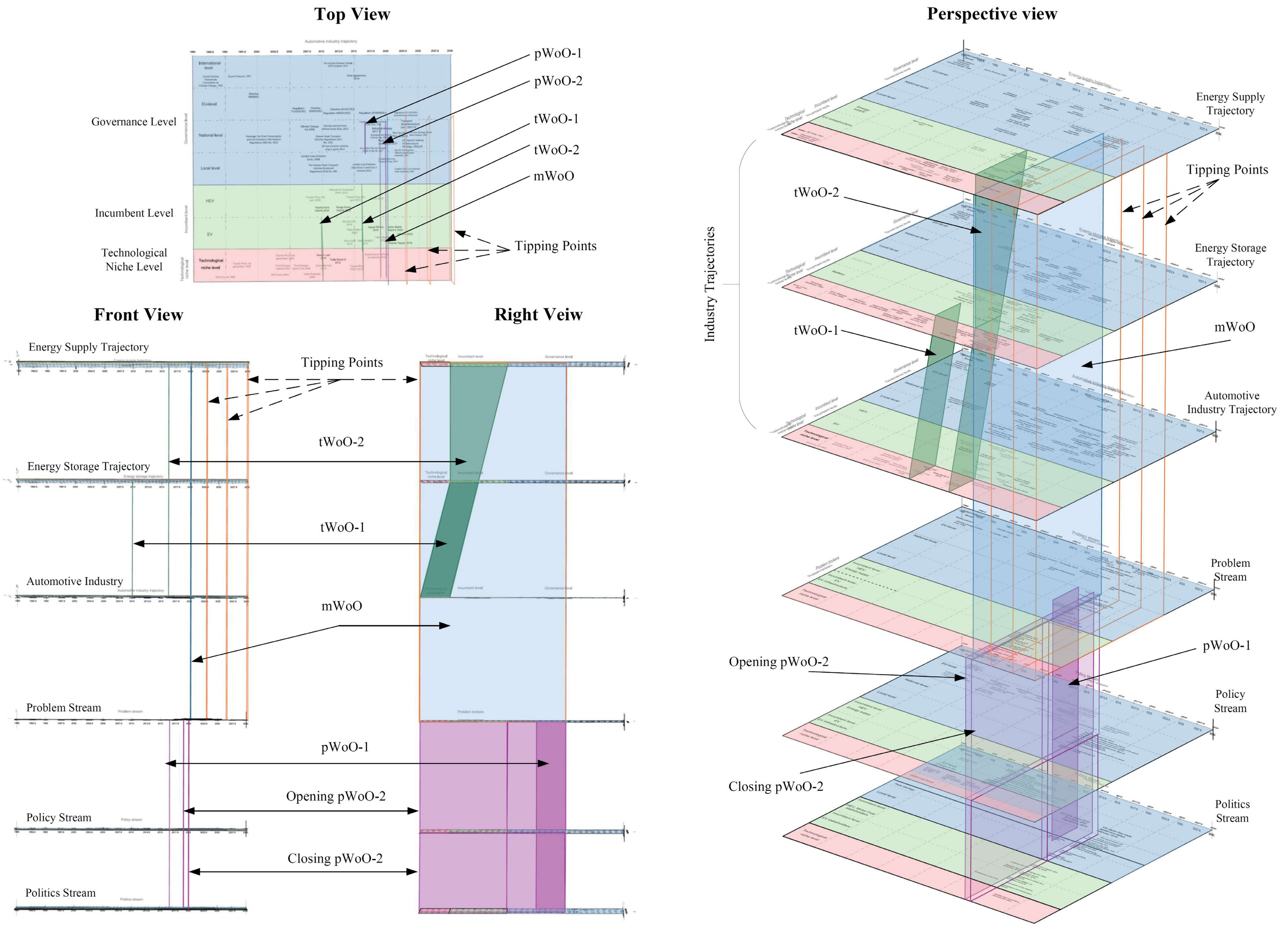


Figure 4.19 Multiview projection and perspective view of MLST

The opening of the mWoO and the shift of EVs to the incumbent level can cause multiple problems such as excessive energy demand, energy security and lack of interoperability in EV charging. This can affect customer satisfaction and slow down further EV market uptake. In order to prevent this, three tipping points and EVET interventions are expected up to 2030 (orange frames in Figure 4.18 and Figure 4.19) providing recommendations to the government and stakeholders. The tipping points and the problems associated with the EV technology market uptake can open follow up pWoOs feeding back to the policy agenda process.

The MLST and multiple WoO conceptualise the two-way linkages between technology and the policy agenda in the development of the new EV market. In the next section, the key actors and their roles in the process of policy agenda setting within the context of the MLST will be explained in detail.

4.4 Key Stakeholders and Their Roles in the EV Transition

When analysing the data, 5 key stakeholders were identified in the process of the net-zero policy agenda setting in the UK automotive industry between 2017-2020. It is worth mentioning that the present research focuses on the supply side of market creation and does not include an investigation of customer behaviour or the demand side of this process. The key stakeholders identified include Technology Innovators, Policy Entrepreneurs and Policymakers. While analysing the sub-set of activities of the key stakeholders, additional stakeholders in the process were also identified, whose roles were entirely focused on the specific sub-set of activity of key stakeholders. Such additional stakeholders include Knowledge Brokers and Bricoleurs. These concepts are theoretical codes in the proposed grounded theory that were matched with the literature at the initial and second stages of theory development. Each theoretical code has its own properties and dimensions that will be discussed within subsections dedicated to the specific theoretical codes. The subsections will open with a definition of the key stakeholders, followed by a detailed explanation of the characteristics of each stakeholder, along with quotes from interviews and archival data. This way innovative insight on the characteristics of stakeholders and their role in the policy agenda process will arise. This is in line with pragmatist GT.

4.4.1 Technology Innovators

Technology Innovators (TI) – individuals or groups of individuals who work outside the formal governmental system and who are involved in creating innovations within the industry trajectories; for example, senior managers of legacy carmakers, or startups. In the FOI data technology innovators held positions such as project managers, product development managers, or regional development managers of companies participating in the Taskforce.

4.4.1.1 Incumbent Level and Technological Niche Levels Innovators

Technology innovators identified in the FOI data and interviews work in the energy supply, energy storage and automotive industry trajectories (Appendix 6). With respect to the level of the trajectories, two types of companies were discerned: incumbent level companies and startups. They can be further broken down with respect to the technology they focus on: in the automotive industry, this can be BEV and HEV; in the energy storage industry Li-ion and motor fuels; in energy supply fossil fuels and renewable energy.

In the automotive trajectory, *EV start-ups* can be associated with companies that have emerged in the last decade and are engaged in the production of BEVs only, for example, Tesla, BYD, NIO, Rivian, Xpeng, and Lightyear.

> "Setting up an auto-making company is incredibly costly, especially an EV one. In some respects, legacy automakers are immediately on the back foot. I think start-ups have got way more potential to become EV manufacturers on a large scale, like Tesla, like Rivian, like NIO, Xpeng. All of these start-up companies have a focus on EVs and don't make combustion vehicles" (Int.18).

Among the *EV incumbents*, one can single out those legacy carmakers who took advantage of the first technological window (tWoO-1) of opportunity and began producing electric vehicles back in 2010. These companies include Nissan and General Motors.

> "I think what we will see is the incumbents being replaced unfortunately by other manufacturers. When you've got a Chinese manufacturer, who only builds EVs and came into existence five years ago. How are General Motors going to compete with that? I think you'll see start-ups who are generously financed, NIO, BYD, these Chinese start-ups" (Int.22).

There is a group of carmakers associated with *EV incumbents* that recently added electric vehicles in their model range using the second technological window of opportunity (tWoO-2), including Toyota, BMW, VW, Volvo, and Mercedes.

Using GT terminology, it is possible to say that the properties of the code 'technology innovators' include the categories (groups of codes) related to the EV ecosystem, such as energy supply, energy storage or automotive industry. Dimensions of code reflect the level of the socio-technical system and the type of market where TIs operates, whether this is a fully functioning incumbent level market or a technological niche level market (Table 4.10).

Table 4.10 Coding grid of focused code - Technology innovators

Properties / Dimensions	Automotive Industry	Energy Supply	Energy Storage
Incumbent level	BMW Nissan Ford Honda VW	BP Chargemaster E.ON EDF Energy ScottishPower Innogy Octopus Energy Vattenfall Centrica	AMTE Panasonic LG BYD (Li-ion)
Technological niche level	Tesla BYD NIO Rivian Xpeng Lightyear Project Vector (JLR) CaoCao (Geely) Drive Electric	Elli (VW) V2G EVSE Ltd Nuvve Charging Around Britain Ltd Engenie Pod Point EV Driver Drivenergy Ltd	Nio (Batteryswap) Shell Hydrogen Britishvolt

Note: classification is valid for the period up to mWoO in 2020

4.4.1.2 Coupling Industry Trajectories

The role of TIs within industry trajectories focused on creating innovations and facilitating their transition from the niche level to the incumbent level. This can occur with the advancement of techno-economic parameters of the niche technology, coupling with the complementary technologies at the incumbent level within the ecosystem of the niche technology. In the case under investigation and within the MLST context, TIs couple energy supply, energy storage and automotive industries through the advancement of technology in one or several related industries. TI's activities make it possible to use technology to solve environmental problems at a national level.

In the case of EV transitions in the UK, the coupling of the energy storage industry with the automotive industry happened in two stages, 2010 and 2016, via a technological window of opportunity that led to the shift of EVs to the incumbent level in 2020.

In 2010 the coupling of trajectories/opening technological window (tWoO-1) was associated with the advancement of Li-ion battery technology (battery packs) in the energy supply trajectory, which then was used for the production of the first mass market EV – the Nissan Leaf. The coupling of the energy storage and automotive industry trajectories took place through Tier 1 suppliers of Li-ion batteries for carmakers. In the meantime, the window was opened in the automotive industry due to the beginning of production of the first mass market-oriented EVs.

> "In terms of first opening [WoP] I think it was the early 2010s, so the 2010-2011. It was really the first time there was a vehicle that potentially more people could buy, it was probably the Nissan Leaf in about 2014 when we started to see it more out there" (Int.27).

> "What proved the case [of opening WoO], I think was maybe the Nissan Leaf in the early 2010s, maybe 2011, I think that came out that those are the early pieces of evidence that there could be a mainstream market for EVs" (Int.19).

In Table 4.9 it is possible to see a sharp increase in the number of first-time registered EVs in Great Britain, by 370% in 2011. After this year, the number of EVs registered for the first time constantly increased, although their percentage of the total number of cars registered was still small, reaching only 0.67% by 2018 (Table 4.1).

It is important to mention that in order for the tWoO-1 to be opened, the Li-ion technology itself needed to shift from the technological niche level to the incumbent level, which happened in the early part of 2010.

> "Lithium-ion battery technology, not being ready really until more recently, and a lot of the technology development has been driven by other tech industries. So the fact that batteries have been getting smaller and smaller because of, for example, mobile phones and so on, has led the development in battery ion technology" (Int.26)

Apart from the development of EVs using Li-ion technology and decarbonisation of the energy supply, TIs were responsible for the development of EV infrastructure technology and the widespread adoption of the charging network in the UK. The involvement of TIs in development technologies in both the energy supply and the automotive industries can be associated with coupling activity. In 2014 the total number of charging points increased by

115% compared with 2013, and the number of charging points has continued to increase exponentially (Table 4.6). Despite the development of the network of charging stations between 2010-2014, the number of EV incumbents involved in coupling energy supply and the automotive industry was relatively small. In addition, the energy supply for EVs was not decarbonised at that time. This did not allow the proper coupling of the energy supply and automotive industry trajectories to take place between 2010 - 2016.

> "Tesla had no choice but to put a charging network in place, because if they didn't, then nobody could buy their cars, so they were forced to do" (Int.25). "They were forced to do... To develop a battery company, to develop a car company and to develop a charging infrastructure company simultaneously, they had no choice on that" (Int.25).

> "We are not going to get into charge point solutions, we're not gonna have [Company A] chargers dotted around the place, we have done some in the past but that was about pump-priming the industry" (Int.22).

The second industry coupling point/technological WoO (tWoO-2) was associated with the intensification of decarbonisation of the EV energy supply in the UK in 2016. The coupling of the energy supply trajectory with the automotive industry trajectory took place through electricity providers that started to progressively adopt renewable energy technologies. This event was associated with the work of TIs within the energy supply trajectory.

> "Electric cars and electrification of vehicles has been an option for decades… [However] there was absolutely no point in producing an electric vehicle because of the carbon intensity of the grid… the EVs remained quite a minority thing... But we've seen… the decarbonisation in the UK, in particular, as an example, has been incredible. The CO2 of the grid [at night] now is … frequently dips below 100 [grams of CO2 per kilowatt hour]. So at these CO2 figures for electricity, [EVs] pretty much, that's the only option in town... Whatever you think about bio-fuels, whatever you think about hydrogen, they can't compete with those CO2 figures" (Int.22).

During the shift of renewable energy to the incumbent level in 2016 the energy generation from coal dropped by 77% compared to 2005 and accounted for 9% of the total electricity generated. At the same time, electricity generated from wind and solar energy accounted for 13.7% of the total (Table 4.5). Additionally, the number of charging points continued to increase exponentially and reached 4182 units across the UK, a factor of 2.13 compared with 2014 (Table 4.6). At this point, energy supply, energy storage and automotive industries were coupled and the environmental problems in the transport sector could be addressed through the use of EV technology. This moment can be associated with a significant reduction in the environmental impact of well-to-wheel processes of EVs in the UK – the metrics that were used in TEM during the pWoO-1.

The coupling of the trajectories can occur not only through Tier 1 suppliers or electricity providers but also through initiatives of carmakers via vertical integration or diversification strategies. In this case, TIs operate in multiple industries which allows them to produce complete technical solutions to anticipated environmental problems.

> "Tesla again are probably indicative of the way forward by providing a complete energy solution, which is the power wall, the solar roof and now energy supply as well. They are effectively able to power your entire home and that is a very interesting move" (Int.22).

Using vertical integration or diversification strategies reinforces the link between the trajectories. However, this strategic option is not affordable and feasible for the majority of OEMs. As indicated in interviews this can be an option for incumbent actors oriented on a broad mass market segment.

> "I think there's only a certain number of car companies, I think that will have the appetite to do that [developing charging network]. Maybe with General Motors and Ford and Daimler all pitch in together to build something out" (Int.18).

> "If you want to get into energy companies, I only think VW have got VW or Toyota and Nissan and Renault especially the only companies really that are big enough to pull that off all the other ones I can't see JLR investing in new renewable energies it's kind of economy to scale" (Int.28).

This statement was confirmed while analysing FOI data as three companies mentioned in the interview were also mentioned in EVET documents: Nissan, VW, and Ford. In addition, BMW and Honda were also identified in the archival data, along with Tesla.

EVET, as noted, facilitates the EV transition and reinforces the link between the industry trajectories. Notably, the companies participating in EVET were involved in coupling trajectories using vertical integration and diversification strategies. This underlies the importance of these strategies used by stakeholders to drive the EV transition process.

> "Looking at the investments the carmakers are making this is already happening [diversification into mobility-as-a-service and energy sectors and vertical integration with battery and digital industries] e.g. VW/Elli, Volvo/Lynk&Co, Geely/CaoCao, BMW/DriveNow, and it's also happening the other way i.e. the energy industry investing in automotive technology e.g. BP Ventures/Ryd in the news today. And then I agree within 5 years [in 2025] this will be the norm" (Int.24).

TIs of incumbent level actors play an important role, not only in coupling the trajectories, but also in the shift of technology within the trajectory. For example, BP – an incumbent actor who works within the energy supply trajectory – had a stake in the UK EV charging point business back in 2018. At that time the EV charging business, then a niche level market, accounted for 8312 charging devices across the UK. BP acquired EV charging company, Chargemaster, in June 2018. Following BP other incumbent actors entered the market. For example, EDF Energy acquired Pod Point in 2020, and Shell acquired Ubitricity in 2021. Nowadays, BP Pulse (formerly BP Chargemaster) is the third largest Charge Point Operator (CPO) in the UK, following Pod Point and Ubitricity. These three incumbent level actors respectively account for 7.2%, 11.8% and 15.6% of the total 37,055 installed charge points in 2023 (Zap Zap, 2023). Since 2018, the number of installed charging devices increase by a factor of 4.45. Based on this it is possible to say that incumbent actors are contributing to the shift of technology from the niche level to the incumbent level within the trajectory.

> "Generally, the strategy of BP was always if you cannot beat let's join and therefore whatever new innovations will develop in the market, they were always there… it's not a surprise that Chargemaster was a natural step for them to acquire because that is a mood in the market and obviously if the electric vehicles would be one of the parts of the automotive industry, certainly BP should have a stake on these things" (Int.1).

Not only startups and incumbents from automotive and energy supply trajectories were involved in the coupling of the trajectories. There are examples of TIs in the energy storage industry using forward vertical integration coupled with automotive industry trajectories. For example, BYD started out as a battery manufacturer in 1995 at the market niche level and now operates in the automotive industry (Int.28) at the incumbent level.

> "There are two examples of companies who kind of rip up that rule book and there's a Chinese company BYD who started as a battery pack or cell assembly for consumer electronics and then through economies of scope went up and became a car manufacturer and then the other way is Tesla started off as a car manufacturer vertically integrated downwards … to make cathode materials and refine lithium from some clay in America." (Int.28)

To sum up, coupling niche technology in the automotive industry with incumbent level technology in energy storage and energy supply industries facilitates the shift of niche level technology to the incumbent level. In the case under investigation, the coupling happens within two windows tWoO-1 and tWoO-2. In tWoO-1 the EV technology was coupled with Li-ion technology through Tier 1 suppliers, while in tWoO-2 the EV technology was coupled with renewable energy technology through electricity providers. The coupling of the trajectories is sequential and cumulative as the trajectories were not decoupled afterwards. The coupling can be supported through the initiatives of carmakers, energy supply and energy storage companies, such as backward and forward vertical integration or horizontal diversification. The role of TIs within industry trajectories focused on creating innovations and facilitating their shift from the niche level to the incumbent level, by advancement the technology in the target industry and through coupling with related industries.

4.4.1.3 Problem Brokering within the Bricolage Process

Problem Brokers (PB) – individuals who work outside the formal governmental system and frame problems within the problem stream based on their values, emotions and knowledge (Wildavsky, 1979; Baumgartner and Jones, 2010; Kingdon, 2014). The PB role can be thought of as one specific subset of activities that policymakers, PE or TI undertake, and it remains strictly a PB role only if the actor engages solely in problem brokerage.

Bricolage is a process in policymaking that involves arbitration and the recombination of policy ideas to create bespoke solutions that fit a problem (Deruelle, 2016).

Tracing the Bricolage Process

In the EVET meetings, some TIs were seen to undertake problem brokering activities within the bricolage process. Problem frames were formulated in the form of questions that were then debated during the multiple WP meetings. That was, for example, the case with WP4 which focused on the topic of data accessibility for decision-making. Out of 91 pages of the report, 69 pages were dedicated to the question raised by TIs. An analysis below shows the development problem frame and its influence on the final policy paper, the UK electric vehicle infrastructure strategy (2022b).

During the fifth WP meeting the question by TI was formulated as follows:

> "How could sharing of data (e.g. around demand forecasting) help the energy sector better meet the energy impacts of EVs?" (FOI 32)

After the series of debates and WP meetings, an additional question was added to the initial question:

"How could sharing of data (e.g. around demand forecasting) help the energy sector better meet the energy impacts of EVs? How should we use data and how could sharing it be enabled and encouraged?" (FOI 106)

Below provided comments from the WP Leader and WP Sponsor and their understanding of the questions.

"This question is about the delivery of energy and enabling all actors in the direct energy supply (i.e. generators, suppliers, DNOs) to deliver that energy to customers at the most competitive price and with the least environmental impact. Third parties (e.g. aggregators) may well play a crucial role. We think the second part of the question also implies "What barriers need to be removed to make this happen?". (FOI 106)

The problem frame that was formulated by WP Leaders in response to TI questions focused on both industry and national levels thus the industry level problem was linked with a broader context.

"This [shift to EVs] would represent an increase in energy to be delivered by the UK electricity system over current levels of between 20-40% by 2040. Given that the electricity system has very limited headroom at certain locations at times of peak demand, the key question is at what time of day and where will this additional energy will be delivered? Answering this question (and ensuring that EV charging occurs at times of lower demand) will be crucial to meeting the energy impacts of EVs" (FOI 106)

In response to these questions, five proposals were provided by the WP Leader and WP Sponsor to the government and industry stakeholders. These proposals were discussed on WP meetings and presented to TIs. Two of these proposals are shown below Q4.1 and Q4.5.

"Q4.1 The Government (or delegated body) must track and openly publish monthly data on EV adoption (and associated infrastructure)

Q4.5 OEMs should collect and share anonymised, statistical data on EV usage patterns, charging and energy consumption to enable accurate medium and long-term demand forecasting. This will ensure that charge point infrastructure (and the upstream energy system) is effectively planned and efficiently deployed - with reduced risk of under- or over-investment (thereby avoiding short-term constraints or stranded assets)" (FOI 106)

The priority of proposals was set using the MoSCoW prioritisation as "should have" (S) and "must have" (M) priorities in the short, long and medium terms, see Table 4.11.

Table 4.11 MoSCoW prioritisation for Q4.1 and Q4.5

Q4 Proposals				
	Proposal	Short Term (by 2020)	Medium Term (2021-2025)	Long Term (2026-2030)
Q4.1	The Government (or delegated body) track and openly publish monthly data on EV adoption (and associated infrastructure).	M	M	M
Q4.5	OEMs should collect and share anonymised, statistical data on EV usage patterns, charging and energy consumption to enable accurate medium and long-term demand forecasting.	S	S	S

Source: FOI 106

The draft of policy recommendations (Q4.1-Q4.5) was reviewed by the Steering Group members and included in Theme 3 – Utilising and protecting data for better consumer outcomes "Proposal 10 – Access to data; Establishing industry-wide data sharing arrangements" (FOI 87). It was noted that Energy Data Taskforce (EDTF) have similar recommendations [standardising data sharing agreements, FOI 69] and it was recommended to change the proposal to emphasise that the industry should work on creating comprehensive data sharing arrangements.

> "Proposed change - Industry should cooperate to develop comprehensive data sharing arrangements (including standardisation where appropriate) and exchange mechanisms in conjunction and alignment with implementation of Energy Data Taskforce (EDTF) recommendations [standardising data sharing agreements, FOI 69], as well as advise Government and relevant regulators if industry licenses or codes need changing or if legislation is required to allow such sharing of data by 2021. Government and regulators to review progress and to take action if necessary" (FOI 88)

In the final EVET report, proposal Q4.5 was formulated as follows:

> "Market participants should collect and share anonymised, statistical data on EV usage patterns, charging and energy consumption with relevant parties in order to allow the energy and transport systems to work effectively together and provide value to all market participants" (FOI 87).

The policy proposal was included in the final policy paper, the UK electric vehicle infrastructure strategy (2022b) which was published in March 2022 and included data sharing arrangements in the action plan.

> "We are addressing barriers to data sharing which can impede decision making" (2022b, p.62).

> "We will consider the potential sharing of private chargepoint location and energy data with specified parties to support network planning. We will aim to consult on additional measures to ensure we are taking a systems-wide approach for a safe and secure transition to smart charging" (2022b, p.73).

Based on this analysis we can see that TIs were able to participate in the bricolage process by framing the problem through the questions that were later debated by the members of the WP and Steering Group with multiple amendments of the policy proposal until it reached its final destination.

4.4.2 Policy Entrepreneurs

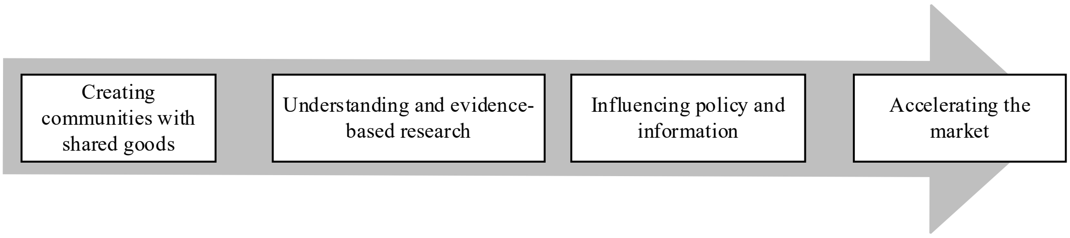
Policy entrepreneurs (PE) – individuals or groups of individuals who work inside or outside the formal governmental system to introduce, translate, and implement innovative ideas into public sector practice (Kingdon, 1984; Roberts and King, 1991). Policy entrepreneurs couple problem, politics and policy streams within a window of opportunity (WoO) opened in the problem stream or politics stream. PE can set proposals to the government and has clear policy preferences on how to solve the problem. "Policy entrepreneurs, people who are willing to invest their resources in pushing their pet proposals or problems, 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). PEs seek "anticipated future gain in the form of material, purposive, or solitary benefits" (Kingdon, 2014, p.179).

4.4.2.1 Defining Policy Entrepreneurs

Two groups of individuals were identified who couple problem, policy and politics streams and can be referred to as policy entrepreneurs - Senior Managers of LowCVP and certain members of the EVET Steering Group.

LowCVP

LowCVP (renamed to Zemo in 2021) was an independent non-profit partnership responsible for accelerating the EV transition in the UK (Zemo, 2023c). The main objectives of LowCVP were bringing in key stakeholders from the government, academia, energy supply, energy storage and automotive industry together to accelerate the shift to zero emissions vehicles; provide evidence-based research, "influencing policy and information" and "accelerating the market” (LowCVP, 2020b). LowCVP ran multiple projects simultaneously. For example, in 2022 Zemo, delivered 50 initiatives, initiated earlier, both at the local and national levels with the aim of accelerating decarbonisation of transport (Zemo, 2023b). The sequence of activities undertaken by LowCVP to accelerate the shift to zero emissions vehicles is depicted in Figure 4.20.



Source: adapted (LowCVP, 2020b)

Figure 4.20 A sequence of activities to accelerate the shift to ZEV

LowCVP has a long history of supporting the government with the decarbonisation of the transport industry. For example, in 2014 the DfT, in collaboration with LowCVP, established the Transport Energy Task Force to help meet renewable transport fuel targets (LowCVP, 2014). Between 2014-2017 the Transport Energy Task Force was responsible for updates to the Renewable Transport Fuel Obligation (RTFO), where directors of LowCVP took an active role. The confirmation of the importance of LowCVP in policymaking and its influence on the process can be found in multiple sources including the UK Parliament.

> “The DfT’s Transport Energy Task Force (TETF), made up of Government representatives and a wide range of stakeholders including Ensus, reported in March 2015 with agreed policy recommendations. These, together with the policy changes required by the “ILUC (Indirect Land Use Change) Directive” published in September 2015, will allow the UK to move towards the 10% energy target for transport. However, even if policy changes are implemented with ambition, full compliance will remain challenging.” (UK Parliament, 2020b).

In the context of MLST, the senior managers of LowCVP who were responsible for providing policy recommendations to the national level policies were associated with the national level policy entrepreneurs.

Within the first policy window (pWoO-1), LowCVP organised industry-specific events aimed at generating policy ideas related to the decarbonisation of transport. In addition, LowCVP’s Transport Taskforce informed DfT concerning fuel decarbonisation. Over the period July 2016 – November 2017 (16 months) LowCVP contribute to consultations regarding the Transport Energy Model that informed the government about the impact of various types of vehicles and fuels (DfT, 2018). The evaluation of the environmental performance of vehicle technologies and fuels was made based on a well-to-wheel approach (DfT and OLEV, 2018). The output of the model underpins the policies set out in the Road to Zero Strategy (DfT, 2018). LowCVP was also invited to update assumptions of the Transport Energy Model in 2018, where senior managers were able to consult the government, later in 2021 TEM was phased out (OZEV, 2021).

The Road to Zero strategy includes a summary of TEM which is evidence that LowCVP even then prioritised electric vehicles as potentially net-zero with respect to well-to-wheel analysis (DfT and OLEV, 2018, p.122). This can be considered as a coupling technology solution with a policy solution and problem frame. At a time EVs were coupled with an energy supply trajectory wherein renewable energy technologies (wind and solar) were shifted to the incumbent level. This significantly simplifies the task of PE to couple the technology with the policy stream as the well-to-wheel processes of EV were objectively more effective compared with other technologies such as HEV or FCEV.

Another example of LowCVP being involved in coupling technology solutions with policy solutions and problem frames is the development and inclusion of the 46-point policy plan in the Road to Zero. According to the Managing Director of LowCVP (now CEO of Zemo):

> "The Road to Zero highlights a 46-point policy plan – LowCVP members are key to many of these" (LowCVP, 2018).

This plan set the targets to end sales of new conventional petrol and diesel cars and vans by 2040 where the majority of cars will be ZEV (DfT and OLEV, 2018). It also includes the point of establishing EVET "in order to plan for future electric vehicle uptake and ensure the energy system can meet future demand in an efficient and sustainable way" (DfT and OLEV, 2018, p.5). This can be considered salami tactics, by breaking down a big task into multiple smaller tasks to manage complexity, build momentum and overcome resistance.

It is worth noting that the main government body responsible for the development of the paper was OLEV. This is a national level strategic policy document that sets the target for ZEV uptake up to 2040 at the national level. Thus, LowCVP during this period worked at the national level. In the next stage of transitions, LowCVP was more focused on industry-specific policies and policy recommendations. Within the MLST context, this is visualised as the second policy window (pWoO-2) which includes not only the national level of the policy streams but also technological niche and incumbent levels Figure 4.21.

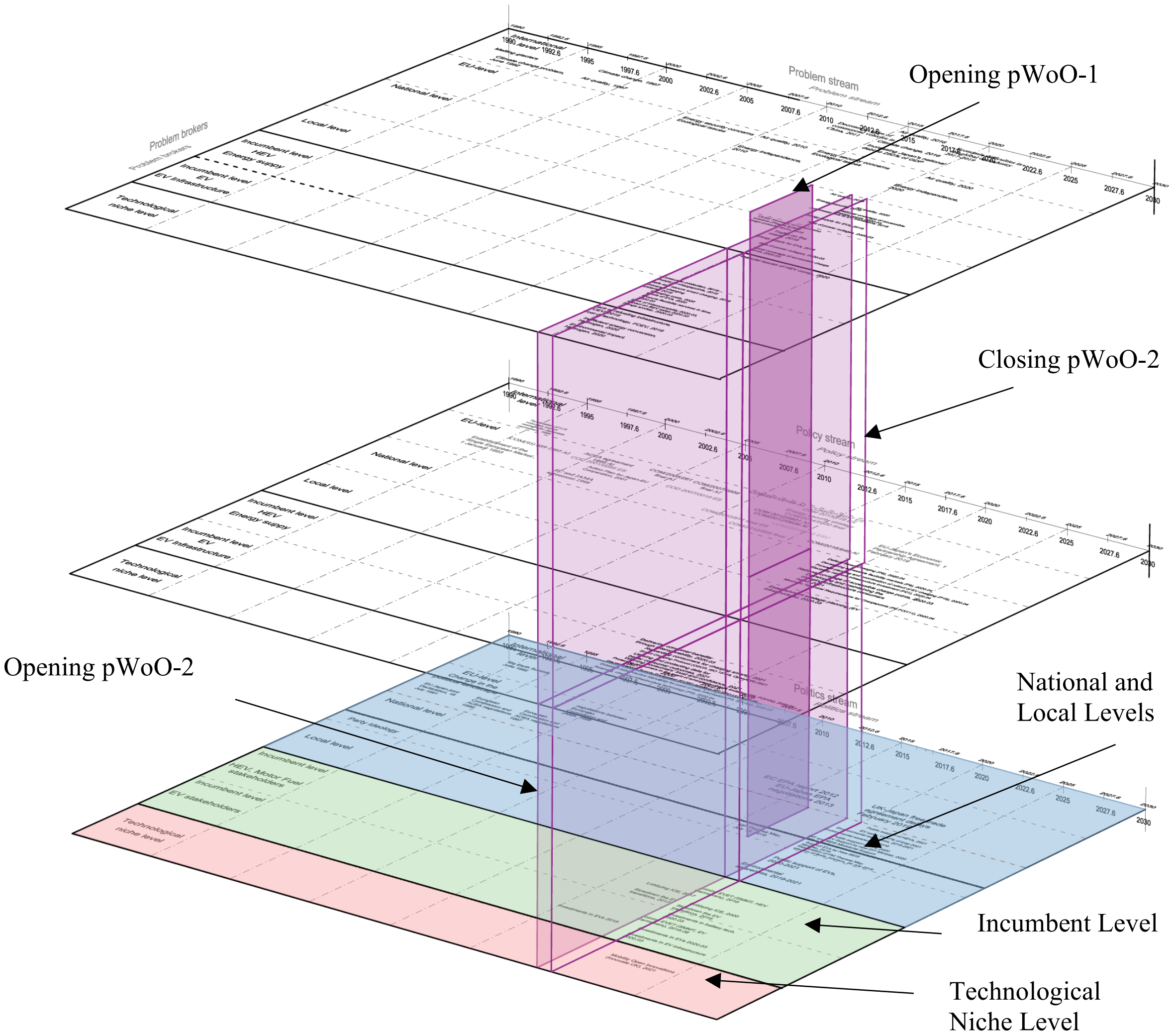


Figure 4.21 pWoO-1 and technological niche and incumbent levels of pWoO-2

In the second policy WoO (pWoO-2) in June 2018, one month before the release of the Road to Zero strategy, EVET 1.0 was established for the purpose of providing policy proposals regarding the energy supply issues for EVs, as outlined in the Road to Zero strategy. The secretary functions of EVET were undertaken by the LowCVP manager who took the same role and led Transport Taskforce while providing policy proposals for RTFO amendments (LowCVP, 2014). Over the period 2018 – 2020, within pWoO-2 a Senior Manager from LowCVP worked closely with WP Leaders and was involved in all stages of the development of the final EVET report that was presented to the Secretary of State for Transport and members of the House of Lords.

Members of the Steering Group (Leaders of the WP and WP Sponsor)

In addition to senior managers of LowCVP, the following PE were identified: senior manager BEAMA, senior manager EnergyUK, senior managers Energy Networks

Association, and academic from the University of Leeds. As indicated in Section 4.2 they are members of the EVET Steering Group. In addition, they undertake the role of WP leaders, with the exception of the academic from the University of Leeds who took the role of WP2 Sponsor.

According to Kingdon (2014) PEs are individuals who are coupling problem, policy and politics streams within a pWoO. It was found that the actions of these actors correspond to Kingdon's (2014) definition of PE. Firstly, these actors were involved in framing the problems while preparing WP reports and debating with WP members, as indicated in Section 4.4.2.2. and 4.4.1.3. Secondly, they were involved in the creation of policy ideas and writing up the policy proposal to the government, which can be associated with working within the policy stream. Finally, and most important, these participants were able to couple the politics stream. This happen on January 14, 2020, when the final EVET report, split into the themes that correspond to WP topics, was presented to the Secretary of State for Transport and other members of the House of Lords.

Each PE presented the policy proposals related to the WP topic he/she worked. The list of the themes that were presented and by whom are shown below:

- Theme 1 – Delivering Consumer Benefits through Interoperability; Presented by the senior manager BEAMA, Steering Group member and WP Leader in WP3 focused on functional requirements of smart chargers;
- Theme 2 – Rewarding Consumers for Charging Smartly; Presented by EnergyUK, Steering Group and WP Leader of WP2 that focused on the topic of EV users' engagement in smart charging and energy services;
- Theme 3 - Utilising and Protecting Data for Better Consumer Outcomes; Presented by Energy Networks Association, Steering Group and WP Leader of WP4 that focused on data accessibility for decision-making;
- Theme 4 – Winning Consumers' Trust and Confidence; presented by an academic from the University of Leeds, Steering Group and WP Sponsor in WP2 focused on EV users' engagement in smart charging and energy services;
- Theme 5 – Developing and Maintaining Infrastructure needed by Consumers; Presented by Energy Systems Catapult, WP Leader in the WP1 focused on Common strategic understanding of the requirements of the energy system.

With their roles in coupling all three streams within pWoO-2, it is possible to consider these individuals as PE.

4.4.2.2 Problem Brokering

PEs routinely act as problem brokers. Indeed, identifying an issue as a problem is a key role assigned to PEs. 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) write specifically about PEs acting as PBs.

Within pWoO-1 PEs framed the problems at the national level while working on the Transport Energy Model and Road to Zero strategy. The problems were associated with "air pollutant and greenhouse gas impacts" and the level of "tailpipe oxides of nitrogen (NOx)" that needed to be reduced (DfT, 2018, p.4). In the Road to Zero, the problem was formulated in a 46-point policy plan and also related to air quality and the level of NO_2 emissions (DfT and OLEV, 2018).

Within pWoO-2 PEs were responsible for the presentation of WP outcomes to the government which include 21 problems linked with policy recommendations. The problem frames were presented in Section 4.3.2.1 (Table 4.3) and Section 4.3.3.2 (Table 4.8) and include energy supply issues for EVs, safe and secure smart charging, supply of chargepoints, data interoperability, consumer protection, charging costs and costs of EVs.

Coupling National and Industry-Specific Problems

Analysing the problem brokering activities of PEs indicates that PEs not only frame industry-specific problems but also couple them with national level environmental or energy security problems. Within the MLST context, this can be associated with coupling industry-specific problems in incumbent and technological niche levels of the problem stream, with national level problems of the problem stream.

Examples of industry-specific problems include:

- Barriers/access to getting a connection for EV charging infrastructure;
- Poorly maintained and operated chargepoints;
- Absence of flexibility energy market;
- High energy system costs;

The broader national problem:

- Emissions from the transport sector.

The text below provides an example of coupling an incumbent level problem with a national level problem within the problem stream by the WP2 Leader and WP2 Sponsor:

> "Reaching net zero emissions by 2050 will require transformative change across the UK economy. A *switch from ICE vehicles to EVs* will form a key part of decarbonising transport, currently the *largest emitting sector*" (FOI 104)

Another example is provided in Section 4.4.1.3, subsection "Tracing the Bricolage Process" when the Leader of WP4 coupled the problem of data accessibility with the national problem of energy supply.

Based on this it is possible to confirm those leaders of WPs coupled problems in multiple levels of the problem stream. This approach allows us to justify the need to solve the particular industry-specific problem and ultimately increase the chance of the acceptance of a proposal.

MoSCoW prioritisation technique

The prioritisation of policy recommendations was made by PEs using the MoSCoW technique. Applying this technique relates to the problem brokering activity performed by PEs, as it involves framing the problem and setting the timeline to resolve it. An example of its application is provided below. The technique includes three planning horizons: short-term (by 2020), medium-term (2021-2025) and long-term (2026-2030). MoSCoW stand for *Must have, Should have, Could have*, and *Won't have* where *Must have* requirements has the highest level of priority, *Won't have* requirements have the lowest level of priority.

An example of recommendation and requirements to prevent a problem associated with the EV market uptake and increase energy demand is shown in Table 4.12.

> "Recommendation 1 Provide forward visibility of proposed EV chargepoint connections to ensure sufficient electricity network capacity and capability is available at all voltage levels to support both the EV transition and the future needs of national and local energy systems." (FOI 103, p.25)

This table was formulated and filled by the leader and sponsor of WP1. It is possible to see that Recommendation 1 relates to two layers (or elements of the EV ecosystem) of the EVET Framework (see Figure 4.6) - Regulations (rows with pink colours) and Information and Data (rows with orange colours) - and includes 7 requirements to meet by these layers/elements of the EV ecosystem. Five requirements encompass Regulations and two refer to Information and Data. These have different priorities across time horizons. For example, Regulation requirement for "establishment of a strategic planning capability which would … roll-out of EV infrastructure" include *should have* priority in the short term (by 2020) and *must have* priority in the medium term (2021-2025). It can be concluded that the government took into consideration these priorities as the UK infrastructure strategy (2022b) was released in 2022 the year, when this measure had a 'must have' priority. In this case the PE, by using MoSCoW, set an urgency for specific requirements and the problems associated with them.

Table 4.12 MoSCoW prioritisation for Recommendation 1 WP1

Framework Layer	Requirement	Short Term (by 2020)				Medium Term (2021-2025)				Long Term (2026-2030)			
		M	S	C	W	M	S	C	W	M	S	C	W
Regulation	Establishment of a strategic planning capability which would deliver forward planning and coordination of roll-out of EV infrastructure in volumes aligned to anticipated local and national need. This would be chaired by Government working in conjunction with regional and local energy and transport forums, and would comprise network, energy, transport, local authority, CPO and automotive sector stakeholders.		*			*				*			
Regulation	A regulatory framework that encourages efficient, coordinated and economic transmission and distribution by future-proofing investment in new network infrastructure as far as reasonably practicable – i.e. where the incremental capacity beyond immediate need is justified on the basis of (probable) future EV charging and (possible) heat pump demand (and losses savings)			*		*				*			
Regulation	Ofgem's RIIO ED2 and ED3 strategies to provide a framework that allows for well justified anticipatory (or highly anticipatory) network investment in capacity and capability to serve proposed EV infrastructure (and in future heat electrification) as part of Ofgem's new Business Plan Incentive				*	*				*			
Regulation	RIIO ED2 and ED3 provisions to include uncertainty mechanisms related directly to supplying EV charging infrastructure allowing partial reopeners to enable ex-poste adjustments to DNOs' allowed revenues in respect of higher or lower than forecast requirements for network reinforcement				*		*				*		
Regulation	A form of regulatory governance that embraces the whole of the electricity system including opportunities to exploit beyond the meter assets and technologies in developing an efficient, coordinated and economic electricity system – i.e. not limited to Transmission and Distribution asset investment				*	*				*			
Information and Data	EV charging infrastructure providers to share forward visibility of proposed EV charge point connections – including locations, numbers and types of charger, and power requirements		*			*				*			
Information and Data	Network companies to publish information regarding network capacity headroom, emerging constraints, and plans for future network reinforcement and extensions (extending the scope of current Long-Term Development Statements and Heat Maps)		*			*				*			

Source: FOI 103, p.25

4.4.2.3 Bricolage

Bricoleurs – individuals who work either inside or outside the formal governmental system. They make suggestions for particular policies based on their knowledge, knowing which policy ideas the policymakers are ripe for, wherein they recombine policy ideas into bespoke policy solutions that fit a specific problem and which are capable of solving it (Deruelle, 2016). The members of the Steering Group were involved in the bricolage process, specifically in commenting and changing WP proposals, but they did not present the final EVET report to the Secretary of State for Transport, were therefore considered as Bricoleurs. These include Automotive Council UK, SMMT, Electric Vehicle Supply Equipment Trade Association, National Grid, and Ofgem.

According to McFadgen (2019), bricolage can be a subset of activities of policy entrepreneurs while experimenting to address social-ecological issues. In the case under investigation, PEs within the policy stream, through a process of bricolage, determine which policy options to present to policymakers – the Secretary of State for Transport and members of the House of Lords. This involves collaboration with the EVET stakeholders by combining and recombining policy ideas into the final policy proposals and the final EVET report.

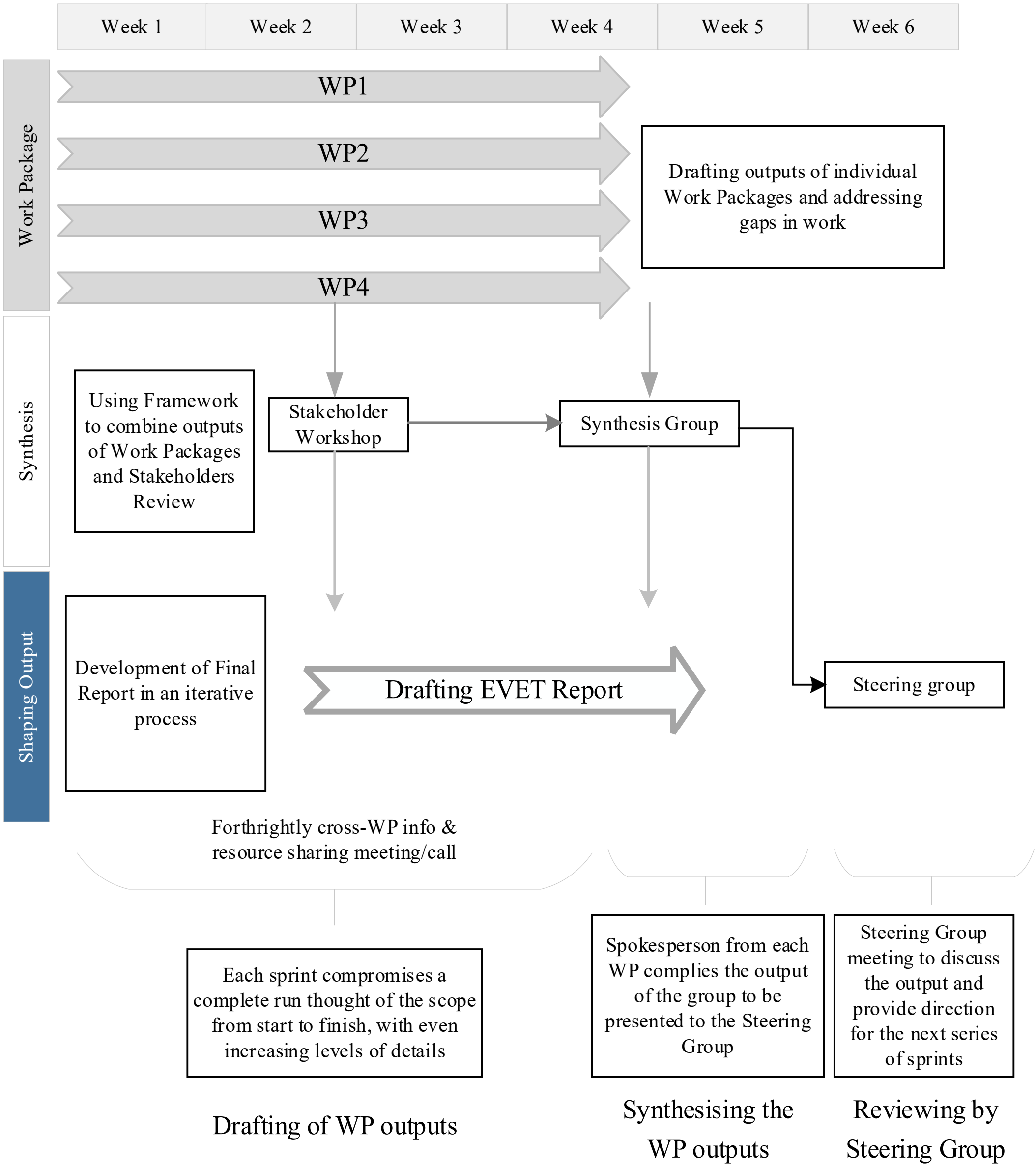
Table 4.13 RACI classification

EVET Core Activities	**EVET Steering Group**	**Secretariat**	**Govt & Ofgem**	**EVET Members**	**Community**
Convening the EV community	A	R	C	C	I
Co-ordinating Action across the EV community	A	R	C	C	I
Monitoring progress & updating proposals	A, R		C	C	I

Source: adapted FOI 111

Based on the analysis of FOI data, the RACI classification for the participants of the bricolage process was created as part of the present research which is shown in Table 4.13. R (responsible) shows the person/group whose role was for getting the job done; A (accountable) refer to the people/group who delegate and approve the work; C (consulted) - stakeholders knowledgeable in the task whose role was to consult other members; I (informed) - people who have to be informed, typically do not provide input to the process. It was found that the EVET secretariat – LowCVP senior manager – fulfilled secretariat functions but also actively participated in EVET steering group meetings, thus playing a multifaceted role. The manager was responsible not only for convening the EV community, and coordinating action across it, but also monitoring progress and updating proposals, thereby being involved in all stages of the policy proposal preparation process. Based on this it is possible to say that LowCVP PE – the senior manager – is one of the main persons who managed the bricolage process within the policy stream.

The bricolage process includes three general stages: drafting WP outputs, combining WP outputs, and reviewing the draft of the final report by the Steering Group. This process is shown in Figure 4.22 and will be described below. It is important to mention that the process depicted in Figure 4.22 can have multiple iterations. For instance, within pWoO-2 the bricolage process includes 8 sprints of 6 weeks each. However, it took 21 months before the release of the final report, due to the delays in preparing WP reports and Covid.



Source: adapted FOI 19 cf, FOI 72;

Figure 4.22 Six-week sprint within the bricolage process

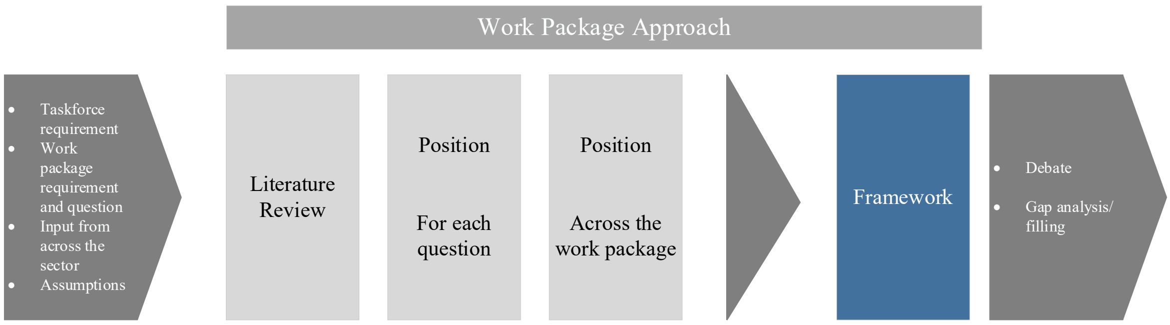
Drafting of WP Outputs

In the first stage, policy ideas were generated within each WP by members of the WP, including industry stakeholders experienced in WP topics (FOI 55). Each WP focuses on a specific topic, presented earlier. The stakeholders involved in the WPs included WP leaders, WP sponsors and WP organisations/volunteers. The policy ideas were generated during WP debates between the members of the WP (FOI 55). The WP Leaders, identified earlier, were knowledgeable in the WP topics. For example, the Energy Systems Catapult is a consulting and research organisation which has a broad strategic understanding of the EV transition process. This allowed ESC representatives to lead WP1 which focused on the strategic aspects of mass EV uptake. The trade association for the UK's energy industry - Energy UK - led the WP focusing on enhancing the EV user's customer experience. BEAMA, a trade association for manufacturers of energy infrastructure technologies and systems, led the WP focused on the functional requirements of smart chargers. The Energy Networks Association, knowledgeable in energy transmission and distribution, led WP4 that focused on data accessibility for decision-making in the EV, infrastructure and energy value chain.

The WP Leaders were supported by WP Sponsors who have industry-specific knowledge and can provide research and consultancy support, with the WP Leaders and WP Sponsors being members of the EVET Steering Group.

In addition, each WP was staffed by volunteers from EVET stakeholder organisations which included energy companies, carmakers, consulting organisations, engineering companies, and financial organisations. In total 350 organisations contributed to the WPs, of which 108 were identified and included in Appendix 6.

The Work Packages addressed its objective and specific questions posed by the Steering Group in their "terms of reference"; collect and review evidence; draft the WP report; present the emerging themes of the WP to the Synthesis Group, and adapt their work in response to the actions agreed by the Synthesis Group (FOI 55).



Source: adapted FOI 40

Figure 4.23 Work package approach

The process drafting of WP outputs includes 4 stages (Figure 4.23):

1. Literature Review – this includes an in-depth literature review to provide knowledge frames with respect to the WP topic;
2. Consolidation of the positions for each question – this is linked with the representation of a preliminary set of coherent positions for each question, based on the findings of the literature review and practical experience.
3. Development of the high-level positions – this suggests synthesising opinions across the WP topic questions;
4. Development of the framework to support further analysis – identification of tipping points, and of the gaps in knowledge that will need to be filled. This stage contributed to the development of the EVET Framework and, in the first instance, related to WP1. The EVET Framework is discussed in Section 4.3.2 and shown in Figure 4.6.

In the MLST context, drafting WP outputs relates to the activity within the incumbent level of the policy stream and national and incumbent levels of the problem stream, where industry-specific policy solutions link with national and industry-specific problems. Apart from the participation of PEs and TIs, this involves the participation of knowledge brokers.

Knowledge brokers (KB) – work outside the formal governmental system and frame knowledge in order to be understandable in the political world (Zohlnhöfer and Rüb, 2016). They supply the concise evidence that is most relevant to understanding the problem (Cairney, 2018) and they tend to be neutral toward the problem without partisanship (Pielke Jr, 2004). Litfin (1994) associated KB mainly with scientists.

In Figure 4.23, knowledge brokers are involved in the literature review stage and can be associated with scientists cited in the WP reports. Knowledge brokers do not couple the streams but only provide frames of knowledge. The coupling between the problem and policy stream is made by WP Leaders and WP Sponsors that can be associated with bricolage activity within the incumbent level of the MLST. Bricolage activity is a subset of activities performed by PEs.

Synthesising the WP Outputs, drafting the final report

The next stage after the drafting of WP outputs is synthesising them across multiple WPs, into the draft of the EVET report (Figure 4.22). At this stage, the answers to the questions in each WP are synthesised with respect to the EVET framework and framework of use cases (FOI 60, FOI 35). The framework of use cases refers to the four scenarios of the EV transition paths (viable futures) that will be discussed in Chapter 5, section 5.4.1.4 and which are illustrated in Figure 4.14. The synthesis stage also involves discussions of the current situation in the EV transition, pathways and the constraints that might interfere with progress, plausible future scenarios, interventions that would mitigate the constraints, and characteristics of interventions (FOI 60).

In order to gather feedback from a broader group of stakeholders, Stakeholder Workshops were organised which included the participation of about 120 delegates. Three Stakeholder Workshops were conducted wherein the EVET Report was developed iteratively. If any gaps or new questions were identified during these workshops, they were used to guide further work in the respective WPs.

After the Stakeholder Workshops, the draft of the EVET report was reviewed by the members of the Synthesis Group. This included WP Leaders, WP Sponsors and some members of Steering Group such as LowCVP, Energy Systems Catapult, Office for Low Emission Vehicles and Ofgem representatives. The role of the Synthesis Group was to: discuss the outputs and issues identified by each WP; ensure the outputs of the WPs were consistent; draw out emerging themes and draft outputs of the Taskforce; present the emerging themes of the Taskforce to the Steering Group and propose how to address issues identified by the WPs (FOI 55).

Reviewing the draft of the final report by the Steering Group

Following the consolidation of WP outputs and drafting the final report, the next stage of the bricolage process included reviewing the draft of the EVET report by the Steering Group. This included representatives of the government who were also involved in the bricolage process increasing the chance the policy proposal acceptance.

The Steering Group's task was to: review the progress of the Taskforce, and decide on changes to processes and ways of working as required; review the emerging themes of the Taskforce and identify new work areas as required; determine the approach to addressing issues identified by the Synthesis Group; ensure that a framework is established to provide coherence to the taskforce work; set the objectives of the next sprint; establish the requirements for the output of the Taskforce; and endorse the conclusions and recommendations of the Taskforce. Individual Steering Group members also worked with stakeholders to access appropriate expertise and support the dissemination of interim and final conclusions (FOI 55).

After the eight iterations of the bricolage sprint represented in Figure 4.22, the final report was ready to be presented to the government ministers and MPs. It is worth mentioning that there were delays at the end of the process and the duration of the final sprints took more than 6 weeks. The EVET WP Report launch took place on January 14 2020. The following delegates were present:

- Secretary of State for Transport, MP Chris Grayling
- Minister for Future Transport, MP George Freeman
- 11 MPs or members of the House of Lords
- Over 240 delegates
- 30 media representatives

The Taskforce event, where the proposals were presented by the WP leaders, was chaired by the CEO of LowCVP. At this point, policy and politics streams were coupled at national and incumbent levels and thus represent PE activity performed by WP leaders and LowCVP Senior Managers.

Bricolage within the Transport Taskforce

A similar approach to the development of policy proposals was identified while analysing Transport Taskforce data. Transport Taskforce focused on the energy supply policy proposals during pWoO-1. The process also included multiple stages for proposal development. The process also involved contributions from industry stakeholders and trade associations for compiling the policy ideas, while the LowCVP managers took the secretariat function.

> "Stakeholder Group: will meet limited number of times; wide group of invited stakeholders formed to review progress and receiver broader input; LowCVP provides secretariat;
>
> Steering group: will meet monthly or as required; chairperson (same as Stakeholder Group); formed for trade associations (and chairperson from sub groups) to oversee progress; LowCVP provides secretariat;
>
> Sub-Groups will meet as required: Chairperson chosen by steering group; formed for stakeholders with specific interest; LowCVP provides secretariat" (LowCVP, 2017)

The secretary functions of the Transport Taskforce were undertaken by the same LowCVP senior manager who took a similar role and led EVET (LowCVP, 2014). It is possible to note that LowCVP PEs used a similar approach to the bricolage process within pWoO-1. This underlies the fact that LowCVP is very experienced in providing policy proposals to the government and can be associated with serial PEs who systematically identify and utilise windows of opportunity (James, 2018).

Policy Proposals Amendments

The Steering Group members play an important role in each stage of policy proposal development, by providing comments on WP reports which were then amended by the WP Leaders.

Below is an example of the involvement of the Steering Group (SG) in WP report development. That took the form of a Q&A.

> "[WP leader question:] Should on-street charging to be included in WP2? [SG's answer:] Yes. Important to consider how to make on-street charging smart. Public charging reliable and interoperable of connectors is not in scope. However, open standards to allow interoperability between chargepost operators are in scope." (FOI 24, 17/10/2018)

Below is an example of amendments industry-specific WP recommendations by SG members after the steering group meeting.

> "[WP leader question:] Proposal 11 [Chargepoint Registration] – will EVET be offering an opinion on who should be maintaining the single asset register? [SG's answer:] This could be a very substantial task. At this stage we don't envisage government having to build and maintain a chargepoint register. I think what we'd like to see is something along the lines of 'To facilitate the availability of open and accurate chargepoint data.'" (FOI 88)

The following correction corresponds to WP proposals 1-5 that required amendment by WP leaders before the next steering group meeting.

> "[PE comment] 10. Theme 1 should be renamed. Again, this could be misleading and does the proposals an injustice. Proposals 1, 2, 4, 5 are not focussed just on interoperability but are a lot broader (e.g. cyber) A theme name of "delivering consumer benefits through interoperability" doesn't seem accurate for the majority of these proposals." (FOI 88)

The above examples correspond to the work within the policy stream at national and incumbent levels, focusing on amendments and combining policy ideas to which the policymakers are ripe. The work at national and incumbent levels is linked with the fact that policy recommendations were addressed to both strategic policy – the national level; and industry-specific policy instruments – the incumbent level.

Tracing the WP Leaders' Involvement in the Bricolage Process

In Section 4.4.1.3 we saw the involvement of TIs in the bricolage process by framing the problem at the beginning of the process. This subsection provides an example of WP Leaders' involvement, using a similar approach. Furthermore, an example will be provided of how problem frames and policy solutions are coupled on multiple levels of the MLST, via bricolage.

Below the problem frame is provided through the question formulated by the WP Leader and the Sponsor in the WP2 EVET meeting.

> How best to deliver consumer engagement with smart charging? (FOI 21 cf)

In the follow up sprints the industry-specific problem – EV charging operations – were linked with national level problems – public perception and EV uptake. This way the importance of the problem frame and the policy solution related to it had been highlighted. The MoSCoW prioritisation was not used in WO2, thus this is another way to prioritise the problem and solution.

> "Delivering a Good User Experience for EV Charging: Ensuring that public EV charging infrastructure is effectively developed, operated and maintained is important to growing public confidence and trust in EVs. Poorly maintained and operated chargepoints create the risk of delivering a poor charging experience for EV users and adversely impacting public perception and uptake." (FOI 104)

The following solution was suggested after a series of WP meetings:

> Industry should enable roaming services to deliver a seamless electric vehicle charging experience between public networks. (FOI 66)

It was later framed as a proposal to the government:

> "Proposal 5: Industry to deliver roaming services for a seamless EV charging experience everywhere" (FOI 104)

In the draft of the Final Report, which includes the summary of WPs recommendations, Proposal 5 was renumbered and reworded as Proposal 3 "Enabling roaming services to deliver a seamless EV charging experience between public chargepoints" (FOI 87). The information in the proposal says that:

> "Roaming should allow drivers to access any public chargepoint, without signing up to multiple apps or memberships, through a single identification or payment method or through use of an existing subscription" (FOI 87)

Before presenting to the government this proposal was reviewed by steering group members and the following comment was left:

> "Also, commercial terms for roaming interoperability need to be agreed. It's a laudable aim but can't be pushed through easily if some membership schemes are unwilling." (FOI 88)

Reviewing the FOI documents, it was found that the recommendation focused on the strategic document for explaining objectives to stakeholders. This recommendation was discussed in the MoSCoW prioritisation subsection of Section 4.4.2.3. It was developed in WP1 but it supports WP2s proposal, as strategic EV infrastructure policy can reduce the obstacles for advancement of roaming interoperability.

> "Recommendation 1: … A strategic planning capability convened by Government and comprising network, energy, transport, local authority, CPO and automotive sector stakeholders, should be established to define and agree an overall *EV infrastructure strategy* and take responsibility for forward planning and coordinated rollout of EV infrastructure in order to mitigate the risk of over-capacity or underprovision in different regions, and ensure the timely provision of electricity network capacity." (FOI 103).

The EV infrastructure strategy was published in March 2022. It not only reflects the recommendation to prepare a strategic document from WP1, but also reflects the problem frame regarding the development of a roaming service in WP2.

The following government commitment regarding the roaming service was identified in the EV infrastructure strategy.

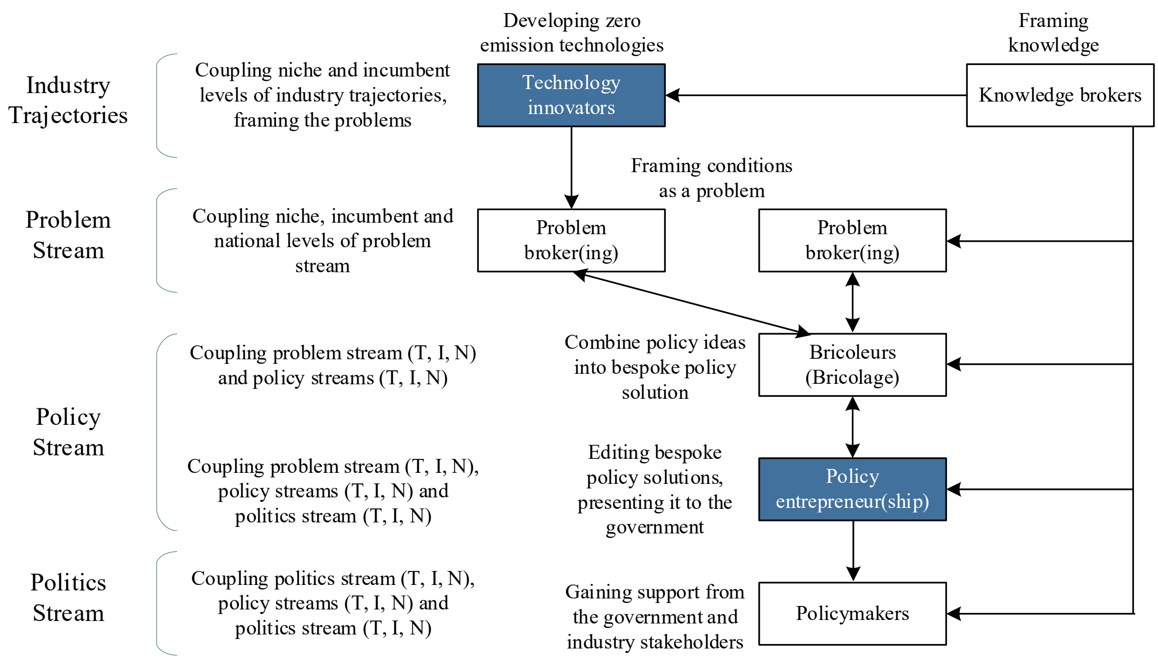
> "Our commitments: Regulate to make sure public chargepoints are reliable and easy to use. We will also be supporting fleet electrification by introducing payment roaming across the public chargepoint network" (DfT, 2022b, p.11).

This example shows the chain of activities starting from framing the problem through the question by PE and finishing with the inclusion of industry-specific solutions in strategic policy. It also demonstrates how the national level proposal from WP1 – EV infrastructure strategy – supports the industry-specific proposal WP2 – roaming services in EV charging, thereby establishing a link between the policy problems and policy solutions at multiple levels of the MLST within pWoO-2. Based on this, it is possible to say that PEs' problem frames and follow up activities are an important element of the bricolage process, wherein PEs work in collaboration with other stakeholders of EVET.

Conceptualising Bricolage

Conceptualisation of the bricolage process reflects the idea that a distinction should be drawn between policy entrepreneurs as individuals, and policy entrepreneurship as a process, "allowing us to isolate different facets of entrepreneurial activity" (Ackrill and Kay, 2011, p.74).

Figure 4.24 depicts the bricolage concept as a subset of the activities performed by policy entrepreneurs where TIs plays an important role. Technology innovators work within the technological stream and, by coupling industry trajectories, they improve the market potential as well as the efficiency of well-to-wheel processes of the focal technology. This makes it possible to pair it with policy proposals addressing environmental problems. Technology innovators can act as problem brokers if they frame a condition as a problem and link their technological solution to this problem. In addition, TI can work within the policy stream by sharing ideas with members of WPs.



Note: T – technological niche level; I – incumbent level; N – national level

Figure 4.24 Conceptualisation of the Bricolage Process

Other actors can also participate in problem brokering activities, such as bricoleurs, or policy entrepreneurs, as was discussed in Section 4.4.2.2 "Problem Brokering". The problem brokering activities relate to the problem stream.

Within the policy stream, TIs, bricoleurs and policy entrepreneurs are involved in the bricolage process by sharing policy ideas in response to the problem frames formulated in the problem stream. Bricoleurs and policy entrepreneurs are also involved in synthesising and amending policy proposals. This process ultimately results in preparing the final EVET report.

In the next step, PEs move forward and present the final report to the Secretary of State for Transport and members of the House of Lords; which is associated with the coupling of the politics stream. This activity distinguishes PEs from bricoleurs and other actors.

Knowledge brokers stand apart from TIs, PEs and bricoleurs as they do not engage in coupling streams, but provide intellectual contributions by framing the knowledge. This knowledge can be used by other actors either while coupling the industry trajectories, farming problems within the problem stream, preparing the EVET final report, or by policymakers while evaluating the final report.

The roles of the key stakeholders of the study in relation to the bricolage process are summarised in Table 4.14. It can be seen that TIs can work within both tWoO and pWoO. Within tWoO, TIs couple industry trajectories, while within pWoO, they frame the technology-related problems with the aim of solving industry-specific and national-level problems. In addition, within pWoO, TIs are capable of sharing technology-related policy ideas with members of the WP. This indicates their ability to couple problem and policy streams on both national and incumbent levels. The fact that TIs are coupling industry trajectories distinguishes them from other actors.

Bricoleurs are involved in the policy stream and focus on amending and synthesising policy ideas that address industry-specific and national-level problems. These activities are associated with coupling problems and policy streams on both incumbent and national levels. PEs also work within pWoO, but are also involved in coupling the politics stream at the national level by presenting policy proposals to the policymakers at the national level. Their involvement in coupling the politics stream at the national level distinguishes them from other stakeholders. Knowledge brokers provide intellectual contributions within both tWoO and pWoO, but do not engage in coupling streams.

Table 4.14 The roles of key stakeholders in relation to the bricolage

Actors/Activities	**What streams couple**	**In which stream work**	**In which level of the stream work**	**In which window work**
Policy entrepreneurs/ Policy entrepreneurship	Policy, problem, politics	Problem, policy, politics, industry trajectories	National, incumbent, niche levels	Policy window

Actors/Activities	What streams couple	In which stream work	In which level of the stream work	In which window work
Bricoleurs / Bricolage	Policy, problem	Problem, policy	National, incumbent, niche level	Policy window
Knowledge brokers	na	Policy, industry trajectories	National, incumbent, niche levels	Technological window Policy window
Problem brokers / Problem brokering	na	Problem	National, incumbent, niche levels	Policy window
Technology innovators	Industry trajectories, Policy, problem	Policy, problem, politics, industry trajectories	National, Incumbent, niche levels	Technological window Policy window

4.4.2.4 Mobilising Policymakers and Industry Stakeholders' Opinions

Ackrill and Kay (2011, p.72) state that "the politics stream contains factors creating an environment conducive to agenda-change". The main actor groups who work within the politics stream include politicians, the general public, interest groups (Kingdon, 2014), and others involved in shaping the political climate and influencing policymakers' receptivity to policy ideas. These actors can "operate either as an impetus or as a constraint" (Kingdon, 2014, p.87). In the case of the EV transition, the list of actors was clarified by including incumbents and technological niche actors, as they can support or delay the transitions.

> We could see already that the release of the new policy has been delayed for months by intensive lobbying and not everyone is happy about this [EV transition]" (Int.2).

In this regard, the political stream in the MLST includes not only politicians, the general public and interest groups in the context of both national and local levels, but also industry stakeholders in the context of the technology niche level and incumbent levels.

The role of PEs within the political stream is to mobilise policymakers' and industry stakeholders' opinions in favour of favoured policy solutions. LowCVP has a long history of collaborating with industry stakeholders and was capable of organising industry-specific events during pWoO-1, as well as engaging 108 companies to join EVET in pWoO-2. For example, within pWoO-2 the support from industry stakeholders was secured by inviting influential trade associations as well as TIs from the automotive and energy supply industries to participate in the bricolage process. Moreover, SMMT, BEAMA, ENA, EVSE, and

TechUK, as members of the Steering Group, took the role of bricoleurs (EVSE and SMMT) or PEs (BEAMA, ENA, TechUK). Using a well-tested bricolage process, and reputational capital accumulated from the previous project, allowed LowCVP PEs to gain support from industry stakeholders. This can be conceptualised as coupling the politics streams at the incumbent and technological niche levels.

Mobilising policymakers' opinion at the national level, as well as those of industry stakeholders, is related to the accumulated reputational capital. LowCVP collaborated with the government for more than a decade, which simplifies the task of getting policy solutions accepted by DfT and BEIS MPs. The high level of reputational capital accumulated by the managers of LowCVP can be evident in the following statement provided by Michael Ellis MP, Minister of State for Transport.

> "… we established a Transport Energy Task Force with the Low Carbon Vehicle Partnership and published a strategy for renewable transport fuels in 2017. This built on the success of the Renewable Transport Fuel Obligation (RTFO) scheme, which saw the average greenhouse gas savings… government can't deliver … these in isolation… we need the Low Carbon Vehicle Partnership. With the unique contribution you all can make. Not just in the short term. But right through our journey to zero emissions… And we are hugely grateful to have you all on board." (DfT and Ellis, M, 2019).

Additionally, representatives of OLEV were members of the synthesis group and were able to clarify the government's vision regarding each proposal, before presenting the final EVET report to the Secretary of State for Transport. As the representatives from the government were involved in bricolage, this increased the chance of the proposal being accepted at the ministerial level.

The final WPs were presented by Senior Managers from LowCVP. These are very experienced speakers who had presented policy proposals to the government before and who were able to deliver policy proposals very effectively. In addition, the WP leaders and WP Sponsors, who are knowledgeable in WP topics, were involved in presenting the final result. Their involvement contributed to the mobilisation of policymakers' opinions. This can be considered as coupling the politics streams at the national level, corresponding to PE activity.

EVET includes other members from government research and consulting organisations, such as the CEO of the Energy System Catapult (ESC), who chaired the steering group meeting. There are two reasons why this study concludes that senior manager of LowCVP, who held the secretary role of EVET, had the leadership role in PE activity. Firstly, analysing FOI data it became clear that he worked closely with WP leaders and was involved in all stages of policy proposal development in all 4 WPs, as reflected in FOI data and the RACI analysis (Table 4.13). He also was able, jointly with WP leaders, to amend the final policy proposals before presenting them to the government. This can be associated with work within the policy stream, both on national and incumbent levels. Secondly, among the many EVET stakeholders, the manager of LowCVP was involved in leading the discussion of the WP reports at the Steering Group meetings. For example, while presenting on June 2019 (Figure 4.25) the total duration of the meeting was 180 minutes, out of which 145 minutes were led by the LowCVP PE (in Figure 4.25 the PE's name is redacted). This is the case for most of the steering group meetings suggesting deep involvement by the LowCVP PE in the proposal preparing process.

Time	Item	Description	Lead	Purpose	Paper
14:00 5min	**1.**	**Welcome** • Guidance on competition law • Tour of the table	Chair	Governance	
14:05 5min	**2.**	**Minutes**	Chair	To be agreed	EVSG-M-19-04
14:10 10min	**3.**	**Government update – questions only** (written update taken as read)			
		• **OLEV & BEIS update**		For Info	EVSG-P-19-22
		• **Ofgem verbal update**		For Info	
		• **Energy Data Taskforce verbal update**		For Info	
	4.	**Work Programme**			
14:20 10min	**4.1**	**Work Package Updates – questions only** • Taken as read	WP Leaders	For Info	EVSG-P-19-23
14:30 105min	**4.2**	**Framework & Recommendation** • Problem statements, Triggers & Test Cases	[redacted]	For input	EVSG-P-19-24
		• Initial draft recommendations		For input	EVSG-P-19-25
16:15 15min	**4.3**	**Smart Chargepoint Consultative paper** • For circulation to Auto Sector		For input	EVSG-P-19-26
16:30 10min	**4.4**	**Main Report** • Structure & Synopsis	[redacted]	To be agreed	EVSG-P-19-27
16:40 15min	**4.5**	**Stakeholder Workshops** • Proposal for remaining workshops	[redacted]	For input	EVSG-P-19-28
16:40 15min	**4.6**	**Sprint Objectives** • Confirmation of objectives for next sprint	[redacted]	For input	EVSG-P-19-29*
16:55 5min	**5.**	**Date & venue of next meeting** • Venue and date to be confirmed (offers Welcome)	Chair	To be agreed	
17:00	**8.**	**Meeting close**	Chair		

* Presentation on the day

Source: FOI 65, 2019.06.04

Figure 4.25 Agenda for the Steering Group meeting on June 9, 2019 (Meeting 9)

4.4.2.5 Salami Tactics

This tactic is evident with the LowCVP approach during the EV transitions, which was supported by the government. The significant issue of the EV Transition was split into multiple manageable tasks to resolve. The first split of policy moves was associated with the development of policy proposals for strategic policy – Road to Zero – and presenting these policy proposals during the first window of opportunity (pWoO-1). The second policy move related to work on the industry-specific policy proposal for policy instruments within the second policy window (pWoO-2). The FOI data also revealed that after the finishing EVET-1.0, which operated within pWoO-2 and discussed in this chapter, the work on EVET-2.0 was initiated (FOI 107). The next phase was to involve the inclusion of new members in steering groups such as The Urban Transport Group and Citizens Advice (FOI 117). pWoO-3 was then expected to focus on the local level of the streams, and the policy proposals addressing "community engagement, to disseminate and socialise the work underway" (FOI 111).

According to Kingdon (2014, p.200) the policy stream is characterised by a "policy primeval soup, [where] many ideas float around, bumping into one another, encountering new ideas, and forming combinations and recombinations". In the MLST context, the policy streams include a "primeval soup" of policy ideas related to national, incumbent and technological niche level problems. In the UK's EV transition context, this study sees LowCVP senior managers, WP Leaders and a WP Sponsor as the key agents for generating industry-specific policy ideas within the policy stream, using the bricolage process. LowCVP brought experts together from academia and the energy supply, energy storage and automotive industries to facilitate this process.

Within pWoO-1, LowCVP PEs organised industry-specific events aimed at generating policy ideas regarding the decarbonisation of transport. In addition, LowCVP's Transport Taskforce informed DfT regarding the decarbonisation of fuels. These activities contributed to the development of the Transport Energy Model and the Road to Zero Strategy. Within the MLST context, the work of PEs related to the national level of the policy stream, as policy proposals addressed the national level strategic policy documents and did not include policy recommendations to industry-specific policy instruments related to the EV transition.

Within pWoO-2, PEs were identified as the EVET secretary (LowCVP PE) and WP leaders, where the EVET secretary took a leading role in the proposal development process. As this is not the first project by LowCVP's PE, the processes were effective and the PE had the reputational capital to lead this project. It is worth mentioning that there were about 108 companies involved in this process, thus the policy solution – the final EVET report – was compiled from multiple ideas offered by EVET stakeholders, via bricolage. Other actors involved in the bricolage process included TIs, who were able to frame the problems;

bricoleurs, who supported the bricolage process and made the WP proposal amendments; and knowledge brokers who provided knowledge frames to the stakeholders of the process.

4.4.3 Policymakers

Policymakers are individuals or groups who have the authority for making and implementing policies (Blum, 2018; Cairney, 2018; Mallett and Cherniak, 2018). This section focuses on the policymakers identified in FOI and interview data and their roles in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry.

4.4.3.1 Government Departments and Policy Priorities

Over the period 2017-2022, multiple strategic policy documents were released in the UK, which indicate the government shifted focus from low emission vehicles to zero emission vehicles. Such policies include the Industrial Strategy (HM Government, 2017), Road to Zero Strategy (DfT and OLEV, 2018), The Ten Point Plan for a Green Industrial Revolution (HM Government, 2020) and UK Electric Vehicle Infrastructure Strategy (DfT, 2022b). These strategic policy documents, and the government departments involved in policymaking, are depicted in Table 4.15. The policy priorities of these policies are shown in Table 4.16. The main departments involved in the policymaking relevant to the case under investigation were DfT, BEIS and OLEV. In Table 4.16, it is possible to see a significant change in policy priority from 2017 to 2022, from low emission to zero emission goals. The policy priory of the Industrial Strategy focused on the decarbonisation of the automotive industry by investing in EV infrastructure and providing car grants. Moving to the Road to Zero strategy, the document set the target for ZEV up to 2040 and includes the 46-point policy plan to achieve this target. The Ten Point Plan announced the revised, and even more ambitious, target to phase out petrol and diesel vehicles in 2030. Finally, the EV infrastructure Strategy set the minimum number of charging stations by 2030.

The Secretary of State played a crucial role in the policy shift and in the EV transition in general. It is common for the Secretary of State to give the final internal approval of the policy ideas to be included in the final policy paper, with the subsequent release of the policy after Parliamentary scrutiny. The release of strategic policy set the long-term orientation and drives innovation and technological change (Rogge and Reichardt, 2016).

Table 4.15 Strategic policy papers and the government departments

Date of release	**Title of a policy paper**	**Secretary of State**	**Department**
27 November 2017	The UK's Industrial Strategy	Rt Hon Greg Clark MP (Conservative Party)	Business Energy and Industrial Strategy (BEIS)
9 July 2018	Road to Zero Strategy	Rt Hon Chris Grayling MP (Conservative Party)	Department for Transport (DfT); and Office for Low Emission Vehicles (OLEV)
18 November 2020	The Ten Point Plan for a Green Industrial Revolution	The Rt Hon Alok Sharma MP (Conservative Party)	Business, Energy and Industrial Strategy (BEIS)
25 March 2022	UK Electric Vehicle Infrastructure Strategy	Rt Hon Grant Shapps MP (Conservative Party)	Department for Transport (DfT)

Table 4.16 Policy priorities of strategic policy papers

Policy paper	**Policy priority linked with the transformation of the automotive industry**
The UK's Industrial Strategy	"support electric vehicles through £400m charging infrastructure investment and an extra £100m to extend the plug-in car grant", making "25% of all cars in the central government department fleet ultra-low emission by 2022" (HM Government, 2017, pp.50, 128)
Road to Zero Strategy	"put the UK at the forefront of the design and manufacturing of zero emission vehicles, and for all new cars and vans to be effectively zero emission by 2040" (DfT and OLEV, 2018, p.2)
The Ten Point Plan for a Green Industrial Revolution	"end the sale of new petrol and diesel cars and vans from 2030", "allow the sale of hybrid cars and vans that can drive a significant distance with no carbon coming out of the tailpipe until 2035" (HM Government, 2020, p.14)
UK Electric Vehicle Infrastructure Strategy	installing a minimum of 300,000 public chargepoints by 2030, "but there could potentially be more than double that number" (DfT, 2022b, p.44)

4.4.3.2 Multiple Levels of Decision Making

At the national level, the policymakers were identified as DfT, BEIS and OLEV, to whom the interim and final work packages were presented. Information on their involvement is presented below.

> "Government updates: OLEV & BEIS update; [Head of the Office] provided an update for OLEV" (FOI 15 Minutes 28 Apr 2020).

Additionally, as discussed in Section 4.4.2.3, Chris Grayling MP, Secretary of State for Transport (July 2016 to July 2019) was mentioned as a policymaker to whom the final EVET report was presented on January 14, 2020. This can support the statement that these stakeholders can be considered as policymakers.

Grant Shapps MP, Secretary of State for Transport (July 2019 to September 2021) was mentioned in the context of government support for the activities of EVET and the support of the EV transition at the national level.

> "It was noted that the new DfT Minister A is very keen on electrification of transport." (FOI 113, 2020.04)

George Freeman MP, Minister of State at the Department for Transport (July 2019 to February 2020) was mentioned in the EVET Launch Event under the section Government Perspective. During the meeting, the final EVET report was presented to the government. After that meeting on March 16, 2020, the work of four WPs was finished and pWoO-2 was closed.

The EV transitions were further supported by the government, through the release of The Ten Point Plan for a Green Industrial Revolution (HM Government, 2020), which set the target to phase out petrol and diesel vehicles by 2030 (HM Government, 2020). This policy was released by the Prime Minister's Office, 10 Downing Street and the MP Alok Sharma, Secretary of State for Business, Energy and Industrial Strategy. The importance of this policy was mentioned in Interview 27 with the Head of OLEV.

At the local level, the Mayor of London Sadiq Khan (May 2016 – present) was considered as a policymaker. In addition, members of City Councils can be associated with this group. On the official website of the Mayor of London, it is said that Sadiq Khan "provides citywide leadership and creates policies to improve London for all" (Greater London Authority, 2023). The FOI data indicate that the local government is in the competence of establishing local level Taskforces, such as the Electric Vehicle Infrastructure Taskforce (EVIT) responsible for providing recommendations at the local level. The members of EVIT Steering Groups comprise experts from OLEV and LowCVP.

> "It was noted that the London Mayor had set up an Electric Vehicle Infrastructure Taskforce (EVIT) and questioned to what extent did the two overlap [with EVET]? It was noted that there was significant difference between the two with London's EVIT focusing on developing a charge post rollout plan to 2025 to support London's air quality strategy. OLEV sit on the EVIT and LowCVP has had a meeting to discuss co-ordination of activity at a working level, and so there was little concern of duplication." (FOI 7)

The competence of the Mayor of London in steering the strategic papers at the local level, with the support of EVIT, confirmed by London's 2030 Electric Vehicle Infrastructure Strategy, indicates that the "electric vehicle infrastructure delivery plan, [was] steered by the Mayor's EV Infrastructure Taskforce" (Transport for London, 2021, p.6) where the role of EVIT was to bring in industry stakeholders to provide recommendations on "how, when and where to increase London's electric vehicle infrastructure" (Mayor of London, n.d.). These facts support the statement that the Mayor of London can be considered a local level policymaker who provides citywide leadership and develops policies locally.

The archival data and interviews also revealed the EU level of policymakers impacting the EV transition in the UK, through EU level standards.

> "European Standards for Emission, sets a maximum or sets some boundaries for vehicles and vehicle manufacturers to ensure that their vehicles meets certain emission standard" (Int.12).

> "It's [sustainability transitions] been very much driven by in not UK but international regulation and that's all off the back of increasing international concern for things around climate change" (Int.27).

In addition, the positive cases from the EU can be a part of the bricolage process and impact policy proposal development. For example one of the questions that was discussed in WP1 was:

> "How applicable are international examples (e.g. California, Norway) to GB in terms of overcoming network constraints and the adoption of smart charging?" (FOI 103)

Based on the analysis provided by knowledge brokers, it was concluded by PEs that "some of the attractive technologies and models found through the research can be successfully integrated into the GB ecosystem" (FOI 103).

Using grounded theory terminology, EU level policymakers ehave the properties of th code 'policymakers', wherein the specific government body or individuals can be considered as a dimension related to this code.

There is no global government, however the participants frequently mentioned international treaties such as the Paris Agreement or Kyoto Protocol. This was related to the international level of policymaking, where entities involved are intergovernmental organisations, such as the United Nations.

Table 4.17 shows the properties and dimensions of theoretical code 'policymakers', where governance levels refer to the properties of the code; dimensions are associated with government bodies and individuals. DfT, BEIS and OLEV are open codes that correspond to national level policymakers within the dimension - government bodies.

Table 4.17 Coding grid of theoretical code - Policymakers

Properties / Dimensions	Local level (UK)	National level (UK)	EU level	International level
Government bodies	City Councils	- DfT; - BEIS - OLEV - HM Treasury	European Commission	United Nations - International Organisations (UN)
Individuals	Mayor of London Sadiq Khan	- Rt Hon Greg Clark MP (BEIS); - Rt Hon Chris Grayling MP (DfT); - The Rt Hon Alok Sharma MP (BEIS); - Head of OLEV; - Rt Hon Grant Shapps MP (DfT) - Lord Richard Harrington MP (BEIS) - Rt Hon Jesse Norman MP (DfT)	na	na

4.4.3.3 Setting the Principles for the Development of Policy Recommendations

The role of policymakers in the shift of agenda from low emission to zero emission goals corresponds to the four principles for future strategy development outlined by Greg Clark MP, Secretary of State for Business, Energy & Industrial Strategy (July 2016 to July 2019). These principles are intended to guide not only policymakers but also other actors involved in the agenda setting process.

> "Business Secretary, Greg Clark … highlighted 4 principles for future strategy development for the power sector. These principles have relevance for the work of the Taskforce and should be borne in mind in its deliberations. [These include:]
>
> 1. Market principle – make use of market mechanisms to take full advantage of innovation and competition wherever possible;
>
> 2. Insurance principle – given intrinsic uncertainty about the future, government must be prepared to intervene to provide insurance and preserve optionality;
>
> 3. Agility principle – energy regulation must be agile and responsive if it is to reap the great opportunities of the smart, digital economy;
>
> 4. No free-riding principle – consumers of all types should pay a fair share of system costs." (FOI 38).

While interviewing the Head of OLEV it was mentioned that there will be "another tipping point as we [government] really start to trigger that mass market" (Int.27). Based on this the government approach to the first principle mentioned by Greg Clark requires clarification.

Further analysis of the FOI revealed that the government using market-oriented policies to establish the marketplaces for ZEV technologies, by developing EV infrastructure and employing economic incentives to discourage using ICE. This was made, for example, by releasing the Smart Charging regulation, introducing an Ultra Low Emission Zone (ULEZ), and increasing taxes for ICE while keeping taxes low for EVs.

> "Rather than try and focus on mandating specific data availability, it is recommended that, wherever possible, the government supports the development of a commercial market mechanism that will act as an enabler to realising this value and reducing unnecessary grid upgrade costs. By establishing a viable marketplace, the commercial incentive will seed innovation organically." [FOI 106].

Based on this, it is possible to say that the government, by using the 4 principles, outlined the direction for the policy proposals for which it was ripe. This then guided the bricolage process led by PEs. Thus, one of the roles of policymakers in the EV agenda setting process in the UK has been to set the principle that guides other actors involved in the development of policy recommendations.

4.4.3.4 Problem Brokering

Another role of policymakers during the agenda shift towards EVs was framing the problems. Within the MLST context, this relates to problem brokering activities within the problem stream. The problems that were framed by the government in the Road to Zero strategy relate to the national level and are associated with energy security and air quality. While formulating the problems, the government also linked them with the technological solution – EVs. At this point the government had ceased to be technologically neutral.

> "Since 2013/14, the UK has become a net importer of oil… The transition to zero emission vehicles could partly replace our reliance on imported oil with largely UK generated energy sources, helping to improve the UK's long-term energy security" (DfT and OLEV, 2018, pp.30–31).

The importance of problems was also confirmed during the interview with the Head of OLEV.

> "I think technologies are quite good at solving issues so they can almost come of need of public consensus but it's very iterative. You can shift the public opinion if the technology is helping, you can help them [technologies], you can shift the political thing if the public opinion changes and it is all needs to be iterative. If I was to pick one first it needs to be the sense that there is a problem that needs to be solved" (Int.27).

While setting up the EVET the problem frames were used by the representative from DfT. The environmental problem and its solution were the first points in the welcome message by Jesse Norman MP, Parliamentary Under Secretary of State for Transport

> "Jesse Norman [MP, Parliamentary Under Secretary of State] opened by reaffirming the Government's ambition for almost every car and van to have zero carbon emissions by 2050 which will deliver environmental and health benefits for the UK" (FOI 7).

According to Knaggård (2015, p.456) one of the "most authoritative forms of knowledge is scientific" that can be used by problem brokers to "strengthen the validity of their frames". With this, the frames formulated by the government are supported by scientific research. For example, the problems and their solutions in the Road to Zero strategy were informed by the Transport Energy Model developed by DfT (DfT, 2018). TEM used statistical analysis and a well-to-wheel approach to compare the energy consumption and energy emissions of different types of vehicle.

It was also found that the representatives of the government who set the problems have an academic background, adding credibility to the government problem frames. For example, the problem of decarbonisation of industries that were mentioned in the Industrial Strategy and the environmental problem mentioned in the welcome message for the EVET was delivered by Greg Clark MP (BEIS) and Jesse Norman MP (DfT) respectively. Both policymakers have a research background and PhD qualifications, which potentially added credibility to the messages that had been delivered.

4.4.3.5 Opening Windows of Opportunity

As discussed in Section 4.3.3.2 policymakers were responsible for opening policy windows of opportunity in July 2016 and June 2018. The first pWoO (pWoO-1) associated with starting work on Transport Energy Model allowing "stakeholders from industry, academia, environmental groups and Government, including vehicle manufacturers, fuel suppliers, vehicle and environmental consultancies, environmental lobby groups and other Government Departments" (DfT, 2018, p.5). The second pWoO (pWoO-2) was opened in June 2018 when the OLEV at the request of ministers from BIES and DfT set the EVET "with the objective of making proposals to Government and Industry on 'how to ensure the GB energy system is ready for and able to best exploit the mass take up of electric vehicles?'" (FOI 13 Project Proposal Mart 2020).

To sum up, in the case of the UK, policymakers operate at multiple levels of decision making, both national and local, and are the key actors in the agenda setting process and the EV transition in general. The national level of governance is associated with DfT, BEIS (now split into the Department for Business and Trade and the Department for Energy Security and Net Zero) and OLEV (now OZEV). The local level of governance identified in the data includes the Mayor of London and City Councils. One of the roles of government is to set the principles for the development of policy recommendations. These principles include: making use of market mechanisms to take full advantage of innovation and competition (market principle); readiness of the government to intervene to provide insurance and preserve optionality of the future power system (insurance principle); agility of energy regulation to reap the smart and digital economy (agility principle); fair share of system costs among the customers (no free-riding principle). Government representatives were involved in problem brokering activities by framing the problem around the environment issues and energy security. In addition, the government was involved in opening two policy windows of opportunity. The first window of opportunity was opened in July 2016 by initiating the work on the Transport Energy Model, while the second policy window of opportunity was linked with the establishment of EVET in June 2018. The government ceased to be technological neutral after the release of the Road to Zero strategy in July 2018 and, as sees in Section 4.4.2, the PE contributed to this shift.

It is important to mention that policymaking in the EU is an important element of agenda setting and the EV transition process in the UK. This is related to the pressure that EU standards put on the automotive industry. The successful EV transition cases in the EU became part of the bricolage process and influenced the development of policy proposals at the national level.

4.5 The Process of the EV Transition

Within the MLST context, the EV transition in the UK over the period 2010 – 2020 was shaped by means of the opening of a series of windows of opportunities for EVs: tWoO-1, tWoO-2, pWoO-1, pWoO-2 and mWoO. The actors involved in this process were technology innovators, policy entrepreneurs, bricoleurs, knowledge brokers and policymakers. Different sets of actors were involved in different windows: technology innovators participate in tWoO, pWoO and mWoO, technology innovators, bricoleurs, policy entrepreneurs and policymakers are the main actors in pWoO. By opening technological windows of opportunity sequentially and coupling automotive, energy storage and energy supply industry trajectories, the well-to-wheel processes of EVs are decarbonised, reducing the total environmental impact of the niche technology – EVs. This starts from energy generation and storage (the well) to energy consumption by EVs (the wheel). The decarbonisation of well-to-wheel processes ultimately makes the technology appropriate to solve environmental problems.

The first technological window of opportunity (tWoO-1) was opened in 2010. At the time, the niche level technology mass market-oriented EV powertrain was coupled with incumbent level technology Li-ion batteries, which allowed the production of the first mass market-oriented EV – the Nissan Leaf. The second technological window of opportunity (tWoO-2) for EVs was opened in 2016 in the energy supply trajectory and was associated with a shift of renewable energy from the niche level to the incumbent level, signifying a considerable decarbonisation of the energy supply for EVs. The shift to cleaner sources of energy took place jointly, with the decreasing the cost of batteries and increase in EV infrastructure. This allows us to say that in the second tWoO-2 all three trajectories - automotive, energy storage, and energy supply - were coupled. On the one hand, this demonstrated the efficiency of well-to-wheel processes of EVs; on the other hand, it indicated the market potential of the technology. This made EVs a viable environmental solution for the air quality problem. As EVs were in the niche level, coupling with the automotive industry happened on the niche level, while with the energy supply and energy storage this happened on the incumbent level. This facilitated the shift of EVs from the market niche level to the incumbent level, the same level at which the EVs complementary technology is located. TIs played a significant role at the stage of coupling industry trajectories by creating innovations, facilitating the transition of technology complementary to EV from the niche level to the incumbent level, and increasing the efficiency of well-to-wheel processes of the focal technology. The next stage involves opening a series of pWoO which will provide policy support for EV market uptake.

In July 2016, the Department for Transport (DfT) initiated work on the Transport Energy Model (TEM) to understand the relative environmental performance of different fuels and types of vehicles (DfT, 2018). This model underpins the policies set out in the Road to Zero strategy (DfT, 2018), which was developed by OLEV. The work on the TEM and Road to Zero continued over 24 months from July 2016 to July 2020 when the Road to Zero was released. Over this period, DfT consulted with industry stakeholders, academia, trade associations, consultants, and other Government Departments, who were able to contribute to the model and policy plan. This period is considered as the first policy window of opportunity during the EV transition. It opened at the national level of the problem stream and related to air quality and energy security problems (DfT and OLEV, 2018). This work was supported by the government and UK Prime Minister Theresa May, who was appointed on July 13, 2016.

The PE within pWoO-1 coupled the streams at the national level, as the work at this stage focused on the strategic policy paper that set the national level policy targets and policy plan. The first policy windows of opportunity resulted in the release of the Road to Zero strategy, signalling a shift in the government's stance on technological neutrality. It was an important moment in the EV transition timeline. LowCVP Senor Managers who had earlier collaborated with the government undertook the role of PE and contributed to the development of the 46-point policy plan of the Road to Zero strategy. They were also responsible for including EV technology in the TEM and prioritising it in the decarbonisation of the automotive industry. As this technology had effective well-to-wheel processes and was available in the market, this simplified the task for the PE to pair this technology with the policy solution. In addition, the PE included the policy point for launching EVET to provide policy proposals to prepare the energy system for EV market uptake.

The industry-specific policy recommendations for the policy instruments to facilitate the EV uptake were set in the second policy window of opportunity, pWoO-2, after the launch of EVET in June 2018. This corresponds to the salami tactics used by the LowCVP and supported by the government.

In 2018, there was a generally positive attitude of the public toward the government's plan to phase out petrol and diesel vehicles by 2040. This is evident in the survey provided by YouGov (2018a). In addition, there was increased awareness of environmental problems in society (YouGov, 2018b). The strategic document – Road to Zero – which set the target for ZEV uptake, was ready for release at the national level of the automotive industry trajectory in July 2018 and signified the government's support for EVs. These two factors made it easier for PEs to couple the policy and politics streams once pWoO-2 was opened.

pWoO-2 opened in the problem stream, which can be inferred from the following. Despite the fact that the Road to Zero sets the target for ZEV uptake, the national energy system was not ready for the mass transition to EVs. Moreover, EVs were still at the market niche level and required an enabler for the widespread adoption of technology and transition to the incumbent level. The unreadiness of the energy system for EV mass market uptake relates to both national and incumbent level problems, as the risk of power outages associated with this problem can impact not only the industry stakeholders but also broader social groups. The lack of widespread adoption of EVs was associated with a technological niche problem.

This technology was on the niche level at that time and the problem of demand for this niche technology was primarily an issue of actors involved in the development of this technology on the niche level. In response, the government established the Taskforce that served as the enabler for the mass take up of EVs.

The establishment of EVET caused the opening of the second policy WoO-2 in June 2018. For the first time, EVET brought together key stakeholders from the government, the automotive and energy industries (FOI 87). It encompassed the national, incumbent and market niche levels of the problem, policy and politics streams, as it provided a platform to formulate national and industry-specific policy solutions to the national and industry-specific problems that required support from the national and industry level actors to make the EV transition possible.

EVET aimed to formulate policy proposals addressing EV energy supply issues, which are mutually dependent on the issue of the widespread adoption of EVs. EVET was required to identify problems that the incumbent and technology niche companies may face during the EV transition; and provide policy solutions for the government to address these problems. Based on this, it was found that EVET stakeholders were capable of contributing to the bricolage process, by means of which the policy proposals were developed. This process involved framing the problem, developing policy proposals and amendments, and synthesising proposals into the final report which was then presented to the Secretary of State for Transport and members of the House of Lords. The PE was involved in presenting the report that can be conceptualised as coupling problem and policy streams with the politics stream, with the subsequent closure of the windows in March 2020. As a result of pWoO-2, EV infrastructure policies were released, such as the UK electric vehicle infrastructure strategy (DfT, 2022b) and The Electric Vehicles (Smart Charge Points) Regulations (HM Government, 2021) fostering EV market uptake.

The release of the Road to Zero strategy as a result of pWoO-1 indicates the shift in policy agenda from low emission to zero emission targets which is then supported by initiating the work on industry-specific problems within pWoO-2. This sends a strong signal to the industry stakeholders on the preferable technology for transitions. The EV market WoO was partly opened in September 2019, within pWoO-2, when the percentage of change in the EVs registered for the first time sharply increased by 141%. The share of EVs out of the total number of cars registered in the UK was 1.64% that year. The EV market continued to demonstrate substantial growth the year after in 2020 by 184% compared to the previous year. The proportion of newly registered EVs accounted for 6.59% of total cars registered in the UK. At that time more incumbent actors were involved in manufacturing, EVs thus the model range of EVs was diversified considerably. Most EV models showed significant growth in 2020. The increase in total EV market share and diversification of the EV model range signifies the shift of EVs to the incumbent level, making them a mass-market product.

4.6 Theory Validation

According to Strauss and Corbin (1998), the theoretical findings generated as a result of the analysis are preliminary and should be validated by participants. The theory and answers to research questions must be understandable and based on their data. At the same time, the theory should not fit the details of every participant "because the theory is a reduction of data and built upon a compilation of cases" (Corbin and Strauss, 2015, p.204). This validation process was undertaken in different ways, as we now describe.

The MLST framework and the research findings were presented at three conferences:

- International Public Policy Association (IPPA), 6th International Conference on Public Policy. Toronto Metropolitan University, Toronto, 27-29 June 2023. Vaulx en Velin: IPPA
- University of Colorado Denver School of Public Affairs, Conference on Policy Process Research (COPPR) 2023: Advancing Policy Process, Theories, and Methods. Denver, United States, January 12 -14, 2023. Denver: University of Colorado
- International Public Policy Association (IPPA), 3rd International Workshops on Public Policy. Corvinus University of Budapest, Hungary, 28-30 June 2022. Vaulx en Velin: IPPA

Feedback was received from the discussants of the panels, which helped to improve the theory and framework. Below is the feedback from Professor Dana Archer Dolan from Geroge Mason University, Policy Fellow and Adjunct Professor in Public Policy.

> In section 4 [Section 0 of PhD thesis - Key stakeholders and their roles] of your paper, where you identify the "key agents" - would it be useful to reformulate these as "key activities" instead? In fact, I've been wondering for some time whether Asa Knaggard's notion of the problem broker should be treated as a set of activities performed by Kingdon's policy entrepreneur, rather than as a separate role, distinct from the PE. Distinguishing between actors and activities is well aligned with Kingdon's approach to separating "participants" from "processes". The benefit, I believe, would be flexibility for a particular individual or group to engage (or not) in multiple activities -- something you hinted at when you refer to

"TIs who act as PEs and PBs". If so, then the actor is the policy entrepreneur, while the activity is "problem brokering." Also, isn't the "Technology Innovator" working in the policy stream as well as the problem stream? Finally, I'd want a justification for restricting any of these activities to only individuals inside (or outside) government.

Professor Dana Archer Dolan, Geroge Mason University, Policy Fellow and Adjunct Professor in Public Policy

Validation was also provided by interviewees. Participants were asked to check the clarity of the theory and answers, as well as the consistency of the data they shared. Feedback was received from 6 participants that confirmed the validity and relevance of the research. Below is some of the feedback.

"In terms of my comment on the synopsis I agree with everything. Looking at the investments the carmakers are making this is already happening [diversification into mobility-as-a-service and energy sectors and vertical integration with battery and digital industries] e.g. VW/Elli, Volvo/Lynk&Co, Geely/CaoCao, BMW/DriveNow, and it's also happening the other way i.e. the energy industry investing in automotive technology e.g. BP Ventures/Ryd in the news today. And then I agree within 5 years this will be the norm" (Int.24).

Feedback from interviewee no. 3 and 30 are provided in Appendix 9 "Theory Validation Feedback".

4.7 Summary

Based on the analysis of data, the following summary can be written, structured according to the research questions.

RQ1. How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry?

Technology is an important element of the agenda setting process related to technology-centric issues, such as the decarbonisation of transport. In order to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry, this study developed considerably and then used the concept of windows of opportunity.

By using the grounded theory approach and analysing EVET archival data and interviews it was found that the shift of policy agenda from the low emission targets to the zero emission targets is driven by the focal technology – EV. In order for the shift to take place the focal technology needs to be coupled with complementary technologies that have become a mainstream technology within its industry (reached the incumbent level in the industry trajectory), for example Li-ion batteries and renewable energy technologies (mainly wind and solar). The coupling takes place within technological windows of opportunity by niche actors in the focal industry - EV carmakers or incumbent actors in the complementary industries for example Tier 1 suppliers or energy suppliers.

The technological window is associated with developments in energy storage, automotive and energy supply industries, facilitating the shift of EVs to the incumbent level. The development in these industries allows advocates of EVs to justify the capability of this technology to solve environmental problems. By coupling industry trajectories via tWoOs the efficiency of the well-to-wheel process of the focal technology improved. There were two technological WoOs before EVs could be used in the agenda shift.

The first technological window of opportunity (tWoO-1) opened in 2010 in the technological niche level of the automotive industry trajectory and was associated with coupling the EV mass market-oriented powertrain with Li-ion batteries. The coupling was made by an EV carmaker – Nissan, and Tier 1 suppliers of Li-ion packs, who were conceptualised as TIs. This resulted in the production of the first mass market-oriented EV – the Nissan Leaf. Within the theoretical framework – MLST, this was conceptualised as coupling the niche level of the automotive industry trajectory with the incumbent level of the energy storage trajectory.

The second technological window of opportunity (tWoO-2) for EVs was opened in 2016 in the energy supply trajectory. The usage of coal dropped significantly this year alongside a shift toward cleaner energy sources (wind and solar). That was conceptualised as a shift of renewable energy technologies from the niche level to the incumbent level, signifying a considerable decarbonisation of the energy supply for EVs. The coupling of the automotive industry trajectory and the energy supply industry trajectory was made by energy suppliers - TIs. This made EVs a viable environmental solution for the air quality problem.

Despite the positive trend in the sales of EVs in 2016, this technology was still at the niche level, accounting for just a fraction of a percent of total vehicle sales. However, RE technologies and Li-ion technologies were on the incumbent level of the respective trajectories. The shift to cleaner sources of energy in 2016, jointly with decreasing the cost of batteries and increase of EV infrastructure, allows us to say that in the second tWoO-2 all three trajectories - automotive, energy storage, and energy supply - were coupled. On the one hand, this demonstrated the efficiency of well-to-wheel processes of EVs; on the other hand, it indicated the market potential of the technology. This helped the EV to be used as a technology for the policy agenda shift.

It is important to mention that MLST does not operate with the cultural and behavioural elements of the socio-technical regime and mainly focuses on regulatory and technical aspects of transitions, such as technologies, policies, and infrastructures. In this regards, the shift of technology from the technological niche level to the incumbent level can be associated with a shift from a niche market to a sustainable and competitive mainstream market. With such an approach, technology after the shift to the incumbent level/mainstream market (opening tWoO) can move back to the niche level/niche market in the case of disruption (closure tWoO).

The closure of tWoO, exemplified by the case of tWoO-2, could be related to the shift of RE back to the niche market. This can for example happen the energy generation from coal significantly surpasses that from RE. In such a case, RE would shift back to the niche level, causing a reduction in the effectiveness of well-to-wheel processes of EVs. This would effectively lead to the closure of tWoO-2. However, it is important to note that, since tWoOs are cumulative, the closure tWoO-2 does not imply a decoupling with Li-ion that took place within tWoO-1. Given the potentially significant duration of tWoO, the moment a tWoO opens could be considered a coupling point between industry trajectories.

In the UK case, the shift of agenda took place after the closure of the first policy window of opportunity (pWoO-1) and the release of the Road to Zero strategy. pWoO-1 is associated with the work initiated by DfT in July 2016 in response to the problem of "the environmental impact of road vehicles" (DfT, 2018, p.4). The work included two stages. The first stage focused on the analysis of the "relative environmental performance of different fuels and technologies" within the Transport Energy Model (DfT, 2018, p.4). The second stage involved the creation of the strategic policy paper – the Road to Zero strategy. The development of the TEM was important as it informed the government of the environmental impact of various types of vehicle technologies and fuels and thus underpinned the policies set out in the Road to Zero (DfT, 2018).

Analysing the TEM documentation, it was found that LowCVP prioritises EVs as potentially net-zero in respect to well-to-wheel analyses (DfT and OLEV, 2018, p.122). The fact that EV technology was coupled with an energy supply trajectory wherein renewable energy shifted to the incumbent level significantly simplifies the task of PEs to couple the technology with the policy stream. This is due to the fact that the well-to-wheel process of

EV were objectively more effective compared with other technologies such as HEV or FCEV.

Another example of pairing the EV technology solution with a policy solution is the inclusion of the 46-point policy plan in the Road to Zero. This plan set the targets to end sales of new conventional petrol and diesel cars and vans by 2040 where the majority of cars will be ZEV (DfT and OLEV, 2018). It also includes the point of establishing EVET "in order to plan for future electric vehicle uptake and ensure the energy system can meet future demand in an efficient and sustainable way" (DfT and OLEV, 2018, p.5). EVET focuses on providing industry-specific policy proposals that informed industry-specific policy instruments. The establishment of EVET refers to the opening of the second window, pWoO-2 in June 2018.

After the closure of pWoO-1 in July 2018, the Road to Zero was released. The release of the Road to Zero strategy and subsequent initiation of EVET ended the government stance of technological neutrality and indicated the shift in policy agenda from low emissions to zero emission goals. Based on this example it is possible to see that technology plays a significant role in the shift of policy agenda, while WoO can explain the sequence of stages in this process.

RQ2: Who were the key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020 and what were their roles in this process?

While analysing the data, 5 key stakeholders were identified in the process of net-zero policy agenda setting in the UK automotive industry between 2017-2020. It is worth mentioning that this research focuses on the supply side of market creation and does not include the investigation of customer behaviour or the demand side of this process. The key stakeholders identified include Technology Innovators, Policy Entrepreneurs and Policymakers. While analysing the sub-set of activities of the key stakeholder, additional stakeholders in the process were identified, whose role was entirely focused on a specific sub-set of activity. Such additional stakeholders include Knowledge Brokers and Bricoleurs.

The role of TIs within industry trajectories focused on creating innovations and facilitating their shift from the niche level to the incumbent level by advancement of the technology in the target industry and through coupling it with the related industries. Within the bricolage process, PEs were involved in problem brokering activities, framing the problems through the questions, triggering the discussion of the policy proposal that could potentially reduce barriers to the shift of the technology.

Two groups of individuals were identified who coupled problem, policy and politics streams and can be referred to as policy entrepreneurs - Senior Managers of LowCVP and members of the EVET Steering Group, which included senior manager BEAMA, senior manager EnergyUK, senior managers Energy Networks Association, academic from the University of Leeds. The members of the Steering Group who undertook the PE role also concurrently performed as WP Leaders (BEAMA, EnergyUK, Energy Networks Association) and WP Sponsor (University of Leeds). PEs were involved in the development of policy proposals and in presenting these proposals to the members of the House of Lords, and the Secretary of State for Transport.

The members of the Steering Group who were only involved in commenting and changing WP proposals, but did not present the final EVET report to the House of Lords and the Secretary of State for Transport, were considered as Bricoleurs. These include Automotive Council UK, SMMT, Electric Vehicle Supply Equipment Trade Association, National Grid, and Ofgem.

Scientists cited in the WP reports, who intellectually contributed to the WP literature review stage, can be identified as Knowledge brokers. They did not couple the streams but only provided frames of knowledge.

The government departments mentioned in the primary data and relevant to the case under investigation were considered as policymakers. These include DfT, BEIS and OLEV. In addition, the Secretary of State for Transport and members of the House of Lords to whom the final EVET report was presented, were associated with this group of stakeholders.

RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK?

Within the MLST context, the EV transition in the UK over the period 2010 – 2020 was shaped by means of the opening of the series of windows of opportunities for EVs: tWoO-1, tWoO-2, pWoO-1, pWoO-2 and mWoO. The actors involved in this process are technology innovators, policy entrepreneurs, bricoleurs, knowledge brokers and policymakers. The different actors involved in different windows: technology innovators participate in tWoO, pWoO and mWoO, bricoleurs, policy entrepreneurs and policymakers are the main actors in pWoO. By opening technological windows of opportunity sequentially and coupling automotive, energy storage and energy supply industry trajectories, the well-to-wheel processes of EVs are decarbonised, reducing the total environmental impact of the niche technology – EV. This starts from energy generation and storage (the well) to energy consumption by EVs (the wheel). The decarbonisation of well-to-wheel processes ultimately makes the technology appropriate to solve environmental problems.

The coupling of industry trajectory makes it possible to shift an agenda to net zero technologies. This took place within the first policy window that was opened by DfT in July 2016, when work on the Transport Energy Model (TEM) was initiated. At this time PEs were able to couple the technological solution with the national problem and provided the 46-point policy plan in favour of ZEV. This plan was included in the Road to Zero strategy. As a result of this policy, the government shifted away from being technologically neutral to focusing on EVs. This contributed to the shift of the policy agenda from low emission to zero emission goals.

The industry-specific policy recommendations for the policy instruments to facilitate the EV uptake were provided in the second policy window of opportunity, pWoO-2. This corresponds to the salami tactics used by the LowCVP and supported by the government. The second policy WoO-2 was opened in June 2018 and associated with the establishment of EVET that provided policy proposals for Government, industry and Ofgem. The policy instruments that were informed by EVET facilitated the development of EV infrastructure and preparing the energy system for the EV mass market uptake. As a result of pWoO-2, EV infrastructure policies were released, such as the UK electric vehicle infrastructure strategy (DfT, 2022b) and The Electric Vehicles (Smart Charge Points) Regulations (HM Government, 2021). The release of the Road to Zero strategy and shift of policy agenda as a result of pWoO-1, as well as launching EVET that targeted industry-specific problems within pWoO-2, sent a strong signal to industry stakeholders on the preferred technology for transitions. The sequence of tWoO and pWoO and support from the government, public and industry stakeholders opened mWoO in 2020. This year the proportion of newly registered EVs accounted for 6.59% out of the total cars registered in the UK. At that time more incumbent actors were involved in manufacturing EVs thus the model range of EVs was considerably diversified wherein most of the EV models showed significant growth in 2020. The increase of EV market share and diversification of the EV model range signify the shift of EVs to the incumbent level, making them a mainstream product.

Chapter 5 Discussion

Following the GT method, once the theoretical framework has been developed; and answers to the research question given, the results are compared with the literature discussed in the literature review chapter in order to identify similarities and differences and locate theory within the larger body of professional theoretical knowledge (Corbin and Strauss, 2015; Bryant, 2017). The new literature can be brought in while comparing the findings (Corbin and Strauss, 2015).

This chapter is divided into five sections. Section 5.1 "The Role of Technology in Agenda Setting" discuss the role of technology in the shift of the policy agenda to net zero targets within the context of windows of opportunity in the UK automotive industry. There is very little literature that analyses such a phenomenon within the UK context. Thus, the research findings will be compared with articles that focus on different countries, notably Germany, India and The Netherlands. Section 5.2 "The Impact of the Policy Agenda on Industries" discusses the findings related to the impact of the policy agenda on the automotive industry. At the time of writing, no articles have been identified that analyse this topic within the context of agenda setting in the automotive industry in the UK. Thus, the articles that focus on Germany, Sweden and Austria will be used.

Section 5.3 "The Key Stakeholders in Policy Agenda Setting" restates the key stakeholders who have been identified in the research and their roles in this process of setting the EV policy agenda in the UK automotive industry between 2017-2020. Then the notion of stakeholders and their roles identified in the research will be compared with the policy agenda-setting literature. The primary focus will be on the literature that has used the UK automotive industry case. Sections 5.1 – 5.3 thus provide a comparison of the agenda setting literature, mainly the MSF, with the research findings.

In Section 5.4 "Analysing Transitions in the UK" the comparison will be made on the broader context. The MLST and MLP frameworks will be compared as well as the explanation of EV transitions in the UK by using these frameworks. In addition, we also analyse the policy mix literature, as it provides a typology for policy instruments as well as tools for analysing the link between policy and technological change which stands in direct relation to the developed theoretical framework and the topic discussed in Section 5.4. Section 5.5 "Summary" summarises the chapter.

5.1 The Role of Technology in Agenda Setting

This section discusses the findings linked with RQ1: How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry?

The answer to RQ1 is linked to the opening series of tWoO and pWoO, resulting in a shift of policy agenda. The first technological window of opportunity (tWoO-1) opened in 2010 at the technological niche level of the automotive industry trajectory and was associated with coupling the niche level technology – the EV mass market-oriented powertrain – with the incumbent level technology – Li-ion batteries – within the automotive and energy storage industry trajectories, respectively. This resulted in the production of the first mass market-oriented EV – the Nissan Leaf.

The second technological window of opportunity (tWoO-2) was associated with the shift of RE technology to the incumbent level in 2016, which significantly decarbonised the EV energy supply. Within the theoretical framework – MLST – this was conceptualised as coupling the niche level technology – EVs – with incumbent level technology – renewable energy (mainly solar and wind generators) of the automotive and energy supply industry trajectories, respectively. As tWoOs were not decoupled, they are sequential and cumulative. In addition to these, the coupling was reinforced by decreasing the cost of batteries and expanding the network of EV infrastructure.

The series of tWoOs resulted in increased efficiency of well-to-wheel EV processes, as well as their market potential, making it possible for PEs to justify the use of EVs as a solution for environmental problems. After the coupling of automotive, energy supply, and energy storage trajectories, the EV technology was paired by the PEs with a strategic policy solution for the environmental problem. In the case under investigation, this happened in the first pWoO-1 over the period 2016 – 2020, when the work on the Transport Energy Model and Road to Zero took place. Over this period, the PEs contributed to the Transport Energy Model where they were able to prioritise EVs as potentially net-zero in respect to well-to-wheel analyses. In addition, PEs contributed to the inclusion of the 46-point plan in the Road to Zero strategy, an initiative ending the government's stance on technological neutrality. The policy plan favoured EVs by setting targets for EV uptake and phasing out petrol and diesel vehicles. The shift in the policy agenda from low emission to zero-emission happened after the release of the Road to Zero strategy in 2018.

Reviewing the literature that focuses on the processes of policy agenda setting, specifically the MSF, it was found that such research do not incorporate the concepts of multiple WoO.

The closest research to this study is Derwort, Jager and Newig (2022), who analysed policy change toward sustainability in Germany's energy sector over the period 1970 – 2018. These authors used both the MLP and MSF in their analysis and confirmed the importance of the policy-technology relationship. They argued that political decisions trigger socio-technical change and protect innovative technologies from market pressure. After that, these technological advancements provide new solutions to the policy stream "feeding back into the political agenda" (Derwort, Jager and Newig 2022, p.693). Thus, there are two-way linkages between the technology and policy agenda. Derwort, Jager and Newig's (2022) findings correlate with the findings of the present study.

The main difference is that the current research identified that the advancement of technology and follow up activities of PEs led to the shift in policy agenda. Thus, this research argues that the role of individuals is crucial in the policy shift, both within tWoO and pWoO. Additionally, the research has identified that in the UK case, the pWoOs opened by the government were more planned events; while Derwort, Jager and Newig (2022) associate this with focusing events, such as oil crises or nuclear incidents, that influence the policy system. Both of the research studies agree that the technology at the moment of pWoO needs to be advanced enough to be capable of solving the policy problem.

Kingdon (2014, p.17) admits that the development of new technologies, such as more efficient batteries for electric vehicles "can create a considerable pressure for policy change". However, independent of science or knowledge, the policy ideas may be "built gradually through a process of constant discussion, speeches, hearings, and bill introductions" (*ibid*). Thus, technological development is just one part of the process of policy change. It is difficult to disagree with this statement, and this research indicates that apart from technologies and technology innovators, there are other actors, for example, bricoleurs or policy entrepreneurs, who play significant roles in agenda setting and policy change. However, if there is room for technologies in policy agenda setting, how can we conceptualise their role in setting the net zero policy agenda?

In order to understand the impact of technology on the policy process, Goyal, Howlett and Taeihagh (2021) use the concept of the technology stream, which depicts "the context and activities that contribute to technology innovation, such as research, prototype development, patenting and licensing, the establishment of a business venture, market creation, and technology transfer". The main activity of technology innovators in the technology stream is R&D (Goyal, Howlett and Chindarkar, 2020). Additionally, they can protect, nurture, and empower innovations (Raven et al., 2016) by shaping policy and regulatory developments.

Policies can drive innovations which, in turn, can lead to an increasing number of policy activities (Goyal, Howlett and Taeihagh, 2021). Thus, the authors also recognise the two-way linkages between the policy agenda and technologies. The technologies in the agenda setting process can be considered as solutions to policy problems, or a source of the problems (Goyal, Howlett and Taeihagh, 2021).

The implication of industry trajectories used in this study further develops the concept of the technology stream. Goyal, Howlett and Taeihagh's (2021) concept of the technology stream is unclear as to the role of technology in windows of opportunity. This is important to know for the agenda setting process. Moreover, in the case of sustainability transitions, there can be multiple technological solutions, and they may be interrelated. If there are multiple innovations influencing the policy agenda process, which of them should be included in the technology stream and, if there are multiple innovations, what are their interrelationships?

To clarify this aspect, the MLST adapted the elements of socio-technical regimes used in the MLP literature, such as technologies, policies, and infrastructure. In this way, the technology streams are not only considered as the activities contributing to technology innovations. Rather, they broadly encompass the evolution of technologies contributing to the revenue streams of the TIs enterprises who work in the different types of markets – niche market or mass market; and different levels of the socio-technical system - technological niche or incumbent levels – respectively. This broader conception of the technology stream allows us to trace the shift of technologies from the niche level to the incumbent level and the impact of this shift on policy agenda setting. Furthermore, it can help to link multiple industries into one system. The technology stream in this context is referred to as the industry trajectory.

Another contribution to the Goyal, Howlett and Taeihagh's (2021) work is that in this research the active role of TIs in agenda setting has been confirmed. This was particularly evident in the bricolage process, where TIs were able to frame industry-specific problems and share policy ideas with members of WPs.

One study that focuses on the impact of technology on the policy agenda is Salas Gironés, van Est and Verbong (2020). The authors focus on the case of the impact of autonomous driving on the policy agenda in the Netherlands. They conclude that this technology shaped the policy agenda, as it was considered a solution to social problems such as reachability, quality of life, and road safety. Policy entrepreneurs thus linked mobility problems with social problems via automated driving technology. In this way, the policy stream was linked with the problem stream and the politics stream, resulting in the shift of autonomous vehicle experimentation to real-world applications. Their conclusions on the importance of technology in shaping the policy agenda, and the significant role of PEs in this process, are in line with the present research.

One of the main findings of this study, that contribute to the literature discussed above, is that this research also recognises the importance of advancement in complementary industries preceding the pWoO, in which TIs are instrumental. By bringing in the concepts of multiple WoO and multiple industry trajectories, it argues that developments in complementary industries within tWoOa, support policymakers via opening pWoO; and the effectiveness of PEs within pWoO leads to the shift in the policy agenda to net zero targets in the UK automotive industry.

5.2 The Impact of the Policy Agenda on Industries

This section continues the discussion of research findings, comparing them with MSF literature. The focus of this part will be on the impact of the policy agenda on the automotive industry. This topic is related to mWoO concept, which is essential to answering to RQ3 question: "What theory can be developed to explain the transition to EVs witnessed in the UK?". The MLP literature pertinent to mWoO will be discussed in Section 5.4 "Analysing Transitions in the UK".

In the research, it was found that following a series of WoOs, namely related to tWoO-1, tWoO-2, pWoO-1, pWoO-2, and the shift of the policy agenda to net-zero goals, the mWoO was opened, signifying the shift of the focal technology – EV, to the incumbent level. This implies the direct impact of the policy agenda on the automotive industry, and EV market particularly.

There are no articles that discuss this topic specifically using the MSF, or in the UK context, and there are very few that analyse this aspect in other regions. The few that we were able to find are Werner and Onufrey (2022) - Sweden, Derwort, Jager and Newig (2022) - Germany, Kulmer et al. (2022) – Austria, which will be compared with the findings of the present research.

This study has found that the policy agenda and subsequent policy change can significantly impact the automotive industry and promote EV market uptake. Werner and Onufrey (2022) use a comparative case study of two demonstration projects that focused on the electrification of trucks in Sweden. The authors used an adaptation of the MSF and came to the conclusion that interactions between multiple actors such as carmakers, infrastructure companies, logistic companies, academics and other industry stakeholders may couple the streams and "aid social embedding of new technologies" (2022, p.1). The present research came to a similar conclusion, but also indicated that multi-actor collaboration can lead to market uptake by EVs, though for such an outcome the coupling of multiple levels of streams and trajectories is required.

Derwort, Jager and Newig (2022) analysed the sustainability transition in the energy sector in Germany over the period 1970 – 2019, using the MLP and MSF frameworks. The authors found that agenda setting, and policy change can influence the socio-technical transitions and pave the way for innovative technologies by increasing their demand (Derwort, Jager and Newig, 2022). This can, for example, follow the adoption of policy instruments such as feed-in-tariffs (1990), the Renewable Energy Act 2000, or a series of laws pursuing for example nuclear phase-out decisions. Using the MLST terminology policies are appear in the market WoO. The innovative technologies themselves can be used as a solution in the policy stream and feed back into the political agenda (Derwort, Jager and Newig, 2022). Thus, not only the policy agenda and the following policy change influence the industries, but industries can impact the policy agenda as well.

In the case of the EV transition in the UK, Derwort, Jager and Newig's (2022) findings require further clarification. If we focus primarily on EV technology this research has identified the sequential relationship between technology, policy, and market uptake. The first mass market EVs appeared on the niche market without policy support. However, to shift this technology to the incumbent level, policy support is required. In addition, at the incumbent level, the uptake of EV technology can give rise to industry-specific problems such as energy supply. Thus, there is feedback to the problem stream at the incumbent level. This condition can then be framed as a problem and coupled with policy and politics streams.

Kulmer et al. (2022) explore the diffusion of low-carbon technologies such as photovoltaics, residential heat pumps, and electric vehicles over period 1950 – 2018 in Austria, using market statistics and applying the MSF. The authors elaborated a mathematical model to identify turning points and then applied the MSF to reconstruct the critical events in the politics, policy and technology streams. The critical events within the streams were identified using interviews and document analysis and by applying principles from grounded theory. Applying the MSF helped to understand key factors influencing turning points identified using the mathematical model.

The authors find that the policy agenda played an important role in accelerating the market uptake for low-carbon technologies. This happened as a result of convergence of political strategies (political stream), ad-hoc subsidy programmes (policy stream) and product development (technology stream), which boosted the market diffusion of low-carbon technologies (Kulmer et al., 2022). In multiple turning points, substantial changes occurred in the streams that subsequently changed the pace and shape of technology diffusion. The authors state that policy mixes should seek an "optimal interplay of complementary technologies that jointly contribute to carbon emission reduction or even sustainability targets" (Kulmer et al., 2022, p.11).

The findings of the present study are in line with those of Kulmer et al. (2022). These authors, in identifying areas for further research, suggested analysing the interrelationships between complementary technologies over the diffusion process and their feedback to the politics stream. The introduction of tWoO used in this study responds to this recommendation, although the present research was undertaken prior to becoming aware of that study. The importance of multi-industry interactions in transitions was identified independently, which amplifies the importance of this aspect.

The turning points that Kulmer et al. (2022) mentioned relate to mWoO in the MLST. In this research, it was found that indeed the interactions of technologies in the tWoO can influence the streams, which subsequently trigger a mWoO/turning point and thus impact the technology diffusion.

Applying MLST can supplement the approach of Kulmer et al. (2022), as its multi-level structure facilitates the analysis of actors related to the mWoO/turning point. Bringing in the different types of window, tWoO, pWoO and mWoO, can also help identify the moments when the technologies start to complement each other, and when this causes both the policy change and change in technology diffusion.

5.3 The Key Stakeholders in Policy Agenda Setting

This section discusses the answer to RQ2: Who were the key stakeholders in setting the EV policy agenda in the UK automotive industry between 2017-2020, and what were their roles in this process? The key stakeholders that were identified in the data have had roles identified as policy entrepreneurs, problem brokers, technology innovators, bricoleurs and policymakers. These findings – and who specifically took on each role – will be discussed and compared with the literature in what follows.

5.3.1 Policy Entrepreneurs

The present research contributes to understanding of the concept of policy entrepreneurs from both empirical and theoretical perspectives, using the FOI data and interviews from the direct participants in the agenda setting process. What follows compares the results of the present research with the existing literature to clarify our understanding of the notion and the role of PE in the UK automotive industry.

In the case under investigation, the secretary of EVET is considered the PE. This individual is an experienced project manager and director of LowCVP – an organisation responsible for accelerating the EV transition in the UK. The PE was not only able to frame problems at the incumbent level, but also amend the policy proposals coming from bricoleurs, or suggest alternative proposals. In addition, the PE met regularly with the government and was in a position to present WP to policymakers. The PEs interest can be associated with purposive and reputational gains, as this PE had been working on sustainability projects for over a decade and had certainly shown values and beliefs in line with the objectives of EVET. In addition, successfully achieving the EV transition would increase further his status and influence in the industry.

EVET is not the only role undertaken by the PE. Before this, he worked on the amendments to the Renewable Transport Fuel Obligation between 2014 – 2017. His colleagues were also involved in consultations on the Transport Energy Model and the development of the 46-point policy plan in the Road to Zero strategy. Based on that, it is possible to conclude that the PE has played a significant role in the decarbonisation of multiple industries in the UK over at least the period 2014 – 2020 and is directly involved in the shift of the policy agenda from the low emission to zero emissions goals.

In the literature (discussed next) which uses the case of agenda setting for decarbonisation policies in the UK, including in the UK transport sector LowCVP was not mentioned as a PE, but rather Friends of the Earth, Mayor of London Sadiq Khan, Transport for London, Carplus, the Waste & Resources Action Programme (WRAP) and the Ellen MacArthur Foundation.

According to Carter and Jacobs (2014), one of the main indicators of a policy shift towards ambitious targets for reducing GHG and CO2 emissions in UK transport policy between 2006 – 2009 was the Renewable Transport Fuel Obligation (RTFO) first introduced in 2008. The NGO Friends of the Earth (FoE) was identified as a PE. FoE coupled the streams by pointing out that the "government fails to deliver emission reduction target", then, in the form of a Climate Change Bill, they identified the solution and won the cross-party political support for it (Carter and Jacobs, 2014, pp.133–134).

Upon analysing LowCVP data related to pWoO-1, where they acted as PE, it was identified that the organisation was involved in amendments to the RTFO in 2017. Further analysis revealed that LowCVP was involved in RTFO consultations in 2007 (LowCVP, 2007). This is in line with expectations, as LowCVP was announced by the government in 2002 to provide consultation on and facilitate the shift to low carbon transport (HM Government, 2002). In addition, this research identified that the LowCVP director, who was involved in EVET, also participated in amendments to RTFO in 2017. Apart from these, the directors of LowCVP were also responsible for the development plans for Road to Zero and later amendments to the EVET policy proposals. This is considered as direct involvement in policy making which is attributed to PEs and stands in contrast with FoE. Using Knaggård's (2015) terminology FoE in this case would be considered PB. If we further apply MLST then FoE can be associated with PB that framed the problem on the national level of the problem stream. Then this problem frame was used while coupling problem, policy and politics stream at the national level by PEs.

Maltby (2021) identified NGOs Client Earth as problem brokers, while legal actions against the government problem framing activities. In the FOI data used in the research NGO were also involved in problem framing activities, and there were not involved in policy proposal amendments. Based on the FOI it is possible to note that this was the role of LowCVP. Following this it would be more appropriate to say in the case of a policy shift in the transport sector the LowCVP can be associated with the PE, but NGOs such as FoE or Client Earth as problem brokers at the national level. It is worth noting that such a rigorous approach is appropriate if we aim to separate PB and PE, and consider as PEs those individuals directly involved in preparing policy recommendations which is the case in this study.

Cooper-Searle, Livesey and Allwood (2018) used the case of policy agenda setting to study material efficiency solutions in the UK automotive industry. The authors mentioned such NGOs as Carplus, WRAP and the Ellen MacArthur Foundation as PEs. In the case under investigation, using the FOI documentation as well as , interviews, no evidence was found to support the argument that these actors were PEs. Within the MLST context, they would be considered as national level problem brokers as, typically, NGOs are involved in framing conditions as a problem, but are not involved in preparing policy proposals for the government.

Additionally, Cooper-Searle, Livesey and Allwood (2018) identified Transport for London (TfL) as an internal PE. In FOI documents (FOI 89), they are referred to as a local government body. With this regard within MLST there were considered as a local government.

Maltby (2021) analysed the role of PE and PB in response to the air pollutant problem in the UK and came to the conclusion that the Mayor of London, Sadiq Khan, acted as a local level Problem Broker and Policy Entrepreneur while linking politics and problems stream with the ULEZ policy solution. At the national level, however, there was less consensus on possible policy responses in 2021, thus the streams were not coupled completely.

In the FOI data, the Mayor of London was mentioned repeatedly as a local authority who established the Electric Vehicle Infrastructure Taskforce (EVIT) that focused on "charge post rollout plan to 2025 to support London's air quality strategy".

> "It was noted that the London Mayor had set up an Electric Vehicle Infrastructure Taskforce (EVIT)" (FOI 7). "OLEV sit on the EVIT and LowCVP has had a meeting to discuss co-ordination of activity at a working level, and so there was little concern of duplication" (FOI 4).

The establishment of EVIT to consult on achieving strategic policy goals at local level mirrors the DfT and OLEV approach, who established EVET at national level. Bearing in mind that the Mayor of London established EVIT and launched ULEZ, on his official website it stated "Sadiq Khan is the current Mayor. He provides citywide leadership and creates policies to improve London for all" (Greater London Authority, 2023). The Mayor of London more likely acts as a local level policymaker. The impact of LEZ and ULEZ on national level discussed in 4.3.1.1 "Automotive Industry Trajectory".

The recent strategy policy paper at the local level - London's 2030 Electric Vehicle Infrastructure Strategy – indicates that the "electric vehicle infrastructure delivery plan, [was] steered by the Mayor's EV Infrastructure Taskforce" (Transport for London, 2021, p.6) where the role of EVIT was to bring in industry stakeholders to provide recommendations on "how, when and where to increase London's electric vehicle infrastructure" (Mayor of London, n.d.). Based on the fact the EVIT is involved in the development of strategic policy papers at the local level, the secretary of EVIT is considered as a PE. This correlates with the national level EVET where the secretary of EVET is involved in amendments of recommendations to the national level policies and who is considered a PE at the national level.

Another actor is the Environmental Audit Committee, mentioned by Maltby (2021). It was not identified either in interviews for this research or in the FOI data. This organisation was set up by the UK House of Commons to provide an audit of the government department's performance against net-zero targets. This can involve auditing DfT, BEIS and DEFRA. Due to the fact that it provides recommendations to the departments allows it to be considered as a PE that operates within the government system. This actor was identified only at the stage of comparing findings with the literature and its involvement in the EV transition process can be scrutinised as a topic for future research.

Theoretical contributions of this research to the concept of PE are associated with the fact of analysis of this role is undertaken through the multi-level lens of MLST. This can be applied while analysing the activities of all key stakeholders discussed in this chapter. A PE can work not only at the national level, but also in the incumbent and technological niche levels of the streams. PEs are coupling streams and trajectory in the corresponding level separately, or at all levels jointly, depending on the focus of a given policy solution - national, local, incumbent or technological niche level of the streams and trajectories.

Based on this fact, in the case of the EV transition in the UK, the streams were coupled at national, incumbent and technological niche levels, as EVET addressed policy proposals to deal with the problems at all of these levels. The coupling of streams at national, incumbent and technological niche levels are evident if we look at the types of policy proposals the EVET WP suggests: *developing national coverage of accessible charge points* (national level), *improving smart charging coordination* (incumbent level), *setting minimum technical requirements for chargepoints* (niche level). Maltby (2021) adds to this by finding that the streams were also coupled at the local level in London, where ULEZ dealt with local level problems such as air quality in London.

Another important conclusion following from this study is that a PE can be involved in multiple pWoO that can ultimately lead to EV market uptake and opening a mWoO. As multiple pWoO are linked with the issues of the same solution – EVs – the strategy PEs adopted were related to salami tactics

It is also worth noting that the self-interest of PEs in the case under investigation can be not only financial. According to Kingdon (2014, p.204) self-interest of PE could be reputational, purposive or simply derived from the "pleasure in participating" in pushing their policy solution. Characteristics of PEs are "much as in the case of a business entrepreneur" (Kingdon, 2014, p.127). It was found that PEs do not necessarily need to be carmakers who mainly have financial interest in EV transitions. This can be for example directors of

LowCVP. In this particular case the PE interest can be associated with purposive and reputational gains, as this PE has been working on sustainability projects for over the decade and has had values and beliefs that correspond with the objectives of EVET. In addition, successfully achieving the EV transition may increase his status and reputation in the industry.

5.3.2 Problem Brokers

In the literature that uses the UK case of policy agenda setting in the automotive industry, the following actors who frame the problems were identified: Client Earth, Greenpeace and the Environmental Audit Committee (Maltby, 2021). Their role was to frame the problem as urgent and to lobby for action (Maltby, 2021).

ClientEarth was mentioned in Interview 12 as an influential environmental NGO which pushed environmental issues in 2017. Based on the interview and the fact of legal actions against the government undertaken over the period 2017-2020, it is possible to confirm that they framed the problem as urgent in terms of achieving net zero goals. Within the MLST context, they frame the problems at the national level in pWoO-1 and pWoO-2. However, their impact on the incumbent level of the problem stream is not confirmed. This is due to the fact that ClientEarth was not identified in FOI data from EVET. This is not surprising as this NGO deals mainly with broader social problems, while the incumbent level problems of EVET are more specific and mainly concern industry issues such as the lack of interoperability of charging points. Based on this it is possible to say that ClientEarth indeed acted as a problem broker at the national level, but it did not act as PE or bricoleur within the EVET process of the EV policy agenda, in the incumbent or technological niche levels of the problem stream.

Greenpeace is also mentioned in interview data (Int 12), as an NGO which organised a powerful demonstration in 2020 against climate change. Using MSF terminology this can be considered as a focusing event. The MLST also allows the added point that Greenpeace acted as problem broker at the national level within pWoO-1 and pWoO-2. However, their involvement in EVET and coupling streams on the incumbent level, as with ClientEarth, cannot be confirmed.

Maltby (2021) also used term ‘knowledge brokers’ (KB) for those who simplified information and provide it for evidence-based decisions. In both Maltby's (2021) study and this research, KBs were not involved in coupling streams. According to Knaggård (2015)

KBs work within problem the stream but in contrast to PBs, they did not involve emotions and values in this process. The present study also identified scientists who provide literature reviews and share information with EVET stakeholders. They were considered as actors who frame the knowledge that informs policy ideas in the policy stream. Based on the FOI data it is also possible to state that another difference between PBs and KBs is that PBs frame problems within the problem stream, whereas KBs framed knowledge within policy stream, making information understandable for policymakers and EVET stakeholders. In case where KBs framed the problem, within MLST context, they were viewed as problem brokers.

5.3.3 Technology Innovators

To date, there is no literature that identifies technology innovators within agenda setting process in the UK automotive industry. By looking at other contexts, technology innovators are seen to work within the technology stream and are responsible for R&D projects, technological inventions, "nurturing, protecting, and empowering novel technologies" (Goyal, Howlett and Chindarkar, 2020, p.54), as well as linking the technology narrative with the socio-political agenda (Smith and Raven, 2012). Goyal, Howlett and Chindarkar (2020, p.52) also state that technology innovators have inherent technological, social and political knowledge and are competent in "promoting a technological solution to a societal "need" or a policy problem". Cohen and Naor (2013) associated technology innovators in the automotive industry with the CEO of a car company who had been involved in promoting electric vehicles in Israel through collaborations with bureaucrats, politicians and lobbyists. Thus, their role was associated with that of a PE and was peculiar to their activity.

In the present research, the role of TI in the policy agenda setting process has been clarified. In line with Goyal, Howlett and Chindarkar's (2020) research it was found that technology innovators are responsible for the development of technological solutions in automotive and related industries. In addition, it was confirmed that TI has promoted technological solutions to a policy problem. It was further clarified that TI can link an industry-specific problem such as a lack of EV charging interoperability with national level problems such as air quality. This activity can be associated with problem brokerage.

The fact that TIs can act as PEs, outlined by Cohen and Naor (2013), was partly confirmed in the collected data, as TIs couple streams with the assistance of bricoleurs and PEs. This can be due to UK specifics. In the EVET WP meeting, the problems were framed in the form of questions by TIs, that were discussed in the second stage by members. TIs may propose policy solutions to problemst such as charging protocols. This is not reflected in FOI data, but it was noticed during personal observations in one of the EVET stakeholder meetings. After discussion, the problems and solutions are compelled by WP leaders who prepare the WP draft and acted as bricoleurs. This refers to the third stage. In the fourth stage policy proposals are checked by the PE, amended if necessary and returned to bricoleur to the final corrections. After that, the final WP was presented by the PE to the government for consideration. Thus, in the UK context, given its bureaucratic procedure, TIs do not provide written policy recommendations directly to policymakers but rather work through the chain of intermediates. TIs can use verbal interventions, as witnessed during EVET meetings; however, the policy recommendations identified in the final policy paper were included in the final WP reports, which do not always reflect verbal interventions used by TIs.

Goyal, Howlett and Taeihagh's (2021) conclusion that “the alignment of problem, policy, politics, and technology – through policy entrepreneurship – influences the timing and design of technology regulation” is confirmed by this research, which further elaborates on this point. By using MLST terminology, in the first stage TIs frame the industry-specific problem within the problem stream. The second stage includes coupling of the problem stream, policy stream and politics stream at the incumbent level by bricoleurs. The presentation of the final WP refers to coupling politics streams with policy streams at the national level by PEs. The final decision on the inclusion of policy solutions in the final policy is made by policymakers. The joint work of TIs, bricoleurs, PEs and policymakers can lead to the release of the national level regulation that includes TIs industry-specific policy ideas. Thus, it is possible to conclude that Tis, instead of directly addressing policy solutions to the government, take the role of PBs and work with bricoleurs and PEs to include the policy idea in the final policy.

From the MLP perspective, technology innovators can work within the incumbent level (Filippini and Vergari, 2017) or technology niche level (Markard and Truffer, 2008; Geddes and Schmidt, 2020). In cases where TIs work within the incumbent level, they can be associated with incumbent innovators (Filippini and Vergari, 2017) or incumbent actors (Geels, 2018a). In the pursuit of strategic reorientation, the incumbent actors can be involved in technological niche innovations and be a part of this level (Geels, 2018a).

Niche innovators are involved in creating radical innovations (Geels, 2002), that are significantly different from the current socio-technical regime technologies (Geels, 2018b). The term ‘niche actors’ is associated with entrepreneurs, start-ups, spinoffs (Geels, 2018b), engineers and innovators (Christensen, 2013; Geels, 2018a). Radical innovations at the niche level have the potential to change society and are aiming to be used at the regime level

(Geels, 2011) or substitute the regime technology and reconfigure the socio-technical system (Geels, 2018a). For example, within the EVET context, one of the most notable representatives of a startup and niche innovator company was Tesla's senior manager who participated in most EVET meetings and was considered a TI who took the role of problem broker.

In the MLP literature, incumbents in the automotive industry play an important role in the electrification of the fleet, along with the government (Wentland, 2016; Helveston et al., 2019; Hoeft, 2021; Wang and Wells, 2021). Incumbents have invested heavily in EVs since 2010 (Hoeft, 2021). Jointly with technological niche companies, they are taking part in experimenting with vehicle architecture, batteries, and charging infrastructure (Helveston et al., 2019). The incumbent level actors that have a project on the niche level identified in the FOI data were Nissan and BMW, specifically senior managers of these firms took part in EVET.

In the case under investigation TIs are linked with incumbent and technological niche level actors. TIs participate in agenda setting processes, not only by framing industry-specific conditions as a problem, but also by creating innovations and facilitating their transition from the niche level to the incumbent level. This, for example, can be associated with the technology under investigation – EVs that in 2010 appeared in the technological niche level of the automotive industry trajectory and 10 years later had shifted to the incumbent level.

Incumbents not only from the auto industry take part in the EV transitions and electrification of transport, but also incumbents from related industries. For example, incumbents from grid operators, utilities, and ICT (Wentland, 2016). Wang and Wells (2021) state that the convergence of different regimes is a source of innovation and structural change in the automotive industry. The EVET archival data, interviews and follow-up analysis confirm the synergistic relationships of incumbents from related industries. Examples of TIs from the automotive industry include BMW, Nissan and Tesla; TIs from the energy storage industry AMTE, Panasonic, LG, and Britishvolt; TIs from the energy supply industry E.ON, EDF Energy, ScottishPower, and Innogy. In total, the FOI data include 138 companies, shown in Appendix 6. TIs from the automotive industry were involved in the development of EVs; TIs from the energy storage industry contribute to the development of battery packs; TIs from the energy supply provide decarbonisation of the energy supply and contribute to the development of the EV infrastructure. The joint action of these TIs makes the EVs a viable technological solution to environmental problems that can be paired with the policy solution.

5.3.4 Bricoleurs

According to Deruelle (2016) bricoleurs are individuals or groups who are active in both the problem and the policy stream and actively participate in opening a problem window. They select elements of ideas in the policy stream that the policymakers are ripe for and couple problem and policy streams by formulating a bespoke solution that fits the existing problem (Deruelle, 2016).

The research investigates the concept of bricoleurs within the UK automotive industry context using EVET archival data. By adding the incumbent level within the problem, policy and politics streams, it was found the bricoleurs can be a leader of EVET Work Packages and formulating industry-specific bespoke solutions. They are related, for example, to research organisations or trade associations having expertise in WP topics. Bricoleurs are aware of the ripeness of the politics stream which is associated with the receptiveness of policymakers to policy ideas. In the case under investigation, policymakers (DfT, BEIS) determined a technological solution – Evs – and were receptive to the policy ideas that helped to prepare the electricity system for the mass take up of EVs. Bricoleurs can use the PB problem frame on the incumbent level of the problem stream to initiate a discussion within the WP meeting and trigger the process of generating policy ideas within the incumbent level of the policy stream. These policy ideas can then be combined and recombined by bricoleurs, resulting in their inclusion in the final work package. The final WP can be considered as a bespoke policy solution that includes the policy ideas to which policymakers are ripe. By supporting the drafts and the final version of a WP, bricoleurs couple politics with the policy stream on the incumbent level. While preparing the WP, the PE was able the intervene in the process and amend some of the policy ideas. The final WP was then presented to the government by the PE, which couples the streams on the national level.

Examples of bricoleurs include, "member of the European Parliament or a national delegate within EU Council formation of the European Union" (Deruelle, 2016, p.62) or government researchers (Blum, 2018). Copeland (2022) states that the work of the President of the European Commission – Jean-Claude Juncker – and European Commissioner for Employment, Social Affairs, Skills and Labour Mobility – Marianne Thyssen – can be considered as bricoleurs over the period 2014 to 2019.

Based on analysis of EVET data and by applying MLST this research suggests that bricoleurs can work within the incumbent level of the streams and can be associated with leaders of EVET WP. These are Energy Systems Catapult – leader of WP1; EnergyUK - leader of WP2; British Electrotechnical and Allied Manufacturers' Association (BEAMA) - leader of WP3, and TechUK leader of WP4.

The work packages topics are focused on:

WP1 - common strategic understanding of the energy system requirements needed to support mass EV uptake;

WP2 - the engagement of EV users in smart charging and energy services;

WP3 - functional requirements of smart chargers to support mass EV uptake;

WP4 - data accessibility from the various sources of data in the EV, infrastructure and energy value chain.

This research shows that bricoleurs can work outside of the government system and they can be research or trade organisations knowledgeable in the policy solution topic.

According to Deruelle (2016), bricoleurs couple problem and politics streams by framing the problem in the problem stream and then selecting policy ideas and creating fit solutions in the policy stream. The politics stream is coupled with the fact of selection of policy ideas by bricoleurs that resonate with policymakers' preferences and to which policymakers are ripe to.

It was found that bricoleurs, by including problem frames and discussing them during WP meetings, can mobilise industry stakeholders' opinions to support the policy ideas included in bespoke policy solutions – seen in the final versions of WPs. This can be conceptualised as a coupling of problem, policy and politics stream on the incumbent level. In addition, bricoleurs work together with PB and PE while preparing policy solutions. For example, they used PB's problem frames while discussing WP, amend WP by request of PE and delegate presentation WP to the government by PE.

Based on this it is possible to say that this research supports the inclusion of bricoleurs in the policy agenda process and provides an example of how bricoleurs work within the context of EVET and MLST.

5.3.5 Policymakers

Policymakers are individuals or groups who have the authority make and implement policies (Blum, 2018; Cairney, 2018; Mallett and Cherniak, 2018). Below examples are provided of policymakers identified in the literature that used the case of policy agenda setting in the UK automotive industry.

Maltby (2021) provided a definition of policymakers but did not name them explicitly. It is quite important to identify them in this research as it is possible to confuse them with policy entrepreneurs. For example, Maltby (2021) identified one PE at the local level as the Mayor of London, Sadiq Khan. However, as discussed earlier, the FOI documentation indicates that the Mayor of London established EVIT, the organisation to provide policy recommendations at the local level; while the role of the Mayor of London is "to create policies to improve London for all" (Greater London Authority, 2023). In this way, it would be more appropriate to say that the policymaker at the local level is the Mayor of London, Sadiq Khan, while the PE is the chair or secretary of EVIT. However, it is worth noting that policymakers can take the role of PEs and the above statement is true if we are aiming to separate these two actors for analytical purposes.

This study separates policymakers and policy entrepreneurs and considered individuals from government departments and high-profile groups (for example OLEV) as policymakers. This is in line with the studies of Begley and Berkeley (2012), Carter and Jacobs (2014) and Cooper-Searle, Livesey and Allwood (2018).

Carter and Jacobs (2014) mentioned Ed Miliband, the Secretary of State for Energy and Climate Change (in the Department for Energy and Climate Change) as a policymaker. Begley and Berkeley (2012), by analysing policy processes in the low carbon vehicle sector, associated with policymakers the Department for Business, Innovation & Skills; Department for Transport; Department of Energy and Climate Change; and the Office of Low Emission Vehicle (Begley and Berkeley, 2012). Cooper-Searle, Livesey and Allwood (2018), in addition to DfT, BEIS, and OLEV also mentioned the Department for Environment, Food & Rural Affairs (DEFRA). Within the MLST context, these actors can be classified as policymakers at the national level.

Compared with the previous studies the present research clarifies policymakers involved in the EV transitions and policymaking in the UK automotive industry at national and local levels over the period 2017 - 2020. The interviews and archival data were used to identify the actors who can be named as policymakers. In the FOI data, they were typically named as 'government'. At the national level, policymakers include:

MP Grant Shapps Secretary of State for Transport (July 2019 to September 2021);

MP Chris Grayling, Secretary of State for Transport (July 2016 to July 2019);

MP Alok Sharma, Secretary of State for Business, Energy and Industrial Strategy (February 2020 to January 2021);

MP Andrea Leadsom, Secretary of State for Business, Energy and Industrial Strategy (July 2019 to February 2020);

MP Greg Clark, Secretary of State for Business, Energy & Industrial Strategy (July 2016 to July 2019);

MP Richard Harrington, Parliamentary Under Secretary of State for Business, Energy & Industrial Strategy (June 2017 to March 2019);

Head of Office for Low Emissions Vehicles (later renamed as Office for Zero Emissions Vehicles).

At the local level, the Mayor of London Sadiq Khan (May 2016 – present) was considered a policymaker. In addition, members of City Councils can be associated with this group.

It is important to mention that among the policymakers indicated above, the Secretary of State in government departments plays a crucial role in the policy approval process. It is common for the Secretary of State to make the final internal approval of the policy ideas to be included in the policy paper. In the next stage, after the cross-departmental coordination and Parliamentary scrutiny, the policy can be implemented through the existing regulatory framework.

5.4 Analysing Transitions in the UK

This section discusses the findings related to RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK? In Sections 5.1 - 5.3, the discussion mainly focuses on the agenda setting literature and MSF specifically. This section compares the theory that was constructed based on MLST and its comparison with sustainability transitions research – and specifically the MLP. In addition, a comparison of MLST with the policy mix literature, as well as the literature that focuses on the co-evolution of socio-technical systems and policy mix will be made, given that the link between policy mix and technological change discussed in policy mix literature stands in direct relation with the developed theoretical framework.

5.4.1 Multi-Level Perspective Framework

This section summarises the theories of the EV transition using the MLST and MLP. In the first part MLST theorisation is presented; the second part focuses on the MLP.

The main argument of MLST is that the EV transition in the UK over the period 2010 – 2020 was shaped by means of the opening of the series of windows of opportunities for EVs: tWoO-1, tWoO-2, pWoO-1, pWoO-2 and mWoO. The actors involved in this process are technology innovators, problem brokers, bricoleurs, policy entrepreneurs and policymakers. The different actors involved in different windows: technology innovators participate in tWoO, pWoO and mWoO, problem brokers, bricoleurs, policy entrepreneurs and policymakers are the main actors in pWoO. By opening technological windows of opportunity sequentially and coupling automotive, energy storage and energy supply industry trajectories, the well-to-wheel processes of EVs are decarbonised, reducing the total environmental impact of the niche technology – EV. This starts from energy generation and storage (the well) to energy consumption by EVs (the wheel). The decarbonisation of well-to-wheel processes ultimately makes the technology appropriate to solve environmental problems.

In the next stage over the series of policy windows of opportunity, the technology is paired with policy solutions. This can be considered as policy support activities for the technology of interest and is related to the 'salami tactics' where each policy window deals with a specific policy-technology issue. Salami tactics involve splitting the risky policy move into multiple manageable tasks increasing the chance of acceptance of policy proposals by policymakers (Ackrill and Kay, 2011). The first policy window is related to setting the targets for the market uptake of zero-emission vehicles in strategic policy. The second policy window focuses on the inclusion of policy recommendations with policy instruments that address the industry-specific problems of the niche technology, such as the development of EV infrastructure and preparing the energy supply. The policy window resulted in the release of the policy paper that facilitates the transition of technology to the incumbent level. Finally, the market window of opportunity opens, signifying the shift of technology to the incumbent level and the beginning of mass market uptake.

In the MLP literature, socio-technical transitions include four phases: experimentation, stabilisation, diffusion/disruption, and institutionalisation (Geels, 2019). At the stage of experimentation, innovators clarify the techno-economic performance of radical innovations, their socio-cultural acceptance, and political feasibility (Kemp, Schot and

Hoogma, 1998). This stage includes experiments in laboratories and the creation of demonstration projects (Geels and Raven, 2006).

At the stage of stabilisation, innovations find a market niche, a dominant design is determined, a reliable flow of resources appears, and product cost and performance are improved (Geels, 2019). At this stage, innovations are supported by intermediaries such as innovation agencies, as well as influential actors who share the vision for these products (Geels, 2019; Kivimaa et al., 2019). In addition, a positive view of the social groups is important, as opposition groups can make it difficult to legitimise innovation (Geels, 2019).

At the diffusion/disruption stage, "the radical innovation diffuses into mainstream markets" (Geels, 2019, p.192). There are two reasons for this. Firstly, the productivity of innovation improves, there are economies of scale, complementary technologies are developed, and more influential actors support innovation (Geels, 2019). Secondly, due to the development at the landscape level, pressure appears at the regime level, destabilising the regime, and a window of opportunity opens (Geels, 2018b). This phase is characterised by tensions between the niche level and the regime level. This is manifested in the form of economic competition with existing technology, business competition between newcomers and incumbents, and political conflicts between political actors and interest groups with different interests (Meadowcroft, 2009; Christensen, 2013; Geels, 2019). Finally, there can be struggles between different social groups with different visions regarding a given innovation (Roberts and Geels, 2018).

The institutionalisation stage involves replacing the old socio-technical system and changing regulatory programmes, user behaviour, professional standards, visions of normalcy, and technical capabilities (Geels, 2019).

The next section compares the MLP literature that focuses on EV transitions in the UK, with the MLST.

5.4.1.1 Windows of Opportunity in the MLP and MLST

As one of the core elements of the MLP, the concept of windows of opportunity is particularly relevant to this study. MLP refer to windows of opportunity that allow niche technologies to shift from the technological niche level to the incumbent level (regime level) and become a mainstream technology. The founder of the framework used the case of the automotive industry in the context of the UK (Geels, 2018b) and the USA (Geels, 2005). According to Geels (2005) windows of opportunity are opening through (1) the emergence of new technologies at the technological niche level; (2) the existence of a problem at the regime level; (3) the emergence of new policies, or changes in consumer preferences, changes in the economy, demographics at the landscape level which put pressure on the regime level; (4) decreasing resistance of incumbent actors at the regime level, which leads to breakthrough niche technologies at the regime level

Analysing the MLP literature discussing the process of EV transition in the UK, it was not clear in which year the window of opportunity was opened and closed for EVs. The opening and closure points are important as they can help distinguish the stages in the transitions. One of the areas where the MLST can complement MLP research is that it provides information on the type of windows opened for EVs and when the windows of opportunity opened and closed.

Analysis using the MLST suggests the beginning of transitions happened with the opening of the first technological window at the technological niche level. During the first tWoO the niche level technology coupled with incumbent level technology from complementary industries within the niche technology's ecosystem. Over time this coupling helps the niche technology to become an incumbent level technology. For example, in the case of the EV transition in the UK, the niche technology – the first mass-market oriented EV Nissan Leaf – was coupled with incumbent level technology, the li-ion battery, in 2010. Over time the coupling with another incumbent level technology – renewable energy (solar panels and wind turbines) – helped EVs to reach the incumbent level. The tWoO is closed when one of the complementary technologies shifts back to the niche level. Within the MLST framework, the idea of the shift back of incumbent technology is possible as it associates the technological niche level with a niche market, wherein the incumbent level is a mass market. Thus, technology can move from one market to another in the case of disruption.

It was found that there are a series of tWoO. The second tWoO was opened in 2016 when the energy generation from RE passed the energy generated from coal, signifying the beginning of significant decarbonisation of the EV energy supply. At this point, it became possible to use EVs to solve environmental problems. The niche technology, EV, was coupled with the two incumbent level technologies – li-ion batteries and renewable energy.

After the series of technological WoO, the series of policy WoO were opened. To clarify an earlier discussion, the first policy pWoO-1 resulted in the release of a strategic policy – Road to Zero – which set targets for EV uptake. The second, pWoO-2, helped to resolve industry-specific problems such as the development of a network of charging stations, and the development of market flexibility, resulting in the provision of sufficient energy supply. The pWoO is closed when consultations are closed and the final decision for the inclusion of policy ideas in the policy paper is made. Following a series of tWoO and pWoO the mWoO is open when the niche technology shifts to the incumbent level and starts to take up the market. After this point, the niche market shows a sustainable and significant increase in market share.

The moment of opening the market WoO can also be associated with the tipping point when the market share of a new technology significantly increases. Gladwell (2010, p.12) states that "the tipping point is the moment of critical mass, the threshold, the boiling point". According to Whittington et al. (2019, p.325) that innovation diffuses following the S-curve model with slow start-up, followed by "accelerating growth (the 'tipping point') and finally a flattening of demand (and a potential 'tripping point')".

The mWoO/tipping point happened in the UK in 2020 when EVs accounted for 6.6% of all newly registered cars. If we compare the proportion of the newly registered EVs out of the total in 2018 and 2019 it was 0.67% and 1.64%. Over two years from 2018 to 2020 the number of new registered EVs increased from 15.6 to 106.7 thousand EVs annually, or 683% (DfT, 2022d) and this number continues to increase reaching 263.2k newly registered EVs in 2022, 16.3% out of total. The year 2019 is considered a partly opened mWoO as the diversification of EV models was limited at that time and most of the increase in EV registration was accounted for by sales of the Tesla Model 3, where the closest competitor, the Nissan Leaf, experienced drop of customers. In 2020 the model range of EVs grew significantly and the majority of the EVs models showed a significant increase in sales. At the same time, from 2018 to 2020 the number of new registered petrol and diesel vehicles decreased by 32% and 60% respectively (DfT, 2022d).

The market WoO for EVs will close when the registration of EVs will be overtaken by another technology and the sales of EVs start to decrease reaching the marginal level while the sales of a new technology start to increase reaching firstly the mWoO/tipping point and then the tripping point.

5.4.1.2 Transition Pathway

According to the MLP literature, there are four pathways in the sustainability transition process in the automotive industry: transformation, reconfiguration, substitution, and de-alignment and re-alignment (Geels and Schot, 2007; Mazur et al., 2015; 2018; Marletto, 2019; Kivimaa et al., 2021). In the transformation pathways, the basic mobility system stays the same, while regime actors adapt to external pressure, and modify the direction of innovative activities (Geels and Schot, 2007; Marletto, 2019). In this case, participants in technological niches cannot benefit from pressure from the landscape level. In reconfiguration pathways, niche technologies are initially used to solve local problems, but then replace parts of the mobility system at the regime system (Geels and Schot, 2007; Kivimaa et al., 2021). There is an integration and absorption of new actors at the regime level (Marletto, 2019). With the substitution pathway, disruptive innovation accumulates at the niche level and then seizes the window of opportunity due to pressure from the landscape level to replace the regime level. De-alignment and re-alignment occur when there is a wide divergence of pressure from the landscape level to the regime level, the regime is displaced, leaving a vacuum for an undeveloped niche innovations system (Geels and Schot, 2007; Kivimaa et al., 2021). The resulting uncertainty stabilises on a dominant innovation as a result of trial and error.

Mazur et al. (2015; 2018) argued that sustainability transitions in the UK automotive sector follow a reconfiguration pathway. According to Hussaini and Scholz (2017), the dynamics of the transformation pathway in the UK have the characteristic of transformation, reconfiguration and substitution. Gould, Wehrmeyer and Leach (2016), however, argue that the EV market in the UK follows transformation and technological substitution pathways.

The present research agrees with Mazur et al. (2015; 2018), that the EV transition in the UK follows a reconfiguration pathway. The implications are elaborated below. The reconfiguration pathway suggests gradual but substantial changes in the architecture of the current socio-technical regime. The landscape developments create opportunities and pressure on the socio-technical regime causing "the interaction between multiple component innovations and the regime" (Geels and Schot, 2007, p.413). Following this pathway the regime actors survive, and there is competition among the niche suppliers of technologies. In addition, the transition is driven not by one breakthrough innovation, but by "sequences of multiple component innovations" (Geels and Schot, 2007, p.413). To sum up, in the reconfiguration pathway, components of the socio-technical regime changed over time via adaptation of component-innovations. The technical components of the regime that incrementally change include physical artefacts, infrastructures, hardware and software systems, while social components refer to social practices, norms, values, institutions, regulations and standards.

Based on the analysis of the interviews and FOI data it was found that the elements of the socio-technical regime in the automotive industry in the UK were incrementally changed over time starting from introducing innovation in the energy storage technology – li-ion batteries – which were then adopted by carmakers. The second stage includes decarbonisation of the energy supply by replacing refuelling stations with charging points providing infrastructure for EVs, and subsequently replacing petrol fuel with electricity. Finally, the ICE powertrains began to be replaced by EVs when the mass market car manufacturers started increasingly adopting this technology.

This research contributes to the MLP literature, identifying that the pressure on the socio-technical regime can be associated with tWoOs that couple related industries within the EV ecosystem, which leads to the reconfiguration of the socio-technological regime in the automotive industry. In this case, the pressure came from the regime level of the related industry. Additionally, the pressure can be linked with the policy shift that set the strategic targets addressing industry-specific problems in favour of a specific technology. This is associated with pressure on the landscape level. Niche innovations such as EV powertrains can also put pressure on the regime. By putting pressure sequentially and by introducing and adopting component-innovations, the automotive industry's socio-technical regime in the UK is thus being reconfigured.

One of the distinctive elements of the MLST is that it also pays attention to the role of individuals in the policy agenda setting process. The important role of the director of LowCVP in RTFO amendments as well as in the EVET policy making was noted. During the EV transition, the salami tactic was used wherein policymakers and PEs were the main actors in this process whose role was to split the agenda into multiple parts and stimulate changes in different elements of the socio-technical regime. The inclusion of the agenda setting perspective to MLP can provide a more comprehensive understanding of the specificity of the reconfiguration pathway and, more broadly, the EV transformation.

5.4.1.3 Niche-Regime Interaction

The transformation of one socio-technical regime can be interrelated with another. In the MLP this interaction is conceptualised under the term multi-regime interactions, which take the form of *competition*, *symbiosis* or *integration* (Raven and Verbong, 2007; Geels, 2018b; Rosenbloom, 2020). Competition forms of interaction suggest rivalry between regimes in meeting a societal function; in symbiosis, the regimes complement each other's; as for integration, two regimes merge in one inter-modal system to provide social functions (Geels, 2018b; Rosenbloom, 2020). Rosenbloom (2020) while analysing multi-system interactions, also identified as niche-regime, regime-regime and niche-niche interactions, that can be within one socio-technical system or across multiple systems. In the case of multi-system interactions, the interaction appears between the levels of the system and in addition to previously explained types of interactions added an additional type – spillover – which suggests incorporating knowledge and practices of one regime/niche level into another level. It was found that the notion of interaction between the levels of the system, as well as types of interaction, is applicable to the case of the shift of policy agenda setting from low emission vehicles to zero emission vehicles.

The MLST do not operate with the cultural and behavioural elements of the socio-technical regime, such as cultural discourses and user patterns, instead focusing mainly on regulatory and technical aspects of transitions such as technologies, policies, and infrastructures. These aspects of the socio-technical regime are conceptualised as industry trajectories. The interactions between industry trajectories take the form of the technology window of opportunity, when the shift of niche technology to the incumbent level takes place in one of the related industries which complements or adds value to the niche technology under investigation; and ultimately facilitates the shift of this technology from the niche level to the incumbent level.

The interactions between trajectories in the case under investigation are *symbiotic*. This is in line with Geels's (2018b, p.88) study which states that a "shift towards battery-electric vehicles, for instance, would create symbiotic linkages between electricity and auto-mobility regime". Coupling automotive, energy storage, and energy supply trajectories allows us to decarbonise energy generation and energy storage as well as the in-vehicle energy use well-to-wheel processes of the EV. This makes this technology appropriate to solve environmental problems and simplifies the process of pairing it with policy solutions to address social problems. This reflects Nilsson and Nykvist's (2016) statement of the importance of bringing in the well-to-wheel concept in low carbon energy transition research to inform policymaking. The MLST conceptualises this under the term of cumulative coupling of complementary industry trajectories for EVs. Within the MLP literature this can be seen as niche-regime interactions, as mentioned by Rosenbloom (2020).

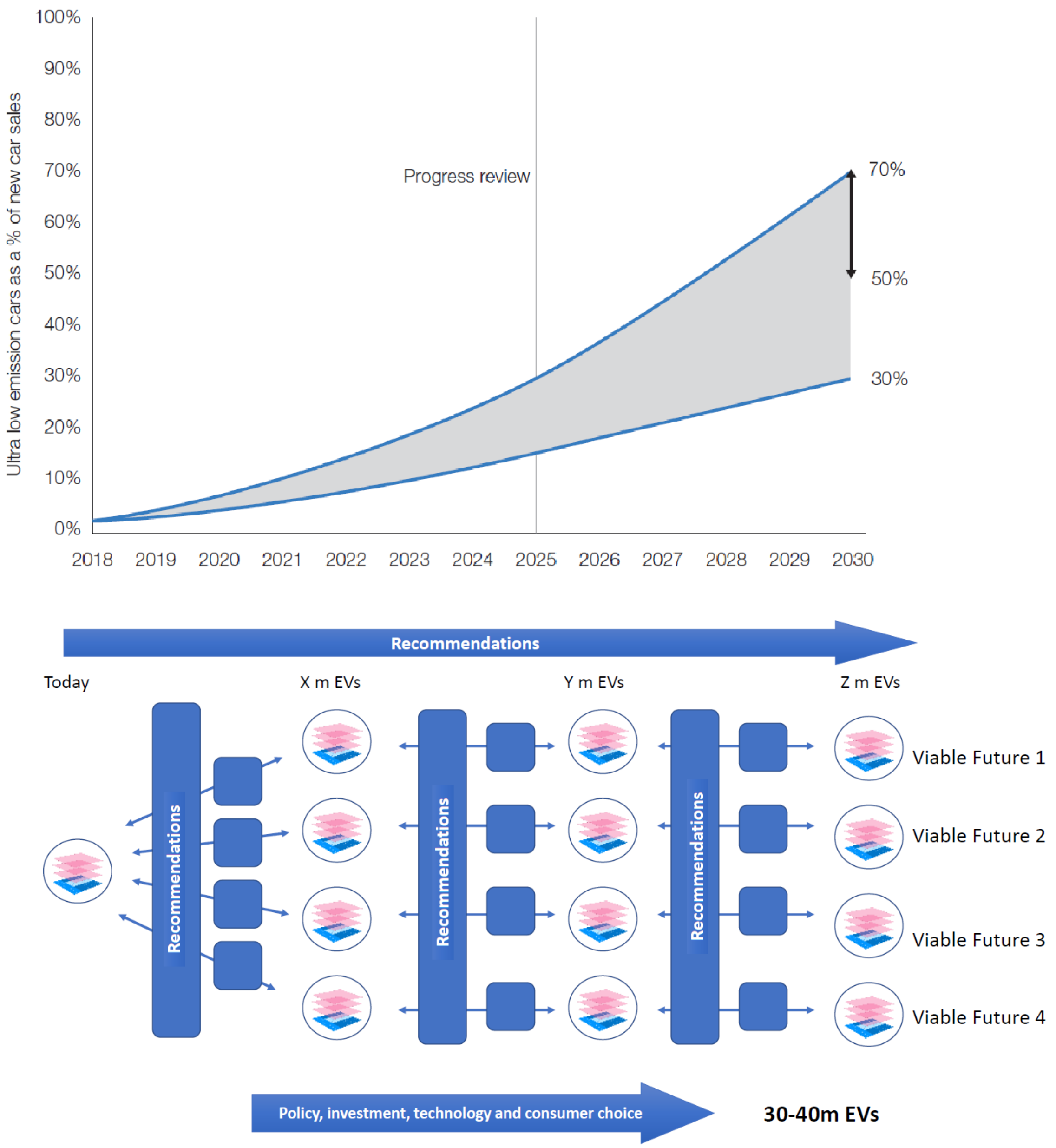
Among multi-system interactions identified by Rosenbloom (2020), the concept of niche-regime interactions is more appropriate to this case given that within tWoO-1 the niche technology – EV – is coupled with incumbent level technology, the li-ion battery (see Section 5.4.1.1). Something similar happened in tWoO-2, when the niche level technology – EV – coupled with incumbent level technology – RE. Based on this it is possible to say that interactions between automotive, energy storage and energy supply industry trajectories have niche-regime form, they are symbiotic, sequential and cumulative. This represents a notable contribution to the MLP literature.

Over the course of time, the shift of niche environmentally friendly technologies to the incumbent level can be observed in other complementary industries within the EV ecosystem. This can lead to coupling new industries with the industries that have already been coupled in previous tWoO/coupling points. Based on the sequential, cumulative and progressive nature of the coupling trajectories, and given the specificity of the reconfiguration pathway which the EV transition in the UK follows, it is suggested that new symbiotic interactions with new industry trajectories can be observed in the future which in turn will affect the EV agenda setting process.

5.4.1.4 The Future of the Automotive Industry in the UK

While analysing FOI data, it became clear that stakeholders on EVET expect multiple tipping points by 2030. The development of automotive transitions can follow one of four scenarios Home Charging (viable future 1), Filling Station (viable future 2), Taxi/Car Sharing (viable future 3) or Hive/Depot-based (viable future 4), see Figure 5.1. A combination of them is also possible. The policy recommendations provided by EVET in combination with external factors can push the development of the automotive industry in one of those directions.

Some of the closest research in the MLP literature that discusses the future perspectives of the automotive industry in the UK are Skeete (2018; 2019) and Marletto (2019). Skeete (2019) analyses the role of incumbents in sustainable transitions in the UK. Their earlier work is devoted to autonomous vehicle transitions and the incumbents' vision of Level 5 autonomy (Skeete, 2018). Similar to the present research, Skeete uses elite interviews with policymakers and carmakers in the UK. The author concludes that UK incumbents are driving the industry towards technological innovation as a result of the regional regulatory framework and government support (Skeete, 2019). Autonomous technologies have disruptive potential and can affect ownership in urban areas. The author also believes that the role of personal mobility will be reduced as more people will shift toward shared mobility services. The incumbents are preparing for the transformation to autonomous technologies by investing in R&D, experimenting with MAAS business models, collaborating with industry stakeholders and exploring new insurance models (Skeete, 2018). This is consistent with the findings of this study, considering that autonomous vehicles can reach the incumbent level after a series of technological and policy windows of opportunity.



Source: FOI 60 cf, FOI 67 cf

Figure 5.1 Tipping points, 2018-2030

The importance of autonomous vehicles and reconfiguration of the industry was also supported in the interviews.

> "Looking at the investments the carmakers are making this is already happening [diversification into mobility-as-a-service and energy sectors and vertical integration with battery and digital industries] e.g. VW/Elli, Volvo/Lynk&Co, Geely/CaoCao, BMW/DriveNow, and it's also happening the other way i.e. the energy industry investing in automotive technology e.g. BP Ventures/Ryd in the news today. And then I agree within 5 years this will be the norm" (Int.24).

Comparing Skeete (2018) findings with the FOI data it is possible to say that they are the most close to Taxi/Car Sharing or its radical form Hive/Depot-based EVET scenarios. The "Taxi" or "Car Sharing" scenario (viable future 3) suggests low private ownership and high uptake of Mobility-as-a-Service (MaaS), where opportunity charging occurs throughout the day (grazing), wherein individual consumers have little control over the cars and charging choices. At the same time fleet managers have some control over vehicle choices and potentially electricity providers, but little control over public charge posts used by their fleet drivers (FOI 67 cf).

The "Hive" or "Depot-based" scenario (viable future 4) is the most radical and has the following characteristics: low private ownership, high uptake of MaaS, fleets of vehicles operating all day and "returning to base" to charge, customers being able to schedule in the best times to charge assets, and fleet managers having full control over EVs, charger posts, and electricity providers (FOI 67 cf).

If the transition follows the Hive/Depot-based scenario it will be the most aligned with the shared transition pathway discussed by Marletto (2019). This is a hybrid transition that involves substitution and de-alignment and re-alignment of the socio-technical system. If the transition follows this pathway the system will change through cooperation between information and communications technology (ICT) companies such as Google and Baidu, as well as internet-based rental and sharing providers (e.g. Uber and Car2Go) and public transport providers (Marletto, 2019). Another characteristic of this socio-technical system is that it involves the popularity of collective shared urban mobility, and widespread adoption of Level-5 autonomy, wherein the decision on charging is made by the vehicle.

It is worth noting that there is no consensus among the interviewees on the perspective of carsharing, as currently people still prefer private ownership that could continue in the future.

> "According to my working experience, I have some interviews for people that are commuters, daily commuters, the percentage was very low of those who were willing or were already using car sharing" (Int.14).

However, it is possible that ICT companies will diversify into the automotive industry due to experience in the development of electronic systems, software, expertise in digital mapping and investments in autonomous systems (Int.17).

> "Apple looking at things like LiDAR technology and autonomous vehicle technology, so I feel as though they are looking at it [EV manufacturing]. Google again, that's been a little bit more open, but still it looks as though they're keeping it quite under wraps. The area, which I think is fascinating" (Int.17).

The smart transition pathway is one of the most extreme pathways that was suggested by Marletto (2019). It is associated with the substitution of the system, where "energy operators enter the domain of urban mobility and take over the dominant position of the individual car socio-technical system" (Marletto, 2019, p.227). This is a very innovative pathway that was not identified in FOI data, however it was discussed during the interviews.

Participants consider the possibility of energy operators diversifying in the automotive industry to be unlikely (Int.18). However, energy operators can collaborate with carmakers in terms of EV distribution and offering EV-specific tariffs.

> "I'm not saying that they're suddenly gonna make cars or anything, but in terms of having an impact on a current industry, I think what Octopus are doing are really interesting. Just look at the number of tariffs that they have, and they're basically refining their tariffs to all sorts of various customers" (Int.18).

The final scenario identified Marletto (2019) was named the individual transition pathway. It corresponds to a reconfiguration mobility system, where an important role is played by carmakers. The role of individual cars will have the dominant position in urban mobility. It is expected that ICE technology will be substituted by EVs, while oil companies will leave the network of innovators of autonomous driving. This scenario most closely relates to Home Charging or Filling Station scenarios identified in FOI data. However, it is worth noting that FOI data shows that oil companies such as BP and Shell are actively involved in EVET and can be a part of this network. In the research, BP and Shell were classified as TIs.

The "Home Charging" scenario (viable future 1) suggests a high level of private ownership and high utilisation of home charging. It is expected that charging will mainly occur overnight, wherein individual consumers will have a high level of control over their choices of electric vehicle, charge point, and electricity provider (FOI 67 cf).

The "Filling Station" scenario (viable future 2) assumes high private ownership and high usage of "filling stations" for rapid charging. Charging occurs in this scenario throughout the day, with peaks during the morning and evening commute; individual consumers will have control over the type of EV, but little else. It is also expected that charging will be decided by a third-party "filling station" operator (either rapid charging from the grid or on-site storage) (FOI 67 cf).

Comparing interviews, FOI data and secondary materials, in total eight scenarios were identified, of which 3 overlapped. This can be integrated into the following five scenarios Filling Station, Home Charging, Hive/Depot-based Taxi, Car Sharing and Smart Transition. Which of them can describe the transitions in the UK?

One of the findings of this study is the importance of the role of policy agenda setting in the EV transitions process in the UK, as well as the vital role of individuals in it. The EVET is one of the main platforms in the UK responsible for accelerating EV market uptake. Under favourable external condition, this study believes that the EV transitions will most likely follow the EVET stakeholders plan which was discussed by the government, industry stakeholders and PE. If this is the case, then the following statement can help identify the most probable future:

> The following [viable futures 1-4] are meant as extreme examples of possible visions of the future, designed to act as "stress tests" for the taskforce's recommendations. Any true future would be a combination of different types of charging and business models. In these extreme cases, one form of charging scenario becomes the predominant method (Nearly everyone charges at home / nearly everyone charges at a petrol station etc.) (FOI 67 cf)

Based on this it is possible to suggest that the future transition of EVs by 2030 will most likely include a combination of Home Charging and Filling Station scenarios. Among the secondary literature, the individual transition pathway identified by Marletto (2019) is one of the closest to this study.

5.4.2 The Policy Mix Literature

This section compares research findings with the policy mix literature. Specifically Rogge and Reichardt (2016) focus on the development policy mix analytical framework; whilst Edmondson, Rogge and Kern (2020) analysed the co-evolution of the policy mix and the house-building socio-technical system in the UK between 2006 and 2016, with the focus on zero carbon homes.

In the first part, the MLST will be compared with the policy mix analytical framework developed by Rogge and Reichardt (2016). This provides a typology of policy instruments, as well as tools for studying the "link between policy and technological change in the context of sustainability transitions" (Rogge and Reichardt, 2016, p.1626). This stands in direct relation with the theoretical framework developed herein and the topic discussed in Section 5.4. Both the MLST and the policy mix analytical framework can be used to analyse sustainability transitions in the UK automotive industry and can complement each other.

The second part compares the findings of this research with Edmondson, Rogge and Kern (2020). Edmondson, Rogge and Kern (2020) used FOI data requested from the Zero Carbon Task Force covering the period 2006-2016, while the present research uses EVET FOI data covering the period 2018-2020. The transition to zero carbon homes was not as successful as the transition to zero emission vehicles. The comparison of conceptualisation of the processes underlines the net zero transition in the UK in both cases can help us better understand policymaking in the UK.

5.4.2.1 The Policy Mix Analytical Framework

According to Rogge and Reichardt (2016), to achieve complex policy objectives such as sustainability transitions, it is important to consider the interaction of different policy instruments and measures. To analyse the dynamics and effectiveness of the policy mix, the authors elaborated the policy mix analytical framework that consists of the three building blocks: policy processes, elements of the policy mix, and characteristics of the policy mix. The building blocks of the policy mix framework can be specified along the policy field, governance level, geography and time dimensions (Rogge and Reichardt, 2016). The explanation of the policy mix framework and its comparison with the MLST and research findings are provided below.

The elements of the policy mix refer to the content of the policy mix (Rogge and Reichardt, 2016). The elements of the governance level of the industry trajectory in MLST can be considered as content of the policy mix. This includes the long-term objectives of policy – policy strategy – and a mix of different types of policy instruments helping to achieve the strategic objectives. In the MLST both policy strategy and policy instruments are included in the governance level of multiple industry trajectories. There is no differentiation between strategy policy and instruments of policy mix and they are not separated in the MLST. This could be a focus for future research.

Policy strategy is important in sustainability transitions (Rogge and Reichardt, 2016) as it provides long term direction (Hillman and Hitt, 1999) and guidance for innovation systems (Hekkert et al., 2007). The importance of policy strategy in the mix of policy was confirmed empirically in the case of EV transitions in the UK. It is possible to see that one month before the release of the Road to Zero strategy, the government set the EVET framework to provide a policy proposal for the policy instruments aligned with the policy strategy. The Road to Zero strategy manifested the shift in policy agenda in the automotive industry from low emission to zero emission targets, which resulted in the beginning of mass market EV uptake in 2020.

Policy processes of the policy mix refer to the political problem-solving processes that take place among different constrained social actors who are searching for solutions to social problems (Rogge and Reichardt, 2016). Policy processes determine the policy mix. This building block of the policy mix framework can be associated with the processes underlined in the coupling and decoupling of problem, politics and policy streams, for which the MLST can facilitate the analysis. This research indicates that the policy process underlining the agenda setting stage of policy making can indeed influence the policy mix and the content of not only policy instruments but also the policy strategy. Using the MLST it is possible to separate different actors and their activities inherent to the agenda setting stage of the policymaking process. The policy mix framework also includes the policy implementation stage of the policy process as the MLST allows policy process and outcomes to be traced. It can be used for analysing the policy implementation stage as well.

The third building block refers to the characteristics of the policy mix and includes four dimensions consistency, coherence, credibility and comprehensiveness. The consistency of the policy mix is associated with the alignment of policy instruments with strategy; coherence indicates if there is a synergy in policy processes; capability indicates how reliable the policy mix is; and comprehensiveness describes how extensive it is (Rogge and Reichardt, 2016). Based on these characteristics it is possible to evaluate the effectiveness of the policy mix. The characteristics of the policy mix are not included in the MLST, but by combining policy mix framework and the MLST it would be possible to evaluate the impact of actors of the policy agenda setting process on the effectiveness of the policy mix as well as vice versa.

Finally, each building block of the policy mix framework includes multiple dimensions: policy field, governance level, geography and time (Rogge and Reichardt, 2016). The MLST incorporates all four dimensions. For example, industry trajectories have a specific policy field whether it be energy supply, energy storage or automotive industry. The streams and trajectories break down into the governance level: international, EU, UK and local levels. The content of the MLST, such as policies and events, has been included based on the analysis of the policy documents, FOI data, interviews and secondary data focusing on the UK. This is related to the geographical dimension of the policy mix framework. Finally, the MLST includes the time dimension, allowing us to trace the evolution of technology and policy.

There are elements of the MLST that can contribute to policy mix research. The MLST operates with the concept of windows of opportunity and breaks down the transition process into three stages: coupling trajectories (tWoO-1, tWoO-2), providing policy solutions (pWoO-1, pWoO-2) and market uptake (mWoO). Applying the MLST framework can help clarify the meaning of the effectiveness of policy mix as it is suggested that the goal of policy mix should be different in each of these stages of transition. The MLST also brings technology into policy making and includes multiple industry trajectories. By using its structure it is possible to trace the evolution of policies and technologies in multiple industries and how this affects the content of the policy mix.

Another aspect that complements policy mix research is the fact that the MLST pays attention to the role of individuals in policy making. It recognises that not only policymakers are involved in the policy making process but also industry stakeholders. The framework uses problem, policy and political analytical levels that themselves break down into governance, incumbent and technological niche levels. Applying these analytical levels allows us to scrutinise in a more comprehensive way sophisticated strategies stakeholders use to impact multiple policy agenda in multiple industries that determine the policy mix. Additionally, the MLST is an interactive 3D framework, thus it can simplify the representation of the complex interaction between multiple levels of policies, technologies, industries, and decision-making.

Finally, the multi-level streams and trajectory structure suggests that there are multiple levels of industry-specific problems related to the technologies in the market niche or incumbent levels. EVET data showed that each of these problems can be addressed by a different set of policy recommendations. Taking this into consideration, the dimension section of the policy mix analytical framework can be supplemented with the market level of the technology that the policy instrument is aiming to push, be it a niche market or mass market technology. This can be aligned with the time dimension of the analytical framework as, during the net-zero transition process, at the beginning of the transition the policy mix should deal with the problem of technology at the niche level market, as technology has not yet reached the incumbent/mass market level. In the second stage of transition after mWoO, the policy mix can address the problems of the technology becoming a mass market product.

5.4.2.2 Co-evolution of Policy Mix and Socio-technical System

One of the closest policy mix studies to the present study is Edmondson, Rogge and Kern (2020). These authors analysed the co-evolution of policy mix and socio-technical system using the case of zero carbon homes in the UK. The authors also used archival data from the Zero Carbon Task Force which operated over the period 2007 – 2014 in the UK and focused on low carbon transitions in the house-building industry. The analytical framework suggested that the policy mix and socio-technical system have a reciprocal relationship. The changes in policy mix via resource allocation, interpretive and institutional effects influence the socio-technical system which, in turn through socio-political, administrative and fiscal feedback, influences policymaking and the policy mix. The authors find that the transition was unsuccessful because of a lack of clarity and consistency in the policy mix, economic downturn, and changes in the policy mix under the new government which, jointly, undermined the momentum and generated negative feedback. According to Edmondson, Rogge and Kern (2020), during the WoO policymakers need to design policies that generate positive feedback and sustain momentum after the closure of a WoO.

Matching the timeline of transitions discussed in Edmondson, Rogge and Kern (2020) and the present study, it is possible to say that the decarbonisation of the automotive industry also was not achieved at that time. The zero emissions targets did not even get set in this industry. To demonstrate the wider applicability of the MLST, we now consider the home-building case drawing on this framework.

One of the aspects of a successful transition toward net zero in the industry of interest involves coupling both with energy supply and energy storage trajectories. In 2014, that did not happen either in house-building or in the automotive industry. The mix of policy strategy and instruments should focus over this period on coupling house-building, energy storage trajectories and energy supply trajectories. This means that the policy mix should emphasise providing strategy and policy instruments in multiple industries to facilitate the shift from niche zero emission technologies to the incumbent level, thus contributing to the decarbonisation of the house-building industry. In the house-building industry, such technologies include smart grids, power walls and solar energy.

The case of the EV transition showed that for the zero-emission policy agenda, the coupling between the complementary industries facilitates the shift of EVs if some of the complementary industries have net zero technology that shifted from the niche level to the incumbent level. In the UK energy generation from renewables overtook energy generation from coal in 2016. This signifies the shift of RE from the niche to the incumbent level. This technology can be coupled with others such as smart grids, power walls or EVs which simplify pairing these technology solutions with policy solutions within the policy window.

The next stage involves opening a series of pWoO wherein the niche technology of interest is paired with policy solutions. The first pWoOs should result in the release of strategic policy which set the net zero goals for the industry of interest. The other pWoOs should result in the release of policy instruments, facilitating the achievement of strategic policy goals.

The EV transition case indicates that the taskforce was quite effective in providing industry-specific policies and facilities for the achievement of net-zero strategy policy goals. The EVET was established one month before the release of the Road to Zero strategy. Following this example in the case of the house-building industry, it would be more effective to set the Zero Carbon Homes Taskforce close to the release date of the net-zero strategy for house-building. By analogy with the EV case, the series of pWoO should result in the release of industry-specific policies addressing the problems net zero homes face. After that, it is possible to expect the opening mWoO for mass take up of net zero homes technology.

The role of individuals in this process also needs to be taken into account. The PE who works within the pWoO needs to be experienced and successful as it was with the PE from LowCVP, who successfully applied salami tactics and solve the big issue of the EV transition by breaking it into smaller, more manageable tasks. In the case under investigation, the PE announces series EVET 1.0 – 2.0 that worked on different WPs aiming to reach Road to Zero goals.

By looking at Edmondson, Rogge and Kern's (2020, p.156) case from the agenda setting perspective over the period of investigation, also evident is the lack of support in the politics stream at national (government, public) and incumbent (industry stakeholders - house-builders) levels, which made it difficult to add new instruments in the policy mix. Moreover, the condition of the economic downturn mentioned in the article, a more experienced PE could frame this condition as a problem. They might be more successful in presenting policy proposals to policymakers to tackle this economic problem, which could potentially relegate the problem of net zero homes to the background. In such a situation, policies that focus on the decarbonisation of the housing industry could be delayed.

It is important to mention also how Edmondson, Rogge and Kern's (2020, p.156) co-evolutionary framework can supplement MLST research. In the present research, the MLST is used to analyse the interaction of policies and technologies over the agenda setting process. The MLST pays less attention to social feedbacks of socio-technical systems, which the co-evolutionary framework for policy mixes focuses on.

The social feedbacks followed the implementation policy-mix, leading to subsequent changes in the socio-technical system. These feedbacks can influence policymaking and can change the policy mix. They include socio-political feedback, which refers to the response of actors to the policy mix, fiscal feedback associated with the cost rise concern of actors, and administrative feedback associated with the perception of the policy mix by government departments (Edmondson, Rogge and Kern, 2020). The feedback as a result of the implementation of a policy or policy mix can be included in the politics stream, as they inform the follow up policy agenda.

The second element that complements the MLST is the concept of policy effects which influence actors' behaviour and can change the socio-technical system. It includes resource effects – the effect of resource allocation, interpretive effects – the effect of information policy mix on the actors' cognition, and institutional effects associated with the effect of the policy mix on existing rules and arrangements (Edmondson, Rogge and Kern, 2020, p.138). Applying both the MLST and co-evolutionary framework jointly can thus enhance our understanding of the effect of feedback on the policy agenda and policy mix. This includes feedback from both the technical and social sides of socio-technical system in multiple industries across multiple levels of governance.

5.5 Summary

In this chapter, Section 5.1 has discussed the role of technology in setting the policy agenda for EVs. There is very little research that uses the technology concept within the policy agenda setting context and even fewer articles analysed UK policymaking through this lens. Thus, the research findings were compared with articles that focus on other contexts. For example, Goyal, Howlett and Taeihagh (2021) associate the technology stream with research, prototype development, patenting and licensing, the establishment of a business venture, market creation, and technology transfer. Based on this approach the role of technology in windows of opportunity was unclear and if there were multiple innovations influencing the policy agenda process, which of them should be included in the technology stream and, if there are multiple innovations, what are their interrelationships.

This research found that in setting the policy agenda for EVs, not only was the development of EV technology important, so too was the development of energy supply and energy storage elements of the EV ecosystem. The technologies in complementary industries contributing to the decarbonisation of EV well-to-wheel processes have to shift from the niche level to the incumbent level. During the sustainability transitions, in order for the technology to be successfully paired with policy solutions in the policy stream, the well-to-wheel processes of this technology need to be decarbonised. That was the case for EVs, which allowed PEs to pair a technology solution with a policy solution within the policy WoO, which as a consequence shifted EVs from the niche level to the incumbent level. This conceptualisation adds further understanding to the articles that operate with the concept of technology in agenda setting.

Section 5.2 discusses the findings related to the impact of the policy agenda on the automotive industry. The findings of this study are in line with the findings of Kulmer et al. (2022), that the policy agenda plays an important role in accelerating the market uptake for low-carbon technologies. These authors recommend further research analysing the interrelationships between complementary technologies over the diffusion process and how coupled market development feedback to the politics stream (Kulmer et al., 2022). The tWoO that was introduced in the present study responds to this recommendation. In this research, it was found that indeed the interactions of technologies in tWoO can influence the streams, which subsequently trigger a mWoO/turning point and impact technology diffusion. Applying the MLST can supplement the work of Kulmer et al. (2022), as our multi-level structure facilitates the analysis of actors related to the mWoO/turning point. In addition, bringing in the concepts of tWoO, pWoO and mWoO can help to identify the moments when the technologies start to complement each other, which subsequently causes policy change and change in technology diffusion.

Section 5.3 compares the findings related to RQ2: Who were the key stakeholders in setting the EV policy agenda in the UK automotive industry between 2017-2020, and what were their roles in this process? The key stakeholders identified in the data were policy entrepreneurs, problem brokers, technology innovators, bricoleurs and policymakers. In a first analysis of the agenda setting in the UK automotive industry, the director of LowCVP was identified as a policy entrepreneur, managers of Energy Systems Catapult, BEAMA, Energy UK, and Energy Networks Association (ENA) as bricoleurs, senior managers of carmakers and energy companies as technology innovators and problems brokers. Their interaction in windows of opportunity fosters the transitions to EVs. Maltby (2021), analysing the role of PEs and PBs in response to the air pollutant problem in the UK, came to the conclusion that the Mayor of London, Sadiq Khan, acted as a local level Problem Broker and Policy Entrepreneur, while linking politics and problems stream with ULEZ policy solutions. Based on the analysis of FOI data, this research considers Sadiq Khan as a local level policymaker who set EVIT, while the secretary of EVIT is considered as a PE. This correlates with the national level EVET, where the secretary of EVET – the director LowCVP – is involved in amending recommendations to national level policies and considered as a PE at the national level. However, it is worth noting that policymakers can take the role of PE and the above statement is true if we are aiming to separate these two actors for analytical purposes.

Section 5.4 discusses the findings related to RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK? In this section, MLST and MLP frameworks were compared as well as the explanation of EV transitions in the UK by using these frameworks. In the MLP literature, socio-technical transitions include four phases: experimentation, stabilisation, diffusion/disruption, and institutionalisation (Geels, 2019). One of the core elements of MLP particularly relevant to this study is the concept of windows of opportunity, that open at the diffusion/disruption stage. The MLST can complement MLP research as it provides information on the type of windows opened, as there can be multiple windows, which facilitates the EV transition. In addition, it highlights the important role of individuals in putting pressure from the landscape level on the socio-technical regime. The main argument of the MLST is that the EV transition in the UK took place by means of the opening of a series of windows of opportunity for EVs: tWoO-1, tWoO-2, pWoO-1, pWoO-2 and mWoO. The technological windows (tWoO-1, tWoO-2) allowed decarbonisation of well-to-wheel processes of EVs, policy windows (pWoO-1, pWoO-2) contribute to policy change resulting in the release of strategic policy, as well as demand and technology push policies. This led to the opening of a market WoO and the beginning of mass market uptake of EVs. The actors involved in this process are technology innovators, problem brokers, bricoleurs, policy entrepreneurs and policymakers. The different actors involved in different windows: technology innovators participate in tWoO, pWoO and mWoO, problem brokers, bricoleurs, policy entrepreneurs and policymakers are the main actors in the pWoO.

Considering scenario planning identified in FOI data, and comparing the findings with the MLP literature, it is possible to suggest that the future transition of EVs to 2030 will most likely include a combination of the Home Charging and Filling Station scenarios. These scenarios suggested a high level of private ownership, high utilisation of home charging, and high usage of "filling stations" for rapid charging. Among the secondary literature, the individual transition pathway identified by Marletto (2019) is the closest to this study.

Section 5.4 also discussed the policy mix literature, as it provides a typology for policy instruments as well as tools for analysing the link between policy and technological change, which stands in direct relation to the MLST. By comparing Rogge and Reichardt's (2016) policy mix analytical framework it is possible to say that characteristics of a policy mix are not included in the MLST. By combining the policy mix analytical framework and the MLST it would be possible to evaluate the impact of actors in the policy agenda setting process on the effectiveness of the policy mix, and vice versa.

There are elements of the MLST that can contribute to policy mix research. The MLST operates with the concept of windows of opportunity and breaks down the transition process into three stages: coupling trajectories (tWoO-1, tWoO-2), providing policy solutions (pWoO-1, pWoO-2) and market uptake stages (mWoO). Applying the MLST framework can help clarify the meaning of the effectiveness of the policy mix, as it is suggested that the goal of the policy mix should be different in each of these stages of transition. In addition, the multi-level streams and trajectory structure suggests that there are multiple levels of industry-specific problems related to the technologies in the market niche or incumbent levels. EVET data showed that each of these problems can be addressed by a different set of policy recommendations. Taking this into consideration, the dimension section of the policy mix analytical framework can be supplemented with the market level of the technology that the policy instrument is aiming to push, be it a niche market or mass market technology.

Comparing Edmondson, Rogge and Kern's (2020, p.156) co-evolutionary framework with the MLST, it can be concluded that the MLST is more focused on technological aspects of transitions, as it was designed to analyse technologically related policy agendas. Edmondson, Rogge and Kern (2020, p.156) pay greater attention to social aspects. Applying both the MLST and co-evolutionary framework can enhance our understanding of the effect of feedback on the policy agenda and policy mix. This includes feedback from both the technical and social sides of socio-technical systems in multiple industries across multiple levels of governance.

Section 5.5 concludes the chapter.

Chapter 6 Conclusion

This chapter concludes the thesis. It comprises five sections. Section 6.1 “Policymaking Implications” discusses the potential applications of the research in policymaking. Section 6.2 “Contributions to Knowledge” highlights the original contribution the research has made. Section 6.3 “Limitations” outline the boundaries of the study. 6.4. “Conclusion” summarises the main findings. Section 6.5 “Recommendations for Future Research” suggests directions for future research.

6.1 Policymaking Implications

The MLST bring in ideas from multiple frameworks, notably the MSF and MLP. In addition, it offers novel concepts such as multiple WoOs, multi-level streams and industry trajectories. According to Van der Heijden (2013) such a pluralist approach to policy analysis can overcome the limited focus of individual lenses and provide a more comprehensive explanation of complex phenomena. Basu et al. (2019, p.1) argue that meta-frameworks are particularly helpful for analysing cases involving “inter-sectoral linkages, the diverse agents and multilevel governance trends”. For example, such type of frameworks have been applied to analyse the sustainability transition of urban energy systems (Basu et al., 2019) and sustainability transitions in the energy sector of Germany and Japan (Cherp et al., 2018). The MLST complements this approach to studying sustainability transitions by focusing primarily on the agenda setting aspect of policymaking.

According to Edmondson, Kern and Rogge (2018, p.12) “timing and sequencing of policies should be relative to the phase of the transition”. The MLST can facilitate identifying the phases of transitions by introducing the concepts of WoOs. The MLST breaks down the transition process into three stages: coupling trajectories (tWoO-1, tWoO-2), providing policy solutions (pWoO-1, pWoO-2) and market uptake (mWoO). Applying the MLST framework can help clarify the meaning of the effectiveness of the policy mix, as it is suggested that the goal of the policy mix should differ at each of these stages of transition. In the first stage, policy should address coupling industry trajectories, which subsequently lead to an increase in the efficiency of well-to-wheel processes for the net zero technology of interest. In the second stage, within the pWoO, policymakers should first focus on the release of strategic policy, which corresponds to Rogge and Reichardt (2016), and then on policy instruments that contribute to achieving this strategy. Within mWoO, as indicated by EVET data, policy interventions aim to maintain the momentum of the uptake of the target technology. This can be achieved by addressing industry-specific problems that affect customers' perceptions of a focal technology, such as the lack of interoperability of EV charging or an underdeveloped energy flexibility market. The effectiveness of such an approach, in conjunction with the effective actions of stakeholders, is evident in this study. As this research illustrates, following the sequence of WoO and the effective actions of EVET stakeholders, which were supported by the government and public, EVs not only became a mainstream product in 2020 but also continue to increase their market share presently.

Within the agenda setting domain, the MLST facilitates the advancement of the original MSF as well as its technology-centric adaptation provided by Goyal, Howlett and Chindarkar (2020). The sequencing of WoO offered by the developed theory allows for an explanation of which innovations have a better chance of being coupled with a policy solution. For example, as in the case of EVs, the link between Li-ion, RE and EVs within tWoO improved the efficiency of well-to-wheel processes, as well as the marketability of the technology. This makes it a more viable solution to the environmental problem. From a practical perspective, such an analysis can help evaluate the feasibility and acceptance of a specific technology solution to policy problems during the agenda setting process.

Bringing in the concept of mWoO further advances the MSF, indicating the two-way linkages between policy agenda and technology. In the case under investigation, it was found that after coupling the technology with the policy solution within pWoO, the policy agenda shifted to net zero. After that followed mWoO, that fed back to the industry trajectory, signifying the shift of EVs to the incumbent level. We can continue as it is expected that within mWoO there will be a series of tipping points influencing the policy agenda by means of problems or success of EV uptake. From the policymaking perspective, the recognition of mWoO can lead to more relevant, effective and forward-looking policies. This is linked with the argument of recognising stages in the EV transition. Knowing the stages, policymakers can better align policy development with current market conditions.

The multi-level structure of industry trajectories and streams advances our understanding of policymaking processes. On the one hand, the multi-level structure of streams and trajectories delineate in finer detail the levels at which actors of policy processes operate, be it at the local, incumbent or technological niche level. This subquery provides a nuanced understanding of the bricolage processes identified in the research, where we saw how PEs coupled national and industry-specific problems together or incorporated industry-specific policy proposals in multiple policy papers at the national level. Such a detailed understating of the policymaking context can facilitate coordination between actors in the policy process. On the other hand, dividing policy proposals into local, incumbent or technological niche levels, which, as observed, can be included in multiple policies, can inform the development of a more coherent policy mix.

Finally, by integrating multiple levels of governance, with incumbent and technological niche levels in multiple industry trajectories that co-evolve over time, the MLST can be illustrated as a 3D framework for chronological mapping of policies and technologies, that can be used for stages of policymaking other than agenda setting. For instance, during the implementation stage, it can be used to assess the interrelationship between technologies and the policy mix across multiple industries.

6.2 Contributions to Knowledge

According to Sovacool, Axsen and Sorrell (2018) studies fall into one of the three types of novelty, or combinations thereof: methodologically-novel, theoretically-novel and empirically-novel studies. This study provides empirical and theoretical novelties.

An empirical contribution can be associated with a new description of a phenomenon that challenges existing assumptions or reveals something previously undocumented (Ågerfalk, 2014). Sovacool, Axsen and Sorrell (2018, p.19) state that "empirically-novel articles reveal new insights through new applications of existing methods and theories (e.g. to different regions, contexts or research questions), as well as through analysis of new types of evidence or data".

The empirical contribution of this study is linked to the analysis of the unique archival data and interview data collected from the direct participants of the policy agenda setting process during the EV transition in the UK. At the time of completion of the research, no studies were found that used the opinions of participants of the EVET steering group to analyse such a process. In addition, no studies were identified that used archival data from EVET. More broadly, researchers tend to engage with actors through interviews, not the minutes of meetings of key bodies, despite the advantages of the latter – coverage of actors, the timely recording of debates, and the opportunity to trace the details of debates over time.

In the present case, this dataset helps to clarify the process of a shift of policy agenda from low emission to zero-emission targets, the key stakeholders and their role in this process. Decarbonisation of well-to-wheel processes of vehicles was found to be important before they can be effectively used by policy entrepreneurs. The policy entrepreneurs used salami tactics by breaking down the problem of net-zero transitions into multiple manageable tasks, such as setting net zero strategic objective – the 46-point policy plan first – then dealing with industry-specific problems by setting EVET 1.0 – 2.0. Directors of LowCVP were identified as policy entrepreneurs, managers of Energy Systems Catapult, BEAMA, Energy UK, and Energy Networks Association (ENA) as bricoleurs, senior managers of carmakers and energy companies as technology innovators and problems brokers. Their interaction in windows of opportunity fostered the transition to EVs.

Theory shows how and/or why a phenomenon occurs by using concepts and their interrelationships (Ågerfalk, 2014). According to Sovacool, Axsen and Sorrell (2018, p.19) theoretically-novel research contributes to "creating, testing, critiquing, or revising some type of academic concept, framework or theory". Theoretical contributions advance our understanding of academic concepts and interrelationships and must be discussed in relation to existing theory in order to be established as a contribution (Ågerfalk, 2014).

The main outcome of grounded theory is a comprehensive study of a phenomenon, conceptualisation of data, and identification of the relationship between concepts, with subsequent theorising. This study offers theoretical contributions to theories of the policy process, by bringing technology transitions into the policy process and introducing the concepts of multiple windows of opportunity, as well as multi-level streams and industry trajectories. The developed theoretical framework can facilitate an analysis of policy processes dealing with industry-specific problems such as a shift from low emission to zero emission technologies. Using the case of decarbonisation of the automotive industry in the UK, the relationship between technological, policy and market windows of opportunity in related industries has been identified, as well as their relationship with the agenda setting process. The relationship between concepts was visualised using the interactive 3D modelling technique. Analysis of the theoretical literature using the concept of windows of opportunity revealed the novelty of this approach, which can be further used to analyse agenda setting and sustainable transitions in other industries and regions.

Finally, using the developed framework, the EV transition in the UK was theorised. This clarifies the explanation of the transitions process provided by the MLP literature. It has highlighted the important role of individuals putting pressure from the landscape level on the socio-technical regime. The sequence of opening and closing windows of opportunity was clarified, as well as the types of window involved in the transition process. In addition, future scenarios of the EV transition in the UK have been provided.

6.3 Limitations

There are several limitations to the study, primarily associated with the regional and industry specificity of the theory and its subjectivity.

The first limitation is associated with the regional specificity of the constructed theory. The research involved the collection of data from the UK Taskforce and experts. Based on this data the theoretical framework and theory were elaborated. The theory and framework are regional and industry-specific and thus may require adaptation when applied to other contexts.

The second limitation is associated with subjectivity. Apart from the archival data, the interviews used in the research encompass the opinion of experts, which inherently include elements of subjectivity. In addition, as the researcher is involved in collecting and interpreting the data, the theory inventible contains subjective elements.

To overcome the limitation of subjectivity, the theoretical framework and theory were presented and validated by the interview participants, as well as by the scholars at conferences. The preliminary theory and answers to the research questions were tested and validated during the second round of interviews. The final theory and answers to the questions were validated in the last stage by sending textual information to the research participants. Participants were asked to check the clarity of the theory and answers, as well as the consistency of the data they shared.

The theoretical framework and theory were presented to the scholars specialised in the MSF at the 6th International Conference on Public Policy in Toronto Metropolitan University on 29 June 2023 (Panel T01P03: Advancing the Comparative Study of The Multiple Streams Framework); the Conference on Policy Process Research in University of Colorado on 12 January 2023 (Panel on Advancing Policy Process, Theories, and Methods); and the 3rd International Workshops on Public Policy in Corvinus University of Budapest on 28 June 2022 (Panel T01W10: Policy Entrepreneurship and Agency in Theories of the Policy Process).

Verbal and textual feedback received from the scholars was instrumental in the final shaping of the theory. The textual feedback from Professor Dana Archer Dolan is presented in Appendix 9. In addition, Appendix 9 includes feedback from the interview participants.

6.4 Conclusion

This study aimed to develop a theory, using a grounded theory approach, that can explain the role of technology and individuals in shifting the policy agenda from low emission goals to zero-emission goals, as well as the impact of the shift in the agenda on the automotive industry in the UK between 2017-2020. As part of this work, extensive fieldwork interviews and documentary analyses were undertaken that allowed fr an exploration of the interlinkages in a context where policymakers seek to create a significant and sustainable new market (i.e., cars with zero tailpipe emissions) via policy incentives and where the basic technology exists (e.g., batteries), but where investment in technological development must come from the private sector, especially from several related industries within the automotive ecosystem. Moreover, these private sector actors have considerable self-interest in the shape of those policy incentives. The study was thus interested in exploring the dynamic and two-way linkages between technology and policy in the development of this new market.

For this work, MSF, MLP and MLG concepts were utilised to understand how technology, market and policy factors have jointly worked to put the British automotive industry on a specific trajectory. By adopting a pragmatist grounded theory approach, it was found that this trajectory has come about through the interplay between technology innovators, bricoleurs, knowledge brokers and policy entrepreneurs (PE) performing activities in different types of window of opportunity – technology, policy and market – to achieve the ultimate goal of a functioning market for electric vehicles. This research answered three interrelated research questions. RQ1: How do windows of opportunity help us to understand the role of technology in the shift of the policy agenda from low emission to zero emission goals in the UK automotive industry? RQ2: Who were the key stakeholders in setting the EVs policy agenda in the UK automotive industry between 2017-2020 and what were their roles in this process? RQ3: What theory can be developed to explain the transition to EVs witnessed in the UK?

To visualise the complex interactions of the different agents and their activities in multiple windows of opportunity, an interactive 3D model was developed. It was found that the EV transition in the UK over the period 2010 – 2020 was shaped through the opening of several windows of opportunity for EVs: technological windows of opportunity (tWoO-1, tWoO-2), policy windows of opportunity (pWoO-1, pWoO-2) and market windows of opportunity (mWoO). Different actors were involved in different windows: technology innovators participated in tWoO, pWoO and mWoO; bricoleurs, policy entrepreneurs, knowledge brokers and policymakers were the main actors in pWoO. By opening technological windows of opportunity sequentially and coupling automotive, energy storage and energy supply industry trajectories, the effectiveness of well-to-wheel processes of EVs were improved, reducing the total environmental impact of the niche technology – EVs. This started from energy generation and storage (the well) to energy consumption by EVs (the wheel). In addition, to this, the marketability of the technology was improved through the reduction in the cost of Li-ion batteries, as well as the extensive development of EV infrastructure. The improved effectiveness of well-to-wheel processes, along with the increased market potential of the technology, ultimately makes EVs an appropriate solution to environmental problems.

In the next stage, over the series of policy windows of opportunity, the technology was paired with policy solutions addressing the national level environmental problem by means of the uptake of the focal technology - EVs. The first policy, pWoO-1 resulted in the release of a strategic policy – the Road to Zero – which set targets for EV uptake and subsequently shifted the policy agenda to a net zero target. The second, pWoO-2, aimed to resolve industry-specific problems of EVs, such as the development of a network of charging stations, and the development of market flexibility, facilitating the market uptake of EVs. This approach refers to the salami tactics used by policy entrepreneurs – senior managers of LowCVP – and supported by the government. This involved splitting risky policy moves into multiple manageable tasks, increasing the chances of achieving the intended policy outcome. Following a series of tWoO and pWoO, the mWoO was opened signifying the shift of the focal technology to the incumbent level, where EVs become a mainstream product. After this point, EVs showed a sustainable and significant increase in market share.

The opening mWoO and the shift of EVs to the incumbent level can cause multiple problems, such as excessive energy demand, energy security concerns and lack of interoperability in EV charging. These issues can impact customer satisfaction and slow down EV market uptake. In order to prevent this, three tipping points and EVET interventions are expected up to 2030, providing recommendations to the government and stakeholders. The tipping points and the problems associated with the EV technology market uptake can open follow up pWoOs, feeding back to the policy agenda process.

6.5 Recommendations for Future Research

EVET continued its work after the closure of pWoO-2. As indicated in EVET data (FOI 111), EVET-2 was initiated in March 2020, wherein the Steering Group for EVET-2 should include local authorities. In relation to this, future research could shift focus to the local level and apply the MLST in analysing policymaking within this context. This analysis could benefit not only from using EVET-2 archival data, but also data from local level Taskforce such as Electric Vehicle Infrastructure Taskforce.

Another possible area for future research could be the analysis of the relationship between policy mix and the policy agenda in automotive or other industries. In this case, the MLST can be supplemented with Rogge and Reichardt's (2016) analytical framework. In addition, Kulmer et al.'s (2022) mathematical model could contribute to the analysis by identifying turning points during the sustainability transitions in the industry of interest.

It is expected that multiple tipping points will occur up to 2030. The MLST could be further developed by including additional EV Tier 1 industries such as the software industry, semiconductors, sensors and artificial intelligence. More broadly, in response to Geels' (2018b, p.100) recommendation to "study a broader range of niche-innovations" the MLST could incorporate interactions between transport and other socio-technical regimes such as agriculture and urban planning. In this case, using MLP terminology, the policy agenda will be analysed within the context of niche-regime or regime-regime interactions in multiple socio-technical systems.

Finally, the developed theory can be advanced by expanding geographical areas of analysis, whether focusing on the automotive or a different industry. The application of the MLST to countries with political systems different from that of the UK is of particular interest.

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Appendix 1. List of Networking Events

No	Event
Pilot study	
1	NBS: Global Responsibility Week, RSB Lab on 7 March 2018
2	Ultra Low Emission Vehicles event in Nottingham City Council on 30 June 2018
3	Green GB week even in Nottingham City Council on 16 October 2018
4	The Electric Vehicle energy taskforce, a conference organised by the UK government Low Carbon Vehicle Partnership (LowCVP) on 30 July 2019
Second round of interviews	
5	SMMT webinar dedicated to the problems and their solutions associated with Covid 2020.06.20
6	SMMT webinar dedicated to the problems and their solutions associated with Covid 2020.06.30
7	EU-UK Negotiations Webinar 2020.07.01
8	REA The Future of Payments for EV Charging 2020.07.06
9	LowCVP Building an environmentally conscious industry webinar 2020.07.10
10	LowCVP Conference - RESET 2020 2020.07.15
11	The Energyst EV week 2020.07.22
12	The Energyst EV week 2020.07.23
13	2020 Future Energy Scenarios 2020.07.27
14	2020 Future Energy Scenarios 2020.07.29
15	Cenex Low Carbon Vehicle Event 2020.08.13
16	The Decarbonising Transport and Infrastructure Conference 2020.09.23
17	EV infrastructure summit 2020.10.7-8
18	Wales Transport Strategy event 2020.10.14
19	IEA Bioenergy Webinar 2020.11.17
20	All energy 2020.11.4-5
21	International EV Batteries 2020 Cost-Effective Engineering for Hybrid and Electric Vehicles 2020.11.11-12
22	Cenex online Low Carbon Vehicle (LCV) and Connected Automated Mobility (CAM) 2020 Events 2020.11.18
23	Cenex online Low Carbon Vehicle (LCV) and Connected Automated Mobility (CAM) 2020 Events 2020.11.19
24	WMG Electric machines and power electronic drivelines 2021.01.26
25	WMG Life cycle, recycle and reuse 2021.02.09
26	Advanced Propulsion Centre Roadmap to Net-Zero webinar 2021.02.10
27	WMG Micro-mobility 2021.02.23
28	WMG Electricity networks and charging 2021.03.08

Appendix 2. List of FOI Data

Reference	Date	Meeting	Title
FOI 1	2018.06.11	Meeting 1	Agenda
FOI 2	2018.06.11	Meeting 1	Terms of Reference
FOI 3	2018.06.11	Meeting 1	Terms of Reference, Presentation
FOI 4	2018.06.11	Meeting 1	Work Package (WP) Development
FOI 5	2018.07.17	Meeting 2	Agenda
FOI 6	2018.07.17	Meeting 2	Competition Law Compliance
FOI 7	2018.07.17	Meeting 2	Minutes
FOI 8	2018.07.17	Meeting 2	Terms of Reference - Comments and proposed amendments for discussion
FOI 9	2018.07.17	Meeting 2	Work Package Development, Presentation
FOI 10	2018.07.17	Meeting 2	Landscape and Evidence Base, Presentation
FOI 11	2018.09.11	Meeting 3	Covering letter
FOI 12	2018.09.11	Meeting 3	Agenda
FOI 13	2018.09.11	Meeting 3	Competition Law Compliance
FOI 14	2018.09.11	Meeting 3	Minutes
FOI 15	2018.09.11	Meeting 3	Terms of Reference and Steering Group Membership (Final)
FOI 16	2018.09.11	Meeting 3	Work Programme, Presentation
FOI 17	2018.09.11	Meeting 3	Work Packages Descriptions
FOI 18	2018.09.11	Meeting 3	Stakeholder Group launch proposal
FOI 19	2018.10.22	Meeting 4	Progress Report Sprint Objectives, Presentation
FOI 20	2018.10.22	Meeting 4	WP1 (Strategic Understanding) progress report, Presentation
FOI 21	2018.10.22	Meeting 4	WP2 (Engaging Users in Smart Charging and Energy Services) progress report, Presentation
FOI 22	2018.10.22	Meeting 4	WP3 (Technical Requirements of Smart Charging) progress report, Presentation
FOI 23	2018.10.22	Meeting 4	WP4 (Accessible data for decision making) progress report, Presentation
FOI 24	2018.10.22	Meeting 4	Issue Register
FOI 25	2018.10.22	Meeting 4	Work Package Sprints
FOI 26	2018.12.06	Meeting 5	Agenda
FOI 27	2018.12.06	Meeting 5	Minutes
FOI 28	2018.12.06	Meeting 5	Progress Report Sprint objectives, Presentation
FOI 29	2018.12.06	Meeting 5	WP1 Progress Report, Presentation
FOI 30	2018.12.06	Meeting 5	WP2 Progress Report, Presentation
FOI 31	2018.12.06	Meeting 5	WP3 Progress Report, Presentation
FOI 32	2018.12.06	Meeting 5	WP4 Progress Report, Presentation
FOI 33	2018.12.06	Meeting 5	Glossary and Abbreviations
FOI 34	2018.12.06	Meeting 5	Assumptions and Externalities
FOI 35	2018.12.06	Meeting 5	Use cases discussion document
FOI 36	2018.12.06	Meeting 5	Second Stakeholder Seminar, Presentation
FOI 37	2019.01.21	Meeting 6	Agenda
FOI 38	2019.01.21	Meeting 6	Minutes
FOI 39	2019.01.21	Meeting 6	Progress Report Sprint Objectives, Presentation
FOI 40	2019.01.21	Meeting 6	WP1 Update, Presentation
FOI 41	2019.01.21	Meeting 6	WP2 Update, Presentation
FOI 42	2019.01.21	Meeting 6	WP3 Update, Presentation
FOI 43	2019.01.21	Meeting 6	WP4 Update, Presentation

Reference	Date	Meeting	Title
FOI 44	2019.01.21	Meeting 6	WP1 Emerging Themes, Presentation
FOI 45	2019.01.21	Meeting 6	Use Case Architecture
FOI 46	2019.01.21	Meeting 6	Second Stakeholder Seminar
FOI 47	2019.01.21	Meeting 6	Letter to DfT Jesse Norman MP
FOI 48	2019.03.04	Meeting 7	Agenda
FOI 49	2019.03.04	Meeting 7	Minutes
FOI 50	2019.03.04	Meeting 7	Progress Report Summary, Presentation
FOI 51	2019.03.04	Meeting 7	Consolidated Emerging Themes, Presentation
FOI 52	2019.03.04	Meeting 7	Sprint Objectives and Timeline
FOI 53	2019.04.25	Meeting 8	Agenda
FOI 54	2019.04.25	Meeting 8	Minutes
FOI 55	2019.04.25	Meeting 8	Role of the Steering and Synthesis Groups
FOI 56	2019.04.25	Meeting 8	OLEV Update
FOI 57	2019.04.25	Meeting 8	BEIS Update
FOI 58	2019.04.25	Meeting 8	Energy Data Taskforce (EDTF) Update
FOI 59	2019.04.25	Meeting 8	Work Package Update, Presentation
FOI 60	2019.04.25	Meeting 8	EVET Framework Revised, presentation
FOI 61	2019.04.25	Meeting 8	Main Report Structure
FOI 62	2019.04.25	Meeting 8	Sprint Objectives, Presentation
FOI 63	2019.04.25	Meeting 8	Revised Sprint Objectives and Timeline
FOI 64	2019.06.04	Meeting 9	Minutes
FOI 65	2019.06.04	Meeting 9	Agenda
FOI 66	2019.06.04	Meeting 9	Work Package Updates
FOI 67	2019.06.04	Meeting 9	EVET Framework, Presentation
FOI 68	2019.06.04	Meeting 9	EVET Draft Recommendations, Presentation
FOI 69	2019.06.04	Meeting 9	Energy Data Taskforce References (EDTF) to EVET
FOI 70	2019.06.04	Meeting 9	WP3 Consultation Paper
FOI 71	2019.06.04	Meeting 9	Main Report Structure
FOI 72	2019.06.04	Meeting 9	Stakeholder Workshop Proposal
FOI 73	2019.06.04	Meeting 9	Revised Sprint Objectives and Timeline
FOI 74	2019.07.22	Meeting 10	Glossary and Abbreviations
FOI 75	2019.07.22	Meeting 10	Minutes
FOI 76	2019.07.22	Meeting 10	Government & Ofgem Updates
FOI 77	2019.07.22	Meeting 10	Consolidated Recommendations
FOI 78	2019.07.22	Meeting 10	Report Structure
FOI 79	2019.07.22	Meeting 10	Getting stakeholder feedback
FOI 80	2019.10.09	Meeting 11	Agenda
FOI 81	2019.10.09	Meeting 11	Minutes
FOI 82	2019.10.09	Meeting 11	Government and Ofgem Updates
FOI 83	2019.10.09	Meeting 11	EVET Update for Steering Group
FOI 84	2019.10.09	Meeting 11	Timeline To Completition, Presentation
FOI 85	2019.10.09	Meeting 11	Launch Media Plan
FOI 86	2019.10.09	Meeting 11	Reports Design
FOI 87	2019.10.09	Meeting 11	EVET Final Report Working Document – 2 October
FOI 88	2019.10.09	Meeting 11	Consolidated comments on Main Report
FOI 89	2020.01.08	Meeting 12	Agenda
FOI 90	2020.01.08	Meeting 12	One Birdcage Walk, Westminster, EV Energy Taskforce report launch: Q&As for participants

Reference	Date	Meeting	Title
FOI 91	2020.01.08	Meeting 12	EVET 2.0 Terms of Reference, Draft
FOI 92	2020.01.08	Meeting 12	Priority Area: Linking Smart Meters/Smart Charging
FOI 93	2020.01.08	Meeting 12	Priority Area: Link to standards/Publicly Available Standards for Demand Side Management
FOI 94	2020.01.08	Meeting 12	Priority Area: Classification/assessment of evolving smart charging capabilities
FOI 95	2020.01.08	Meeting 12	Priority Area: Interoperability roaming
FOI 96	2020.01.08	Meeting 12	Priority Area: Pilot/trial at scale to test EVET proposals
FOI 97	2020.01.08	Meeting 12	EVET Steering Group Meeting Agenda
FOI 98	2020.01.08	Meeting 12	Minutes 10 Oct 2019
FOI 99	2020.03.16	Meeting 13	Agenda
FOI 100	2020.03.16	Meeting 13	Minutes 8 Jan 2020
FOI 101	2020.03.16	Meeting 13	Minutes 16 Mar 2020
FOI 102	2020.03.16	Meeting 13	Launch Communications Media, Presentation
FOI 103	2020.03.16	Meeting 13	WP1 Report (Strategic Understanding)
FOI 104	2020.03.16	Meeting 13	WP2 Report (Engaging Users in Smart Charging and Energy Services)
FOI 105	2020.03.16	Meeting 13	WP3 Report (Technical Requirements of Smart Charging)
FOI 106	2020.03.16	Meeting 13	WP4 Report (Accessible data for decision making)
FOI 107	2020.03.16	Meeting 13	EVET 2.0 Project Proposal
FOI 108	2020.04.28	Meeting 14	Minutes 16 Mar 2020
FOI 109	2020.04.28	Meeting 14	Agenda
FOI 110	2020.04.28	Meeting 14	EVET Stakeholder Feedback, Presentation
FOI 111	2020.04.28	Meeting 14	EVET 2 Proposal Review, Presentation
FOI 112	2020.04.28	Meeting 14	EVET Proposal Status Assessment
FOI 113	2020.06.02	Meeting 15	Minutes 28 Apr 2020
FOI 114	2020.06.02	Meeting 15	EVET 2 Prioritisation Process, Presentation
FOI 115	2020.06.02	Meeting 15	Requirements capture approach, Catapult Presentation
FOI 116	2020.06.02	Meeting 15	EVET2.0 Launch Media Plan
FOI 117	2020.06.02	Meeting 15	EVET Additional Members

Appendix 3. Participant Information Sheet, Consent Form, Interview Schedule

Sustainable Motoring, Renewable Energy and Renewable Fuels: the role of the automotive industry

Ural Arslangulov

Doctoral Researcher, Nottingham Business School,

Nottingham Trent University

Participant Information Sheet

Thank you for agreeing to consider participating in this research project. Before you decide whether to grant me an interview, it is important that you understand the reasons why this research is being carried out, and what your participation will involve. Please take the time to read the following information carefully. If you have any questions at all, please ask me.

What is the purpose of the research?

This study arises from the growing interest in government plans to implement an industrial strategy and transform the transport sector by 2040. The main purpose of the research is to develop a new conceptual model for assessing the impact of policymakers' decisions on the technological choices of carmakers for low carbon transitions in the UK. The study includes cases of policymakers and companies from the automotive and related industries.

The importance of the research is that the new theory will help policymakers reconfigure the transport sector more effectively, by involving incumbent actors and new entrants in the low-carbon transitions process, at the same time creating windows of opportunity for emerging technological innovation companies to break out of their niches. From the firms' perspective, understanding policymakers' governance strategy in the industry will help them to anticipate preferable technological choices that may be required in the future to respond to policy signals and develop R&D strategies for the reconfiguration of the UK transport sector.

Why have I been chosen to take part?

I am approaching you for an interview because of your role and position as a key stakeholder. Your expertise and insights will provide me with important information for my research on sustainability transitions in the transport sector and will help in assessing impact of policymakers' decisions on companies' technological choices. In addition, our meeting will allow me to examine whether any changes are necessary to the study itself.

What do you want me to do?

I would like you to take part in a semi-structured interview lasting approximately 30 minutes. It will take place at your workplace or via Skype/phone, and will be arranged at a time convenient for you. The topics to be covered are set out on the attached interview schedule. These questions show the core set of issues I would like to address in my interview with you, but other questions may be asked as the conversation flows.

Do I have to take part?

You are free to take part or not without giving any reason. You can skip any question you do not want to answer, and you can stop the interview entirely at any point, if you so wish. If you decide to take part, you will be given an interview schedule and this information sheet to keep, and you will also be asked to sign a consent form.

How can withdraw my data if I change my mind later?

You will be free to withdraw your data during the interview, and for up to **four weeks** afterwards, without needing to give a reason. Each consent form has the "Unique identifier" line at the top. Please choose a **unique identifier** that includes **six random letters and two digits**. This unique identifier will be assigned to all your data and files. If you wish then to withdraw your data from the project, please contact me, quoting this identifier. I will then send a confirmation email when I receive the unique identifier to confirm your data have been destroyed.

What will happen to the information I give in my interview?

I shall ask for your written permission to audio record the interview, purely to ensure that the information you give me is transcribed accurately. Otherwise I shall take written notes. The audio recording of the interview will be transcribed and used in my research to determine theoretical concepts and key phenomena of the study. Interview data will be used in my PhD thesis and in publications related to this research. I shall also publish a short, executive summary of the results and recommendations and circulate it amongst participants. The transcription will be undertaken by a professional service. The external provider adheres to the General Data Protection Regulation and the Data Protection Act 1998. It also complies with the guidance of the UK Information Commissioner's Office. In addition, the external provider holds current ISO 9001 Certification. It is thus fully compliant with NTU Data Management Policy.

How will I handle confidentiality and data security issues?

For transcription purposes, interview recordings will be encrypted and saved on a USB flash drive secured with a PIN code. The flash drive and consent forms will be stored at home in a locked desk. The laptop will be protected by an antivirus and password. To prevent theft of the laptop in my absence at the workplace, the laptop will be fixed to a desk with a barrel lock security cable. I will never leave my laptop unattended outside Nottingham Trent University. I shall only store the data in the office in a lockable cupboard. When working on an NTU PC, all data analysis files will be stored on a USB flash drive with PIN code. The audio recording device will never be left unattended in public places when it contains interview recordings. The audio data will be encrypted for transcription and saved on the home flash drive and then deleted from the recorder.

At what stage will the data be anonymised and how will this be done?

In the interview, no personal information will be recorded. No names will be used in any publications arising from this research. Under the assumption of anonymity, I shall assign you and all participants pseudonyms, unless you give explicit permission for me to use your name in my research outputs. Direct quotations may be used. It is in theory possible that some people may be able to infer your identity from a direct quote. Direct quotes will, therefore only be chosen for use where this indirect identification cannot occur. I shall write up my research in such a way as to minimise the chances of this happening – but I cannot offer an absolute, 100%, guarantee of total anonymity.

How long will the data be retained?

The interview recordings will be destroyed as soon as they have been transcribed. Interview transcripts will be retained by myself with the unique identifiers attached, until all research outputs from the project have been written. This period will not exceed 10 years. At that point, all remaining materials, including emails, consent forms, etc, that have not been fully anonymised, will be destroyed. In addition, in accordance with government Open Data policy, fully anonymised versions of the transcriptions, with identifiers removed, will be made publicly available by the end of the PhD studies. Under these guidelines, selected redaction is permissible in order to preserve participant anonymity.

Who will have access to the data?

Myself and my supervisors, who are fully informed about the confidential nature of the data. We shall not discuss the non-anonymised information with anybody. The audio recordings will be transcribed by an external service provider, under conditions of confidentiality outlined above.

What are the possible disadvantages and risks in taking part?

The main cost to you will be the time needed to be interviewed. I hope, however, that you will find the interview and the research topic interesting.

Contacts for further information

Please feel free to contact me about the research project at the following address. If you have any further questions, you can also contact my Director of Studies, Professor Rob Ackrill. Our contact details are provided at the end of the Consent Form.

Sustainable Motoring, Renewable Energy and Renewable Fuels: the role of the automotive industry

CONSENT FORM

Unique identifier:

Please read and confirm your consent to being interviewed for this research by ticking the appropriate box(es) and signing and dating this form

1. I confirm that the purpose of the research has been explained to me, that I have been given information about it in writing, and that I have had the opportunity to ask questions about the research. ☐
2. I understand that my participation is voluntary, and that I am free not to answer individual questions during the interview, to withdraw from the interview, and to withdraw my data from the project up to **four weeks** after the interview, if I change my mind about participation, without needing to give a reason. ☐
3. I give permission for the interview (either in person or Teams/Skype/phone) to be audio recorded by the researcher either by using an audio recording device (if in person/phone) or audio recording software (if Teams/Skype/phone). ☐
4. I give permission for the recorded audio to be transcribed by an external service provider and I understand that I can request to see a copy of the confidentiality agreement provided by the external service provider. ☐
5. I understand that anonymity is the default, so by checking this box I give permission for you to use my name, without a pseudonym, in your outputs. ☐
6. I agree to take part in this research and I am 18 or over. ☐

Name of participant	Date	Signature

Ural Arslangulov

Name of researcher	Date	Signature

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Semi-structured interview schedule
Code Assigned:

Research title: **Sustainable Motoring, Renewable Energy and Renewable Fuels: the role of the automotive industry**

Principal investigator: Ural Arslangulov, N0762565@my.ntu.ac.uk, Doctoral School, Nottingham Trent University.

Director of study: Professor Robert Ackrill, robert.ackrill@ntu.ac.uk, Department of Economics, Nottingham Business School, Nottingham Trent University, T: 0115 848 4234.

1. Interview introduction

The interview will take 40 minutes.

The main purpose of the interview is to discuss the optimal technological responses of carmakers in response to the demands of decarbonization.

2. List of questions

1. Do you agree to take part in this interview?

2. In your opinion, what are the prospects for autonomous vehicles in the field of personal mobility in the medium term?

3. How can decarbonisation policies change the business model of carmakers?

4. In your opinion, what is the optimal technological response of carmakers to the decarbonisation policies?

5. In your opinion, are the environmental and technological considerations of policymakers, energy companies and carmakers mutually reinforcing, or mutually exclusive?

6. Why sustainability transitions have taken place in the last decade?

7. Is there anything else that you would like to add that we have not covered, or that you would like to say more about?

Appendix 4. Hierarchy of Codes and Coding Grids

The hierarchy of codes shows the relationship between open codes, subcategories and categories of open codes which assign focused codes and the theoretical code that is discussed in a specific section of the chapter. The theoretical code can link subcategories of open codes and categories of open codes. This approach aligns with Bryant (2017) and Charmaz (2006) coding procedure discussed in Chapter 3.

The coding grid of theoretical codes shows the relationships between theoretical codes through cross-cutting open codes that are part of both theoretical codes. For example, in Table 2 Toyota Prius 3rd and Nissan Leaf are cross-cutting open codes and they are parts of both Incumbent level (a subcategory of theoretical code Automotive Industry Trajectory) and Technological Window of Opportunity (theoretical code) theoretical codes. This indicates that these cross-cutting open codes have relevance across multiple theoretical codes and can help to build relationships between them.

Table 1 Hierarchy of Codes of Automotive Industry Trajectory

Open Codes	**Subcategories of Open Codes (Focused codes/Concepts)**	**Categories of Open Codes (Focused codes/Concepts)**	**Theoretical code**
London Ultra Low Emission Zone expansion	Local Level	Governance level	Automotive industry trajectory
Road to Zero	National Level		
Directive 2009/33/EC	EU Level		
Paris Agreement	International Level		
Tesla Model-Y Jaguar I-Pace VW ID.4 Porsche Taycan	EV	Incumbent level	
Toyota Prius 3th Tpyota Auris Toyota Prius 4th Mitsubishi PHEV LEVC	HEV		
Nissan Leaf Chevrolet Volt Toyota Mirai FCEV Tesla Roadster	-	Technological market niche	
Toyota Prius 3th Tpyota Auris	-	Technological Window of Opportunity (2010)	

Open Codes	**Subcategories of Open Codes (Focused codes/Concepts)**	**Categories of Open Codes (Focused codes/Concepts)**	**Theoretical code**
Nissan Leaf Chevrolet Volt			
Toyota Prius 4th Mitsubishi PHEV Toyota Mirai FCEV Tesla Model X	-	Technological Window of Opportunity (2016)	
Tesla Model-Y Jaguar I-Pace LEVC	-	Problem Window of Opportunity (2018)	
Road to Zero	-	Policy Window of Opportunity (2018)	
VW ID.4 Porsche Taycan	-	Market Window of Opportunity (2020	

Table 2 Coding Grid of Theoretical Code - Automotive Industry Trajectory

Catego-ries / Subcategories	Technological Window of Opportunity (2010)	Technological Window of Opportunity (2016)	Problem Window of Opportunity (2018)	Policy Window of Opportunity (2018)	Market Window of Opportunity (2020)
Local Level					
National Level				Road to Zero	
EU Level					
International Level					
EV			Tesla Model-Y Jaguar I-Pace		VW ID.4 Porsche Taycan
HEV	**Toyota Prius 3rd** Tpyota Auris	Toyota Prius 4th Mitsubishi PHEV	LEVC		
Technological market niche	**Nissan Leaf** Chevrolet Volt	Toyota Mirai FCEV Tesla Model X	Autonomous Vehicles (Level 4-5) 2018		

Note: colours of rows reflect the category of codes to which subcategories of codes are related

Table 3 Hierarchy of Codes of Energy Supply Trajectory

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Nottingham Energy Strategy 2010-2020	Local Level	Governance level	Energy Supply Trajectory
Renewables Obligation Order No.785	National Level	Governance level	Energy Supply Trajectory
Directive 2003/96/EC Directive 2009/28/EC Directive 2009/72/EC	EU Level	Governance level	Energy Supply Trajectory
Paris Agreement Kyoto Protocol United Nations Framework Convention on Climate Change	International Level	Governance level	Energy Supply Trajectory
Tesla Solar Lightsource Access to Flexibility Markets	Energy supply	Incumbent level	Energy Supply Trajectory
Shell NewMotion BP Chargemaster Home Charging model, 2022	EV Infrastructure	Incumbent level	Energy Supply Trajectory
Chargemaster NewMotion Lightsource SolSource BetterPlace V2X	-	Technological market niche	Energy Supply Trajectory
Tesla Solar Lightsource Shell NewMotion BP Chargemaster	-	Technological Window of Opportunity (2010)	Energy Supply Trajectory
BetterPlace	-	Technological Window of Opportunity (2016)	Energy Supply Trajectory
Tipping points	-	Problem Window of Opportunity (2018)	Energy Supply Trajectory
Trigger points	-	Policy Window of Opportunity (2018)	Energy Supply Trajectory
-	-	Market Window of Opportunity (2020	Energy Supply Trajectory

Table 4 Coding Grid of Theoretical Code - Energy Supply Trajectory

Categories / Subcategories	Technological Window of Opportunity (2010)	Technological Window of Opportunity (2016)	Problem Window of Opportunity (2018)	Policy Window of Opportunity (2018)	Market Window of Opportunity (2020)
Local Level					
National Level					
EU Level					
International Level					
Energy supply		Tesla Solar, 2016 Lightsource BP Solar, 2017			
EV Infrastructure		Shell NewMotion, 2017 BP Chargemaster, 2018			
Technological market niche	Chargemaster, 2008 NewMotion, 2009 Lightsource, 2010 SolSource, 2009 BetterPlace (Battery Swap), 2012				

Note: colours of rows reflect category of codes to which subcategories of codes are related

Table 5 Hierarchy of Codes of Energy Storage Trajectory

Open Codes	**Subcategory of Codes**	**Category of codes**	**Theoretical code**
Deployment of alternative fuels infrastructure regulation 2016 LN.2016/222	Local Level	Governance level	Energy Storage Trajectory
Climate Change Act Renewable Transport Fuel Obligation 2007 (Amendments 2013, 2015, 2018, 2021) The Motor Fuel GNG Reporting Regulations 2012 No.3030	National Level	Governance level	Energy Storage Trajectory

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Directive 2003/30/EC Directive 2012/27/EU Directive 2014/94/EU Directive (EU) 2015/1513	EU Level	Governance level	Energy Storage Trajectory
Kyoto Protocol Paris Agreement United Nations Framework Convention on Climate Change	International Level	Governance level	Energy Storage Trajectory
Li-ion	Batteries	Incumbent level	Energy Storage Trajectory
Petrol fuel Diesel fuel Biodiesel Bioethanol Biogas	Motor Fuels	Incumbent level	Energy Storage Trajectory
Hydrogen Solid-state batteries Sodium-ion batteries Synthetic fuel Algae biofuel (3rd gen) Genetically modified algae (4th gen)	-	Technological market niche	Energy Storage Trajectory
Li-ion Isobutanol	-	Technological Window of Opportunity (2010)	Energy Storage Trajectory
Bioethanol Biomethane Hydrogen	-	Technological Window of Opportunity (2016)	Energy Storage Trajectory
Li-ion Hydrogen	-	Problem Window of Opportunity (2018)	Energy Storage Trajectory
-	-	Policy Window of Opportunity (2018)	Energy Storage Trajectory
-	-	Market Window of Opportunity (2020	Energy Storage Trajectory

Table 6 Coding Grid of Theoretical Code of the Energy Storage Trajectory

Categories / Subcategories	Technological Window of Opportunity (2010)	Technological Window of Opportunity (2016)	Problem Window of Opportunity (2018)	Policy Window of Opportunity (2018)	Market Window of Opportunity (2020)
Local Level					
National Level					
EU Level					
International Level					
Motor Fuels	Bioethanol Biodiesel	Bioethanol Biodiesel			
Batteries		Li-ion	Li-ion		
Technological market niche	Li-ion Hydrogen	Hydrogen	Hydrogen		

Note: colours of rows reflect category of codes to which subcategories of codes are related

Table 7 Hierarchy of Codes of the Problem Stream

Open Codes	Subcategories of Codes	Categories of codes	Theoretical code
Traffic on the roads 2019	Local Level	Governance level	Problem stream
Air Quality 2018 Energy Security2018	National Level	Governance level	Problem stream
Air Quality 2010 Energy Independency 2020	EU Level	Governance level	Problem stream
Climate Change 2016 Air Quality 2016	International Level	Governance level	Problem stream
Safe and secure smart charging, 2019 Supply of chargepoints, 2019 Data interoperability, 2020.03 Consumer protection, 2019 Charging costs, 2020 National coverage of accessible charge points 2020.03	EV, EV Infrastructure	Incumbent level	Problem stream

Open Codes	Subcategories of Codes	Categories of codes	Theoretical code
Procure flexibility services in time, 2020.03 Cost of EVs, 2020 Range anxiety 2020.03 Impact on BEV sales 2020.03			
Financial issues of HEV companies 2020 Job losses due to EV transitions 2018 Energy supply for EVs, 2019 Risk of power outages, 2020.03	HEV, Energy supply	Incumbent level	Problem stream
Lack of refuelling infrastructure FCEV 2019 Cost of technology FCEV 2019 Inefficient energy conversion hydrogen, 2020 Environmental impact hydrogen, 2020	-	Technological market niche	Problem stream
-	-	Technological Window of Opportunity (2010)	Problem stream
-	-	Technological Window of Opportunity (2016)	Problem stream
Energy supply for EVs, Safe and secure smart charging, 2019 Supply of chargepoints, 2019 Consumer protection, 2019 Job losses due to EV transitions 2018 Energy supply for EVs, 2019 Lack of refuelling infrastructure FCEV 2019 Cost of technology FCEV 2019	-	Problem Window of Opportunity (2018)	Problem stream
Traffic on the roads 2019	-	Policy Window of Opportunity (2018)	Problem stream

Open Codes	Subcategories of Codes	Categories of codes	Theoretical code
Air Quality 2018 Energy Security2018			
-	-	Market Window of Opportunity (2020	Problem stream

Table 8 Hierarchy of Codes of Policy Stream

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Establishment strategic planning 2020.03	Local Level	Governance level	Policy Stream
Electric vehicle smart charging Electric vehicle infrastructure strategy Establishment strategic planning 2020.03	National Level	Governance level	Policy Stream
	EU Level	Governance level	Policy Stream
	International Level	Governance level	Policy Stream
Delivering consumer benefits through interoperability Rewarding consumers for charging smartly Utilising and protecting data for better consumer outcomes Winning consumers' trust and confidence Developing and maintaining the charging infrastructure consumers need Communication protocol, 2021	EV, EV Infrastructure	Incumbent level	Policy Stream
Open up flexibility markets 2020.03	HEV, Energy Supply	Incumbent level	Policy Stream
	-	Technological market niche	Policy Stream
	-	Technological Window of Opportunity (2010)	Policy Stream
	-	Technological Window of Opportunity (2016)	Policy Stream

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Delivering consumer benefits through interoperability Rewarding consumers for charging smartly Utilising and protecting data for better consumer outcomes Winning consumers' trust and confidence Developing and maintaining the charging infrastructure consumers need	-	Problem Window of Opportunity (2018)	Policy Stream
Electric vehicle smart charging Electric vehicle infrastructure strategy	-	Policy Window of Opportunity (2018)	Policy Stream
-	-	Market Window of Opportunity (2020	Policy Stream

Table 9 Hierarchy of Codes of Politics Stream

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Public support of EVs, 2020-2021 Environmental awareness, 2019-2021	Local Level	Governance level	Politics Stream
Environmental awareness, 2019-2021 Public support of EVs, 2020 EV sales 11.47% of total 2021 Public support of HEVs, 2021 DfT Minister Support, 2020 BEIS Minister Support, 2019 MP Theresa May, July 13, 2016 MP Boris Johnson, 24 July 2019	National Level	Governance level	Politics Stream
	EU Level	Governance level	Politics Stream
	International Level	Governance level	Politics Stream

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Investments in EVs 2015 Joining EVET, 2018.06 Investments in EVs 2020.03 Investments in EV infrastructure 2020.03 Investments in battery tech. 2020.03	EV stakeholders	Incumbent level	Politics Stream
Joining EVET (SMMT), 2018 Lobbying ICE, 2017, 2020 Slowdown the EV transitions, 2017, 2019	HEV stakeholders	Incumbent level	Politics Stream
Mobility Open Innovations (Innovate UK), 2021	-	Technological market niche	Politics Stream
	-	Technological Window of Opportunity (2010)	Politics Stream
	-	Technological Window of Opportunity (2016)	Politics Stream
	-	Problem Window of Opportunity (2018)	Politics Stream
Public support of EVs, 2020 Public support of HEVs, 2021 DfT Minister Support, 2020 BEIS Minister Support, 2019 MP Theresa May, July 13, 2016 MP Boris Johnson, 24 July 2019 Joining EVET (SMMT), 2018 Mobility Open Innovations (Innovate UK), 2021	-	Policy Window of Opportunity (2018)	Politics Stream
	-	Market Window of Opportunity (2020	Politics Stream

Table 10 Hierarchy of codes of Technological Window of Opportunity (2010)

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Toyota Prius 3rd (2009) Toyota Auris Hybrid (2010)	HEV	Automotive Industry Trajectory	Technological Window of Opportunity
Nissan Leaf (2010) Chevrolet Volt (2010) Tesla Roadster (2008) BYD e6 (2009)	Technological market niche	Automotive Industry Trajectory	Technological Window of Opportunity
Tata Power 2012	Energy supply	Energy Supply Trajectory	Technological Window of Opportunity
Chargemaster 2008 NewMotion 2009 Better Place (battery swap, 2012) SolSource Energy 2009 Lightsource Renewable Energy 2010 Nissan, Endesa (EV inf), 2010 Tesla Supercharger 2012 BYD, 2008 (Solar)	Technological market niche	Energy Supply Trajectory	Technological Window of Opportunity
BP / DuPont JV Butamax Advanced Biofuels LLC (isobutanol) 2009 Shell Codexis, 2009 Biodiesel, 2010 Bioethanol, 2010	Alternative Motor Fuel	Energy Storage Trajectory	Technological Window of Opportunity
AESC (Nissan), GS Yuasa (Mitsubishi), (Li-ion), 2007 Hydrogen, 2010	Technological market niche	Energy Storage Trajectory	Technological Window of Opportunity

Table 11 Hierarchy of codes of Technological Window of Opportunity (2015)

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Toyota Prius 4th (2015)	HEV	Automotive Industry Trajectory	Technological Window of Opportunity
Tesla Model X (2015) Kia Soul EV (2014) VW e-Golf (2014)	EV	Automotive Industry Trajectory	Technological Window of Opportunity

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Toyota Mirai FCEV (2014)	Technological market niche	Automotive Industry Trajectory	Technological Window of Opportunity
Tesla Solar (2012)	Energy supply	Energy Supply Trajectory	Technological Window of Opportunity
Shell NewMotion (2017) BP Chargemaster (2018)	EV Infrastructure	Energy Supply Trajectory	Technological Window of Opportunity
Nesika Energy (ethanol) acquired by BP in 2017 Vivergo Fuels ABF 2015 Biodiesel, 2016 Bioethanol, 2016	Alternative Motor Fuel	Energy Storage Trajectory	Technological Window of Opportunity
Tesla Gigafactory 1, 2017 Li-ion, 2016	Battery	Energy Storage Trajectory	Technological Window of Opportunity
Shell UK hydrogen refueling station 2017 Hydrogen, 2016	Technological market niche	Energy Storage Trajectory	Technological Window of Opportunity

Table 12 Coding grid of theoretical code – Technological Window of Opportunity, 2010

Categories / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
HEV	Toyota Prius 3rd (2009) Toyota Auris Hybrid (2010)					
EV						
Energy supply		Tata Power 2012				
EV Infrastructure						
Alternative Motor Fuel			BP / DuPont JV Butamax Advanced Biofuels LLC (isobutanol) 2009 Shell Codexis, 2009 Biodiesel, 2010 Bioethanol, 2010			

Catego-ries / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
Battery						
Technological market niche	Nissan Leaf (2010) Chevrolet Volt (2010) Tesla Roadster (2008) BYD e6 (2009)	Chargemaster 2008 NewMotion 2009 Better Place (battery swap, 2012) SolSource Energy 2009 Lightsource Renewable Energy 2010 Nissan, Endesa (EV inf), 2010 Tesla Supercharger 2012 BYD, 2008 (Solar)	AESC (Nissan), GS Yuasa (Mitsubishi), (Li-ion), 2007 Hydrogen, 2010			

Note: colour codes of rows refer to the specific levels of industry trajectories: green - incumbent level, pink - technological niche level.

Table 13 Coding grid of theoretical code – Technological Window of Opportunity, 2015

Catego-ries / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
HEV	Toyota Prius 4th (2015)					
EV	Tesla Model X (2015)					
Energy supply		Tesla Solar (2012)				
EV Infrastructure		Shell NewMotion (2017) BP Chargemaster (2018)				

Catego-ries / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
Alternative Motor Fuel			Nesika Energy (ethanol) acquired by BP in 2017 Vivergo Fuels ABF 2015 Biodiesel, 2016 Bioethanol, 2016			
Battery			Tesla Gigafactory 1, 2017 Li-ion, 2016			
Technological market niche	Toyota Mirai FCEV (2014)		Shell UK hydrogen refueling station 2017 Hydrogen, 2016			

Note: colour codes of rows refer to the specific levels of industry trajectories: green - incumbent level, pink - technological niche level.

Table 14 Hierarchy of codes of Problem Window of Opportunity (2018)

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Jaguar I-Pace 2018 Tesla Model Y 2019 Porsche Taycan 2019 Aston Martin Rapid E 2020 Porsche Taycan 2019	EV	Automotive Industry Trajectory	Problem Window of Opportunity
LEVC 2018	HEV	Automotive Industry Trajectory	Problem Window of Opportunity

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Autonomous Vehicles (Level 4-5) 2018	Technological Market Niche	Automotive Industry Trajectory	Problem Window of Opportunity
Lightsource BP 43% Solar developer 2017	Energy supply	Energy Supply Trajectory	Problem Window of Opportunity
Shell NewMotion 2017 BP Chargemaster 2018	EV Infrastructure	Energy Supply Trajectory	Problem Window of Opportunity
V2X, V2G, 2020	Technological Market Niches	Energy Supply Trajectory	Problem Window of Opportunity
Li-ion, 2018 TotalEnergies, Chrysler, Daimler (Li-ion), 2021	Battery	Energy Storage Trajectory	Problem Window of Opportunity
Clean Energy Fuel Corp BP (biomethane) 2017 Petrol, 2018 Diesel, 2018 Biodiesel, 2018 Bioethanol, 2018 Biogas, 2018	Motor Fuels	Energy Storage Trajectory	Problem Window of Opportunity
Solid-state batteries, 2018 Sodium-ion batteries, 2020 Synthetic fuel, 2020 Algae biofuel (3rd gen) , 2020 Genetically modified algae (4th gen), 2020 Hydrogen, 2018	Technological Market Niches	Energy Storage Trajectory	Problem Window of Opportunity
Air quality, 2018 Energy security, 2018	National Level	Problem Stream	Problem Window of Opportunity
Traffic on the roads, 2019	Local Level	Problem Stream	Problem Window of Opportunity
Financial issues, 2020 Necessity of compromise solution (Plug-in hybrid range-extender taxis), 2018 Job losses due to EV transitions, 2018	HEV	Problem Stream	Problem Window of Opportunity
Energy supply for EVs, 2019 Consumer protection, 2019	EV	Problem Stream	Problem Window of Opportunity

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Safe and secure smart charging, 2019 Charging costs, 2020 Supply of chargepoints, 2019 Costs of EVs, 2020 Data interoperability, 2019 Universal charging systems, 2019			
Lack of refueling infrastructure, FCEV, 2019 Cost of technology, FCEV, 2019 Inefficient energy conversion, Hydrogen, 2020 Environmental impact, Hydrogen, 2020	Technological Market Niches	Problem Stream	
Electric vehicle smart charging, 2021 EV Infrastructure, 2021	National Level	Policy Stream	Problem Window of Opportunity
	Local Level	Policy Stream	Problem Window of Opportunity
	HEV	Policy Stream	Problem Window of Opportunity
Delivering consumer benefits through interoperability, 2021 Rewarding consumers for charging smartly, 2021 Protocol, Smart Charging, 2021 Utilising and protecting data for better consumer outcomes, 2021 Winning consumers' trust and confidence, 2021 Developing and maintaining the charging infrastructure consumers need, 2021	EV	Policy Stream	Problem Window of Opportunity

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
MP Theresa May, July 13, 2016 Resignation of PM Theresa May, election of Boris Johnson, 24 July 2019 Environmental awareness, 2019-2021 Public support of HEVs, 2021 Public support of EVs, 2020 DfT Minister Support, 2020 BEIS Minister Support, 2019 Public support of HEVs, 2021	National Level	Politics Stream	Problem Window of Opportunity
Public support of EVs, 2020-2021 Environmental awareness, 2019-2021	Local Level	Politics Stream	Problem Window of Opportunity
Joining EVET (SMMT, HEV carmakers), 2018 Lobbying ICE, 2017 Slowdown the EV transitions, 2017 Lobbying ICE, 2020 Slowdown the EV transitions, 2019	HEV	Politics Stream	Problem Window of Opportunity
Joining EVET (SMMT, EV carmakers), 2018.06	EV	Politics Stream	Problem Window of Opportunity

Table 15 Coding Grid of Theoretical Code – Problem Stream

Catego-ries / Subcate-gories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
International Level						
EU Level						

Catego-ries / Subcate-gories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
National Level				Air quality, 2018 Energy security, 2018	Electric vehicle smart charging, 2021 EV Infrastructure, 2021	MP Theresa May, July 13, 2016 Resignation of PM Theresa May, election of Boris Johnson, 24 July 2019 Environmental awareness, 2019-2021 Public support of HEVs, 2021 Public support of EVs, 2020 DfT Minister Support, 2020 BEIS Minister Support, 2019 Public support of HEVs, 2021
Local Level				Traffic on the roads, 2019		Public support of EVs, 2020-2021 Environmental awareness, 2019-2021
HEV	LEVC 2018			Financial issues, 2020 Necessity of compromise solution (Plug-in hybrid range-extender taxis), 2018 Job losses due to EV transitions, 2018		Joining EVET (SMMT, HEV carmakers), 2018 Lobbying ICE, 2017 Slowdown the EV transitions, 2017 Lobbying ICE, 2020

Catego-ries / Subcate-gories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
						Slowdown the EV transitions, 2019
EV	Jaguar I-Pace 2018 Tesla Model Y 2019 Porsche Taycan 2019 Aston Martin Rapid E 2020 Porsche Taycan 2019			Energy supply for EVs, 2019 Consumer protection, 2019 Safe and secure smart charging, 2019 Charging costs, 2020 Supply of chargepoints, 2019 Costs of EVs, 2020 Data interoperability, 2019 Universal charging systems, 2019	Delivering consumer benefits through interoperability, 2021 Rewarding consumers for charging smartly, 2021 Protocol, Smart Charging, 2021 Utilising and protecting data for better consumer outcomes, 2021 Winning consumers' trust and confidence, 2021 Developing and maintaining the charging infrastructure consumers need, 2021	Joining EVET (SMMT, EV carmakers), 2018.06
Energy supply		Lightsource BP 43% Solar developer 2017				

Catego-ries / Subcate-gories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
EV Infrastructu-re		Shell NewMotion 2017 BP Chargemaste r 2018				
Motor Fuel			Clean Energy Fuel Corp BP (biomethane) 2017 Petrol, 2018 Diesel, 2018 Biodiesel, 2018 Bioethanol, 2018 Biogas, 2018			
Battery			Li-ion, 2018 TotalEnergie s, Chrysler, Daimler (Li-ion), 2021			
Technologic al market niche	Autonomou s Vehicles (Level 4-5) 2018	V2X, V2G, 2020	Solid-state batteries, 2018 Sodium-ion batteries, 2020 Synthetic fuel, 2020 Algae biofuel (3rd gen) , 2020 Genetically modified algae (4th gen), 2020 Hydrogen, 2018	Lack of refueling infrastructure, FCEV, 2019 Cost of technology, FCEV, 2019 Inefficient energy conversion, Hydrogen, 2020 Environmental impact, Hydrogen, 2020		

Table 16 Hierarchy of Codes of Policy Window of Opportunity (2018)

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Vehicles exempt from Vehicle Excise Duty, 2018 Industrial strategy 2017.11 Automated and Electric Vehicles Act, 2018.07 Road to Zero strategy 2018.07 Air Quality Plan for Nitrogen Oxide in the UK, 2017	National Level	Automotive Industry Trajectory	Policy Window of Opportunity
London Ultra Low Emission Zone, 2019	Local Level	Automotive Industry Trajectory	Policy Window of Opportunity
On-Street Residential Chargepoint Scheme 2017 Industrial strategy 2017	National Level	Energy Supply Trajectory	Policy Window of Opportunity
-	Local Level	Energy Supply Trajectory	Policy Window of Opportunity
Renewable Transport Fuel Obligation (Amendment), 2018 Alternative Fuels Infrastructure Regulations 2017 No. 897	National Level	Energy Storage Trajectory	Policy Window of Opportunity
-	Local Level	Energy Storage Trajectory	Policy Window of Opportunity
Air quality, 2018 Energy security, 2018	National Level	Problem Stream	Policy Window of Opportunity
Traffic on the roads, 2019	Local Level	Problem Stream	Policy Window of Opportunity
Electric vehicle smart charging, 2021 EV Infrastructure, 2021	National Level	Policy Stream	Policy Window of Opportunity
-	Local Level	Policy Stream	Policy Window of Opportunity
MP Theresa May, July 13, 2016 Resignation of PM Theresa May, election of Boris Johnson, 24 July 2019 Environmental awareness, 2019-2021	National Level	Politics Stream	Policy Window of Opportunity

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Public support of HEVs, 2021 Public support of EVs, 2020 DfT Minister Support, 2020 BEIS Minister Support, 2019 Public support of HEVs, 2021			
Public support of EVs, 2020-2021 Environmental awareness, 2019-2021	Local Level	Politics Stream	Policy Window of Opportunity

Table 17 Coding Grid of Theoretical Code – Policy Window of Opportunity, 2018

Catego-ries / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
International Level						
EU Level						
National Level	Vehicles exempt from Vehicle Excise Duty, 2018 Industrial strategy 2017.11 Automated and Electric Vehicles Act, 2018.07 Road to Zero strategy 2018.07 Air Quality Plan for Nitrogen Oxide in the UK, 2017	On-Street Residential Chargepoint Scheme 2017 Industrial strategy 2017	Renewable Transport Fuel Obligation (Amendment), 2018 Alternative Fuels Infrastructure Regulations 2017 No. 897	Air quality, 2018 Energy security, 2018	Electric vehicle smart charging, 2021 EV Infrastructure, 2021	MP Theresa May, July 13, 2016 Resignation of PM Theresa May, election of Boris Johnson, 24 July 2019 Environmental awareness, 2019-2021 Public support of HEVs, 2021 Public support of EVs, 2020 DfT Minister Support, 2020 BEIS Minister Support, 2019 Public support of HEVs, 2021

Categories / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
Local Level	London Ultra Low Emission Zone, 2019			Traffic on the roads, 2019		Public support of EVs, 2020-2021 Environmental awareness, 2019-2021
HEV						
EV						
Energy supply						
EV Infrastructure						
Alternative Motor Fuel						
Battery						
Technological market niche						

Note: colours of rows reflect the category of codes to which subcategories of codes are related

Table 18 Hierarchy of Codes of Market Window of Opportunity

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Aston Martin Rapid E 2020 VW ID.4 2022 Porsche Taycan 2019	EV	Automotive Industry Trajectory	Tipping Points
	HEV	Automotive Industry Trajectory	Tipping Points
	Energy supply	Energy Supply Trajectory	Tipping Points
BSI energy smart appliance standard PAS 1788 and 1789, 2021.05	EV Infrastructure	Energy Supply Trajectory	Tipping Points
V2X, V2G, 2020	Technological market niche	Energy Supply Trajectory	Tipping Points
TotalEnergies, Chrysler, Daimler (Li-ion), 2021 Li-ion, 2018	Battery	Energy Storage Trajectory	Tipping Points
	Motor Fuel	Energy Storage Trajectory	Tipping Points
Sodium-ion batteries, 2020	Technological market niche	Energy Storage Trajectory	Tipping Points

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Synthetic fuel, 2020 Toyota's Altona hydrogen plant 2020 Algae biofuel (3rd gen), 2020 Genetically modified algae (4th gen), 2020			
Inability to deliver flexibility services	Pre relevant tipping point	The first tipping point (2020) Problem Stream	Tipping Points
Reinforcement of connections	Post relevant tipping point	The first tipping point (2020) Problem Stream	Tipping Points
5% to 10%	BEV uptake	The first tipping point (2020)	Tipping Points
15% to 25%	BEV uptake	The second tipping point (2026)	Tipping Points
30% to 70%	BEV uptake	The third tipping point (2030)	Tipping Points
High level of private ownership High utilisation of home charging Overnight charging Consumer choices of EVs Consumer choices of charge points Consumer choices of electricity providers	Home Charging	The first tipping point (2020) The second tipping point (2026) The third tipping point (2030)	Tipping Points
High private ownership High usage of rapid charging Throughout the day charging High level of control by consumers Consumer choices of EVs Third-party choices of charge points Third-party choices of electricity providers	Filling Station	The second tipping point (2026) The third tipping point (2030)	Tipping Points
Low private ownership High uptake of MaaS	Taxi/Car Sharing	The second tipping point (2026)	Tipping Points

Open Codes	Subcategory of Codes	Category of codes	Theoretical code
Consumer choices of charge posts Fleet managers choices of EVs Fleet managers choices of electricity providers		The third tipping point (2030)	
Low private ownership High uptake of MaaS Returning to base to charge Consumer choices of times to charge vehicles Fleet managers choices of EVs Fleet managers choices of electricity providers Fleet managers choices of charger posts	Hive/Depot-based	The second tipping point (2026) The third tipping point (2030)	Tipping Points

Table 19 Coding grid of theoretical code – Market Window of Opportunity (2020)

Catego-ries / Subcategories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
International Level						
EU Level						
National Level						
Local Level						
HEV						
EV	Aston Martin Rapid E 2020 VW ID.4 2022 Porsche Taycan 2019					
Energy supply						
EV Infrastructure						
Alternative Motor Fuel						

Subcategories \ Categories	Automotive Industry Trajectory	Energy Supply Trajectory	Energy Storage Trajectory	Problem Stream	Policy Stream	Politics Stream
Battery			TotalEnergies, Chrysler, Daimler (Li-ion), 2021 Li-ion, 2018			
Technological market niche		V2X, V2G, 2020	Sodium-ion batteries, 2020 Synthetic fuel, 2020 Toyota's Altona hydrogen plant 2020 Algae biofuel (3rd gen), 2020 Genetically modified algae (4th gen), 2020			

Note: colours of rows reflect the category of codes to which subcategories of codes are related

Appendix 5. NVivo Codes

At the stage of open coding, 1621 codes were generated, which were grouped into 64 subcategories and 17 categories. Figure 1 and Figure 2 show the categories of open codes - nodes of the first level and subcategories - nodes of the 2nd level. Nodes of the third level - contain quotations from the interviews and can also contain subcategories.

The coding was carried out in NVivo. NVivo project can be downloaded following the link:

https://www.dropbox.com/sh/6xdqil23zhwy07o/AABUUDk6nyCu33D9Skaza3P5a?dl=0

NVivo project file name is "Data analysis.nvp". Apart from the open codes, subcategories of codes, categories of codes and direct quotations the file also contains anonymised interview transcripts.

- Mutually reinforcing and mutually exclusive considerations
  - Carmakers and energy companies
  - Policymakers and carmakers
  - Policymakers and energy companies
- Opening windows of opportunity for widespread adoption of EVs
  - Window of opportunity opened several times for EVs
- Optimal responce of energy companies to decarbonisation policies
  - Continue the aggressive decarbonisation
  - Diversification of energy companies in auto industry
  - Energy sector had a massive shift from oil and coal, particularly towards wind
- Optimal responce of fuel companies to decarbonisation policies
  - [Diversification] transformation
  - Margin and Acquisition EV infrastructure comp
  - They could generate and supply energy. They've got the capital to do it.
- Optimal response of carmakers to decarbonisation policies
  - Strategic responce
- Promotion of auto transport
  - Electric cars
- Role of policymakers
  - Make sure that policy environment helping to make sustainability transitions happen
- Solutions for achieving zero emissions
  - Technologies are quite good at solving issues
  - Zero emission vehicles is a solution make it easier to achieve net zero

Figure 1 Categories and subcategories of open codes NVivo

Name

- Battery manufacturing
  - Battery Manufacturing Strategies debate
  - Cost
  - Deversification of battery manufacturers into auto industry
  - Obstacles to scale up
  - Powerwalls
  - Raw materials
  - Second-life applications and using cells
  - The government needs to do more to support British or battery and cell manufacturers to compete with China
- Challenges for Zero Emission agenda
  - Alignment between different policies
  - Alignment between the decarbonisation policy in transport and manufacturing agenda is important
  - Biofuel industry
  - Challenges associated with BEV
  - Energy sector
  - Hybrids
  - Implementation of Road to Zero policy
  - It might not be fast enough
  - Technological neutrality
  - Transition of the whole fleet from one form of power to another form of power
- Challenges, issues, strands for carmakers
  - Brexit
  - Chinese manufacturer, New OEMs
  - Manufacturing competitiveness
  - Technology transformation
- Experience of using EV
  - Electric vehicle ownership or use, forces the consumer to think about energy in a different way
- Factors intensified sustainability transition
  - [Problems] First there is a problem that needs to be solved
  - [Public opinion] Public opinion in sustainable transitions
  - [Public policies] Public policy in sustainability transitions
  - [Techno-economic factors] Readiness of technology at an economic scale
  - Anticipation
  - Factors are iterative
  - Financial markets not interested in finance high carbone infrastructure and I think they are more dominant than policy now
  - Hybridisation of vehicles
  - International regulation in sustainability transitions
  - Mutually reinforcing and considerations of carmakers and energy companies
  - NGO activities
  - Policy guys are now realizing that closing one industry doesn't necessarily mean loss of jobs, it actually means new opportunities
- Financing Road to Zero
  - If governemnt can provide financial incentives for car manufacturers or users, people will switch to more cleaner ways of traveling
  - The consumer is paying
- Future of internal combustion engines
  - Dropped down by 25% - 40%
  - I don't see internal combustion engine beyond another 50 years
  - In short terms they will be in the market
  - It will be reduced after 10 years for 10% - 15%
  - They will be phased out eventually, but I think it will be a long process to do it (Maybe 30, 40 years)
- Imagining transitions
  - To develop some revolutionary technologies first to make cheaper reliable and safe after that it start to develop very very to quickly
  - Won't be instantaneous quick transformation. Smooth and organic transitions towards this electric vehicles and other renewable sources
- Link between automotive, fuel and energy industries
  - Discussion about technical feasibility between multiple industries and government is a link
  - Electric ecosystem
  - Innovation takes place where mobility, transport, and energy sectors meet
  - Policymakers don't need to be part of the entire conversation between related industries
  - Shell and BP decarbonise because have been told by their money people

Figure 2 Categories and subcategories of open codes NVivo (continue)

Appendix 6. List of EVET Stakeholders

Work Package	Company	EVET classifier	Research classifier	WP Role
Steering Group	Automotive Council UK			
Steering Group	BEAMA (British Electrotechnical and Allied Manufacturers' Association)			
Steering Group	BEIS Energy Team			
Steering Group	ENA (Energy Network Association)			
Steering Group	Energy UK			
Steering Group	EVSE (EV Supply Equipment Trade Association)			
Steering Group	HMT			
Steering Group	LowCVP (as secretariat)			
Steering Group	National Grid			
Steering Group	Ofgem			
Steering Group	OLEV			
Steering Group	SMMT (Society of Motor Manufacturers and Traders)			
Steering Group	TechUK			
Steering Group	ESC CEO			
WP1	The AA		Automotive Association	
WP1	RAC Foundation		Automotive Research and Advocacy Organization	
WP1	BMW		Carmaker	
WP1	Nissan		Carmaker	
WP1	Tesla		Carmaker	
WP1	UPS		Delivery and Logistics Company	
WP1	Charging Around Britain Ltd		Electric Vehicle Charging Company	
WP1	Engenie		Electric Vehicle Charging Company	
WP1	Pod Point		Electric Vehicle Charging Company	
WP1	Nuvve		Electric Vehicle Charging Company (vehicle-to-grid (V2G) technology)	
WP1	ABB		Electrical equipment manufacturing, robotics and	

Work Package	Company	EVET classifier	Research classifier	WP Role
			automation technology/Multinational Corporation	
WP1	Gemserv		Energy and Information Services Company (consulting and governance within the energy, sustainability, cyber security and data protection sectors)	
WP1	Innogy		Energy Company	
WP1	National Grid (ESO)		Energy Company	
WP1	National Grid (TO)		Energy Company	
WP1	Vattenfall		Energy Company	
WP1	Octopus Electric Vehicles		Energy Company/Electric Vehicle Charging Company/Electric vehicle leasing	
WP1	Cornwall Insight		Energy Consultancy	
WP1	Energy Systems Catapult		Energy Research and Development Company	Work package leader
WP1	Delta Energy & Environment		Energy Services Company	
WP1	ELEXON Ltd		Energy Services Company	
WP1	Ricardo Energy & Environment		Energy Services Company	
WP1	Drivenergy Ltd		Energy Services Company (EV charging solutions to the automotive industry, fleets, hospitality and private customers)	
WP1	EA Technology Ltd		Energy Services Company (provider of end-to-end power engineering solutions, Asset Management)	
WP1	ESB Networks		Energy Utility Company	
WP1	Northern Ireland Electricity Networks		Energy Utility Company	
WP1	Northern Powergrid		Energy Utility Company	
WP1	Scottish and Southern Electricity Networks		Energy Utility Company	
WP1	UK Power Networks		Energy Utility Company	
WP1	Western Power Distribution		Energy Utility Company	
WP1	Burns & McDonnell		Engineering, Architecture and Construction Firm	
WP1	Aviva Investors		Financial Services Company	
WP1	HSBC		Financial Services Company	
WP1	Geo Together		Geographical Information Systems Company	

Work Package	Company	EVET classifier	Research classifier	WP Role
WP1	OLEV		Government Agency to support the early market for ultra-low emission vehicles	
WP1	BEIS		Government Department	
WP1	CMS Cameron McKenna Nabarro Olswang LLP		Law Firm	
WP1	Eversheds Sutherland (International) LLP		Law Firm	
WP1	Pinsent Masons LLP		Law Firm	
WP1	Greater London Authority		Local Government Authority	
WP1	Siemens		Multinational Corporation (Digital Industries, Smart Infrastructure, Mobility, Healthcare and Financial Services)	
WP1	Schneider Electric		Multinational Corporation (specializes in digital automation and energy management)	
WP1	Eaton		Power management company/Multinational Corporation	
WP1	Ofgem		Regulator for electricity market	
WP1	Renewable Energy Association		Renewable Energy Trade Association in the UK	Additional contribution
WP1	Intel		Technology Corporation	
WP1	BEAMA		Trade Association for manufacturers and providers of energy infrastructure technologies and systems	
WP1	Energy Networks Association (ENA)		Trade Association for the energy industry	
WP1	UKPIA		Trade Association in refining, renewable fuel production, terminal operations and filling stations	
WP1	Imperial College London		University	
WP1	Newcastle Uni (CESI)		University	
WP2	Lex Autolease		Automotive Leasing Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	Auto Lex	Fleet	Automotive Leasing Company	
WP2	RAC Foundation		Automotive Research and Advocacy Organization	The organisations represented at the Work Package 2

Work Package	Company	EVET classifier	Research classifier	WP Role
				six weekly meetings
WP2	Nissan	Auto	Carmaker	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	BMW	Auto	Carmaker	The organisations represented at the Work Package 2 six weekly meetings
WP2	Tesla	Auto	Carmaker	The organisations represented at the Work Package 2 six weekly meetings
WP2	Citizens Advice	Customer	Charity (independent organisation specialising in confidential information and advice to assist people with legal, debt, consumer, housing and other problems in the United Kingdom)	Topic leads
WP2	Which?	Customer	Consumer Advocacy Organization	
WP2	UPS	Fleet	Delivery and Logistics Company	
WP2	Engenie		Electric Vehicle Charging Company	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	EV Driver		Electric Vehicle Charging Company	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	Ev.energy		Electric Vehicle Charging Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	Pod Point	Charge	Electric Vehicle Charging Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	ChargePoint	Charge	Electric Vehicle Charging Company	Topic leads
WP2	Drive Electric		Electric Vehicle Charging Company	

Work Package	Company	EVET classifier	Research classifier	WP Role
WP2	ABB	Tech	Electrical equipment manufacturing, robotics and automation technology/Multinational Corporation	
WP2	Gemserv		Energy and Information Services Company (consulting and governance within the energy, sustainability, cyber security and data protection sectors)	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	Centrica		Energy Company	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	EDF Energy		Energy Company	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	British Gas	Fleet	Energy Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	National Grid Electricity Transmission		Energy Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	National Grid, Electricity System Operator (ESO)		Energy Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	Zenith	Fleet	Energy Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	National Grid (SO)	Grid	Energy Company	
WP2	Vattenfall	Charge	Energy Company	
WP2	Octopus Energy	Energy	Energy Company/Energy Services Company	
WP2	Kaluza		Energy Management Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	Zenobe		Energy Management Company	The organisations represented at the

Work Package	Company	EVET classifier	Research classifier	WP Role
				Work Package 2 six weekly meetings
WP2	Energy Systems Catapult		Energy Research and Development Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	The Future of Transport (TRL)	Academic	Energy Research and Development Company	
WP2	OVO Energy	Energy	Energy Services Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	UK Power Networks (UKPN)		Energy Utility Company	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	Npower	Energy / Charge	Energy Utility Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	Western Power Distribution (WPD)	Grid	Energy Utility Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	Scottish and Southern Electricity Networks	Grid	Energy Utility Company	Topic leads
WP2	E.ON		Energy Utility Company	
WP2	Scottish and Southern Electricity Networks (SSEN)		Energy Utility Company	
WP2	ScottishPower		Energy Utility Company	
WP2	geo		Geographical Information Systems Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	CGI		Information Technology and Business Process Services Company	
WP2	Greater London Authority (GLA)	Local Authority	Local Government Authority	Additional organisations that fed into Work Package 2 through workshops or interviews

Work Package	Company	EVET classifier	Research classifier	WP Role
WP2	Energy Saving Trust		Non-Profit Organization	The organisations represented at the Work Package 2 six weekly meetings
WP2	Smart Energy GB		Non-Profit Organization (helping everyone in Britain to understand the importance of smart meters and their benefits to people and the environment.)	The organisations represented at the Work Package 2 six weekly meetings
WP2	Shell	Energy / Charge	Oil and Gas Multinational Corporation	Topic leads
WP2	Royal Mail		Postal Services	
WP2	Ofgem	Gov	Regulator for electricity market	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	Renewable Energy Association (REA)		Renewable Energy Trade Association in the UK	Additional organisations that fed into Work Package 2 through workshops or interviews
WP2	Waitrose	Fleet	Retail/Multinational Corporation	
WP2	BT		Telecommunications Company	The organisations represented at the Work Package 2 six weekly meetings
WP2	The British Vehicle Rental and Leasing Association (BVRLA)	-	Trade Association for companies engaged in vehicle rental, leasing and fleet management	Topic leads
WP2	British Electrotechnical and Allied Manufacturers' Association (BEAMA)		Trade Association for manufacturers and providers of energy infrastructure technologies and systems	The organisations represented at the Work Package 2 six weekly meetings
WP2	Renewable Energy Consumer Code (RECC)		Trade Association for renewable energy companies	The organisations represented at the Work Package 2 six weekly meetings
WP2	Energy UK		Trade Association for the energy industry	Work package leader
WP2	Imperial College London	Academic	University	The organisations represented at the Work Package 2 six weekly meetings

Work Package	Company	EVET classifier	Research classifier	WP Role
WP2	University of Leeds (Institute for Transport Studies)		University	Work package sponsor
WP3	Automotive Council		Automotive Research and Advocacy Organization (UK industry-run organisation, work in collaboration with the UK government)	Work package sponsor
WP3	BEAMA		Trade Association for manufacturers and providers of energy infrastructure technologies and systems	Work package leader
WP3	SMMT		Trade association for the United Kingdom motor industry	Work package sponsor
WP3		Chargepoint manufacturers and operators		
WP3		EV Manufacturers		
WP3		Flexibility providers		
WP3		Distribution Network Operators		
WP3		Smart Metering manufacturers		
WP3		Cyber security experts		
WP3		Academics		
WP4	Tesla		Carmaker	Volunteers
WP4	Citizens Advice		Charity (independent organisation specialising in confidential information and advice to assist people with legal, debt, consumer, housing and other problems in the United Kingdom)	Volunteers
WP4	Scottish and Southern Electricity Networks		Distribution Network Operator	
WP4	Pod Point		Electric Vehicle Charging Company	Volunteers
WP4	Nuvve		Electric Vehicle Charging Company (vehicle-to-grid (V2G) technology)	
WP4	Gemserv		Energy and Information Services Company (consulting and governance within the energy, sustainability, cyber security and data protection sectors)	Volunteers
WP4	National Grid System Operator		Energy Company	Volunteers

Work Package	Company	EVET classifier	Research classifier	WP Role
WP4	Octopus Electric Vehicles		Energy Company/Electric Vehicle Charging Company/Electric vehicle leasing	Volunteers
WP4	EA Technology		Energy Services Company (provider of end-to-end power engineering solutions, Asset Management)	Volunteers
WP4	UK Power Networks		Energy Utility Company	Volunteers
WP4	ScottishPower		Energy Utility Company	
WP4	HSBC, Sustainable Finance Unit		Financial Services Company	
WP4	Sustainable Finance Unit		Financial Services Company	
WP4	LowCVP		Independent non-profit partnership to accelerate a sustainable shift to lower carbon vehilces	
WP4	Eversheds Sutherland (International) LLP		Law Firm	Volunteers
WP4	Greater London Authority		Local Government Authority	
WP4	Ofgem		Regulator for electricity market	
WP4	TechUK		Trade Association for companies engaged in information technology and business process services	Work package sponsor
WP4	BEAMA		Trade Association for manufacturers and providers of energy infrastructure technologies and systems	Volunteers
WP4	Energy Networks Association (ENA)		Trade Association for the energy industry	Work package leader
WP4	Imperial College London		University	Volunteers

Appendix 7. Industry Trajectory Policies

Table 1 Policy papers on the automotive industry trajectory

Policy priority	Governance level	Policy paper (open code)	Industry trajectory	Year
Announcement of the government's intentions to ban petrol/diesel vehicles and support the growth of ULEVs (shift to net zero)	National, UK	Transport Decarbonisation Plan	Automotive	2021.07
Announcement of the government's intentions to ban petrol/diesel vehicles support the growth of ULEVs (shift to net zero in multiple industries)	National, UK	Net Zero Strategy: Build Back Greener	Automotive, energy supply, energy storage	2021.10
Policies that encourage consumers to buy EVs	National, UK	the UK low-emission vehicles plug-in grant extension	Automotive	2021
Policies that set emission standards for vehicles that must be met by car owners	Local, UK	London Ultra Low Emission Zone expansion	Automotive	2021
Announcement of the government's intentions to ban petrol/diesel vehicles and support the growth of ULEVs (shift to net zero)	National, UK	Ten point plan for a green industrial revolution	Automotive, energy supply, energy storage	2020.11
Announcement of the government's intentions to support the growth of ULEVs (shift to net zero in multiple industries)	National, UK	The UK government's commitment to reaching net zero by 2050	Automotive, energy supply, energy storage	2019
Policies that encourage carmakers to supply EVs	EU	Regulation (EU) 2019/631, allow ICE oriented companies to join zero-emissions credit pool	Automotive	2019

Policy priority	Governance level	Policy paper (open code)	Industry trajectory	Year
Policies that set emission standards for vehicles that must be met by car owners	Local, UK	London Ultra Low Emission Zone	Automotive	2019
The policy aims to support the growth of the electric and automated vehicle industry in the UK and encourage the adoption of these technologies by the general public	National, UK	Automated and Electric Vehicles Act 2018	Automotive	2018.07.19
Announcement of the government's intentions to support the growth of ULEVs (shift to net zero)	National, UK	Road to Zero strategy	Automotive	2018.07.09
Policies that encourage consumers to buy EVs	National, UK	Vehicles exempt from Vehicle Excise Duty in the UK	Automotive	2018
Announcement of the government's intentions to transition to a low-carbon economy	National, UK	Industrial Strategy	Automotive, energy supply, energy storage	2017
Announcement of the government's intentions to transition to a low-carbon economy	National, UK	Air Quality Plan for Nitrogen Oxide in the UK	Automotive	2017
International agreements	International	Paris Agreement	Automotive, energy supply, energy storage	2016
Policies that set emission standards for carmakers	EU	Commission Regulation 2016/646/EU as regards emissions from light passenger and commercial vehicles (Euro 6)	Automotive	2016
Policies that set emission standards for vehicles that must be met by car owners	Local, UK	London Low Emission Zone (Euro 2 and Euro 2 removement)	Automotive	2015
Policies that set emission standards for carmakers	EU	Commission Regulation 459/2012/EC regards emissions from light passenger and commercial vehicles (Euro 6).	Automotive	2012

Policy priority	Governance level	Policy paper (open code)	Industry trajectory	Year
Policies that encourage carmakers to supply EVs	US, state level	The US Zero-Emission Vehicle (ZEV) program	Automotive	2012
Policies that encourage consumers to buy EVs	National, UK	UK low-emission vehicles plug-in grant	Automotive	2012.02
Policies that encourage consumers to buy EVs	National, UK	Vehicles exempt from Vehicle Excise Duty in the UK	Automotive	2012
Policies aim to improve energy efficiency and reduce energy consumption	EU	Directive 2012/27/EU	Automotive, Energy Supply, Energy Storage	2012
Policies that set emission standards for carmakers	National, UK	Cleaner Road Transport Vehicles Regulations 2011 No1631	Automotive	2011
Policies that set emissions standards for carmakers	Local, UK	Cleaner Road Transport Vehicles Regulations Scotland 2010 No 390	Automotive	2010
Policies that set emission limits for carmakers	EU	Directive 2009/33/EC Directive on the Promotion of Clean and Energy-Efficient Road Transport Vehicles	Automotive	2009
Policies that set emission standards for vehicles that must be met by car owners	Local, UK	London Low Emission Zone	Automotive	2008
Announcement of the government's intensions	National, UK	Climate Change Act	Automotive, energy supply, energy storage	2008
Policies that set emission standards for carmakers	EU	Type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles Regulation 715/2007/EC	Automotive	2007
Policy that focuses on the provision of information on the fuel consumption and CO2 emissions of new passenger cars	National, UK	The Passenger Car (Fuel Consumption and CO2 Emissions Information) Regulations 2001 No. 3523	Automotive	2001
Policies that set emission standards for carmakers	EU	The European Emission Standard for passenger cars Directive 98/69/EC	Automotive	1998

Policy priority	Governance level	Policy paper (open code)	Industry trajectory	Year
Voluntary agreement that sets targets for reducing emissions from new passenger cars	EU	European Automobile Manufacturers' Association agreement	Automotive	1998
International agreements	International	Kyoto Protocol	Automotive, energy supply, energy storage	1997
International agreements	International	United Nations Framework Convention on Climate Change	Automotive, energy supply, energy storage	1992

Table 2 Policy papers on the energy supply trajectory

Policy priority	Governance level	Policy paper (open code)	Industrial trajectory	Year
Comprehensive plan to support the growth of electric vehicle market in the UK (shift to net zero)	National, UK	UK Electric Vehicle Infrastructure Strategy	Energy Supply	2022.03
Regulations that encourage the installation of smart charging points	National, UK	The Electric Vehicles (Smart Charge Points) Regulations 2021	Automotive, Energy Supply	2021.12
Policies that encourage local authorities and property developers to install EV charging points in residential areas	National, UK	On-Street Residential Chargepoint Scheme	Energy supply	2017
Announcement of the government's intentions to transition to a low-carbon economy	National, UK	Industrial Strategy	Automotive, energy supply, energy storage	2017
International agreements (legally binding international treaty) to limit global warming	International	Paris Agreement	Automotive, energy supply, energy storage	2016
Policies aim to improve energy efficiency and reduce energy consumption	EU	Directive 2012/27/EU	Automotive, Energy Supply, Energy Storage	2012

Policy priority	Governance level	Policy paper (open code)	Industrial trajectory	Year
Policies that encourage energy generation companies to supply RE	National, UK	Feed-in tariffs order 2010 No.678	Energy supply	2010
Announcement of the government's intensions	Local, UK	Nottingham Energy Strategy 2010-2020	Energy supply	2010
Policy that sets common rules for the internal market in electricity. In addition, it aims to increase the share of renewable energy	EU	Directive 2009/72/EC concerning common rules for the internal market in electricity and repealing	Energy supply	2009.08
Policies that encourage energy generation companies to supply RE	National, UK	Renewables Obligation Order No.785	Energy supply	2009
Sets a binding target for the EU as a whole to achieve a 20% share of renewable energy (shift demand and supply curve)	EU	Directive 2009/28/EC on the promotion of the use of energy from renewable sources	Energy supply	2009
Announcement of the government's intensions	National, UK	Climate Change Act	Automotive, energy supply, energy storage	2008
Energy Taxation Directive (shift the demand curve)	EU	Directive 2003/96/EC Community framework for the taxation of energy products and electricity	Energy supply	2003
Policies that encourage energy generation companies to supply RE	National, UK	Renewables Obligation Order No. 914	Energy supply	2002
International agreements (legally binding international treaty) to limit global warming	International	Kyoto Protocol	Automotive, energy supply, energy storage	1997

Policy priority	Governance level	Policy paper (open code)	Industrial trajectory	Year
International agreements (legally binding international treaty) to combat climate change	International	United Nations Framework Convention on Climate Change	Automotive, energy supply, energy storage	1992

Table 3 Policy papers on the energy storage trajectory

Policy priority	Governance level	Policy paper (open code)	Industrial trajectory	Year
Policies that encourage fuel supply companies to supply biofuels	National, UK	Renewable Transport Fuel Obligation (Amendment)	Energy storage trajectory	2021
Policies that encourage fuel supply companies to supply biofuels	National, UK	Renewable Transport Fuel Obligation (Amendment)	Energy storage trajectory	2018
Policy that promote the use of biofuels (shift demand and supply curve)	Local, UK	Deployment of alternative fuels infrastructure regulation 2016 LN.2016/222 Gibraltar	Energy storage trajectory	2016
International agreements	International	Paris Agreement	Automotive, energy supply, energy storage	2016
Policies that encourage fuel supply companies to supply biofuels	National, UK	Renewable Transport Fuel Obligation (Amendment)	Energy storage trajectory	2015
Policy that promote the use of biofuels (shift demand and supply curve)	EU	Directive (EU) 2015/1513 the quality of petrol and diesel fuels	Energy storage trajectory	2015
Policy that promote the use of biofuels (shift demand and supply curve)	EU	Directive 2014/94/EU (FOI 105)	Energy storage trajectory, Energy supply trajectory	2014
Policies that encourage fuel supply companies to supply biofuels	National, UK	Renewable Transport Fuel Obligation Order	Energy storage trajectory	2013

Policy that requires fuel suppliers to report the emissions associated with the motor fuels they supply	National, UK	The Motor Fuel GNG Reporting Regulations 2012 No.3030	Energy storage trajectory	2012
Policies aims to improve energy efficiency and reduce energy consumption	EU	Directive 2012/27/EU	Automotive, Energy Supply, Energy Storage	2012
Announcement the government intensions to transition to a low-carbon economy	National, UK	Climate Change Act	Automotive, energy supply, energy storage	2008
Policies that encourage fuel supply companies to supply biofuels	National, UK	Renewable Transport Fuel Obligation Order 2007 No. 3072	Energy storage trajectory	2007
Policy that promote the use of biofuels (shift demand and supply curve)	EU	Directive 2003/30/EC	Energy storage trajectory	2003
International agreements	International	Kyoto Protocol	Automotive, energy supply, energy storage	1997
International agreements	International	United Nations Framework Convention on Climate Change	Automotive, energy supply, energy storage	1992

Appendix 8. Participants' Views on the Prospects of Vehicle Technologies up to 2030

Response \ Interview No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Participants' industry	F	R	R	A	B	I	A	Fn	TP	C	R	C	C	R	Li	I	C	C	C	TP	TP	E	Li	I	A	A	P	Fn	A	BR
Battery electric vehicles	Positive		Positive	Positive	Positive	Positive	Positive	Positive	Neutral	Positive	Positive	Positive	Positive	Positive		Positive	Positive	Positive	Positive	Positive	Negative	Positive	Positive	Positive	Positive	Positive	Positive			Positive
Hybrid vehicles	Positive	Positive		Positive					Positive (light shade)		Positive				Positive			Negative												
Hybrids as a transitional technology				Positive			Positive																			Positive		Positive		
Fuel cell private vehicles	Positive			Negative			Positive	Neutral			Positive		Negative	Negative		Neutral						Negative		Neutral						
Fuel cell commercial vehicles/heavy vehicles				Positive						Positive						Positive			Positive						Positive	Positive				
Biofuels (Flex Fuel Hybrids)	Positive		Positive	Positive						Positive	Positive											Negative		Positive						
ICEs private vehicles																Negative	Negative					Negative	Negative	Negative						
ICEs trucks and heavy vehicles	Positive		Positive																					Positive						
Other modes of transport									Positive				Positive							Positive	Positive									
Autonomous vehicles							Positive	Positive	Positive								Positive													
Range of technologies	Positive		Positive	Positive			Positive (light shade)			Positive	Positive		Positive						Positive	Positive				Positive (light shade)	Positive	Positive		Positive	Positive	

Positive   Neutral   Negative   Not mentioned during the interview

Note, participants' industry: A – automotive, B – biotech, BR – battery recycling, C – consulting in auto industry, E – energy, I – EV infrastructure, F – fuel, Fn – government research funding in auto industry, Li – battery, P – policymaker, R - academia, TP - transport planning government organisations

Appendix 9. Theory Validation Feedback

Professor Dana Archer Dolan, Geroge Mason University, Policy Fellow and Adjunct Professor in Public Policy

"In section 4 [Section 0 of PhD thesis - Key stakeholders and their roles] of your paper, where you identify the "key agents" - would it be useful to reformulate these as "key activities" instead? In fact, I've been wondering for some time whether Asa Knaggard's notion of the problem broker should be treated as a set of activities performed by Kingdon's policy entrepreneur, rather than as a separate role, distinct from the PE. Distinguishing between actors and activities is well aligned with Kingdon's approach to separating "participants" from "processes". The benefit, I believe, would be flexibility for a particular individual or group to engage (or not) in multiple activities -- something you hinted at when you refer to "TIs who act as PEs and PBs". If so, then the actor is the policy entrepreneur, while the activity is "problem brokering." Also, isn't the "Technology Innovator" working in the policy stream as well as the problem stream? Finally, I'd want a justification for restricting any of these activities to only individuals inside (or outside) government.

In Section 5 [Section 0 of PhD thesis - Key stakeholders and their roles] right away you make the point about differentiating between policy entrepreneurs versus policy entrepreneurship -- and that fits with my point above. Based on that, I wanted very much to see Figure 4 [Figure 4.24] inverted, to highlight the activities in boxes rather than the actors. So, along the left of that figure, the processes were all about coupling the streams. In the center and left of the diagram, I suggest that "fram[ing] a condition as a problem" is an activity aimed at stream ripening—in other words, preparing for a coupling. So I have to wonder if "policy entrepreneurship" is just another way of referring to "coupling"? Alternatively, we could ask: what differs between PEship and coupling? I find these conceptual questions really interesting!"

Interviewee 3

"[I am] completely agree, currently urban mobility solutions, for instance the car sharing is grooving market, due to their mobility, flexibility, and budged saving opportunity (car can be taken when demand). In a nearest future only car productions will not be only priority and the main revenue for the companies. The various urban mobility solutions will also partly or completely replace the car productions in some companies or more likely personal vehicles manufacturer will have to create an alliance with experienced in this sector companies" (Int.3).

Interviewee 30

"I've read your conclusions and I think the first and third are fine. You may want to include something about the circular economy as it is the most important aspect of sustainability. Regarding RQ2, if the average consumer is able to afford an EV and the vehicle makers make sufficient money from selling the vehicles, then you can say it might go smoothly but as it stands, EVs are not affordable and vehicle makers do not make any money from them. This could change as they ramp up production but you will need to state this is the case" (Int.30).