From Gas to Electricity: Institutional Innovation in the German Automotive Industry

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The shift of the German automotive industry toward electric mobility is a multi-faceted transition. This research aims to uncover the shift's triggers by examining actors, field-configuring events and exogenous jolts of the past decade through the lens of institutional theory, empirically building upon expert interviews and grey literature. Because the industry comprises deeply entrenched institutions, these present obstacles to change and underscored the slow shift among German manufacturers. Their worldwide renowned expertise in internal combustion engines and economic success bound them within a golden cage. Germany's economic dependence on industry allowed them political influence. Findings revealed that a combination of political, economic and social factors acted as triggers. Foremost, fleet emission regulations pushed manufacturers toward electric vehicles, specifically as the diesel scandal dismantled the diesel engine's institutional dominance. Simultaneously, the threat of losing the Chinese market and increasing competition put pressure on the manufacturers. Consumer adoption grew and amplified awareness of climate change due to a social movement, financial incentives, advancing technology, increasing car models, and improved charging infrastructure. The occurring institutional innovation was not spurred by radical innovation but by an interplay of sudden, as well as incremental developments. It is reshaping institutionalized practices and has introduced opportunities for novel business models, reflecting the evolving landscape of mobility.

Keywords: institutional innovation, field-configuring events, exogenous jolts, actors, German automotive industry, electric vehicle

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Abstract

A transição da indústria automobilística alemã para a mobilidade elétrica é multifacetada. Esta pesquisa tem como objetivo descobrir os desencadeadores dessa mudança, examinando os atores, eventos de configuração do setor e choques exógenos da última década sob a ótica da teoria institucional, construindo empiricamente com base em entrevistas de especialistas e literatura cinzenta. Com as instituições profundamente enraizadas na indústria, estas representam obstáculos à mudança e destacam a lenta transição entre os fabricantes alemães. A sua especialidade mundialmente reconhecida em motores de combustão interna e sucesso econômico os prendeu-os numa "gaiola de ouro". A dependência económica da Alemanha em relação à indústria permitiu-lhes ter influência política. As descobertas revelaram que uma combinação de fatores políticos, económicos e sociais atuou como desencadeador. Primeiramente, regulamentações de emissões da frota levaram os fabricantes a voltarem-se para veículos elétricos, especificamente à medida que o escândalo do diesel desmantelou a dominância institucional do motor a diesel. Simultaneamente, a ameaça de perder o mercado chinês e o aumento da concorrência pressionaram os fabricantes. A adoção pelos consumidores cresceu rapidamente e amplificou a conscientização sobre as mudanças climáticas devido a um movimento social, incentivos financeiros, avanços tecnológicos, aumento dos modelos de carros e melhoria da infraestrutura de carregamento. A inovação institucional ocorrente não foi impulsionada por uma inovação radical, mas por uma interação de desenvolvimentos súbitos e incrementais. Isso está a reformular práticas institucionalizadas e a introduzir oportunidades para novos modelos de negócios, refletindo a paisagem em evolução da mobilidade.

Palavras-chave: inovação institucional, eventos de configuração de campo, choques exógenos, actores, indústria automóvel alemã, veículo elétrico

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List of abbreviations

AC	alternative current
ACEA	European Automobile Manufacturers' Association
BEV	battery electric vehicle
BMW	Bayerische Motoren Werke AG
BMWK	Bundesministerium für Wirtschaft und Klimaschutz (German Federal Ministry for Economic Affairs and Climate Action)
CCS	Combined Charging System
CO_2	carbon dioxide
DC	direct current
EPA	US Environmental Protection Agency
EU	European Union
EV	electric vehicle
FCE	field-configuring event
FCEV	fuel cell electric vehicle
ICE	internal combustion engine
KBA	Kraftfahrt-Bundesamt (Federal Motor Transport Authority)
kW	kilowatt (unit of power)
NEDC	New European Driving Cycle (Neuer Europäischer Fahrzyklus, NEFZ)
NO_x	nitrogen oxides
NPE	Nationale Plattform Elektromobilität (National Electric Mobility Platform)
OEM	original equipment manufacturer
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
SME	small and medium-sized enterprise
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
VDA	Verband der deutschen Automobilindustrie (German Association of the Automotive Industry)
VW	Volkswagen AG
WLTP	Worldwide Harmonized Light Duty Test Procedure

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1. Introduction

The story of the modern car begins in 1886 with Carl Benz and the Benz patent motorcar number 1, an automobile passenger car with an internal combustion engine (ICE) (J. Davis, 2016: 409). Nevertheless, the first electric vehicle (EV) was already invented years earlier. In the early 1900s, the EV gained massive popularity, yet quickly disappeared again from the streets (Thompson, 2017). The 1960s and 1970s gave way to environmental concerns, increasing pollution and exploding oil prices (Kovarik, 2023), which some accounts say, gave impetus to the new era of electric mobility. Yet, the few attempts at electric mobility by manufacturers remained mostly unsuccessful and temporary.

As, in the past decade, climate protection increasingly gained momentum and initiated a political and societal debate, EVs started to resurface again. Moreover, within the last three years, EV registrations increased at a tremendous pace in Germany. The question arises why it took the automotive industry roughly a century to again focus on this alternative driving mechanism and for it to gain increasing acceptance within the general public.

To understand why this paradigm shift towards electric mobility is occurring, it is imperative to assess the German automotive industry, its history, structure and recognized engineering excellence. A complex system of tight interlocked suppliers and industries, nationally and internationally, has developed, enclosing market players through interdependencies and contractual obligations. The significant contribution to the German economy makes the relationship between politics and the automotive industry one of mutual influence, as manufacturers voice their interests and political actors aim to balance economic interests, environmental concerns, and societal needs while shaping the industry's trajectory.

The industry displays deeply rooted institutions and institutional structures. These derive their value from their historical and symbolic meaning (Barley & Tolbert, 1997) and as such are rather resistant to change (Zucker, 1987). By considering the institutional factors at play and the need for a systemic change of industries, politics and society, a more comprehensive understanding of the challenges involved in the transition toward electric mobility can be gained.

1.1 Relevance for theory and practice

Classical economic theories, such as supply and demand, and agency theory, are too narrow to fully capture the complexity of economic affairs and industrial development. Broadening the narrative to include an institutional view, allows to acknowledge that rules set by states and multilateral organizations, legal and cultural norms, industry-specific standards and customs, matter and may even defy economic logic (Greenwood & Hinings, 1996; Sturgeon et al., 2008).

Research into institutions and institutional theory reaches back to the mid-19th century (Scott, 1987). Since then the field has grown extensively stretching from the exploration of causes to consequences of institutional change (Alvesson & Spicer, 2019). The process of institution-building (Barley & Tolbert, 1997) and institutional change (Greenwood et al., 2002; Lounsbury & Crumley, 2007) has been mapped. Factors anteceding institutional innovation have been widely explored, theoretically and empirically, ranging from agency (J.W. Meyer, 2010; Voronov & Weber, 2020), and institutional entrepreneurship (Beckert, 1999; Li et al., 2006; Rao & Giorgi, 2006; Tracey et al., 2011), to environmental jolts (A.D. Meyer et al., 1990; Sine & David, 2003), and field-configuring events (FCEs) (Hardy & Maguire, 2010; Lampel & Meyer, 2008; Schüssler et al., 2014). Yet, these triggering actors and events are still scattered across scientific articles, with different wordings used for similar concepts, and there is no one paper that summarizes and orders them in their role to bring about change. Likewise, this also has not been done within the automotive industry.

Understanding that organizational achievement is influenced by the environment in which the organization exists, entails understanding the dynamic that surrounds them (Tushman & Anderson, 1986). Integrating the concept of institutions and identifying factors that contribute to institutional change is crucial in this sense, not only for managers across industries to improve organizational performance but also for policymakers and practitioners addressing societal challenges and promoting social, economic and environmental change.

1.2 Objective

The German automotive industry displays a highly institutionalized setting, formed since the invention of the modern car over the course of the last century. Given that institutions are highly resistant to change, it is now most interesting to observe a transformation: the renaissance of the EV. The past few years have shown a massive increase in original equipment manufacturers (OEMs) producing and investing in EVs, as well as EV registrations (KBA, 2023b).

Applying institutional theory to the German automotive industry allows to view the change from a lens that takes into consideration the organizations themselves but also their environment and their interactions. In this sense, this thesis aims to first theoretically order the anteceding factors of institutional innovation, to then transfer the developed knowledge to the German automotive industry and its transition toward electric mobility with a focus on the last decade. The objective is to establish the occurrences that led to the initiation of institutional innovation in this sector. For this purpose, two building blocks of institutional innovation are examined in particular: actors, as well as market occurrences in the form of jolts and field-configuring events, leading to two research questions:

1. Which actors contributed to the transition of the German automotive industry in the years 2012 to 2022?
2. Which exogenous jolts occurred, and which key field-configuring events did the actors participate in?

This thesis introduces the concepts of institutional theory and institutional innovation, followed by an account of electric mobility and the German automotive market. Next, the methodological approach is elaborated, encompassing a systematic literature review, grey literature and semi-structured expert interviews. The empirical outcomes are presented in chapter 4 in which the institutional settings of the German automotive industry are elaborated, and market occurrences structured on a time sequence and explained in view of their relevancy leading to the increasing adoption of EVs in the German market. Subsequently, they are incorporated with the theoretical findings in the discussion. The paper will conclude with a presentation of implications, limitations and outlook.

2. Theoretical and conceptual foundation

To set the scene of the paper, the concept of an institution is construed, followed by an account of institutional theory and innovation. Moreover, the German automotive industry is elaborated upon to give an overview of the current market and its economic position, as well as the EV. Key terms are explained and outlined.

2.1 Institutions

There is no one definition of an institution. Some accounts report institutions to be certain types of organizations, e.g. banks (designated as financial institutions), other times individuals and concepts are referred to, such as the president and presidency (L. Davis & North, 1970), again others ascribe it to normative cultural conventions, such as the marriage (Ganesh, 1980).

From a sociological point of view, institutions, as humanly contrived social phenomena, (Hughes, 1936) are the informal and formal rules of a society that govern behavior (Hughes, 1936; North, 1991). They have evolved over time through interactions that reflect how people and groups should act (Ruttan & Hayami, 1984). As such they are accumulations of previous actions embedded within norms, logic and interpretative concepts, and provide templates for interaction that guide communications and suggest which conducts to punish or to encourage

(Barley & Tolbert, 1997; Greenwood et al., 2014). Institutions derive value from their historical and symbolic significance (Sine & David, 2003) and legitimacy given by the society at large (Ganesh, 1980). They thus exhibit a strong resistance to change (J.W. Meyer & Rowan, 1977). This discerns what makes a civilization a civilization (Hughes, 1936).

Transferring this concept to the organizational level, many structures echo institutionalized statutes (J.W. Meyer & Rowan, 1977) that reflect the collective beliefs that have developed through the frequent encounters of companies. The agreement on what is appropriate conduct, causes conformity to this constructed social reality by lessening ambiguity (Greenwood et al., 2002) and uncertainty in exchange (North, 1991), and sets standards about the right to utilize resources. Institutions thus offer stability to expectations and assurance about how others are most likely to behave (Ruttan & Hayami, 1984). Following institutionalized practices increases the legitimacy of the organization (J.W. Meyer & Rowan, 1977).

For the sake of analogousness, key terms have to be addressed: The process of legitimizing societal processes is referred to as *institutionalization* (J.W. Meyer & Rowan, 1977). The *institutional environment* or *institutional field* comprises elementary political, social and legal guidelines that regulate economic and political action (L. Davis & North, 1970). *Organizational fields* are the organizations that collectively make up a recognized sector of institutional activity (DiMaggio & Powell, 1983). Within this work, it refers to the German automotive industry. Referring to a set of organizational activities, some authors use the term *practices* (King & Pearce, 2010; Lounsbury & Crumley, 2007).

2.1.1 Institutional theory

Institutional theory appears throughout social sciences. It emerged from sociology asking why individuals make certain choices, and studies the social structures and cultural norms that shape behavior and guide action. Political sciences analyze how political processes and outcomes are shaped. In economics, the question shifts to how choices are made and assesses the impact of institutional factors on economic growth, innovation and development. Lastly, within organizational and management studies, institutional theory analyzes how organizations and institutions are created, maintained and changed over time (Rao & Giorgi, 2006; Zucker, 1987).

The recognition of institutions and their significance within organizational life has evolved into the institutional theory of the firm. Its most fundamental assumption is that organizations must conform to the institutional environment they operate in (J.W. Meyer & Rowan, 1977). Organizational actions are seen as the product of normative pressure rather than economic forces. The theory has emerged due to its ability to explain organizational behavior that contrasts economic logic, e.g. an organization adopting an approach that does not improve task efficiency or performance (Greenwood & Hinings, 1996; J.W. Meyer & Rowan, 1977).

This reflects the common understanding of institutional and neo-institutional theory with the latter one becoming progressively dominant after 2000 (Alvesson & Spicer, 2019). Both underline that the relationship between an organization and its environment is reflected in a conformity that limits the scope and rationality of action. They are however ascribed different origins. While the *old* theory rather focuses on power, political tradeoffs and alliances, the newer approach focuses on the stability of institutions as caused by the legitimacy it yields to organizations (DiMaggio & Powell, 1991; Greenwood & Hinings, 1996). As neo-institutional theory evolves, the institutional arena is not viewed as static any longer but incorporates strategic interactions of players competing over the legitimacy of different organizational forms (Hensmans, 2003).

The key argument of neo-institutional theory stresses that legitimacy raises the likelihood of survival (Tolbert & Zucker, 1983; Zucker, 1987). Figure 1 shows the two ways of achieving legitimacy as depicted by J.W. Meyer and Rowan (1977):

On the one hand, organizational efficiency as a source of economic success can legitimate behavior and thus institutional support. This ensures access to resources and positively influences organizational survival (J.W. Meyer & Rowan, 1977).

On the other hand, institutionalized methods, or myths, offer already legitimated means of how to behave. Shifting away from prescribed logics can lead to a deficiency of institutional support and resources and thus eventually to diminished distinguishing competency (Van de Ven, 1986). Ultimately, organizations are under strain to adopt institutionalized structures to attest their commitment to collective rules (J.W. Meyer & Rowan, 1977) and retain legitimacy even though the adoption may not lead to operational efficiency (Tolbert & Zucker, 1983).

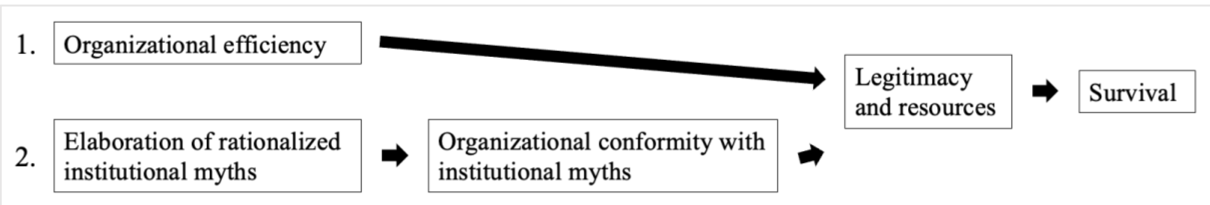

Figure 1: Organizational survival (Source: J.W. Meyer and Rowan (1977: 353))

This process of conforming to the institutional environment is called *isomorphism* and is influenced by coercive, memetic and normative mechanisms which limit behavioral options and trap organizations within an “iron cage” (DiMaggio & Powell, 1983: 147):

1. Coercive isomorphism emerges from demands imposed by other organizations which they depend on, intending to secure resources and income. Moreover, policymakers may enforce adherence through regulatory directives (DiMaggio & Powell, 1983).
2. Mimetic isomorphism refers to an imitation of other organizations. Changes in the organizational environment or technological innovations may lead to uncertainty as it makes construing the logics from the past more challenging (Wezel & Saka-Helmhout, 2006). It thus may seem logical to act similarly to organizations they discern to be more effective or legitimate. This leads to a bandwagon effect in which others follow suit while the actual effectiveness of a given activity is ignored (A.D. Meyer et al., 1990).
3. Normative isomorphism stems from shared norms and values within a professional environment, such as professional standards and codes of conduct (DiMaggio & Powell, 1983), and is enforced by collective establishments, including unions and trade associations (Phillips et al., 2000).

While the first represents enforced conformity, the latter two are voluntary (J.W. Meyer & Rowan, 1977). Other than that, also inducement strategies exist in which incentives are given to encourage conformity (Scott, 1987).

This conformity gives rise to institutionalized complex structures that pose challenges to change. As institutionalized practices take hold, a network of suppliers and sellers is formed, and contractual obligations are established, creating a system "of separate but interlocking players who are reciprocally dependent upon each other" (Vermeulen et al., 2007: 535). This leads to a "chicken-and-egg" problem of who initiates change (Vermeulen et al., 2007: 535). Especially incumbents can be averse to change as it may jeopardize the market arrangements that allow them to be in a position of power and hold their competitive edge (King & Pearce, 2010). Still, in real-life innovation occurs and institutional change can be observed.

While institutional theory stresses the agencies that make up an institutional environment, such as the state and professional associations, it ignores other elements that make up the organization's environment, such as competitors, customers and resources (Scott, 1987).

This paper adopts the more novel view of neo-institutional theory to be able to more thoroughly cater to the concept of institutional innovation and its causes later on.

2.1.2 Institutional innovation

Institutional innovations are "novel, useful and legitimate changes" in institutional constraints that tear at an organizational field and include shifts in present institutions or the establishment of new ones (Raffaelli & Glynn, 2015: 409). It presents the "exit from one state and entry into another state" (Rao & Giorgi, 2006: 270). This may alter institutional arrangements, power structures, interpersonal interactions, and well-established habits (Raffaelli & Glynn, 2015) as society or organizations adapt. It reflects societal change (Tolbert & Zucker, 1983) which only unfolds through historical eras (Raffaelli & Glynn, 2015).

Earlier academic work posits that institutional innovation or change is driven socially, culturally, and politically by the environment. Institutionalists found exogenous shocks of the macroenvironment, most prominently technological innovation (Barley, 1986; Tushman & Anderson, 1986), new legislations (Scott, 1987; Zucker, 1987) and considerable economic changes (Barley & Tolbert, 1997) critical in the development of the organizational environment. This research progressed to depict organizations as entities that react to each other, and jolts as enablers of entrepreneurial opportunity (Powell et al., 2017; Rao & Giorgi, 2006). The earlier perspective reflects the influential power at the time (Powell et al., 2017).

More recent research has taken a look at institutional entrepreneurship as a cause (Beckert, 1999; Li et al., 2006), and social movements as an enabler of change (Hensmans, 2003; King & Pearce, 2010; Rao et al., 2000) instead of a mere consequence of disruption and shocks (Hiatt et al., 2009). It is argued that rules and regulations are not created automatically but require some form of action or push to bring them to fruition (Rao & Giorgi, 2006). This evolution is also based on the digital area, in which the organizational focus has developed a view on issues rather than on products, on serving a wide range of stakeholders, on crossing boundaries and exchanging ideas and information. With this comes a shift in influencing factors of institutional change. Actors, agency and intentional change have to be considered (Powell et al., 2017). Increasingly research is conducted into the *how* of the change, i.e. the strategies used to legitimize novelties (Patala et al., 2019; Powell et al., 2017).

Because this work's focus lies on the antecedent factors (presented in the following chapters), figure 2 depicts a simplified model of institutional change. To determine if an antecedent is a significant trigger, it is essential to comprehend the process and the level of impact it must have in order to be recognized as such.

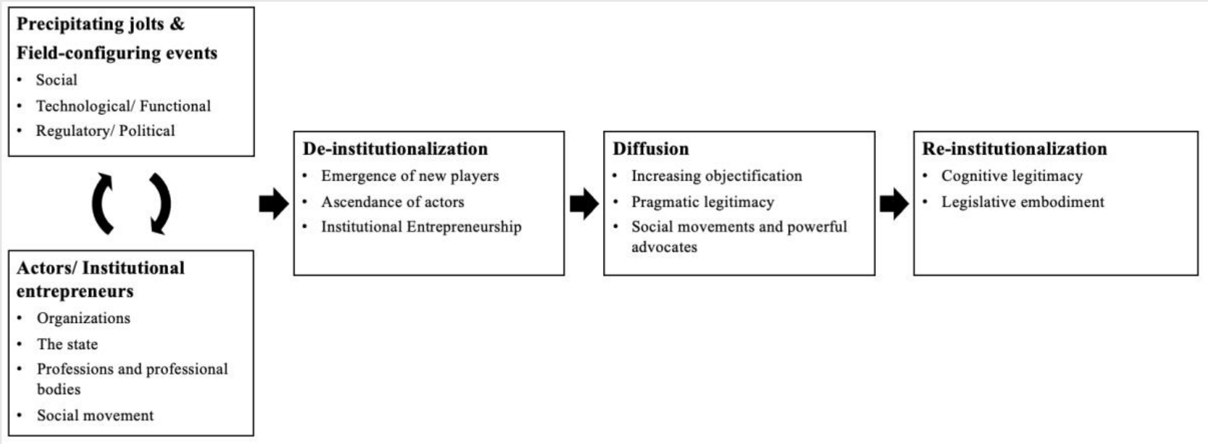

Figure 2: Process of institutional change (Source: own figure based on Greenwood et al. (2002: 60) and Oliver (1992:567))

For the transformation toward a new institution to occur, old logics have to be defied. Social, functional and political pressures can prompt such a process of de-institutionalization in which the legitimacy of established organizations and their practices is challenged (Oliver, 1992). Most commonly, the implementation of radical novel practices leads to questions being raised on the current approach (Lounsbury & Crumley, 2007). This can lead to an unstable state of crisis or conflict, which requires effort to sustain normalcy (Rao & Giorgi, 2006). Executives and industry experts may feel overwhelmed and unable to fully understand or comprehend the extent of the change (A.D. Meyer et al., 1990). Other times, as novelty opens up opportunities in the market, incumbents are not willing to respond as they prefer to maintain the status quo. This leads to an institutional void (Hensmans, 2003) and encourages technical and economic development that may alter what is regarded as proper business conduct (King & Pearce, 2010).

Challengers enter the playing field and align themselves to face incumbents and to enforce radical change (Hensmans, 2003). It becomes more difficult for challenged organizations to convince their partners to continue pursuing relations with them. When firms fail, opportunities arise for newcomers to acquire resources at lower costs. The borders between resource niches waver which may cause shifts in how firms compete for resources. A new competitive landscape develops (Hiatt et al., 2009). Derived from the resource-dependence view, those who hold resources others are reliant on, can affect the behavior of the dependent. The more legitimized the sources and in accord with widespread beliefs, the more power the possessor holds (Hargrave & Van de Ven, 2006).

What distinguishes institutional innovation from innovation is its legitimacy (Raffaelli & Glynn, 2015) given and taken away by stakeholders (Van de Ven, 1986). A population may give legitimacy to an innovation organically or even demand novelty as society is presented with new challenges or develops novel views on an issue (Raffaelli & Glynn, 2015). Yet, mostly, innovations that confute existing mechanisms present serious challenges and may hurt the innovator, socially as this new way inherently lacks legitimacy (Phillips et al., 2000), mentally as it demands dealing with a novel issue, and economically as he/she takes on risk. In case of success, innovators also incur positive externalities, i.e. the costs of legitimizing the novelty while not being its only beneficiary (Rao et al., 2000). Therefore, the benefits for innovators or first movers need to be significant.

How the field is shaped and when, depends on the political interests of actors and favorable political opportunities that provide a conducive environment for the development of new structures. For one, preceding organizational and market failures (Rao et al., 2000), but also accessibility to the political system, advocates and supporters within it, and lack of oppression by those currently in power act as enablers (Rao & Giorgi, 2006).

In the diffusion process across the organizational field, powerful supporters are necessary who advocate the novelty and convey its purpose. It must be convincingly presented as better than a current solution, usually accomplished by either demonstrating its practical and superior functionality to achieve pragmatic legitimacy, or integrating the new idea into existing social norms to achieve moral legitimacy (Greenwood et al., 2002). It has been found that innovators and early adopters mostly base their decision of implementation on the actual operative improvements, thus referring to the former (DiMaggio & Powell, 1983; Tolbert & Zucker, 1983), whereas innovation is most likely to spread if it directly positively influences the reputation of an organization, referring to the latter (Zucker, 1987).

Generally, for innovation to disseminate within the organizational field, organizational knowledge has to be built that can be explained and transferred to the organizational field (Vermeulen et al., 2007). Because actors use their repertoire of preexisting perceptions to interpret novelties (Hargadon & Douglas, 2001), new issues may be legitimized by framing them in a way that transfers the meaning and value of what is already known and accepted (DiMaggio & Powell, 1991; Tracey et al., 2011). In this, professional associations can play a critical role by providing a platform for institutional entrepreneurs to come together, collaborate, engage in discussions, exchange knowledge, and address issues relevant to their field. From this, shared meanings and understandings emerge (Greenwood et al., 2002).

Finally, by gaining cognitive legitimacy, ideas become deeply ingrained and are no longer questioned. Government entities establish regulatory processes that encourage organizations within a specific field to adhere to agreed-upon concepts, thereby strengthening them

(Greenwood et al., 2002). This entry into a new state of behavior, marked by a time of stabilization (Hensmans, 2003), is known as re-institutionalization (Rao & Giorgi, 2006).

Since innovation is a form of change, the terms institutional change and innovation will be used interchangeably.

2.1.3 Institutional actors

Actors express their awareness and give meaning to their political interests through strategic agency (Hensmans, 2003). Agency refers to the capacity to systematically and deliberately influence and shape institutional rules and norms (Beckert, 1999; Voronov & Weber, 2020). Reay et al. (2006: 977) define this as "purposeful change activity". While institutions influence actors, they are not entirely dictated by them (Reay et al., 2006). Contemporary institutionalism places individuals and organizations at the forefront, emphasizing their active and intentional role in shaping the social world (Voronov & Weber, 2020). It further recognizes that organizations and states are composed of individuals. An emphasis is placed on agentic and purposive action, in which individuals are liberated, capable of intentional decision-making and shaping the social world. Individuals are seen as active and legitimate actors, capable of self-reflection which allows them to evaluate critically, rather than, in the old institutionalists' view, passive and dependent participants of society (J.W. Meyer, 2010).

The embeddedness of actors was assessed in relation to their display of agency. Those less entrenched in an established institution, for instance, because they are new to the organizational environment or reside in a newly emerging field, exhibit more agency. Also those who break away due to specific events that dislocate existing structures are considered less embedded as they may realize the necessity of change. These actors are rather able to defy accepted norms and conventions (Reay et al., 2006). At the same time, institutions are characterized by certainty, but they also limit choices. A high degree of certainty or stability within a field allows actors to perceive alternative ways of behavior more clearly. Thus, strategic agency is rather prospective within such stable fields (Beckert, 1999).

From this discussion, the concept of institutional entrepreneurship has emerged which depicts the relationship between agency and institutional change (Munir & Phillips, 2005). While first specified as *action groups* consisting of single or multiple individuals who manage innovation, L. Davis and North (1970) laid the framework for institutional entrepreneurs based on Schumpeter's vision of entrepreneurship. Schumpeter coined the concept of *creative destruction* and entrepreneurs being the driving force behind economic growth, change and innovation (Schumpeter, 1976). Institutional entrepreneurs require additional abilities beyond the ones needed by conventional entrepreneurs, such as managing relationships with public figures, and shaping public perception. Thus, they play a crucial role in promoting economic development and reform as they create larger and more favorable externalities for the economy (Li et al., 2006). Entrepreneurs will defy accepted norms when they believe it to be beneficial (Beckert, 1999). To prompt change, they need to question and challenge existing frameworks (Lounsbury & Crumley, 2007), and be powerful enough to push novel concepts (Hargrave & Van de Ven, 2006).

The concept of institutional entrepreneurs has been critiqued in that it conveys the image of a powerful, heroic figure steering change. This neglects the diverse range of actors and varying activities with different levels of resources (Lounsbury & Crumley, 2007). Nevertheless, they may either belong to a social system or be an outsider to it and utilize existing rules and norms or introduce a new set of rules from a different system to create change (Rao & Giorgi, 2006). They have to be able to attract resources that allow them to legitimize their cause, socio-politically, which entails conforming to legal rules and gaining the support of powerful actors for support, and constitutively, in which the cause becomes taken-for-granted (Rao et al., 2000). When institutional change occurs, it requires the interplay of various groups within the institutional environment, for one the organization itself, but also other organizational actors, the state and professional bodies (Vermeulen et al., 2007).

In the following, organizations as corporate actors, the state as policymakers, professions and professional associations, and social movements are elaborated on as the main change agents.

2.1.3.1 Organizations

Organizations not only adjust to their institutional surroundings but can also actively influence and shape them (J.W. Meyer & Rowan, 1977). Particularly, older and established ones have the power to avert or support change (DiMaggio & Powell, 1983). Some organizations proactively seek to incorporate their objectives and structures into the regulations of regulatory authorities (J.W. Meyer & Rowan, 1977), or negotiate benefiting terms (Vermeulen et al., 2007).

Within organizations, the mechanisms of de-institutionalization rely on the assumption that individuals are aware of the need to abandon established practices and take deliberate action towards doing so (Oliver, 1992). Specific circumstances might drive change more so than others, such as organizational performance issues, conflict or technical innovation.

For instance, within an innovative frame, conflict involves the encounter and dispute of adverse sides: innovative reform and institutional stability (Hargrave & Van de Ven, 2006). It can arise within an organization when accordance with institutional rules becomes a condition for a company's success as discrepancies emerge between technical efficiency and the institution. In turn, they adapt even more institutional structures which then can lead to incompatibility between institutional specifications, as well as between rules originating from different environments (J.W. Meyer & Rowan, 1977).

Performance issues frequently lead to serious concerns about the legitimacy, appropriateness and effectiveness of institutionalized practices, resulting in internal political disagreement over which organizational activities should be discontinued or changed to address current organizational issues. This discussion may spread within the organizational field. The shared understanding of appropriate behavior starts to break down and becomes unstable. The maintained coherence based on institutionalized rules of conduct is eroded (Oliver, 1992).

Further, it has to be recognized that different groups and functions within an organization are not neutral or passive towards each other. The technical boundaries that exist between these groups are often reinforced by cognitive boundaries. As a result, alternative ways of viewing the organization's purpose, appropriate structure, and evaluation of actions may exist. When there is a high level of dissatisfaction among these groups, it can create pressure for change within the organization (Greenwood & Hinings, 1996).

The focus on performance-driven innovation provides another way to understand how change is catalyzed endogenously (Lounsbury & Crumley, 2007). Within organizations, repetitive tasks can become routines and subsequently social definitions of how tasks should be performed. Some routines may be easy to change when better techniques become available, while others are so ingrained in the organization that they are taken for granted and resist change (Zucker, 1987). The emergence of intra-organizational innovators who propose new and unconventional solutions to organizational issues can dimmish the perception of traditional approaches. These innovations may strengthen the firm's competitive advantage or are proposed by powerful stakeholders who no longer want to support a certain organizational practice. They may have conflicting ideas or agendas that prevent them from continuing to support that practice. These innovators may gain political support and persuade others to adopt their ideas, leading to the introduction of alternative organizational values and practices (Oliver, 1992).

Organizations closely observe one another. Just as performance issues, threatened organizational survival and other potential sources of institutional inefficiency are noticed, innovation spreads within the organizational environment. Effective strategies are imitated and institutionalized as pressure is put onto other firms to adopt the same organizational change that has been found successful and legitimized (Greenwood & Hinings, 1996).

Interorganizational collaborations are another mechanism in which conventions and resources of institutions are debated. They can aid partners in developing creative and viable solutions by constructively examining issues and going beyond their narrowly defined range of options, especially when the current challenge is not solvable using existing institutionalized guidelines. Similarly, in multi-sector collaborations, the systems that actors come across can be distinct from those found in their own institutional setting. They can be transmitted as guidelines and instruments for communication and problem-solving to their own industry. Nonetheless, a collaborative practice does not necessarily ensure the incorporation of a certain way of acting into the institutional setting. This will depend on the collaboration partners' power within their institutional environments to influence isomorphic processes (Phillips et al., 2000).

In contrast, interorganizational conflict can lead to a decline in agreements or shared beliefs. Conflicting views do not solely arise during a crisis but also when a collaboration partner has gained power and influence and does not see the value in continuing a particular practice (Oliver, 1992). Thus, while collaborations allow to proactively shape the trajectory of an institutional field (Phillips et al., 2000), conflict may avert that purposeful action (Oliver, 1992).

2.1.3.2 The state

As one of the primary players in designing the organizational environment (Zucker, 1987), the state sets up the fundamental structures which govern the behavior of actors and organizational life, for instance, through rights of ownership and trade acts. Generally, regulatory interventions can have a deterministic influence on market functioning, so significant, that they have the potential to lead to the creation or disbandment of markets, and in that organizations and interests clusters (Vermeulen et al., 2007). Legal changes can modify economic conditions, creating new opportunities for profit or redistribution that corporate actors and entrepreneurs may take advantage of (L. Davis & North, 1970). To achieve their goals, policymakers are prone to use force or incentives (Scott, 1987).

The interests and beliefs of the state are represented in the bills passed (King & Pearce, 2010). Institutional innovations are more likely when the expected benefits to political entrepreneurs initiating the change are higher than the costs associated with bringing about that change. The benefits include prestige and increased political support, while the costs include time, resources, and potential opposition. Already spreading ideologies facilitate political entrepreneurs in mobilizing collective action for institutional change by reducing the costs associated with such efforts when the change conforms to the particular set of ideas (Ruttan & Hayami, 1984).

Within the policymaker administration, it requires political leaders as well as technocrats, i.e., experts in a particular field appointed to a position of power or to advise based on their knowledge. Leaders, such as the president, set the agenda and determine when to involve technocrats. The success of institutional reform relies on leaders assembling a unified team of policy specialists, shielding them from political pressures, and delegating authority for policy formulation and implementation. Technocrats may seem influential due to policy adoption, but their power is derived from a political process that favors their policies, rather than inherent power (Williams, 2002).

Earlier literature portrays organizations as passive recipients of legislation (Zucker, 1987). Yet, legal requirements alone do not guarantee organizational adoption and implementation (Tolbert & Zucker, 1983). Governmental agencies face obstacles and active resistance from various actors in the field, limiting their influence and impact, such as interest groups, professional associations, incumbents and competing organizations, or even internal resistance within the government itself. For instance, lack of clarity in government policies, evidenced by differing goals of government ministries, may lead to varying interpretations and priorities at the regional level. Thus, while government policies may have an impact on shaping markets, they are not the sole determinant of institutional change (Vermeulen et al., 2007).

2.1.3.3 Professionals and professional associations

Professionals are commonly named to be highly influential in creating and maintaining institutions (Fligstein & Mara-Drita, 1996). They have the ability to shape the institutional environment through their expert knowledge, practices, and standards, to influence policy and regulation, and can act as intermediaries between the state and other societal actors (Scott, 2008). Scott (2008) defined a typology of three professions: cultural-cognitive agents, normative agents and regulative professions.

Firstly, cultural-cognitive agents refer to individuals or groups who shape and perpetuate shared cultural beliefs within a particular institution or field. These agents influence and construct the understanding of what is considered legitimate, rational, and appropriate behavior within that social context. Job professions range from the metaphysical in philosophy to empirical ones, such as scientists and engineers (Scott, 2008).

Secondly, normative agents uphold and enforce norms and standards of behavior within an institution. They play a role in promoting principles and maintaining adherence to established norms and guidelines. The credibility and trust placed in science and expertise serve as driving forces behind the expansion of transnational governance based on expert knowledge and measurement. Again, jobs range from theologists to scientists, and commonly include professional associations (Scott, 2008).

Professional associations shape the institutional environment through their methods of operation, directly by imposing regulations and expectations, and indirectly by creating and spreading beliefs about what is rational. They rely on normative and memetic influences to align social structures with their objectives and views, and may seek support from state authorities to further their agendas. Professional associations usually advocate more decentralized administrative frameworks that give professionals greater autonomy (Scott, 1987). Work unions, for instance, may push change or resist it, representing the interests of the workforce (Vermeulen et al., 2007).

Within the diffusion process, professional associations may advocate interests to other actors in the field, acting as formal representatives, working to protect and advance the collective interests. After, they champion and strengthen the agreed-upon through training and knowledge sharing, issuance of certificates and celebratory events. Thus, associations are attributed the durability of institutionalized behaviors (Greenwood et al., 2002).

Lastly, regulative professions are occupational bodies that possess authority and power to regulate and control certain aspects of professional practice (Scott, 2008). By holding positions within governmental, judicial, and administrative systems, these professions acquire authority and power. As a result, they can exercise control, enforce regulations, and make consequential decisions that affect others. These occupations include, among others, the military, domestic law enforcement, the legal sector and managerial positions (Greenwood et al., 2002).

Beckert (1999) summarizes the findings of research which shows that professionals attempt to exert influence to further their own purposes. He also reports about the emergence of social actors who surfaced as opposition to established structures.

2.1.3.4 Social movements

Institutional entrepreneurs are actors who identify political opportunities, and advocate and frame issues (Rao et al., 2000). Because they are typically restricted in power, they form collectives (King & Pearce, 2010) of like-minded individuals to challenge the normative status.

These groups can take various formal and informal forms, from work associations to friendship groups, and are defined by a structured approach and long-term objectives. The collective action of institutional entrepreneurs is known as a social movement (Rao et al., 2000). Because collective action is more difficult to motivate for self-serving purposes (J.W. Meyer, 2010), social movements tend to form around social issues (Rao et al., 2000).

Also, organized political activity may occur through institutional entrepreneurs or politicians purposely seeking to form coalitions with other business groups and formal representations. An example presents the discussion around the formation of the European single market in the early 1980s, in which organizations assembled around a specific initiative. They constituted an elite social movement (Fligstein & Mara-Drita, 1996)

As a collective, actors have the ability to spread the word and advocate an issue (Lounsbury & Crumley, 2007). This is necessary as for new ideas to become widely adopted and an institutional imperative, they must first diffuse (Greenwood et al., 2002). To attract potential supporters, it is critical to infuse knowledge into society about the cause, also promoted on a state level and, for instance, through teaching in schools (Hiatt et al., 2009).

Moreover, the support of powerful actors is crucial for the success of social movements. Therefore coalitions may be formed with professional associations, but also the media, as well as challengers and suppliers (Hensmans, 2003). Since the level of social endorsement has a direct influence on the establishment of institutional innovation (Van de Ven, 1986), both challengers and incumbents share an interest in appealing to actors in the organizational environment (Hensmans, 2003).

Ultimately, individuals become institutional entrepreneurs through the penetrant pushing of issues, the mobilization of powerful actors and societal backing which leads to legitimization. The opportunity to drive change is facilitated through exogenous jolts and FCEs.

2.1.4 Environmental jolts and field-configuring events

2.1.4.1 Environmental jolts

Organizational environments can undergo dramatic and transformative changes that disrupt entire industries (Hensmans, 2003; A.D. Meyer et al., 1990), prompt a state of crisis within an entire field (Sine & David, 2003) and lead to fundamental shifts. They can be triggered by unexpected or seemingly insignificant occurrences (A.D. Meyer, 1982). These environmental jolts, also known as exogenous shocks may be classified into political, functional, and social factors (Oliver, 1992).

First, politically, this may occur, for instance, through regulatory alterations, (Oliver, 1992), the break of novel information, but also rational actions as well as mistakes made by actors (Hudik, 2021).

Secondly, functional factors include notable technological changes (Wezel & Saka-Helmhout, 2006). Technological innovation can be viewed as exogenous as they initiate social responses. They have the power to reshape societies by changing traditional methods and relationships involved in the production of goods and services (Barley, 1986). The impact of technology can go beyond the immediate target group with cross-industrial and institutional effects. Tushman and Anderson (1986) give the example of innovations in semiconductors which not only impact semiconductor firms but also computer and automotive organizations.

Technological evolution is shaped by historical context, individual contributions and market dynamics. It can be driven by historical needs, chance, the brilliance of individuals, or economic demand. Technological change often happens gradually, accumulating small advancements over time until it is interrupted by a significant breakthrough. These changes can be competence-destroying, as they destruct existing corporate skills by requiring novel expertise and abilities, or competence-enhancing, reinforcing existing abilities. For instance, the Diesel locomotive demanded distinct skills and knowledge compared to firms so far specialized in steam engines (Tushman & Anderson, 1986).

The interconnected nature of technologies themselves often necessitates firms to collaborate and invest in complementary components, resulting in the emergence of networks for collective production (Garud & Kumaraswamy, 1995). In addition, incumbent technology is often entangled within a network of competitors, contractors, regulatory bodies, and customers. Innovation thus requires significant adjustments in the existing network of relationships and infrastructure (Hargadon & Douglas, 2001).

Thus, technological breakthrough does not necessarily spark change immediately. It will depend on the environmental circumstances, the legitimacy and functionality of existing solutions, and resistance of powerful actors (Sine & David, 2003). Technological excellence by itself is no guarantee for change, which notably, can be hindered by substitute products and dominant designs (Tushman & Anderson, 1986) and thus will require a political opportunity to support the technological diffusion and legitimization process (Sine & David, 2003).

Thirdly, social jolts refer to changed societal expectations (Wezel & Saka-Helmhout, 2006) or crises, defined as events that create "inconsistencies and tensions in an institutional fabric" (Reay et al., 2006: 979). For instance, Sine and David (2003) refer to the 1973 US oil crisis as the catalyst that sparked a realization about the dependency on cheap oil, mobilizing discussion. Fligstein and Mara-Drita (1996) named the economic crises of the 1980s in a period of growing trade between the states in Europe as pivotal for initiating negotiations and agreements between the countries, which ultimately led to the establishment of the European single market.

2.1.4.2 Field-configuring events

FCEs are frequent or one-time occurring social gatherings (Lampel & Meyer, 2008), characterized by temporal limitations and geographical (physical or virtual) spaces that create formal or informal environments (Hardy & Maguire, 2010). Such pivotal moments range from events within organizations to ones across industries and nations on a global stage. Within an organization, FCEs, such as board and committee meetings, present opportunities to formulate and shape corporate strategies (Schüssler et al., 2015). Other than that, they occur in the form of exhibitions, professional events, award presentations, conferences or technology competitions, that have a transformative impact on the configuration and evolution of organizational environments (Lampel & Meyer, 2008). For instance, international conferences serve as important catalysts for change, particularly when organizations and governments face the challenge of finding global solutions to complex problems (Hardy & Maguire, 2010).

Especially trans-organizational, -industrial, and -national events serve as platforms for various actors within a particular field to come together and exchange ideas, interests, and perspectives (Schüssler et al., 2014), unveil novel products, form networks and conduct business (Lampel & Meyer, 2008). Next to powerful actors, also peripheral ones have the opportunity to voice matters, contribute alternative viewpoints and challenge prevailing norms (Schüssler et al., 2014). FCEs provide a unique frame for discourse (Hardy & Maguire, 2010). This shapes the direction, structure, and dynamics of fields, and influences the establishment of new technologies, the formation of markets, the evolution of industries, and the development of professional practices (Lampel & Meyer, 2008). As such they may trigger jolts.

Mostly, FCEs are initiated and organized by institutional entrepreneurs, but also external actors who have a clear agenda of shaping the field, such as the government. In the process of the event, they occasionally also pursue personal benefits (Lampel & Meyer, 2008).

FCEs can have varying impacts, depending on their field mandate, i.e., stronger or weaker legitimacy, leading to varying levels of recognition and acceptance within their respective fields (Lampel & Meyer, 2008). Typically, prestigious and global events that are widely acknowledged and respected carry such a high field mandate. Schüssler et al. (2015)

exemplarily refer to the Olympic games. Another prominent example of such an event are conferences held by the UN (Hardy & Maguire, 2010).

In contrast to these mega-events, stand so-called interstitial spaces. They are defined as encounters on a small scale where people from various fields occasionally and only for a limited period congregate informally to participate in shared activities, such as amateur clubs, or hobby groups or workshops. In these spaces, individuals have the opportunity to momentarily detach themselves from existing institutional structures, allowing them to collaboratively experiment with new ideas. The idea of interstitial spaces aims to convey the relevance of ordinary interactions between individuals from varying disciplines, that whilst at first thought to be trivial, can present a major potential for the emergence of new practices. Most striking, in this case, are early computer clubs during the 1970s in Silicon Valley without which the modern computer would not exist (Furnari, 2014).

2.1.5 Interplay of actors, jolts and field-configuring events

Jolts and FCEs may lead to the emergence of novel actors and the strengthening of existing ones. By offering fresh perspectives, they can impact the norm that has been socially created (Greenwood et al., 2002). Simultaneously, all events are socially constituted, and shaped and given meaning by the actions of actors (Munir & Phillips, 2005).

Significant changes in technology, cross-cultural interactions, and economic conditions can increase the likelihood that actors will feel the need or realize an opportunity to modify an institution (Barley & Tolbert, 1997). This is because sudden environmental disruptions cause actors to evaluate existing institutional logic and their symbolic value, and initiate the search for new ones. This prompts action as it creates entrepreneurial opportunities. Moreover, this occurs in environments where resources are scarce or there is a crisis (Sine & David, 2003).

While it is possible for individuals to conceive of alternative ways of doing, the resistance of others and the inertia of existing norms can limit their ability to bring about change (Barley & Tolbert, 1997). Especially incumbents have played a major role in such opposition. To create lasting institutional change, actors must mobilize resources and encourage collective action that is change-oriented (King & Pearce, 2010). Contextual changes are often needed to provide these resources and justifications necessary for individuals to collectively challenge established patterns of behavior within institutions (Barley & Tolbert, 1997). This means that in the process of institutional change, actor and occurence cannot be viewed as isolated from each other.

2.2 The German automotive market and electric mobility

Since the invention of the modern car, the automotive industry has played a meaningful role within Germany due to its significance within the economy, global recognition of its engineering excellence, and its role in pioneering the global transition towards EVs. It operates within a highly institutionalized setting which makes the current transformation such an interesting case.

In the following, first, a brief introduction to the origins of the automotive is given, followed by an account of the exhaust pollutions released by an ICE which form the foundation for numerous regulations, and the EV itself. Then, the structure of the German automotive market is depicted, as well as its role within the German economy.

While the term *automotive* refers to all motor vehicles, *automobile* is used to describe passenger cars. In the context of this paper, both words will be used synonymously referring to all kinds of passenger vehicles.

2.2.1 A brief history and major milestones

German engineer Carl Benz is accredited with the invention of the modern car in 1886, an automobile passenger car with an ICE (J. Davis, 2016). By then, however, EVs had already been invented. Accounts report about different inventors, most commonly Robert Anderson who was tinkering with EVs as early as 1832 (Matulka, 2014), and Gustave Trouvé who is ascribed the first official drive with his Trouvé Tricycle in 1881 (Fischer, 2016). In the early 1900s, the EV gained popularity and more EVs than ICE cars were on the streets in the United States of America (US), mostly because they were easier to handle and did not require the laboring manual start of the gasoline motor. Ironically, the advancing of electronics made the starting of an ICE easier, while technological developments made the engine more powerful and quieter. The EV disappeared from the streets (Thompson, 2017).

When global environmental concerns during the 1960s became a major issue, the EV again gained public attention. Cities such as Los Angeles and New York were covered in smog and reported its deadly consequences. The dependence on oil imports became a growing concern, notably in the US and Europe, against the backdrop of geopolitical instability, including the Cold War. The situation was compounded by the Arab oil embargo of 1973 in the US, in which oil prices jumped by about 300 % (Kovarik, 2023; Macalister, 2011; Weyler, 2018).

In Germany, too, the state of the environment had deteriorated significantly in the post-war decades, mainly due to industrial emissions. Responding to the increasing environmental attention and emerging environmental programs of Western countries, the social-liberal government under Willy Brandt first began forming *environmental policy* as an independent field during the late 1960s. This resulted in the adoption of Germany's first environmental program in 1971 (Rink, 2020). In 1972, for the first time, countries convened at the Stockholm *United Nations (UN) Conference on the Human Environment* to form an action plan which laid the basis of the UN Environment Program. It is considered the beginning of international environmental governance (UN, 2023a).

The few attempts by German OEMS to produce EVs were rather experimental in nature. In 1972, Munich, Germany's automotive capital, became the scene of the Summer Olympics and simultaneously the world stage of the presentation of the BMW 1602 Electric, BMW's first EV. During the event, the car served as a transport vehicle for the organizing committee and was used as a camera car during long-distance competitions. With its nearly 60 km range and 350 kg battery, the car was not ready for commercial production (BMW, 2022a). Also Volkswagen (VW) introduced an EV, the Golf I Elektro. Due to technical limitations of the battery technology and impracticality for consumers, these vehicles were quickly discontinued (Mobile.de, 2020; Wildberg, 2014).

The 1990s marked a period of renewed optimism regarding e-mobility, possibly spurred by events such as the Gulf War, which again brought attention to the issue of oil dependency, as well as renewed environmental regulations (Thompson, 2017). In Germany, however, the production of EVs remained isolated attempts by OEMs and newcomers (Mobile.de, 2020). The introduction of the Tesla Roadster in 2006 with a production start in 2008 dawned the start of a "new era of electric mobility", according to Tesla itself (Drori, 2008).

The awareness first raised in the 1960s, has set up motions that developed into a series of events and subsequent agreements regarding climate action on a national, European Union (EU) and global level.

2.2.2 Exhaust emissions of internal combustion engines

The transport sector is a major source of harmful emissions, both for the environment and human health. Pollutants released by car exhaust include carbon dioxide (CO_2), nitrogen oxides (NO_x) and particulate matter (PM) (European Environment Agency, 2016).

CO_2 traps heat in the Earth's atmosphere causing the greenhouse effect and contributing to global warming and climate change (EPA, 2023). Since 1990, the total greenhouse gas emissions in Germany have fallen from over 1.25 million tons of CO_2 to about 750 million tons.

Emissions caused by the transport sector, on the other hand, have hardly changed at all, and their share within total emissions has therefore risen from 13 % to over 19 %. On average, today's passenger cars have an improved environmental impact per kilometer due to technological engine and catalytic converter advancements. However, these CO_2 savings have been offset by a steady increase in road traffic and the trend toward larger and heavier vehicles (Umweltbundesamt, 2023a). In 2010, due to its size and economic power, and position as a logistics hub in the center of Europe, Germany was among the five states accounting for about around 66 % of total road transport emissions in Europe (Puls, 2013).

CO_2 is, amongst others, produced by the combustion of fossil fuels, such as gasoline and diesel, in car engines. The consumption advantage of a diesel engine over a comparable gasoline engine is up to 25 %. Therefore, despite the higher carbon content of diesel fuel, diesel vehicles have a CO_2 advantage of up to 15 % (Bundesverband der Deutschen Industrie, 2018). International efforts, such as the Paris Agreement, aim to limit global temperature rise by reducing greenhouse gas emissions (UN, 2023b). In the transportation sector, regulations, such as CO_2 emission standards and fuel efficiency requirements, aim to limit CO_2 emissions (European Commission, 2023a).

NO_x are a group of gases, among it nitrogen dioxide (NO_2), formed during the combustion process of an ICE, that impact human health (European Environment Agency, 2016) by directly damaging respiratory tissue. NO_x also contribute to the formation of PM (Umweltbundesamt, 2013), tiny solid or liquid particles suspended in the air that when inhaled can enter into the lungs and bloodstream. It can also lead to smog and acid rain (European Environment Agency, 2016). This refers to a secondary formation of PM. In addition, primary PM refers to the direct production of PM, namely gasoline engines (Grunert & Schmitt, 2017), as well as through brake and tire abrasion and the whirling up of dust from the road surface (Umweltbundesamt, 2023c). The heavier the vehicle, the more PM is generated (J. Becker & Ilg, 2022).

NO_x and PM are more heavily produced by diesel compared to gasoline engines (Greenpeace, 2016). Diesel engines emit up to ten times more NO_x than gasoline vehicles (ARD, 2019). The EU set an annual mean limit value of 40 NO_2 $\mu g/m^3$, and established emission standards, such as the Euro standards (currently at Euro Norm 6) for maximum limits on the amount of NO_x and PM that vehicles can emit, aiming to improve air quality and protect public health (Umweltbundesamt, 2023d). Also, engine technologies, such as *selective catalytic reduction systems* (International Organization of Motor Vehicle Manufacturers, 2023a) and *diesel particulate filters* (Urban Access Regulations, 2022) minimize these emissions.

2.2.3 The electric vehicle and infrastructure

Today, several types of EVs exist. The expression *EV* is used as an umbrella term to describe all vehicles that are powered partially or completely by an electric source (Kroher, 2023a). Most commonly the following types are found:

Battery electric vehicles (BEVs) are cars powered solely by a battery which draws its power mainly from charging stations (Opel, 2023). Hybrid vehicles, in contrast, rely on another energy source in addition to a battery, usually fuel that fires an ICE. They come in different increments: A *plug-in hybrid vehicle's* (PHEV) battery is charged via a charging station. Purely electric driving is possible for up to about 60 kilometers depending upon the battery size (Kroher, 2023a). *Full hybrids* and *mild hybrids* solely rely on surplus power from the ICE that is converted into electrical energy, as well as kinetic energy released during braking, to fuel the battery. While full hybrids are capable of a few kilometers of electric driving, mild hybrids commonly only allow for acceleration from a dead stop (Opel, 2023). The batteries of BEVs and PHEVs, too, include these forms of additional energy generation (Kroher, 2023a).

While conventionally EVs are understood to be BEVs and PHEVs, also *fuel cell electric vehicles* (FCEV), commonly known as hydrogen cars, exist. Hydrogen generates electric current, which drives an electric motor (ADAC, 2022b). They are legally recognized as EVs in the 2015 Electric Mobility Act passed by the federal government (Deutscher Bundestag, 2015).

On January 1, 2023, the Kraftfahrt-Bundesamt (KBA) (Federal Motor Transport Authority) reported a total 60.1 million registered vehicles, of which 48.8 million were passenger cars. Of these, 1,013,009 were BEVs, which accounts for a 63.8 % increase compared to the previous year, while 864,712 fell into the PHEV categorization, which reflects a growth of 52.8 % (KBA, 2023c). Figure 3 depicts the development of registered EV passenger cars, split into the categories BEV and PHEV.

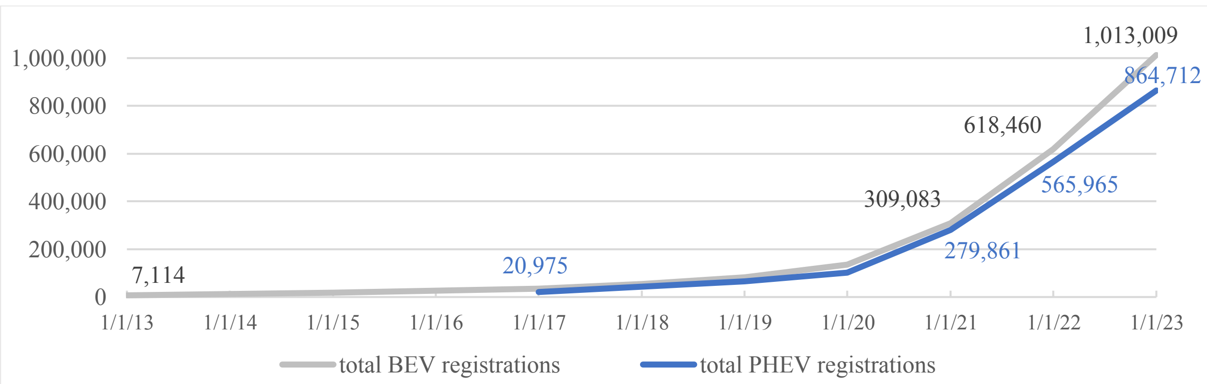

Figure 3: Development of number of registered EVs (passenger cars) in Germany, 2013-2023 (Source: own figure based on data by KBA (2023a))

According to the Bundesnetzagentur's (Federal Network Agency) charging point register, 67,288 standard charging points and 13,253 fast charging points were in operation (Bundesnetzagentur, 2023b). A public *charging station* is a device designed to supply electric energy to charge BEVs and PHEVs. A *charging point* is the physical outlet where an EV can be charged. A charging station may contain one or multiple charging points. One charging point can charge one EV (Bundesnetzagentur, 2023a). Figure 4 depicts the development of number of charging points.

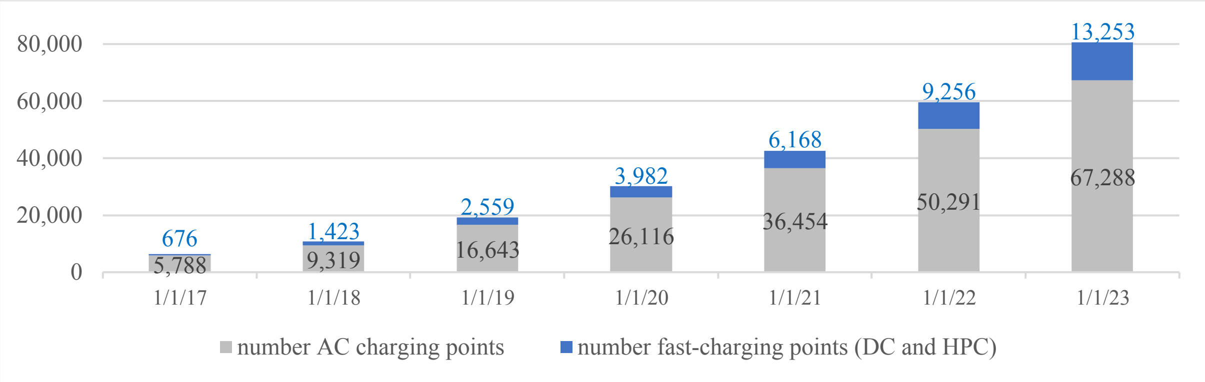

Figure 4: Development of number of charging points in Germany, 2017-2023 (Source: own figure based on data by Bundesnetzagentur (2023b))

Generally, the higher the charging power in kilowatts (kW), the faster an EV can charge its battery. Direct current (DC) stations can provide between 50 kW and 350 kW. If a station is capable of charging more than 150 kW it is called a High Power Charger (HPC). These are reserved for BEVs, which can additionally charge alternative current (AC). The PHEV battery, in contrast, can only receive AC up to 22 kW. In the past, different charging cables and connectors existed, these have been standardized in recent years by the EU to fit universal AC and DC charging points (EnBW Energie Baden-Württemberg AG, 2020). Solely Tesla vehicles are equipped with specific connectors which fit Tesla's own superchargers. Tesla cars, can nevertheless, also use other charging stations with an adapter (Verbraucherzentrale, 2023).

The reach of an EV is foremost influenced by the battery capacity of the EV. In principle, the greater the battery capacity, the greater the range. Moreover, the energy consumption per kilometer plays a decisive role which is influenced by the weight of the car, profile of the route to be driven and the driving style (E.ON, 2023). The weather also influences the performance: More energy is required the larger the battery and the colder the outside temperature. Cold outside temperatures can result in additional consumption of 10-30 %. The range decreases accordingly (Rudschies, 2022). In addition, electronic equipment plays a role, for instance, air conditioning, heating, and headlights can account for about 10-20 % of the total energy consumption of electric cars in actual operation (Umweltbundesamt, 2023b).

Accordingly, the real energy consumption and the range of an EV differs from the battery values tested under laboratory conditions. To ensure comparable values, since 1992, the EU has used the *New European Driving Cycle* (NEDC) (Neuer Europäischer Fahrzyklus, NEFZ) to standardize testing of fuel consumption and emissions for passenger cars and light commercial vehicles (KBA, 2023f). Since September 2017 in effect, and since September 2018 mandatory for all first-time registrations, the *Worldwide Harmonized Light Duty Test Procedure* (WLTP) intends to ensure more realistic values through new test parameters (Kroher, 2023b) which amounts to stricter measures of CO_2 emissions by up to 20 % (BMUV, 2020).

2.2.4 The German automotive industry

2.2.4.1 Key features

The automotive industry is made up of a range of participants. Most prominent are the vehicle manufacturers, also known as OEMs. They are typically major corporations that market their products globally and have strategically positioned their production facilities accordingly (Barthel et al., 2015). They are responsible for designing, engineering, assembling and testing vehicles. They source the necessary components and materials from suppliers (Sturgeon et al., 2008). Renowned German OEMs include Volkswagen Group housing ten brands, including the brands of German origin VW, Audi and Porsche; BMW Group as the parent company of BMW, Mini and Rolls-Royce; Daimler AG, to which, amongst others, Mercedes-Benz, Maybach and Smart belong; and Opel, which is now a subsidiary of Stellantis N.V.

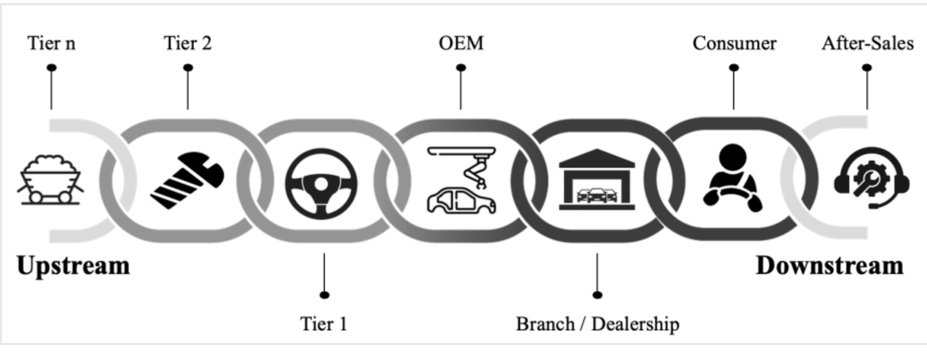

Figure 5: The automotive value chain (Source: own figure)

As depicted in figure 5, OEMs are placed in the middle of the value chain. Upstream, OEMs sit on top of a *Tier*-pyramid which refers to companies that supply OEMs with various components and systems needed to build vehicles. Suppliers are found within the chemical, textile, mechanical engineering, electrotechnical, and steel and aluminum industries (BMWK, 2023a). The direct suppliers are referred to as *Tier 1* suppliers, which have transformed into "mega suppliers" and "system integrators" (Barthel et al., 2015: 11) and operate in globalized settings and production frameworks (Barthel et al., 2010). They provide complete subsystems and modules (Puls & Fritsch, 2020), such as brake and seat systems. Over the past years, OEMs have increasingly shifted competencies in research and development (R&D) to them (Barthel et al., 2015). Among the twenty world's largest suppliers are German companies, such as Bosch, Continental AG, and ZF Friedrichshafen AG (Manager Magazin, 2022).

Tier 1 rely on *Tier 2* suppliers to provide them with sub-components. These suppliers are often highly specialized medium-sized companies. Examples of Tier 2 suppliers include small engineering firms, machine shops and specialized component manufacturers, producing parts such as windows or handles. Next, *Tier 3* suppliers focus on specialized individual parts. Suppliers on lower levels of the pyramid can also skip levels and directly supply *higher* suppliers or the OEM itself (Heras, 2015; Puls & Fritsch, 2020; Sturgeon et al., 2008).

Partnerships, strategic alliances and equity alliances are frequently found between OEMs and their suppliers. These collaborations are formed to share technology, reduce costs, and improve supply chain efficiency, or to meet the required quality standards and specifications (Deloitte, 2023). In this regard, many partnerships last for years or even decades, such as the partnership between BMW and Magna Group which have worked together since 2001 (BMW, 2001).

Downstream, subsidiaries or branch offices (*Niederlassungen)* of the OEMs and their car brands can be found. They typically handle sales, marketing, distribution, and after-sales services for the parent company's products. As direct representatives, they allow for a local presence around the world. In contrast, dealerships, are usually independent traders who are contractually bound to one or more brands (Köstring et al., 2020). It should be noted that the European dealer market is also in a state of flux. In 2020, EY proposed that until 2025 only half of the dealerships will remain (Gall, 2020). In the long term, OEMs plan to go forward with direct sales. An increasing conversion can already be observed (Hoffmann et al., 2019), as well as replacing dealerships with an agency model (*Agenturmodell*). Mercedes-Benz, e.g., already introduced this system in Austria in 2021, and is planning on doing so in Germany in 2023 (Mercedes-Benz, 2021b). These concepts, however, are outside the scope of this thesis.

After-sales services as the most downstream service are also practiced by independent operators and include repairs, maintenance, as well as the provision of spare parts (Grimm et al., 2020).

The relationships between OEMs and tiers are complex as many different suppliers and subcontractors across the globe are involved in the production of a single vehicle. Further, around these functions, many other services are established, especially in the after-sales function, such as logistic companies, repair shops, petrol stations, and other related services that are either directly or indirectly reliant on the automotive economy (BMWK, 2023a).

2.2.4.2 Economic hub

The German automotive sector includes companies that manufacture motor vehicles, produce automotive parts and accessories, and create trailers and bodies. In 2021, they totaled up to a count of 933 OEMs and suppliers, and 44 OEM plants (Germany Trade and Invest, 2022). In terms of revenue, it is the most significant industry in Germany. OEMs contribute to this with over three quarters. As seen in figure 6, after a decline in 2020 due to the COVID pandemic, over € 411 billion in revenues were generated in 2021 and reached an all-time high of over € 500 billion in 2022 (Statistisches Bundesamt, 2023). Two-thirds of the revenue (€ 274 billion) generated by the sector came from exporting around 76 % of passenger cars, mostly to countries outside the EU (BMWK, 2023a).

China, the US and Europe are the three most important automotive markets. Together, they account for two-thirds of global new passenger car registrations. The Chinese passenger car market is leading in this regard, it alone accounted for nearly 30 % of global car sales in 2021 (VDA, 2021). The Chinese market has played a primary role in the sales of German OEMs. Between 2011 and 2020 their import volume from German OEMs rose from 25 to almost 40 %. Since then the number has decreased to about 36 % in 2022 (Ernst & Young, 2023: 25).

German OEMs serve both the mass and the premium segment, nevertheless are internationally highly distinguished and regarded by their emphasis on the premium class (Grimm et al., 2020). Premium is defined by a high value on comfort and technology and also includes, for instance, smaller car classes, such as the BMW 1, or the MINI brand. Demand for the premium category is based on a rather low price elasticity (Barthel et al., 2015). The high global appreciation is seen in strong international sales figures which also makes it reliant on the diverse trends in the markets abroad (Grimm et al., 2020). In 2016, 63 % (Bormann et al., 2018), and in 2021, 65 % of all global premium vehicles sales came from German OEMs (Germany Trade and Invest, 2022). Mercedes-Benz, BMW and Audi are leading (Bormann et al., 2018).

The importance of the German automotive industry for overall economic production has steadily increased. From 1997 to 2017, the gross value added rose from 2.9 % to 4.5 % (Jannsen et al., 2019; Statistisches Bundesamt, 2017). Within the manufacturing sector, this development stands out and is, until today, the industry with the highest contribution to the gross value added (BMWK, 2023h). The supplier side, including further industries, such as the chemical industry, is gaining value added. Thus, suppliers internationally are drawn to Germany as a business site, with the ten largest non-German auto industry suppliers having established operations in Germany (Germany Trade and Invest, 2022).

With more than 3.3 million produced vehicles in Germany in 2021, Germany placed 6th in the ranking of the highest-producing countries and took a leading position in Europe (International Organization of Motor Vehicle Manufacturers, 2023b). Responsible for this were 2.2 million employees, making the automotive industry Germany's largest employer, accounting for 7 % of the country's social security-insured workforce. This includes approximately 786,000 jobs directly within the automotive industry (BMWK, 2023a). Figure 6 depicts the number of direct employees between 2015 and 2022 which has been notably decreasing since 2019. Most influencing was the pandemic as production sites were closed. The resulting shortage of parts continues to this day and affects the number of employees (Manager Magazin, 2022).

From 2008 to 2016, German OEMs shifted their production increasingly abroad. While the number of vehicles manufactured in Germany remained roughly steady, its total contribution decreased from about half to one third. The most important sites are China, followed by the US (Bormann et al., 2018).

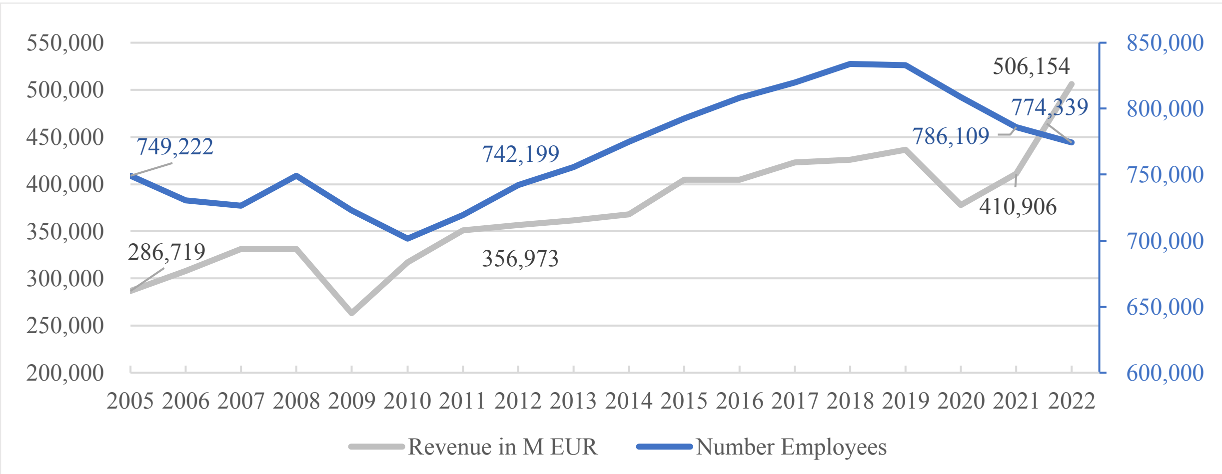

Figure 6: Development of revenue and number of direct employees in the automotive industry (manufacture of motor vehicles and motor vehicle parts), 2005-2022 (Source: own figure based on data by Statistisches Bundesamt (2023) (Code 42111-0003))

3. Methodology

To establish what triggered the transition of the automotive industry, this thesis reviews existing knowledge on institutional innovation and offers novel perspectives obtained through qualitative research. The research design is based upon *grounded theory*, which is the methodological development of a theory from empirically gathered evidence and applies to construct the "social reality of those whose actions combine to impact a given set of human phenomena" (Hansen, 2005: 266). In this sense, initially, a systematic literature is conducted (Denyer & Tranfield, 2009; Denyer et al., 2008) drawing on academic papers. In a second empirical step, grey literature is consulted, and thirdly, interviews are conducted to support or oppose the findings and link them to the practical example of the automotive industry. The concept involves iteratively analyzing data through coding and categorization to detect patterns (Hansen, 2005) based upon the themes of the research questions, i.e. actors, FCEs and jolts.

This chapter provides an overview of the research design and data collection process, and finally, the analysis method.

3.1 Systematic literature review of academic papers

A systematic literature review is a thorough and organized method for combining previous research on a certain subject. The goal is to provide an evidence-based, unbiased summary of the existing literature to guide decisions in practice, policy, and research. It entails employing explicit methods to locate, critically evaluate, and synthesize all pertinent papers on a given research topic. The process begins with a comprehensive database search, followed by a title and abstract review. The subsequent reading of full texts enables data retrieval and in-depth examination of findings (Denyer & Tranfield, 2009; Kable et al., 2012). In management and organization studies this approach aids in understanding how systems work and identifying their mechanisms (Denyer et al., 2008).

3.1.1 Institutional innovation and the process of change

The systematic literature review aims to explore institutions and identify the key actors and occurrences involved in institutional innovation. It serves as the foundation for the theoretical background in chapter 2.

SCOPUS was employed as the main research database. It is run by Elsevier and comprises a comprehensive range of articles from scholarly journals, books, and conference proceedings from various academic fields, reaching from the humanities and social sciences to medicine and technology. The search was carried out on the 28th of April 2023.

Keeping in mind the thesis' objective and theoretical concept of institutionalism, the search was restricted to peer-reviewed academic publications that are available online and published in English. Literature reviews, books, book chapters, conference reports, and other unpublished work were omitted to the greatest extent possible to circumvent grey literature and to gain a clean first impression of original work. Because not all journals are equally reputable for management research, the German Academic Association of Business Research's VHB-JOURQUAL 3 ranking was used as the foundation for the quality check evaluation of journals. Only journals meeting the A+ and A quality standards were accepted. To find journals that weren't listed there, the Scimago Journal & Country Rank was checked, using a Q1 consistency filter. Other than that, peer-reviewed articles with strong citation rates were considered.

The following search string was used: (TITLE (institution* OR “institutional theor*” OR “neo-institution*” OR “institutional change” OR “institutional innovation”) AND TITLE-ABS-KEY (isomorphism OR legitim* OR deinstitution* OR reinstitution* OR jolt* OR “field-configuring event*” OR agen* OR “social movement” OR professional OR entrepreneur* OR technolog*)).

In this regard, the title had to include the first five key terms. In addition, one of the further eleven terms must be contained either in title, abstract or as a keyword. The asterisk symbol * is used as a wildcard by including different word forms or variations, allowing for broader results. The quotation marks “” indicate that the enclosed words are combined in the inquiry.

This search resulted in 34,408 documents. The results were then limited to English articles from peer-reviewed journals in a final publication stage, published between 1970 and 2023 as most literature on institutions started emerging then, and within the subject areas of social sciences, business, management and accounting; and environmental science. This reduced the number to 13,026 documents. Next, the journals were filtered to only include high-quality journals based on the previous criteria and focused on management, organizational and public policy studies, yielding in 701 results. All articles were then scanned by their titles, limiting the search to 81, of which the abstracts were then read.

During these two final steps, to assess the relevance of the articles, inclusion criteria were created in line with Denyer et al.'s (2008: 402) "fit for purpose" method, and two focuses were laid: Firstly, to include articles that allow gaining an understanding of institutions itself, institutional theory and institutional innovation. Secondly, the search aimed to determine anteceding factors of institutional innovation. The aim was not to identify how change is achieved but rather what kind of events and actors can trigger the process of de-institutionalization as a prerequisite for change. The remaining 48 articles were read. Ultimately, the most relevant 25 articles were included in the thesis and served as the foundation for further document collection.

Further appropriate articles were chosen using the *snowball* method, extracting publications based on the citations discovered within the literature. Lastly, the database Google Scholar was consulted to identify further relevant literature published regarding this topic. The method used to assess how well the papers fit and the quality criteria applied mirrored the initial search. Here, for the purpose of summarizing institutional theory, also book chapters, meta-analysis and literature reviews were included in the search results. This search added another 30 documents, which results in a final number of 55 and provided a thorough yet condensed basis for this thesis. For an overview of the sources, see appendix 1.1.

3.1.2 Institutional literature in the German automotive industry

To review the existing literature on institutional literature in the German automotive market, SCOPUS was consulted as a first base on the 10th of May 2023. The inclusion and exclusion criteria, focused on original research, match the ones defined previously.

The following search string was used: (TITLE (institution*) AND (automotive OR automobile OR car OR diesel OR engine OR "electric vehicle*" OR ev) AND TITLE-ASB-KEY (german*)).

The search required the inclusion of the word *institution* or a term derived from its root in the tile, along with an automotive-related term. Additionally, the search was restricted to results related to Germany or the German context. Setting no initial filter, it yielded six results.

Due to the limited available results, ratings were extended to include B-rated journals according to VHB-JOURQUAL 3, as well as Q2 from Scimago Journal & Country Rank. All six results could be found in these categories. Five are peer-reviewed articles and one review (subsequently excluded); four are published in English and two in German, all between 2010 and 2020.

The search aimed to identify original research that includes German organizations or the German industry to highlight institutional factors. Reviewing titles and abstracts, it became clear that two papers dealt with institutional innovation in the German automotive industry and two with German organizations within the international automotive industry. The fifth article was not related to the automotive industry and was therefore ruled out. The remaining four papers were read. Next, a Google search using the same terms, as well as a *snowball* search was conducted, yet no further relevant literature was found. An overview of the literature is depicted in appendix 1.2.

3.2 Qualitative study

As a result of the theoretical examination of the core mechanisms of change, the findings were next applied to the automotive industry. *Grounded theory* grounds the development of theory "in the reality of the informants" (Hansen, 2005: 267), increasing the legitimacy of qualitative analysis. Qualitative studies, being explanatory in nature and aiming to comprehend societal complexities (Kohlbacher, 2006) benefit from the use of grey literature and interviews, providing profound and comprehensive understandings from multiple perspectives.

3.2.1 Grey literature

To broaden the scope of research that addresses the institutional transformation of the German automotive industry, a wide range of perspectives are included that are not singularly written by authors of academic background or have undergone a peer-review process. Grey literature as such represents a heterogenous collection of writing and is categorized by Adams et al. (2017) based on the variables *outlet control* and *source expertise*, respectively reaching from *known* to *unknown* resulting in three types of grey literature. While the innermost corner, representing the highest regarded literature, is left blank, 1st tier grey literature follows which includes book chapters and publications from government agencies. Then, 2nd tier material stems, among others, from news outlets, consultancy studies or company reports. Lastly, classified as most unreliable, 3rd tier information may entail blogs, tweets and other informal communication channels.

By embracing grey literature, publication bias, referring to the selective publication of statistically significant or positive research findings, can be reduced by ensuring a more comprehensive view of the topic and avoiding distortions in the overall evidence base. It further allows to access emergent research that has not been formally publicized yet. It has to be acknowledged that due to the diversity and lack of uniform reporting, the literature has to be chosen critically (Adams et al., 2017; Conn et al., 2003). Following the data collection proceeding of a systematic review (Denyer & Tranfield, 2009; Kable et al., 2012) as previously defined, allows for a rigorous, critical and transparent approach.

In the context of this paper, only 1st and 2nd tier material is considered that originates from evidently credible sources by evaluating its credentials to allow for a high-quality and unbiased review of the empirical part of this thesis. Publications written in English and German are embraced. To be able to observe a change in the market and assess its relevancy, it is crucial to include sources from the past decades.

In the search, the focus lies on reports from official sources. Firstly, federal government documents and websites are considered as they can provide formal documentation on the economy, policies, legislations and industry development, supported by data and statistics. Secondly, work from research institutions is drawn upon, focused on, but not limited to, facilities that collaborate with governmental entities, such as the Friedrich-Ebert Foundation or

Fraunhofer Institute. Considerable work here has examined the automotive industry itself and its role within Germany, as well as the impact of certain occurrences on the German economy, such as the EV itself, or the COVID pandemic. Thirdly, doctoral dissertations are insightful as they base their work on academic as well as empirical data and examine topics in detail. Fourthly, industry-specific information was taken from consultancy reports, working papers and other unpublished reports as they offer case studies, and analysis and are conducted by experts in the field. Lastly, news reports from established publications allow insights into current but also past events, background information and relevant perspectives. Due to scope limitations of this thesis, individual company reports of OEMs or suppliers are not assessed.

To find appropriate grey literature, different keywords were used in various combinations with the terms *automotive industry* and *Germany*, such as: *structural change*, *transformation*, *innovation*, *influencing factors*, *regulatory system*, *environment*, *emissions* and *e-mobility*. Regarding overarching legislative changes, documents from the UN, EU, European Commission and German federal government were specifically searched for. As most federal government documents but also related reports are in German, a separate keyword search in German assisted the inquiry that followed the above-termed keywords.

Due to the diverse nature of the grey literature, Google was used as a generalized search engine (Adams et al., 2017) to allow for broad results. The search strategy was based on initial findings from the keyword search, as well as the interviews which laid the basis for further specific inquiries. This led to a *snowball* system and resulted in detailed and highly relevant literature.

3.2.2 Interviews

The expert interview is a data collection method, commonly applied within organizational research and social sciences due to its universality and ability to explore and understand complex phenomena in depth (Meuser & Nagel, 2009), such as societal issues (Bogner et al., 2009). The open-ended format of interviews allows to investigate the interviewee's understanding and perspective on a specific topic (Cassell, 2009).

Interviews can be characterized by the structure and degree of interviewer guidance by pre-determined questions. Structured interviews generate more objective data, yet are fixed in their questions. In qualitative interviews, semi-structured or unstructured formats enable adaptations of the questions to the interviewee and to follow-up on an issue as deemed necessary. This leads to a more organic and exploratory conversation in which the interviewee has "room (…) to unfold his own outlooks and reflections" (Meuser & Nagel, 2009: 31). Semi-structured interviews use a framework to guide the questions, while unstructured exchanges allow for the most flexibility. The latter however entails the risk of a less focused discussion and potentially missing out on relevant information, especially for inexperienced researchers (Rabionet, 2011).

A semi-structured interview format was chosen to allow an open and knowledgeable discussion enabling an in-depth and precise knowledge gathering without drifting off track, and for better comparability of the interviews, compared to an unstructured format (Meuser & Nagel, 2009).

Notably, the researcher has to be aware that interviews are not the source of objective knowledge and facts but are based on real-life accounts and actual expertise, and are subject to biases and the extent to which honest answers are given (Bogner et al., 2009). The data quality may be influenced by the framing of the questions as well as the interpretation skills by the interviewer (Cassell, 2009).

In the following, the expert selection, interview guidelines and data processing are outlined.

3.2.2.1 Selection of experts

"Who is defined an expert and who not depends on the researcher's judgment" (Meuser & Nagel, 2009: 18). Within this thesis, interview participants are deemed experts because of the specific knowledge they have about the German automotive industry, electric mobility and occurrences of the past decade due to their professional roles and longtime field experience in the sector. Relevant professional groups that are searched for are, firstly, managers and engineers from OEMs to gain an inside view both from a business development angle and a technical standpoint. The focus is on German OEMs as they are in the foreground of the transformation and within the value chain in a powerful position. Secondly, consultants offer a valuable perspective due to their industry knowledge, allowing them to provide an overarching approach to the topic. Their continuous need to stay updated on external developments offers an insightful outside view. Thirdly, association or union representatives can give an insight into the employee perspective and on the political view.

Nine experts from the above-named groups were chosen to gain a view on the topic from different angles. Participants from the German OEMs were a manager, two senior managers with engineering backgrounds, and an engineer. Further, two consultants specialized in the automotive industry, two functional managers within an automotive association and one representative from an employee's association were interviewed. The selected participants had between six and 38 years of experience in the German automotive industry, see table 1, and are thus deemed experts.

	Date	Approx. length of recording (in min)	Approx. experience (in years)	Type of Organization	Practice	Contact with external stakeholders
1	30.05.23	60	12	OEM	**Manager**: Innovation & Piloting in mobility and energy services	Industry associations, Federal Ministries of Transport and Economics; Customers
2	05.06.23	50	34	OEM	**Engineer/ Senior Manager**: Production, R&D, Product Planning, Sales; Overall corporate responsibility for various model lines	Regulatory authorities, Press, Customers, Dealerships
3	06.06.23	50	10	OEM	**Engineer**: Functional development and application for gasoline engines; Functional development and software for electric motors	Suppliers; Regulatory authorities (indirectly via OEM central office)
4	06.06.23	50	7	Consultancy	**Consultant:** Transformation of the automotive industry and EVs	OEMs, Research institutions, Politics, Press
5	07.06.23	50	11	Automotive Association	NPE; Policy department of an OEM; **Functional Manager**: Raw material availability, environment, sustainability	GGEMO, Ministries, Bundestag, Automotive industry, Research institutions, NGOs
6	08.06.23	50	8	Automotive Association	**Functional manager:** Economic intelligence, market development and forecasts of the automotive industry nationally and worldwide, supervision of political processes	Politics, Federal Ministry of Economics, other industries, Embassies, Research institutions
7	09.06.23	45	8	Consultancy	**Consultant:** Premium and volume manufacturers with a focus on German manufacturers; Blockchain and distributed ledger technology in the automotive sector	OEMs, Start Ups, Chinese Greenfield OEMs, Asian Importers
8	13.06.23	55	37	OEM	**Engineer/ Senior Manager**: Chief Development Officer and Development Management Board of German and Chinese OEMs, consulting activities	Suppliers, Press
9	15.06.23	55	6	Employee's Association	Economic issues, industrial structure, labor market policy	Works councils, Politics

Table 1: Overview of interviewed experts (Source: own table)

Reliability and validity was ensured to the best extent possible, since interviews are subject to bias and subjectivity. Open-ended questions encouraged the participants to address issues independently thereby minimizing interviewer bias. They were under no time pressure, and a rather informal setting permitted to respond freely. The assurance of anonymity should limit a social desirability or confirmation bias. The attention the interviewees showed, the openness and sincerity with which they responded, the details and figures provided, and great overlap in the information found across the interviews, allow to place trust in the answers given.

3.2.2.2 Interview guideline

To maximize the benefits of the research, an interview guideline was used to support the structuring of the interviews (Meuser & Nagel, 2009). To develop the questions, a solid understanding based on prior research on the subject matter is crucial (Rabionet, 2011).

First, questions were gathered and evaluated on their applicability to answering the study topic. The questions were then separated into thematic blocks and subcategories, guided by the categorization of the systematic literature review and the initial grey literature review, and aimed to identify actors and occurrences. This division into blocks allows for more flexibility, for instance by not restricting the chronology of the questions to the guideline but aligning them with the answers given by the interviewee ensuring a better conversation flow. Secondly, a higher focus can be placed upon a thematic block according to the respective field of expertise of the respective interview partner and his/her profession.

Prior to the interviews, participants were informed via e-mail about the privacy policy of personal data and the confidential treatment, as well as the audio recording. They were assured that the interview results would be used solely for academic purposes. The interviewees had received this information in written form and had signed it. At the beginning of the interview, it was again affirmed that any details that could give inferences about the own person or organization would be blackened in the transcript. This was aimed to encourage them to focus on the interview and speak freely without having to be concerned about revealing data.

To start, the thesis topic was described, questions clarified and terminology explained. Then, questions about the type of organization, background and organizational function, duration of experience within the automotive industry, and contact with external stakeholders were asked (see table 1). To ensure the protection of personal details, the recording was started only after.

First, the interview began by asking about the institutions of the German automotive industry to identify why it has been enduring and thus could have impeded change. Then, secondly, questions addressed overarching issues on the topic of electric mobility aiming to get a first evaluation of the transformation unbiased from the researcher's later more specific questions. These questions explored when electric mobility was first discussed in politics, society, or companies and its underlying causes.

The main part of the interview aimed to identify first actors within the transformation and secondly occurrences in form of FCEs and exogenous jolts. These occurrences were divided into subcategories based on the process of change as identified by Greenwood et al. (2002) and (Oliver, 1992), The categories differentiated between *social*, *technological/ functional*, and *regulatory/ political* factors. The two additional categories *market* and *competition* were added for a more nuanced examination.

To gain insight into the topic from a customer perspective, the experts were asked to personally evaluate EVs. Lastly, to ensure that all aspects the interviewees wished to mention were addressed, they were asked if any further topics should be discussed. The interview ended by thanking them for their participation. The interview guideline can be found in appendix 3.

3.2.2.3 Data collection and processing

The interviews were conducted between the 30th of May and 16th of June 2023 (see table 1). All interview partners were German speaking, thus the interviews were conducted in German. Roughly one hour was scheduled, two extended this period by about ten minutes. The setting was a Microsoft Teams video call or a telephone call. Solely the interview per se, i.e., the questions and answers given were recorded, the introduction and closing were not.

After, the interviews were automatically transcribed using transcription software. Subsequently, the files were personally reviewed for accuracy, preciseness and comprehensiveness. The transcription was done verbatim, however, small modifications were made, as long as it did not change the content, by excluding filler words, and standardizing punctuation and grammar when appropriate to enhance legibility and clarity. For that reason between speakers, a line was left empty and the paragraphs of the researcher and interviewee were labeled accordingly (Kuckartz & Rädiker, 2019). For data protection reasons, content that could lead to any identification was blackened.

3.2.3 Qualitative data analysis

The collected data from interviews and grey literature is analyzed through systematic coding. Because grey literature is broad in nature, only the most relevant reports that broach the issue of the transition of the automotive industry as a whole are integrated into the coding scheme, excluding, for instance, newspaper articles addressing an observed theme in detail.

Coding allows a researcher to identify patterns and themes that lead to the development of conceptual categories and form the basis of theoretical frameworks (Hansen, 2005). Specifically, part of the data, in this case, text phrases, are fit within a thematic coding category. Thereby "it is allowed and necessary to break up the sequentiality of the text also within passages" (Meuser & Nagel, 2009: 36). In doing so a coding scheme is built that allows a thematic comparison (Meuser & Nagel, 2009).

First, a deductive approach was followed starting with codes that build upon the main theoretical model (Kuckartz & Rädiker, 2019): *actors*, *exogenous jolts* and *FCEs*. As already mentioned, these three items cannot necessarily be separated. For instance, a FCE in the form of a conference is the consequence of a gathering ordered by actors, the same principle applies to jolts. Then, inductively coded subcategories are constructed directly based on the new data. This is an iterative process of constant comparison of data in which codes are adapted or new codes added within categories to fit the data (Kuckartz & Rädiker, 2019). Hansen (2005: 271) compares this process to accumulating clues that build upon each other to solve the “mystery” of the work.

In this regard, an Excel file was set up with the sources on the x-axis and categories on the y-axis. Phrases from the respective data sources were copied to the respective category cell. If a source mentioned a topic within a category multiple times, it was put within the same cell. The phrases were marked with their question number if from an interview or page number of the grey literature to be able to correctly trace it back to its source.

4. Findings

The industry is undergoing a structural change, triggered not by one invention but by a combination of regulatory pressure, climate activism, increasing competition and advancing technology, processes that developed in parallel, yet reinforced each other. As such, institutional innovation occurred incrementally, pushed through actors, FCEs and jolts throughout different moments in time, building up momentum.

In the following, first the institutions of the German automotive market are elaborated on and their role in making it enduring. Then, by inductively developing the occurrences in the market, with a focus on the past decade, based on grey literature and interviews, the core mechanisms of change are identified.

4.1 Institutions in the German automotive market

Institutionalized environments play a decisive role in preventing change. This was already shown by Zimmermann and Bollbach (2015) who followed a German automotive components manufacturer operating in China trying to transfer a lean production system to their production facility there. China exhibits institutionalized structures based on cultural settings and traditional norms that are reflected on the social and organizational level. For instance, century-old family networks, hierarchical management structures and individualistic tendencies manifested in a reluctance to assume accountability, which contradicted the principles of the lean methodology. These institutional barriers hindered a successful transfer of the system. Contrary, Tasli-Karabulut and Keizer (2020) analyzed Japanese and German firms operating in the Turkish automotive industry and found that Turkey as a developing economy lacked institutionalized practices. The firms were thus able to act as institutional entrepreneurs in establishing new methods in their host environment.

Specifically, the German automotive industry displays much institutional activity, through institutionalized organizations and established structures shaped over decades. It is crucial to understand the OEMs' link to the ICE and their interrelation with the other organizations in the institutional environment, in order to recognize how they contributed to the industry's stability. Table 2 depicts the actor groups of the institutional environment which shape the fundamental political principles and organizational guidelines that govern the industry. Their roles are explained in more detail in the following.

	German OEMs	(SME) suppliers	The state	Regulatory bodies	Associations
Role in automotive industry	• Design, engineer, assemble and test vehicles	• Component suppliers of OEMs	• Setting of regulations that directly influence the industry	• Setting and enforcing regulations, safety standards, etc.	• Interest groups of the industry & employees of OEMs and suppliers
Role in success of industry	• Engineering excellence • Brand affiliation • Widespread employment	• Knowledge • Long-term partnerships and collaborations • Specialized processes	• Support of industry as employer and contributor to value added through subsidies & programs	• Established processes and knowledge, setting standards in testing for vehicle safety etc.	• Advocating interests through lobbying & ensuring compliance with tariff contracts
Legitimacy	• History • Quality • Widespread employment	• Fostering efficient supply chains • Contributing to the quality of vehicles • Widespread employment	• Consent of the people • Regulatory authority	• Government mandate, long-standing authoritative entities	• Industry-wide membership successfully representing interests
Role in institutionalization of ICE	• Globally recognized knowledge in building cars and specifically ICEs	• Often specialized in the ICE	• Indirect: Support of industry • Diesel fuel subsidy	• Indirect: Ensuring adherence to standards to ensure safety	• Lobbying favorable policies regarding ICEs • Supporting employees' rights

Table 2: Institutionalized environment of the German automotive industry (Source: own table)

4.1.1 German automotive manufacturers

OEMs play a pivotal **role** in the automotive industry (Interviews 5, 7) by orchestrating the design, production, and assembly of vehicles. Their **success** and thus **legitimacy** is based on their long-standing presence and practices based on the formula of product and production expertise in combination with high-quality mass manufacturing (Bormann et al., 2018). Their political influence and position of power is boosted by strong-led companies and industry groups, widespread employment (Interviews 5, 6) and relatively high unionization rates, as well as their high reputation based on their acknowledged engineering excellency and the iconic position of automobiles in the public perception (Heras, 2015; Sturgeon et al., 2008).

The personal connection of the Germans to the passenger car is based on its 100-year history and its central role in the reconstruction of society in the decades after the second world war, becoming the engine of the so-called economic miracle (Grieger, 2019). Since then it has become a status symbol, representing freedom, prosperity and hard work, and shaped a so-called *Autofahrernation*, a nation of car drivers (Lamprecht, 2017: 78; Seeberger, 2016), which in turn has benefitted the automotive sector (Commerzbank, 2022). Through its promise of mobility (Interview 2), vehicles has become deeply embedded in social and economic structures, shaping people's lives, mobility patterns and identities (Vašek, 2019).

The cultural impact of the German brands is demonstrated by the strong affinity and pride exhibited by both customers and employees (Interview 8). For instance, the "Porsche myth", as termed by the grandson of Porsche's founder (Manager Magazin, 2009), is built upon the brand's successful motorsport heritage, distinctive design language, and the passion of Porsche enthusiasts around the world. It is also reflected by national and regional solidarity. On the first of January, 2023, 62.7 % of the vehicle fleet registered in Germany, were from German OEMs (KBA, 2023a), specifically, VW, Mercedes-Benz, BMW and Audi (KBA, 2022). Regionally, sales correspond to the respective production sites. In Bavaria, more BMWs are sold than Mercedes-Benz and vice versa in Baden-Württemberg (Steiler, 2013).

Specifically, the knowledge on the **ICE** has gained the German manufacturers global recognition (Interviews 3, 4; Knie, 2022). It carries immense historical significance and consumer familiarity. The German Otto-engine (gasoline) and diesel engine still operate much the same as they did a century ago, and have only been adapted in terms of efficiency (Knie, 2002). Especially, the diesel engine was long considered the masterpiece of German engineering (Interview 4). Its popularity stems from lower fuel consumption and thus lower CO_2 emissions compared to the gasoline engine, and has thus also gained governmental support in form of a lower mineral oil tax since the early 1970s (Dienel, 2017).

Most commonly passenger cars’ engines are made up of four cylinders, the V4 (TÜV Nord, 2019). Its significance is literally built in stone: The 1972-built BMW headquarter in Munich is shaped in the form of a V4 and is known as the *Vierzylinder* (V4) (BMW, 2022b). Also, the sound of the motor has become iconic. "To understand a car, you need to hear it", reflects a Porsche senior manager (Enzinger, 2023). This goes so far as that some OEMs offer a sound package with their EVs for a more emotional driving experience. For instance, Porsche has developed a sound system for their EVs that resembles that of their V6 motors (Porsche, 2019).

As knowledge, production structures and partnerships were based around the ICE, the incumbents thus resist any change of the environment and logics that could endanger their success formula.

4.1.2 The suppliers

Most organizations in **supplier** and after-sales roles in the automotive industry fall under the category of the German *Mittelstand (*Interviews 5, 7), small and medium-sized enterprises

(SMEs), that make up over 99 % of all organizations in Germany (Der Mittelstand BVMW, 2023). Over the years, the tiers have formed long-standing partnerships and collaborations with OEMs, and developed system competencies to manage increased specialization and complex supply networks which the Federal Ministry for Economic Affairs and Climate Action termed to be globally unique (BMWK, 2023a). They are internationally recognized as the driving force of innovation (Barthel et al., 2015) and essential in the well-functioning tier pyramid and value structure (Der Mittelstand BVMW, 2023). As such they provide consistent support and contribute to the **success** of the industry, and by generating around 70 % of the value added in the automotive industry, also, to the prosperity of the German economy (BMWK, 2023a). This also contributes to their **legitimacy**.

As the success of the industry relied much on the competencies within the complex ICE, the suppliers specialized in the **ICE** had invested heavily to build competencies and fit their production sites and structures to accommodate it. As such they contributed to the high quality of the ICE and its endurance. Similar to the OEMs, a change in the propulsion system would have drastic consequences on their business.

4.1.3 The state

The German government, deriving its **legitimacy** from the consent of the people and as an regulatory authority, **represents** the interests of Germany as an economic location before the EU (BMWK, 2023a), and as such also the automotive industry. Because the industry presents a symbol of economic power, innovation, engineering capacity and excellence (Interviews 6, 8), its global recognition (Germany Trade and Invest, 2022) reflects on the industry itself, and in turn the government and country by strengthening the quality seal “Made in Germany” (Heras, 2015; Sturgeon et al., 2008).

Knie (2002) observed that since the mid-1950s, a pattern has been forming, which he described as cartel-like manufacturing structures with state regulatory powers, that secured infrastructural specifications that ensure the functionality of the automotive. Since then, a close network (Interview 6) between policymakers and industry developed. There is a regular exchange with lobbyists at the chancellery. Numerous OEM representatives are recognized as experts in technical committees at the EU Commission in Brussels and in parliamentary committees in Berlin. This network also reflects the transition of multiple political actors to the industry and their lobbying offices (Traufetter, 2019).

Due to the automotive industry’s interwoven economic structure, fluctuations in production and revenue can have far-reaching and quantitatively significant repercussions on other industries and organizations of the economy (Jannsen et al., 2019). The government, thus, has a considerable interest in the economic well-being of the industry (Interview 6).

Extensive programs have been established to **support** the industry (Barthel et al., 2010). In 2009, the government offered an environmental bonus (*Umweltbonus*), colloquially also known as scrapping bonus (*Abwrackprämie*) to boost the industry after the global financial crisis. Also, the preferential tax treatment of company cars (so-called *Dienstwagenprivileg*) (Hildebrand, 2022) and commuter allowances (*Pendlerpauschale*) (Die Bundesregierung, 2022a) make it attractive to purchase cars. Extensive public funds were moreover made available: In the years 2007 to 2016, the government granted a total of around € 1.15 billion in subsidies, the majority for R&D but also for investments (Deutscher Bundestag, 2017).

Through its massive backing, the state also indirectly contributed to the endurance of the **ICE**. Moreover, by subsidizing diesel fuel, the government had publicly advocated the diesel **engine** due to its lower emissions compared to the gasoline engine since the 1990s (Jacobs & Quack, 2018).

4.1.4 Regulatory bodies

Regulatory bodies within the institutional environment **serve** as central entities responsible for setting and ensuring adherence to industry standards, safeguarding public interests, and maintaining the overall integrity of the automotive sector (Interviews 6, 7). They set expectations, provide oversight, and shape the behavior of industry participants, **contributing** to the industry's stability and functioning. Regulatory bodies derive **legitimacy** from their government mandate, and acceptance as long-standing authoritative entities.

Due to the decade-long dominance of the **ICE**, most standards were designed around it. As the propulsion technology shifts towards EVs, their role is to design policy frameworks around it.

For instance, the Federal Motor Transport Authority (*Kraftfahrt-Bundesamt,* KBA) as the higher federal authority for road traffic, is, amongst other things, responsible for market surveillance, product safety and conformity verification (KBA, 2021). The Technical Inspection Association (*Technischer Überwachungsverein*, TÜV*)* represents a network of independent state-approved testing and certification organizations responsible for technical monitoring, vehicle safety and environmental standards (TÜV Verband, 2023).

4.1.5 Associations

Trade associations are interest groups, recognized as authoritative bodies representing the collective interests of their members. To do so, they lobby their member's objectives and **engage** with policymakers aiming to affect regulations (Rajwani et al., 2015).

Industry unions represent the interests of the industry by advocating favorable policies and formulating industry standards, **shaping** the industry's structure and practices, and contributing to the adherence to established practices and thus its stability. Their **legitimacy** arises from their industry-wide membership (Interview 6, Schroeder, 2023). On an European level, the European Automobile Manufacturers' Association (ACEA) represents the collective interests of 14 European OEMs (ACEA, 2023). Nationally, for instance, the Association of the Automotive Industry (*Verband der Automobilindustrie e.V.*, VDA) advocates the industry-specific interests of automotive manufacturers and suppliers to policymakers, most prominently less strict emission regulations and thus more favorable policies regarding **ICEs**. Moreover, it promotes innovation, sustainability, and safety in the industry (VDA, 2022a).

Employee's associations represent and protect employees, ensuring a skilled workforce, and ultimately **driving** the industry's prosperity and advancement. They are characterized by high membership rates, democratic processes, and successful negotiations, and are accepted as **legitimate** representatives of workers' interests (Bundeszentrale für politische Bildung, 2019). The German Trade Union Confederation (*Deutscher Gewerkschaftsbund*) is Germany's largest and most important umbrella organization of trade unions and aims to protect the interests of workers, promote social justice and equality at national level (Bundeszentrale für politische Bildung, 2019). Industrial representative association *IG Metall* negotiates collective bargaining agreements for its members.

Employee's associations are in close exchange with work councils within companies, which are an institutionalized representation of employees' interests towards the employer. Its duties are regulated in the Works Constitution Act (BetrVG) (Institut zur Fortbildung von Betriebsräten, 2023). Jointly, they advocate better working conditions and tariff-regulated compensations. By ensuring adherence to contracts, they have contributed to job security (IG Metall, 2019) also of workers in proximity to the **ICE**, and, moreover, ensure that, for instance, production facilities may not be simply closed.

Ultimately, the institutions of the German automotive market provide stability, shared rules, and norms, and influence decision-making. Due to its history and link to economic growth and prosperity, the German automotive industry has become synonymous with Germany itself. For decades, the systems set in motion secured a relatively stable environment that fostered long-term economic growth, employment and international recognition, which institutionalized the automotive industry itself. A change in the configuration of the car, is a scraping against an institution and a transition accompanied by restructuring on a substantial scale.

4.2 Development of the German automotive environment and industry

To understand how institutions change and to develop a picture of the transition of the industry, the process is mapped in a chronological sequence of events, akin to a historical story. This is essential to determine the causal mechanisms that lead to transforming events, and the specific circumstances driving these mechanisms (Hargrave & Van de Ven, 2006).

In the following, time blocks are identified describing their most critical occurrences. The timeline is divided into four phases as seen in figure 8: firstly, *pre 2012* to outline the origins of electric mobility, followed by ranges *2012 to 2015*, *2016 to 2019*, and lastly *2020 to 2022*, describing the development of occurrences and the actors that shaped that time block. For a more comprehensive chronological list and further details, also on the respective regulations, see appendix 2.

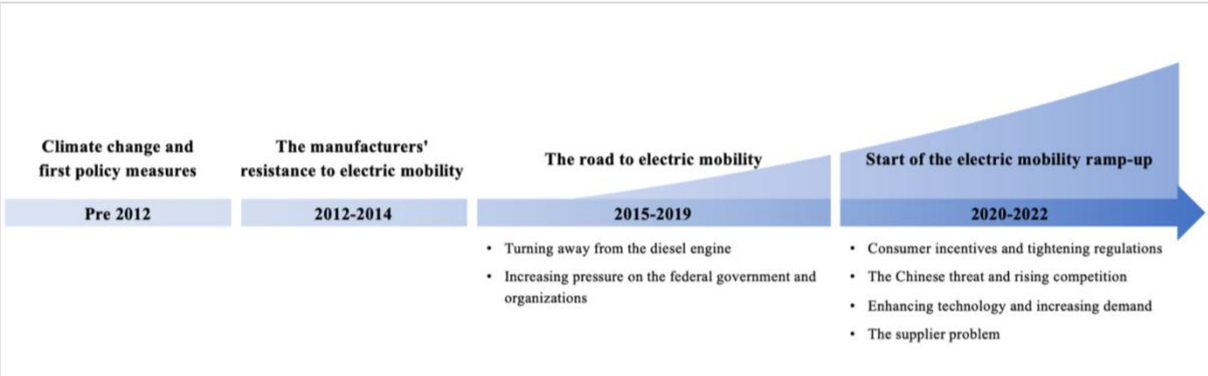

Figure 7: Development of the German automotive environment and industry (Source: own figure)

4.2.1 Pre 2012: Climate change and first policy measures

The years up to 2012 were marked foremost by two major triggers: Politically, first regulative directives addressed climate change (see table 3, *state*). They triggered initial discussions and regulations about innovative and environmentally friendly mobility concepts (Barthel et al., 2010), even though OEMs were rater reluctant to invest in new concepts. Socially, Tesla, through the introduction of the Roadster, showed the technical possibilities of EVs and by that, over time, positively influenced the image of EVs in society (see table 3, *organization*).

Actor	Actor group	Occurrence	FCE/ Jolt	Impact	Role in adoption of EVs
State	UN	**1972:** UN conference on climate protection	**FCE**: Regular social gathering of nations	Begin of **international environmental diplomacy**, leading to further UN climate protection gatherings and directives	Influencing European law in lowering emissions, e.g. EU exhaust emission standards
		1997: Kyoto Protocol	**Political jolt:** Regulatory directive	Enforceable **legal accord** to reduce emissions, foundation for further legislative initiatives to reduce CO_2	E.g. EU regulations on air quality, ACEA agreement in 1998 to lower emissions (unsuccessful)
	US	**1990:** US Zero-Emission Vehicle Act	**Political jolt**: Regulatory directive	**Regulative** initiative forcing OEMs to adhere to stricter emission regulations	First investment in EVs, trial on EVs by German OEMs on Rügen (unsuccessful)
	Germany	**2008:** National Strategy Conference on Electric Mobility	**FCE**: One-time social gathering of politicians and industry	First discussion on the future **role of electric mobility**, including representatives from the automotive industry and associations	Aim of one million EVs registered by 2020, establishment of National Platform for Electric Mobility and Government Program on Electric Mobility, subsidies in R&D
	EU	**2009:** EU Regulation 443/2009	**Political jolt:** Regulatory directive	**Regulatory** impact: Set compulsory CO_2 emission performance standards on a fleet basis from 2015 and 2020/ 2021	Specifically, regulation from 2020/2021 put pressure on OEMs to invest in lower-emission vehicles and EVs to avoid fines
Organi-zation	Tesla	**2008:** Tesla & Model Roadster	**Functional jolt**: Introduction of lithium-ion batteries in EVs **Social jolt**: Change in societal perception	**First BEV** suitable for highways	Demonstration of technical capabilities to society and OEMs, positively influencing the image of EVs

Table 3: Pre 2012: Overview of actors, FCEs and jolts influencing the institutionalization of the electric vehicle (Source: own table)

State: Politically, since the 1970s state actors have played a critical role in promoting climate protection through international and national regulations. Three state actor groups can be identified: 1) The **UN**, as an intergovernmental organization and policymaker, directly influences and regulates nations. 2) Within Europe, the **EU** is the actor that sets climate policy frameworks for its member states and produces regulations and directives. While individual jurisdictions in the respective nations play an important role, the EU has legislative resolution (Unger & Oppold, 2021). 3) **Individual nations** are responsible for national legislatives.

Firstly, the **UN** has been decisive in paving the way toward electric mobility, albeit indirectly. The nations of the world coming together at the 1972 **UN conference on climate protection** served as the first **FCE** as it set the base for the upcoming climate debate (UN, 2023a), putting the topic of environmental protection on international agendas. In 1997, the UN proposed the **Kyoto Protocol** which served as the foundation for following international legislative initiatives. At that time, it was the only enforceable legal accord in the world to reduce emissions. By requiring developed countries to lower their greenhouse gas emissions by 5 % compared to 1990 over the commitment period 2008-2012 (European Commission, 2023c; UN, 2023c), its resolution can be defined as a critical **political jolt** in terms of climate protection, thus addressing the automotive industry by setting national emission guidelines. Within the automotive industry, efficiency improvements of the ICEs in combination with other regulatory measures in Germany were sufficient to surpass the set emission reductions for 2012. The Ecological tax reform and its mineral oil tax, as well as the car tax reform which takes into account the size of the engine and CO_2 emissions, were highlighted as key measures (Barthel et al., 2010).

Following the Kyoto Protocol, in 1998, on behalf of its members, the ACEA voluntarily committed to the European Commission to reduce average emissions from new cars to 140 g CO_2/km by 2008. It was a first display of action by the industry to lower emissions. The value was, however, not reached (European Commission, 1998).

Secondly, influenced by the UN, the **EU** introduced initiatives to lower emissions. Already in 1992, the EU exhaust emission standard 1 for motor vehicles (*Abgasnorm/ Euro Norm 1*) introduced a first direct measure to reduce NOx and PM (Umweltbundesamt, 2020). Most decisively, in 2009, in response to the failed ACEA agreement, the EU decreed **Regulation 443/2009** which set compulsory CO_2 emission performance standards based on the NEDC for new passenger cars in the EU on a fleet basis: From 2015 on, the average CO_2 emissions must not exceed the limit of 130 g CO_2/km. From 2020 on (in its entirety from 2021), a stricter limit of 95 g CO_2/km applies (BMUV, 2020). This is the first decisive **political jolt** that later on directly contributed to the adoption of increasing electric mobility (see next sub-chapters).

Thirdly, the US and Germany introduced national legislations to reduce emissions.

In the **US**, *state* directives had set stricter standards for various car exhaust pollutants, including NO_x and PM, with their Clean Air Act in 1970 (EPA, 2022). The country was under increasing pressure due to poor air quality, notably on the West Coast. Specifically, their **Zero-Emission Vehicle Act in 1990** acted as a **political jolt** by enforcing stricter emission regulations (California Air Resources Board, 2023). It became an example of early political legislative with an international effect and can be accredited first advancements into electric mobility (Interviews 2, 4, 5). If car manufacturers worldwide were to register cars in the US, they had to adhere to strong regulations (California Air Resources Board, 2023).

Within **Germany**, the *state* aimed to reduce emissions. In 2007, Germany's Integrated Climate and Energy Program laid the foundation for a comprehensive energy and climate policy (BMWK, 2023e), for the first time acknowledging the role of electric mobility in achieving climate targets. First concrete initiatives followed under Chancellor Merkel. In 2008, she brought together the automotive and other industries, and environmental and consumer organizations at the **National Strategy Conference on Electric Mobility.** In this first national

FCE, the representatives were to discuss a *National Electric Mobility Development Plan* (Die Bundesregierung, 2008). An objective of one million EVs registered by 2020 was set (Die Bundesregierung, 2009a). To achieve the goals set by the plan, a in 2010 established *National Platform for Electric Mobility* (NPE) brought stakeholders from business, science, politics and society together (NPE, 2018). The agreed points were then taken up in the *Government Program on Electric Mobility* (Die Bundesregierung, 2011b).

Moreover, to meet air quality values set by the EU, in 2008 the German state introduced low emission zones in particularly polluted areas (Wissenschaftliche Dienste des Deutschen Bundestages, 2005). In 2010, it legislatively passed the EU-specified annual average limit value of 40 µg NO_2/m^3 (Umweltbundesamt, 2022b). Within the Economic Stimulus Package II, adopted in wake of the financial crisis, also, funding programs to support the market introduction of electric mobility were initiated (Deutscher Bundestag, 2009: 421, 426).

***Organizations*:** On the manufacturers' side, Germans and US OEMs alike were hesitant to invest in EVs. Their resistance can be exemplified by the General Motors EV1, one of the world's first battery-powered production vehicles, built in reaction to the Zero-Emission Vehicle Act. The company never sold the car, just leased it. In 2003, when the Act was repealed due to pressure from the oil and automotive industries, General Motors, against the wishes of the drivers, stopped the leases and even towed cars. Emission-free vehicles, also from other OEMs, disappeared from the streets again (Postinett, 2006). In Germany, OEMs launched a large-scale EV trial on the island of Rügen with the support of then-Federal Environment Minister Angela Merkel in 1992. Afterward, the topic was removed from the agenda as the automotive industry argued that the market was not ready, nor the technology sufficient (Pander, 2008; Interview 8).

2003 saw the founding of American electric car manufacturer **Tesla Inc**. Five years later, the sports car **Roadster** launched with a range of around 350 km and a driving performance suitable for highways. With a price of about $ 110,000, it was out of the average consumer's price range (Brown, 2016). Also, the car took more than 24 hours to charge and for safety reasons, many vehicles had to be recalled. The firm only narrowly survived the following global financial crisis. And while, in 2010, Tesla went public and reached a $ 2.22 billion valuation (Forbes, 2022), only in 2020 did it first achieve profitability (Ohnsman, 2021).

Even though it had a rocky start, with its founding, Tesla redefined the automotive industry. Its distinction as the first institutional entrepreneur stemmed from its ability to shape public perceptions (Li et al., 2006), acting as a **social jolt**. Initially belittled by established OEMs

(Interviews 2, 3; Grünweg, 2018), it has become a manufacturer of best-selling electric cars, and in the process has also given new meaning to the image of the EV. „Before Tesla, electric mobility was always a subject of compromise, with limitations and ultimately not sexy.“ (Interview 4). All interviewed experts consider Tesla an essential actor in triggering the global transformation toward electric mobility. It drew public attention to the EV and proved that ranges of several hundred kilometers are possible, which can be defined as a **functional jolt.** Further, the management early on realized the need for a systemic change and took matters into their own hands. In a short time, they build a charging infrastructure across the US, later internationally (Tesla, 2023a).

Daimler, too, started experimenting with EVs. In 2008, it commissioned Tesla to electrify a vehicle of its daughter Smart and invested in nearly 10 % of Tesla stock (Tesla, 2010). In 2014 Daimler sold its shares. Speculations attribute this to a clash of cultures between the conventional approach of the German company and the more experimental, radical, and quick approach of the Silicon Valley company (IOL, 2020). The institutionalized structures prohibited exploring alternative ways of operations.

4.2.2 Years 2012-2014: The manufacturers' resistance to electric mobility

The years 2012 to 2014 were marked by two major triggers. Socially, the BMW i3 exposed the German population to electric mobility (see table 4, *organization*). On the regulatory side, the upcoming EU fleet regulations from 2021 put the manufacturers under pressure to act (see table 4, *state*). By lobbying against it, they aimed to resist electric mobility. The German state voiced the industry’s concerns to the EU and advocated an easing of the limits.

Actor	Actor group	Occurrence	FCE/ Jolt	Impact	Role in adoption of EVs
Organi-zation	BMW	**2013:** BMW i3	**Social jolt:** Change in societal perception	First mass-produced purpose-design built BEV by **German** manufacturer	German OEM to gain massive public attention with its BEV, exposing population to EVs
State	EU	**2014:** Modification of EU Regulation 443/2009	**Political jolt:** Regulatory directive	**Regulatory** impact: Future fleet values by 2021 have to be met to avoid fines	Certainty that EVs are necessary to meet future fleet values

Table 4: Years 2012-2014: Overview of actors, FCEs and jolts influencing the institutionalization of the electric vehicle (Source: own table)

***Organizations*:** Until the end of the first decade of the 21st century, the expansion by manufacturers into electric propulsion remained faint. In 2013, German OEMs BMW and VW launched first mass-produced vehicles, the BMW i3 (GoingElectric) and VW e-up! (Jürgen, 2023). French manufacturer Renault revealed the Zoe (ADAC, 2023b), Italian Fiat the 500e (Hybrid-Autos.info, 2023). Why the manufacturers introduced their vehicles at this exact time is uncertain. The fact is that BMW began designing the i3 as early as 2008 (Freitag, 2013). Sources attribute this to growing environmental pressure (Interview 4), increasing competitive pressure from the hybrid sector, including Toyota, the fear that technology companies could enter the market (Freitag, 2013), and the ambition to become an innovation leader (Automotive news Europe, 2013). That Tesla contributed to this pressure is controversial due to its still small-scale operations back then (Interviews 1, 4).

With the **BMW i3,** as one of the first mass-produced electric vehicles from a renowned German automaker, BMW actively pushed into the EV market and gained much attention (Interviews 2, 3, 6, 7). By contributing to a local wave of attention in the public eye, it acted as a **social jolt,** exposing the population to EVs. The i3's unique design according to the purpose-design principle – developing the car specifically for electric driving by designing the car around the battery and using best-suited light materials (Seeberger, 2016) –, advanced features, and high-profile marketing campaigns contributed to its role as a catalyst for conversations around electric mobility. It, moreover, prompted discussions about charging infrastructure, battery technology and government incentives. Nevertheless, in the long run, the model only narrowly reached profitability (Süddeutsche Zeitung, 2022).

However, the values agreed upon in the Kyoto Protocol for 2012 were reached, and the CO_2 emission limitations set for 2015 of 130 g CO_2/km already surpassed in 2014 (IG Metall, 2016a). Through ICE optimizations and a higher focus on smaller models, emission values could be lowered sufficiently (Seeberger, 2016). For instance, Mercedes-Benz gave its smaller car *Model A* a complete redesign in 2012, aiming to positively change its image (ADAC, 2023a). This underlines how OEMs took measures to achieve emission regulations in other ways instead of EVs.

Numerous voices from the automotive industry also publicly opposed electric mobility. Their comments depict the lack of intrinsic motivation to initiate any kind of transformation. For instance, Ferdinand Piëch, VW Chairman of the Supervisory Board, stated in 2012 that he did not think much of electric mobility because he did not see batteries with sufficient durability in the foreseeable future (Backhaus et al., 2012). Daimler chief Zetsche saw the combustion engine still playing a major role in 20 years' time (Spiegel, 2012). Due to cost reasons, Audi stopped production of its electric car (Rother, 2013). Peugeot called EVs optional while not viewing them as a priority (Automotive world, 2014). Fiat even openly requested their customers not to buy the Fiat 500e as the sales were not profitable (Reuters, 2014).

State: The EU's **fleet target of 95 g CO_2/km from 2020** was the next emission regulation coming up. Considering a production life cycle of five to seven years (Interviews 1, 2, 3, 4, 9) and the fact that Mercedes-Benz, Audi and Porsche launched their first BEVs in 2018 and 2019, it can be concluded that this regulation was decisive (**political jolt**) in terms of OEMs making first important decisions about their future. Expert 2 supports this. The interviewee stated that as the respective OEM started to consider designing its first BEV, the limit values and fines were a significant reason.

However, German OEMs aimed to resist this fleet target. According to Seeberger (2016), in 2014, Daimler-CEO Winterkorn put the cost of saving one gram of CO_2 at € 100 million. The manufacturers had to decide whether to invest in electric mobility or in diesel technology and decided to follow the diesel strategy (IG Metall, 2016a). Presumably, they were convinced that the government would ease the restrictions (Interview 9). Due to the industry's national economic importance, the *German state* actively supported the industry's aim.

In the summer of 2013, in the run-up to an upcoming EU vote to decide the CO_2 values beyond 2020, newspapers reported lobbying by the German automotive industry and quoted a letter from the VDA to Merkel, stating that stricter limits could not be complied with and would harm the German automotive industry (Spiegel, 2013a). Particularly, German premium manufacturers, with their heavier vehicles, would have great difficulties meeting their targets. Aggravating, the average weight of cars has increased by 250 kg since 2000. Moreover, SUVs are in much demand on the market, their share increasing in Europe from three to 46 % in the last 22 years (Spiegel, 2023).

Chancellor Merkel intervened in the passing of the EU vote. It is reported that she personally called various state heads to convince them to oppose the motion. Thereupon, the vote was postponed until 2014 (Spiegel, 2013b; Süddeutsche Zeitung, 2013).

In September 2013, CDU emerged as the strongest party in the 18th German Bundestag election, forming a coalition with SPD under Chancellor Merkel (Tagesschau, 2013). In October, members of the Quandt family (major shareholders and founding family of BMW) donated € 690,000 to the CDU, alongside other manufacturers (Deutscher Bundestag, 2013). Allegations arose regarding a connection to Merkel's recent intervention on CO_2 emissions, which the CDU firmly denied (S. Becker & Medick, 2013). Federal Environment Minister Altmaier stated it was not influenced by the automotive industry but aimed to balance environmental protection and European economic interests (Ingenrieth & Marschall, 2013).

Resulting, in spring 2014, **EU Regulation 443/2009's 2020 CO_2 target was modified** by allowing weight-based calculations for the cars. Furthermore, in 2020, to calculate the 95 g CO_2/km limit, manufacturers may exclude 5 % of its vehicles with the heaviest CO_2 emissions. From 2020-2022, a *super-credits* system should facilitate reaching the target of 95 g CO_2/km: Each new passenger car with emissions below 50 g CO_2/km is given extra weight when calculating the manufacturer's overall fleet emissions (European Union, 2014b).

The OEMs with support of the national government successfully achieved a mitigation of the tightening of the limits. Seeberger (2016) described this as a deliberate stalling attitude on the part of the OEMs, similar to a delaying tactic that attempts to conceal the fact that they were neither prepared nor willing to drive the topic of electric mobility forward of their own accord. It is an exemplary depiction of the interconnectedness of German politics and the industry and shows the personal relations at play. Nevertheless, the passing of the emission target gave the manufacturers certainty that upcoming fleet values have to be met in order to avoid fines and prompted a push towards electric mobility.

4.2.3 Years 2015-2019: The road to electric mobility

The years 2015 to 2019 were marked by two forceful effects: first, the manufacturers' aim to rely on the diesel engine to meet fleet regulations was disrupted through the diesel gate and subsequent diesel driving bans resulting in the announcement by VW to quit ICE and setting a precedent in the industry (see table 5, *organization* and *professionals*). Secondly, more stringent climate laws and regulations were set (see table 5, *state* and *professionals*). Increasing climate concerns in the population were diffused through an environmental social movement (see table 5, *social movement*), which in turn put pressure on the federal government to increase their climate protection efforts.

Actor	Actor group	Occurrence	FCE/ Jolt	Impact	Role in adoption of EVs
Organi-zation	OEMs	**2015** Diesel gate	**Social jolt:** Crisis/ Change in societal perception	Start of the **de-institutionalization** of the diesel engine, collapse in new registrations	To meet fleet regulations, OEMs have to increasingly rely on EVs
	VW	**2018** Handelsblatt Summit: VW announces the end of the ICE	**FCE**: Annual social gathering	First major announcement by **German** OEM to fully invest in EVs in the future	Precedent set by major German OEM, impact and on suppliers and certainty that transition is imminent
State	UN	**2015** UN conference in Paris & Paris agreement	**FCE:** Regular social gathering of nations **Political jolt:** Regulatory directive	**Regulatory** impact: goal to limit climate warming to 1.5°C	Basis for further EU regulations to lower emissions and German Climate Action Plan 2050
	Germany	**2016** Climate Action Plan 2050	**Political jolt:** Regulatory directive	**Regulatory** impact: Aim to become climate neutral by 2050	Basis for further political initiatives to lower emissions and boost EV adoption, e.g. Electric Mobility Act

Professio-nals	Normative agents (Umwelthilfe) & regulative professional (court)	**2018** Lawsuit by Deutsche Umwelthilfe against the state of Germany for exceeding EU air quality values	**Political jolt:** Regulatory directive **Social jolt:** Change in societal perception	Contribution to **the de-institutionalization** of the diesel engine: inner-city driving bans for diesel cars permissible	To meet fleet regulations, OEMs have to increasingly rely on EVs
Social movement	Fridays for Future	**2018** Fridays for Future	**Social jolt:** Change in societal perception	**Diffusion** of topic on climate protection in population who put increasing pressure on government and organizations	Increasing awareness in population about climate protection and pressure on organizations to become more sustainable & governments to initiate political measures

Table 5: Years 2015-2019: Overview of actors, FCEs and jolts influencing the institutionalization of the electric vehicle (Source: own table)

4.2.3.1 Turning away from the diesel engine

Organizations: Since 1990, emissions from European road traffic increased. In Germany, the values decreased between 1990 and 2010 by 3.8 %. The diesel engine played a major role in this development. By optimizing the ICE, a reduction of over 25 % of emissions was achieved between 2004 and 2016 for both diesel and gasoline engines (Puls, 2018). Because diesel vehicles have lower CO_2 emissions of up to 15 % (Bundesverband der Deutschen Industrie, 2018) and the potential for optimization has not yet been exhausted (IG Metall, 2016a) German OEMs planned on relying on the diesel engine for the 95 g CO_2/km target achievement (IG Metall, 2016a).

The lack of interest in investing in electric mobility, meanwhile, was evident in the few electric models that were launched on the market. Although the BMW i3 was built according to the purpose-design principle, most of the time manufacturers simply placed electric motors in existing models (Automotive news Europe, 2013; Seeberger, 2016). This is because OEMs wish to continue using their success formula centered around existing knowledge and production patterns (Bormann et al., 2018).

OEMs continued to express public skepticism about the goal of one million EVs by 2020. In 2016, then-Daimler CEO stated that they will continue to invest in improving ICEs as he expects that 75 % of new cars will have motorized engines in 2025 (Nicolai, 2016). Also, IG Metall (2016a) viewed the diesel engine as an indispensable element in effectively reducing CO_2 emissions. Still, they acknowledged that the 2020 emissions target would only be achieved with considerable investment in efficiency technologies, as well as the electrification of conventional drives. The association called for emission levels after 2020 to not be reduced to the same extent as currently targeted. For electrification, they criticized, the charging infrastructure is insufficient, charging times too high and ranges too short.

The fall of the diesel engine, caused by the **diesel scandal**, preempted the OEMs' diesel strategy: In the fall of 2015, the US Environmental Protection Agency's (EPA) accused VW of having manipulated emissions levels in diesel vehicles using illegal software and violating the US Clean Air Act between 2009 and 2015. Soon it became evident that an affected three-liter engine was built by subsidiary Audi (Hulverscheidt, 2015; Timmler, 2018). An e-mail from an Audi engineer from 2007 had surfaced concerning the strict limits for harmful NO_x in the US. The emission values were said to be impossible to comply with without cheating ("ganz ohne bescheißen") (Fromm & Ott, 2016; Spiegel, 2016). In the summer of 2017, the diesel scandal officially reached Germany. Until then, authorities had only assumed manipulation in the US (Timmler, 2018). In 2018, German authorities also started targeting other manufacturers. Porsche and Daimler had to recall vehicles (ADAC, 2021; Bender, 2022). Fines in the three-digit million to billion Euro range followed, top managers were indicted. In 2023, legal proceedings were still ongoing (NDR, 2020, 2023).

The scandal can be classified as a **social jolt** as it triggered a major public backlash and increased scrutiny of diesel vehicles (Tagesschau, 2015), initiating a de-institutionalization process of the diesel engine. The backlash against diesel engines had an indirect effect on the automotive industry's transition towards electric mobility (Interviews 3, 8). The direct effect is reflected in the immediate collapse in new registrations of diesel engines, see figure 8.

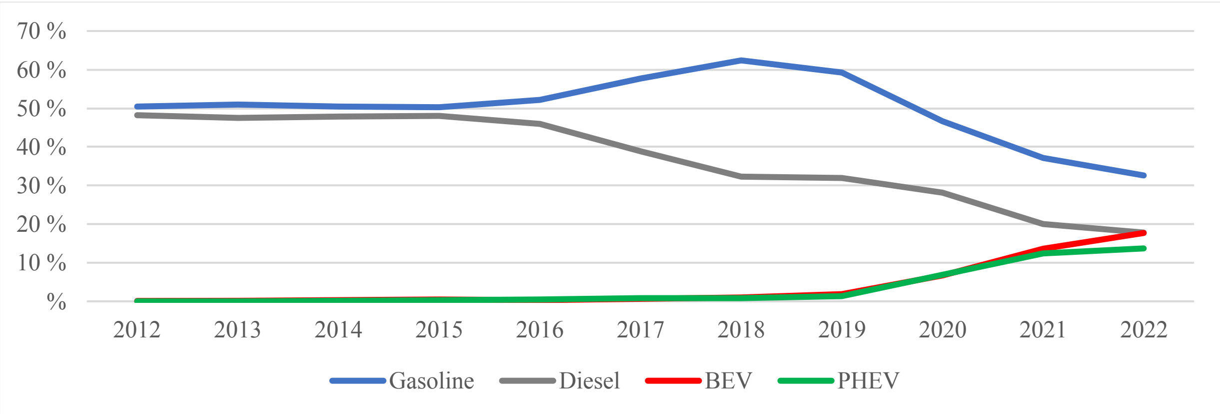

Figure 8: Share (in %) of fuel types in new passenger car registrations in Germany, 2012-2022 (Source: own figure based on data by KBA (2023e))

Although caused by OEMs, the image loss of the diesel engine presents the unintentional consequences of their actions. Presumably, to avert image damage, VW became the first German OEM to announce a significant shift towards electric mobility at the end of 2016. Subsequently, at the 2018 **Handelsblatt summit**, it declared its **intention to phase out ICEs**, with the last ones scheduled to be produced in 2026 (Menzel & Hubik, 2018). For the first time, a German OEM publicly and actively pushed into the field of electric mobility. VW called on suppliers to accompany them in change (Interview 4). This **FCE** can be defined as a turning point, as it set a precedent in the German automotive industry and sent a decisive signal to suppliers but also associations that a transition is imminent (Interview 7).

Professionals: In early 2018, the Deutsche Umwelthilfe (normative professionals) sued the state for exceeding the EU's limit values of 40 µg NO_2/m^3 (EU Regulation 2008/50/EC). Alone in 2016, NO_2 values were exceeded in 26 air quality zones, with Stuttgart reporting a number as high as 82 µg/m^3 (European Commission, 2018). The ruling by the Federal Administrative Court (regulative professionals) allowed **inner-city driving bans for diesel cars** that do not meet Euro 6 emission standards in highly polluted areas (Bundesverwaltungsgericht, 2018). Subsequently, cities like Hamburg, Stuttgart, Berlin, and Darmstadt implemented driving bans, with the list growing over the years, including a ban on Euro 5 diesel vehicles in some parts of Stuttgart since 2020 (Hahn Rechtsanwälte, 2023). This incident, too can be defined as a **social jolt,** adding to the diesel engine's public de-institutionalization. As interviewee 8 put it: "The driving bans ultimately gave a death blow to the diesel". Buying a car that cannot be driven everywhere is decisive in the downturn of these engines (Interviews, 2, 4, 8).

Thus, the effect of the diesel scandal was amplified by inner-city driving ban for diesel cars. As new registrations for diesel vehicles plummeted, in turn, the number of new registrations of gasoline engines rose drastically. Because these engines have higher CO_2 emissions, OEMs were forced to consider how to comply with fleet limits in a different way. In the short period of time available, electric mobility was the most obvious option due to its high degree of efficiency (Interviews 3, 9) and subsidies provided by the state. Also, society was increasingly confronted with the topic, through the publicity level of Tesla, and electric car-sharing vehicles. As the diesel began to break down, society newly reflected on the topic of electric mobility. Yet, not immediately after the diesel gate a new competitive landscape developed in Germany. This is because the production of cars is a complex undertaking with years of development.

Rao et al. (2000) state organizational failure as one possible factor preceding institutional innovation. Here, this failure refers to the actions of various manufacturers within the diesel gate, functioning as a jolt that initiated the de-institutionalization process. Bormann et al. (2018: 23) describe the turning that is set in motion as "transformation by disaster". The institution diesel started to suffer damage, and its image and significance rapidly diminished within the population. This led to a state of instability. It is the necessary conflict that acted as an enabler of the transformation towards electric mobility. As political motives aimed to protect the industry from negative consequences that would reflect on the overall German engineering quality by rigorously and judicial assessing the scandal, it opened up a political opportunity for change. The 2015 Paris Agreement provided the necessary framework to enforce climate laws.

4.2.3.2 Increasing pressure on the federal government and organizations

State: The **2015 Paris UN conference** is the **FCE** to set the 1.5-degree Celsius climate goal which can be defined as a **political jolt** as it set a regulatory directive for nations to follow. Upon the Paris Agreement, more drastic motions followed in Germany such as the 2016 **Climate Action Plan 2050** which defines the nation's aim in 2030 to reduce greenhouse gases by 55 % compared to 1990, and become climate neutral by 2050 (BMWK, 2023f). This **political jolt** followed further measures to stimulate electric mobility. The government adopted the Electric Mobility Act in 2015, to its full extent *Law to Give Priority to the Use of Electrically Powered Vehicles.* The Act provides special privileges for EVs, such as using bus lanes and reserved parking spaces. Other measures included subsidies for purchasing electric cars from 2016 on, the so-called environmental bonus (Deutscher Bundestag, 2015).

Moreover, at the height of the diesel scandal, the government convened five Diesel Summits at the chancellery, gathering representatives from the industry and environmental groups together to address the reduction of car emissions in view of polluted air in the cities, and the future of diesel technology and the role of electric mobility. German OEMs pledged to retrofit around five million diesel vehicles with software updates from which a NO_x reduction of 25 to 30 % was expected. This was, however, just enough to comply with pollution limits and hinder potential driving bans. Environmental organizations critiqued that additional hardware retrofitting could have reduced nitrogen emissions by up to 90 % and that mainly the car manufacturers benefited from the arrangements (Holzer, 2018; Zeit Online, 2017).

Following to the lawsuit by the Umwelthilfe, in 2018, also the EU Commission sued Germany at the European Court of Justice over poor air quality and the systematic disregard of the EU limit of 40 µg $NO2/m^3$ between 2010 and 2016. The lawsuit followed proceedings already opened against Germany in 2015 and 2016 for infringements of air values. The government was accused of massive failures in the emissions scandal, as well as failing to adequately monitor car manufacturers' compliance with regulations (Spiegel, 2018b; Tagesschau, 2018). It again put the government under public scrutiny. In June 2021, the European Court of Justice, convicted Germany of all charges (Kersting, 2021).

Social movement: In 2018, **climate protests** gained momentum, with *Fridays for Future*, initiated by student Greta Thunberg, acting as a **social jolt** by becoming a pivotal force in driving global climate action and can be considered elemental in diffusing the topic. Notably, their second global strike in March 2019 witnessed a participation of nearly 2.3 million people from 130 countries (Fridays for Future, 2023). These protests, ignited by a single actor, transformed into a powerful social movement that mobilized people worldwide, sparked crucial debates and brought together influential actors from politics and society. There is a consensus among experts that the collective outcry for climate action demonstrated the profound impact of activism in promoting awareness, a "change in mindset" (Interview 7) and thus shaping the political agenda (Interviews 2, 4, 7). That social movements have an immense impact, also on the automotive industry, is also exemplified in Guérard et al.'s (2013) analysis on the institutionalization of the diesel particulate filter in Germany.

The increasing climate concerns diffused through the social movement put pressure on the federal government, the EU and organizations:

Firstly, the growing pressure on the government (Unger & Oppold, 2021) presented itself in the establishment of concrete measures to become CO_2 neutral by 2050, and most significantly, the Climate Protection Act (*Klimaschutzgesetz*) in 2019. The NPE was replaced by the National Platform for Future Mobility (NPM) in response to criticism due to its limited focus on electric cars, expanding the platform to include public transport and future concepts such as connected driving (Interview 5). Moreover, the in 2016 introduced environmental bonus was extended beyond 2019 and increased. Within the Master Plan Charging Infrastructure a goal of one million charging points by the end of 2030 was set (Die Bundesregierung, 2019c, 2020b).

Secondly, as the pressure extended to the EU, in 2019 the EU presented the European Green and the subsequent European Climate Law in which the goal of climate neutrality by 2050 and a reduction of net greenhouse gases by 55 % in 2030 compared to 1990 is anchored (European Commission, 2023b).

Thirdly, organizations across industries felt both political/ regulatory and social influences. To respond to the latter, they must consider how to present themselves in a sustainable way to retain the next generation of customers, with a long production time in mind, and especially since the trend had been moving away from private car ownership (Interview 7).

A study from 2018 assumed that German manufacturers would not be able to comply with the fleet values from 2021 (95 g CO_2/km NEDC $\simeq$ 115 g CO_2/km WLTP). Yet, the OEMs succeeded in reaching the limits (RND, 2022). Public pressure and the wish to avoid fines served as crucial motivators to incrementally focus on the electrification of the powertrain

(Interviews 2, 3, 6, 7). In 2018 and 2019, Audi (Audi, 2018), Mercedes-Benz (Rudschies, 2019) and Porsche (Geiger, 2019) launched their first purpose-built BEVs (Interview 1).

The more active push towards electrification was also presented, for instance, in BMW's cooperation with German Hollywood composer Hans Zimmer to produce the sound of the electric cars in the coming years (BMW, 2019). This is to counteract the iconic engine sound. Moreover, in 2018, the HPC-network IONITY, a collaborative effort by various OEMs, opened first charging points. It contributed to the government's efforts to increase the number of public chargers causing the German-wide number started to climb. Figure 4 shows the development of number of charging points in Germany reflected on the first day of the year.

Within the years 2015 to 2019 a disruption was noticeable, foremost triggered by the diesel scandal and driving bans. Both can be identified as environmental jolts, disrupting the order of business and de-institutionalizing the diesel engine, which opened up the possibility of novelty. In society an increased discussion of climate protection was triggered, caused by the social movement in form of protests and putting pressure on the government who pass climate laws. All this also compelled the OEMs to react.

4.2.4 Years 2020-2022: Start of the electric mobility ramp up

In the years 2020 to 2022, a massive increase in EV registrations was noted. This can be ascribed to three major issues: For one, regulatory directives in form of financial incentives on the consumer side and the decision to only allow emission-free cars from 2035 (see table 6, *state*). Second, Chinese OEMs had increasingly started manufacturing EVs themselves, while the imports of German vehicles started to decrease (see table 6, *organization*). Third, over time, technological advances have led to a technological maturity and an extended range while prices for EVs have decreased (see table 6, *organization*).

However, as the transition to EVs is now underway, many suppliers previously specialized in ICEs, face the risk of loss of business and, thus, loss of jobs.

Actor	Actor group	Occurrence	FCE/ Jolt	Impact	Role in adoption of EVs
State	Germany	**2020** Innovation premium (environmental bonus)	**Political jolt:** Regulatory directive **Social jolt:** Change in societal perception	Increase in environmental bonus when buying an EV/ **Financial incentive**	Lowering monetary barriers to buy an EV (as bonus for PHEVs is removed in 2023, massive collapse in sales)
	EU	**2021** Fit for 55	**Political jolt:** Regulatory directive	**Regulation**: Future fleet values by 2021 have to be met to avoid fines	Certainty that EVs are necessary to meet future fleet values
Organi-zation	OEMs	Increasing threat of losing Chinese market / Increasing competition	**Social jolt:** Change in perception of OEMs as to whom consider competition	Increasing number of **Chinese manufacturers**, supported by the state, little market share of	Awareness in OEMs that to be able to compete in the long-term, they have to invest in EVs

				German EVs, foreign EV brands penetrate German market	
		Enhancing technology	**Functional jolt:** increasing range **Social jolt:** Change in perception of	**Technological** impact that assimilates EVs to ICEs in terms of range, price and number of available model	Lowered cognitive and monetary barriers to buy EVs

Table 6: Years 20202-2022: Overview of actors, FCEs and jolts influencing the institutionalization of the electric vehicle (Source: own table)

4.2.4.1 Consumer incentives and tightening regulations

State: In March 2020, the World Health Organization officially declared COVID-19 (*Corona*) a pandemic (Landeszentrale für politische Bildung Baden-Württemberg, 2023). As the economy slowed down, the German state passed the *Corona* economic stimulus package which included measures to promote electric mobility. € 2.5 billion would be invested in charging station infrastructure (Die Bundesregierung, 2020a). Between June 2020 and the end of 2021, later extended to 2022, the **innovation premium** doubled the government share of the environmental bonus subsidy for EVs. Buyers could receive up to € 9,000 when purchasing a BEV (BMWK, 2023b). As a regulatory measure the innovation premium acted as both a **political jolt** and a **social jolt**, encouraging sales.

Between 2020 and 2021, a substantial leap in the number of EVs in Germany was registered. The number of BEVs increased by 126.2 % and PHEVs by 173.9 % (see figure 3) (KBA, 2023a). Due to the correlation to the increase of the environmental bonus, conclusions about its importance can be drawn. Its significance is further affirmed in the removal of the PHEV bonus starting 2023 (BMWK, 2023c; Die Bundesregierung, 2021) which correlates with a noticeable decline in PHEV car registrations. Figure 9 depicts the change in new registrations between January and May 2023 compared to January to May 2022 which decreased by 44 %. Therefore, the bonus represents a jolt in the incline in registered EVs.

Since the environmental bonus itself was already established in 2016, the strong increase in EVs since 2020, thus, cannot be solely attributed to the bonus. Other factors include further financial incentives on the customers' side, such as the car tax exemption for ten years for BEVs (§3d Steuerbefreiung für Elektrofahrzeuge, Kraftfahrzeugsteuergesetz 2002), the decreasing legitimacy of the diesel engine, and increasing acceptance by the population. The latter was also influenced by enhanced technology, expanding infrastructure and more model variety, also in different price segments, as explained in the following chapters.

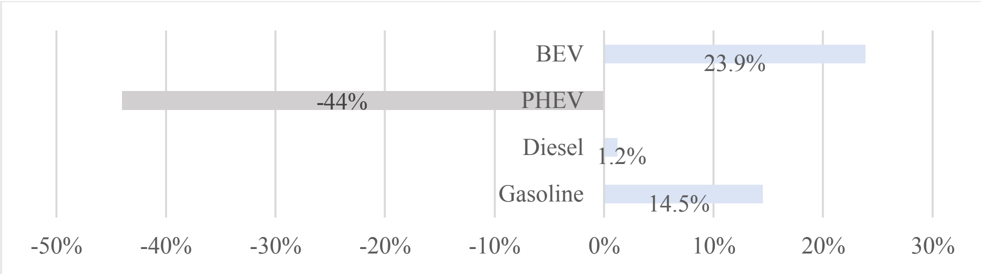

Figure 9: Changes (in %) in share of fuel types of new passenger car registrations, January to May 2023 compared with January to May 2022 (Source: KBA (2023e))

On a European level, in July 2021, the EU package **Fit for 55** introduced a number of proposals to revise EU legislation. It is a follow-up to the European Climate Law and adds a target value of 0 % for 2035: Only emission-free new cars may be registered from 2035 onwards (Europäischer Rat, 2023a, b). This presented the final decisive **political jolt** to the transformation (Interviews 2, 6, 7). The impact of the regulations was directly reflected in the immediate announcements of Mercedes-Benz (Mercedes-Benz, 2021a), Audi (Hägler, 2021) and brand VW (Prem & Schmidtutz, 2021) to withdraw from the ICE until 2035.

Lastly, in November 2022, the European Commission proposed the Euro 7 standard from 2025 on for passenger cars (European Commission, 2022). Effectively this would imply that an electrified fleet is necessary to meet the target which would bring the 2035 zero CO_2 target forward (Interviews 2, 4). Controversy flared up across European OEMs about a too short implementation frame and extra costs that would come along with it. This raises fears that prices would rise disproportionately, especially for small vehicles. In addition, the costs that would go into the implementation of Euro 7 would be lost to R&D on electric mobility. The German automotive industry is also opposed and has called on the German government not to approve Euro 7. As of summer 2023, eight member states have formally protested against the norm which would make it unlikely that a majority of EU member states would vote in its favor (Beckmann, 2023; Tagesschau, 2023c). Whether to be implemented or not, it came as a shock to the OEMs and forced them to increase their efforts into electric mobility (Interviews 2, 4).

4.2.4.2 The Chinese threat and rising competition

Organizations: Within the last years, the aggregated European automotive market has stagnated. Since 2019, the industry has recorded a global economic slowdown. The COVID pandemic and the Russian war on Ukraine have led to supply bottlenecks for precursors and raw materials. Passenger car sales and production remained affected in 2021 and 2022 (BMWK, 2023a). In addition, a paradigm shift is taking place in Germany: Less people are buying a vehicle as a status symbol, while alternative mobility concepts are gaining momentum (Freiwah, 2023). In 2022, the number of new registrations decreased to a level of 30 years ago (VDA, 2023). Nevertheless, after a slump during COVID, the German automotive industry was able to increase its sales in 2022 (Statistisches Bundesamt, 2023). This is because three-quarters of the sales were made in non-European countries (Hüls-Kabir, 2023).

The relevant sales markets are China and the US (Interview 8). Specifically, China significantly contributed to the prosperity of German OEMs (Puls & Fritsch, 2020), responsible for up to 40 % of German automotive exports (Ernst & Young, 2023). However, concerns arose as the Chinese market witnessed a decline in German exports, dropping by 6 % between 2021 and 2022 (VDA, 2022b). ICEs sales are still strong, but experts see a serious threat in the low quotas of German EVs registered in China (Interview 2). Tesla's Model Y has a greater market share in China than the German manufacturers combined (Seidel, 2023).

The past decade, China‘s metropolitan areas were covered in smog as a growing economy resulted in increased traffic (Barthel et al., 2010). From 2000 to 2010 the number of passenger cars rose from one to over five million. Due to urbanization, the country expected millions of people to move to the cities. The production structures of vehicle manufacturers were scattered across the country’s provinces (Bormann et al., 2018). It provided the context for China’s industrial strategic plan *Made in China 2025* (Interview 9) published in 2015 through which the country hoped to become a leading technology nation (Schirrmeister et al., 2020). Within the traffic sector, the idea was to harness the population’s interest in technology and pressure to address traffic issues, to create regional synergies among the widespread smaller companies and thus grow the vehicle sector into a significant national economic force in the coming decades (Bormann et al., 2018). Electric mobility was promoted by establishing policies that benefit EV purchases, for instance by lowering the usually high registration costs and on manufacturer level, through EV quotas and fleet emission regulations (Retzer et al., 2018).

Car production in China surged from just over three million passenger cars in 2005 to nearly 25 million in 2017. This number declined during the pandemic, but rebounding to almost 24 million in 2022 (China Association of Automobile Manufacturers, 2023). In the new energy vehicles sector, BEV production rose from about 300,000 in 2015 to over five million in 2022 (China Association of Automobile Manufacturers, 2023).

Manufacturers also started exporting. Vehicle exports increased drastically from under 760,000 in 2020 to over 2.5 million in 2022, of which about 650,000 were BEVs (China Association of Automobile Manufacturers, 2023), see figure 10. Recently, Chinese carmakers started pushing into the German market. In 2022, for the first time, the KBA listed Chinese EV manufacturers in its manufacturer directory (KBA, 2023d). ADAC counted cars from eight manufacturers with multiple models each, including BYD, currently the largest EV manufacturer (Wieler, 2023). As a result, Chinese manufacturers were responsible for 5 % of BEV sales in Germany in 2022, and a study predicts that the EV market share could rise to 9-18 % by 2025 (Transport & Environment, 2022).

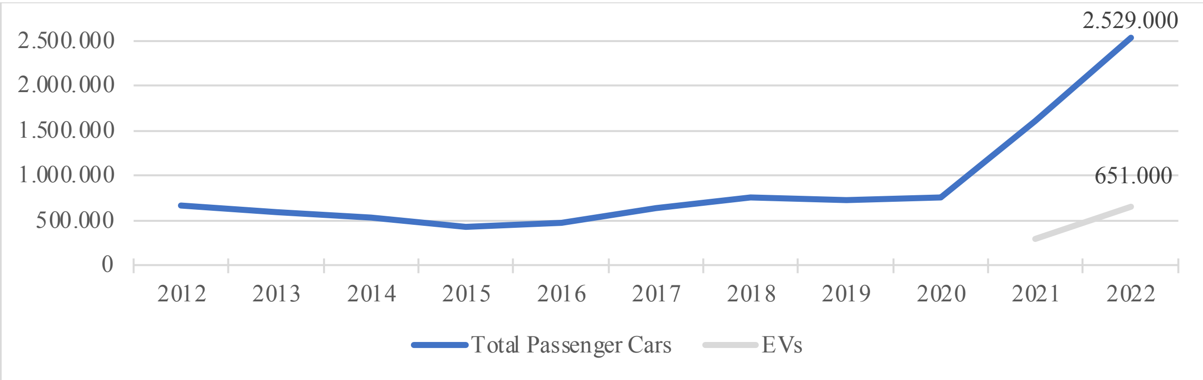

Figure 10: Development of Passenger Car Export from China, 20012 – 2022 (Source: own figure based on China Association of Automobile Manufacturers, 2023)

A similar trend can be observed in the US, where German OEMs are losing importance. The annual export number to the US has continuously decreased from over 600,000 in 2015 to about 360,000 in 2022 (VDA, 2022b). While Tesla's sales figures there rose by 78 % between 2020 and 2021, VW's fell by 13 % (Ernst & Young, 2023).

The European fleet targets for 2020 are stricter than both the US fleet target of 121 g CO_2/km and the Chinese target of 117 g CO_2/km. However, the approved NO_x limit in the US of 70 mg/ mile (1.6 km) is stricter than the Euro 6 standard of 80 mg/ km (IG Metall, 2016a). So far, the Chinese NO_x emission regulations up to *China 6a* have been comparable to the Euro 6. Yet, the introduction of *China 6b* in summer 2023, already announced in 2016, will considerably lower these values (TÜV Süd, 2023). Thus, if the Germans want to sell their cars abroad, they must comply with local standards.

In 2023, Tesla is one of many players that has established itself within the global automotive market. Whereas just a few decades ago it was assumed that OEMs would consolidate (Interview 8), today the opposite effect is occurring. By eliminating the complexity of the combustion engine, the barrier to market entry has fallen considerably which presents a threat to the German incumbents who no longer have the upper hand in technology (Interviews 1, 3, 8).

Thus, the rising competition, specifically from Chinese manufacturers and simultaneously, the potential loss of the Chinese market, can be viewed as a serious jolt, prompting German OEMs to reconsider the future.

4.2.4.3 Enhancing technology and increasing demand

Organizations: The automotive market is demand driven. The ICE had been firmly entrenched in people's minds. In a direct comparison to EVs, concerns arose over higher acquisition costs, limited range with long charging times, inadequate charging infrastructure, and safety issues related to battery incidents and burning vehicles (Lopez, 2014). Specifically, the range and limited availability of charging points have been named by all experts as hindering in the transition, described as an abstract fear (Interview 3) since for the most part long distances are not driven every day. Gradually, with political regulations and subsidies, as OEMs invested in EVs, the technological barriers are alleviated and charging infrastructure extended.

Over the last decade, organizations were able to improve the range of EVs. The BMW i3's reach multiplied from between 130 and 160 km in 2013 (BMW, 2022a) to 300 km WLTP in 2022 (BMW, 2023). The Tesla Model S, first introduced in 2012, was able to increase its range from about 480 km according to the US EPA test (Business Insider, 2011) to over 600 km WLTP (Tesla, 2023b). In 2017, the average range – calculated from all available EVs in the German market – was 241 km (Horváth & Partners, 2020). In 2020, this figure rose to 352 km (Energis, 2023). A further increase in range is forecast over the next few years due to larger batteries and better energy efficiency. In 2025, Horváth & Partners (2020) expect the average reach to be above 700 km.

Great range differences can be found across manufacturers and models and are reflected in the price. A WLTP reach of over 700 km can already be found in the market in 2023. With a starting price of over € 100,000, the Mercedes EQS claims a WLTP reach of 780 km (Mercedes-Benz, 2023). Starting at just under € 40,000, the VW ID.3 indicates a WLTP reach of 400 to 500 km (VW, 2023a). The 2023 Dacia Spring Electric is available from € 22.000 with a reach of about 230 to 300 km WLTP (Dacia, 2023). Now, Chinese models entering Germany are pressuring incumbents, enjoying an estimated € 10,000 cost advantage due to lower production costs in China (Tagesschau, 2023a) while the qualitative discrepancy is relatively low (J. Becker, 2021).

In parallel, the number of public charging stations has increased (see figure 4), while the manufacturers were able to enhance charging capacity allowing up to 350 kW at HPC stations. Already at 150 kW, enabled BEVs can be charged in 30 minutes to 80 % of battery capacity

(Audi, 2020). Furthermore, the complexity of different types of charging plugs and cables has decreased through the introduction of standardized types, such as the CCS (NPE, 2018).

Overall, the number of EV models available on the German market has multiplied from 18 EV models in 2013 to 55 in 2018 (Horváth & Partners, 2019). In 2023, ADAC counts 48 manufacturers offering 260 models from 120 model series (Rudschies, 2023).

Thus, the enhancing technological capabilities of the EV have led to an increasing demand. This can be therefore categorized as a functional jolt resulting in better reach and lower prices, and social jolt, furthering acceptance.

Finally, drivers grew accustomed to seeing EVs on the roads and charging. This took the foreignness out of the technology. Psychologists refer to this as the mere exposure effect (Spektrum.de, 2023). „If you had thrown all these electric vehicles on the market five years ago, the customers wouldn't have been there to buy it“ (Interview 3). This is because departing from the established logic may result in a lack of institutional support (J.W. Meyer & Rowan, 1977). In this case, a too early adoption of electric mobility would have met little response from consumers who could have withdrawn their support by not purchasing.

4.2.4.4 The supplier problem

"For a long time, the credo was that if we abandon the ICE, we will lose parts of the value creation in our country, and that is not desirable." (Interview 4). Comparing the ICE and an electric drive reveals a substantial difference in the component count of about 1,400 to 200 (Barthel et al., 2015). Expert 3 explained how his team surrounding the gasoline engine used to consist of several hundred engineers, now no more than 50 are involved in the electric motor. All experts particularly referred to the missing battery expertise within German companies which mostly buy the parts. Much battery innovation stems from China. Thus, part of the value chain in Germany is disappearing. Also, less work is associated with EVs as more operations are likely to be automated and the aftermarket segment loses its importance (Barthel et al., 2015; Jannsen et al., 2019).

Further, a transition to EVs requires a change in employee qualifications, and an adaption of the technical equipment of production facilities (Grimm et al., 2020). In particular, small and medium-sized suppliers down the tier pyramid are more affected by structural changes due to their highly specialized functions. An establishment of a new department or a change in business requires high investments while becoming competitive is not guaranteed. Many areas demand mature industrial products for which the competencies cannot be developed overnight

(Puls & Fritsch, 2020). Contractually bound, long-standing partnerships exist as well as collective employee agreements, negotiated by works councils and employee associations. A factory cannot simply be closed if it entails laying off employees. This has an impact on work along the value chain, on suppliers, but also on service activities (Jannsen et al., 2019).

These transformational consequences were addressed sparsely by state or associations, possibly, as the job loss did not materialize, or not to the degree feared initially, as the industry is, also in 2023, still positioned as hybrid, producing both ICEs and EVs (Interview 8).

It was not until 2016 that IG Metall (2016a) published a five-point plan for dealing with the transformation, but the report also assumed a more far-reaching diesel strategy in the coming years. The interviewed representative (9) from an employee's association, speaks of a conference in 2017 in which it was still being discussed whether the change would take place at all. It was not until VW at the end of 2018 publicly committed to the electric motor in the future that the scope of this decision became apparent as the VW representative asked the suppliers to join them in the transformation (Interview 8).

The uncertainty among suppliers as to whether and when the transformation among OEMs would take place made planning difficult (Interviews 1, 4). Because the OEMs did not fully convert, many suppliers delayed adapting. The decisive announcement by the industry only took place with the regulation of solely zero emission vehicles from 2035 which now requires massive and short-termed adaptations. To date, many suppliers have failed to adapt to the new challenges (Interview 9).

While a consensus has been reached that, viewed across Germany on a net-basis, there would be a shift in jobs (Interviews 2, 7), it has been recognized that the problem of future job loss lies regionally in centers of competence, for example in the Stuttgart area, which is specialized in the ICE (Interview 9). In addition, the Ukraine-Russia war resulted in increased energy costs. It has led to an intensified discussion of a possible migration of companies moving abroad, either to China due to cheaper production costs, or to the US which strongly promotes companies, for example, through the US Inflation Reduction Act (Interviews 4, 6).

Thus, it could be argued that so far the issue of job loss did not present a direct obstacle in the direct transformation towards electric mobility (Interview 2), although the obligations by the OEMs in contracts and collective and labor agreements certainly influenced their initial hesitations. Now that the transformation has gained momentum, the government and associations are challenged to maintain the economic stability of the companies (Interview 9) while at the same time converting the product portfolio to new technologies and products.

In conclusion, the increasing pressure put on the German automotive industry came from regulatory pressure at home and abroad, increasing demand and competition. The transition does not depict the linear process as outlined in theory but processes evolving in parallel, mutually reinforcing each other, and at times accelerated by actors, jolts and FCEs. It is diffused through the heightened topic of climate protection, and as EVs lose their novelty factor over time and through technological advances. The process differs from most academic literature on institutional innovation as it does not emanate from radical innovations nor a company itself but is stimulated by policymakers. Within the last decade, Tesla, tightening regulations, the diesel gate and increasing Chinese competition can be named as the most significant triggers of the transformation.

5. Discussion

The transition to electric mobility is the second institutional change in transportation history. The introduction of the automobile, starting with Benz's three-wheeled engineering novelty, marked the primary turning point. Poor sales were reflected in public skepticism about replacing horses and carriages. The heights to which the car would rise were unthinkable (IG Metall, 2016b). The current transformation mirrors this in some ways as it cannot be achieved solely by OEMs electrifying the propulsion drive. It requires a structural systemic change.

5.1 Discussion of findings

Institutional innovation, as depicted in this study of the automotive industry, involves three main building blocks that need to align with the transformation: the state, the industry and the population. The roles of these three factors in view of institutional theory, and the transformation's obstacles are discussed in the following.

5.1.1 The struggles of democracy

The climate crisis, as outlined by Unger and Oppold (2021) presents a wicked challenge characterized by its complexity and absence of straightforward remedies. The authors contend that democratic processes, designed to harmonize diverse interests, encounter limitations when addressing climate change. Climate policy objectives often collide with competing priorities like economic growth, equity, and personal freedom. In democratic societies, the necessity for change must navigate the gradual process of pluralistic opinion and consensus building (Interview 6). This corresponds to the objective of achieving one million EVs by 2020, established a decade beforehand. The aim was to foster a socially acceptable transition

(Interview 2) that accommodated all stakeholders and circumvented disruptive consequences that could imperil companies and jobs (Interview 5).

In contrast, China's more rapid transition can be attributed to the state's ability to enforce political and technological advancements on its populace through swift and forceful regulatory and fiscal measures. Less resistance was to be expected from OEMs and a population that did not insist on fossil-fueled private cars due to high registration costs (Bormann et al., 2018).

The German government encountered resistance, primarily by the automotive industry. This case depicts the support institutionalized structures hold through their legitimization. The findings suggest that mere discussions about EVs had limited impact on dismantling these structures; negative consequences played a more crucial role. OEMs faced the risk of substantial fines for non-compliance with fleet values, society witnessed diesel driving bans, and the German state faced charges and prosecution for exceeding air pollution limits. Here, coercive isomorphism through legislative demands (DiMaggio & Powell, 1983) was decisive.

Sources also call upon China's limited concern for the regulatory and technological consensus of Western industrialized nations (Interview 1; Bormann et al., 2018). While Europe debated the origin of the raw materials for battery cells and the high CO_2 consumption during production, raising doubts about the emission neutrality of EVs (Interview 5), China strategically secured access to resources and raw materials in Africa (Interview 1).

In a democracy, governmental actions are influenced by the level of public support politicians receive (Ruttan & Hayami, 1984). Because effective change necessitates influential advocates, political opportunities offer favorable conditions to persuade them and gather further supporters (Rao & Giorgi, 2006; Rao et al., 2000). As the attention turned toward the diesel gate, social movements rising and lawsuits, the government was under increasing normative pressure. The diesel gate presented a form of organizational failure, and as such enabled an opportunity. It took away some power of the car lobby within the government. In contrast, the power held by *Fridays for Future* through its massive support, allowed them to access policymakers in power. Climate protection laws become more stringent.

Political entrepreneurs support institutional innovation if it serves their interests. As a novel ideology spreads, it reduces the costs for political entrepreneurs to mobilize society and garner support (Ruttan & Hayami, 1984). Thus, ideology serves as a crucial resource for policymakers in driving institutional innovation. The climate protests mobilized the population and substantiating the climate protection debate, stimulating a growing ideology. This heightened awareness made the population more receptive to sustainable technology, which required less effort and posed fewer risks for policymakers to adopt stricter climate targets. Ultimately, aligning with popular opinion bolsters political prospects in upcoming elections.

For decades, supporting the automotive industry benefited the German state, contributing to employment and economic prosperity. Merkel continued the work of antecessor "car chancellor" Gerhard Schröder, “albeit more discreetly but equally reliably” from the industry's standpoint (Bollmann & Meck, 2018). While, after the diesel gate, emission controls have gotten stricter (Interview 3) and access to the chancellery more difficult (Bollmann & Meck, 2018), given its significant economic significance, the institutional cohesion between politics and industry remained strong. In 2022, Germany secured an exemption for e-fuel vehicles as zero-emission cars within the EU, blocking a full ICE ban (Tagesschau, 2023b). Speculation suggested that Porsche's influence, driven by its desire to continue producing the model 911 with an ICE, played a decisive role (Welt, 2022).

Moreover, an internal conflict in the German government’s actions and messages was noticeable, that perhaps conveyed a false security to the OEMs to stay within the ICE and did not fully convince the population. For instance, "climate chancellor" Merkel (Strack, 2021) played a pivotal role in personally inviting the industry to the chancellery advocating e-mobility (Interviews 5, 9), also consulting technocrats in form of interdisciplinary panels such as the NPE (Interview 5). On the other hand, climate activists criticized her advocacy of the industry (Bünder, 2019) and the decision to exit coal powered plants only by 2038 (BMWK, 2023g). However, why should a customer invest in a “cleaner” vehicle if the electricity used to charge it produces more emissions than an ICE (Interview 2)?

This lack of clear alignment within the government limited policymakers' influence (Vermeulen et al., 2007). The political initiatives, at least initially, were not sufficient to prompt change.

5.1.2 The industry’s golden cage

Reay et al. (2006) pointed out that those outside an organizational environment or new to a field, are less embedded and may, therefore, realize the necessity of change and exhibit agency. This aligns with the term “grüne Wiese” (green meadow) (Hettich & Müller-Stewens, 2020; Interviews 5, 6), referring to a greenfield site. Investors of Tesla knew the risks of investing in a start-up. Thus, the company could simply focus on its technology (Interviews 2, 3) and unconventionally approach its way of doing business. In contrast, incumbents had to satisfy existing customers and respect previous models (Interview 2). The incompatibility of this new approach to traditional, institutionalized practices also became apparent in the resolution of Tesla’s and Mercedes-Benz’s partnership in the early 2010s.

Also, the Chinese industry was neither hindered by existing collective agreements nor suppliers that could lose during the transformation. The manufacturers were able to adopt the strategy of skipping the ICE technology and investing in new techniques (Interview 5). The lower technical barriers of the EV enabled new players to quickly enter the market (Interviews 1, 3).

In the past decades, the German automotive industry grew highly successful. The adversity of the incumbents to change derived from their wish to maintain the arrangements that enable their position of power. Their processes surrounding the ICE had been built over decades to reflect organizational efficiency (J.W. Meyer & Rowan, 1977). Also, the pressure from shareholders' expectations of profit had to be considered. The fact that the BMW i3 was barely profitable and that Tesla, too, made operating losses for a sustained period, was hardly a reason to invest in electric mobility. The less costly attempt to simply convert existing models into EVs was also rather unsuccessful as it primarily catered to the rather few environmentally conscious individuals while excluding technology-savvy and affluent early adopters, who expect EVs to offer both technological progress and visual differentiation from conventional products (Seeberger, 2016). As warned about by Rao et al. (2000), while early entrants have the opportunity to gain market share, they also incur the costs of legitimizing a new form.

The automotive industry is a low-yield segment, and it is thus more convenient to focus on existing profitable business models and what is feasible without taking major risks (Interview 1). Bormann et al. (2018: 20) titled this as trapped within a "golden cage". It reflects how the institutional environment not only defines action but also confines it (Scott, 1987). The German industry stood at the crossroad between innovative reform and institutional stability (Hargrave & Van de Ven, 2006). Due to their economic power, the German incumbents represent established organizations that can affect and avert change (DiMaggio & Powell, 1983) and they make use of their position by voicing their matters to the state and proactively seeking to incorporate their objectives into the regulations (J.W. Meyer & Rowan, 1977). This is done through lobbying and showcases successful attempts, initially advocating stability.

It also caused the industry to rely on the government to invest in public charging infrastructure. The poor infrastructure development until 2017 can be regarded a "chicken-and-egg" problem (Vermeulen et al., 2007: 535; Interviews 1, 3) of who should invest first, the state or energy suppliers in the infrastructure or the OEMs in EVs. This further decelerated the transition.

Arguably, the institutionalized function of the OEMs caused them to be too sure about the power they held within the state and their influence on the upcoming regulations, and spent energy protesting them instead of preparing strategically for the changeover. Perhaps their narrow focus on their own engineering excellency resulted in an "arrogance" (Interview 9) that kept them for too long from taking upcoming competitors seriously, such as Tesla and the transformation that has occurred in parallel in China. The embeddedness of the OEMs within their institutionalized structures prevented them from recognizing that their ICE's „technological superiority is no guarantee of success" and thus prevented agency (Tushman & Anderson, 1986: 443).

Uncertainty may lead to imitation of those organizations they consider legitimate (Wezel & Saka-Helmhout, 2006). In the first half of the 2010s, there was uncertainty about which technology was going to assert itself. Notably, the German OEMs initially collectively deferred a major transformation. They relied on the established and successful concept of the ICE. Tesla, while experiencing increasing acceptance rates, forced no mimetic pressure on them, possibly a sign that the Germans at first only considered each other legitimate competition. Mimetic isomorphism was thus noticeable among the German OEMs.

Contrary to the bandwagon effect's reasoning that others will follow (A.D. Meyer et al., 1990), after VW's ultimate announcement of withdrawal from the ICE, no direct major transformation announcements by German OEMs followed. Perhaps a majority of OEMs would have been needed in order for the bandwagon effect to fully take effect. Only after the requirements of the *Fit for 55* program, coercive isomorphism became apparent as German OEMs immediately quickly released press statements on their ICE exit plans. It is possible that an increasing number of Chinese competitors entering the German market would have exerted enough pressure that also German OEMs would have increased their EV efforts.

As EVs moved beyond their novelty phase, the automotive industry has come to realize that relying solely on traditional practices may not be the path to the future. As the electric motor gains legitimacy and becomes institutionalized, the industry has to increasingly set on it and adapt its processes in order to survive, even though a change of practices goes against organizational efficiency (J.W. Meyer & Rowan, 1977). Moreover, as further business models are gaining traction, OEMs are embracing innovations borrowed from Tesla. This mimetic isomorphism is evident in various aspects, including software features like over-the-air updates, minimalist interior designs with fewer buttons and bigger screens, exterior elements like flat door handles, and direct sales systems.

Also, normative isomorphism is noticeable as OEMs increasingly present themselves as sustainable to maintain their reputation in a phase of growing climate debate and more demanding customers.

Interestingly, BMW had already signalized its aim to sell 50 % EVs by 2030 yet did not follow up after the *Fit for 55* announcement. Instead, the firm stressed the continuation of the ICE to allow the customers to choose their preferred technology (Braunberger & Theurer, 2022). Also, Porsche disclosed its continuation of model 911 with the ICE (Uhlenbroich, 2021). Possibly, the choice not to fully assimilate represents a strategic move to stand out in the market.

Within institutional innovation theory, it is generally agreed that change is mostly driven by radical new methods that challenge existing approaches and disrupt the established logic (Lounsbury & Crumley, 2007; Raffaelli & Glynn, 2015). The introduction of the commercially available lithium-ion battery in the 1990s marked a technological leap. The Tesla Roadster was the first car to make use of this battery type (Masias et al., 2021), although the EV itself did not represent a radical innovation that was superior to ICEs in a direct comparison and thus did not lead to the defying of established institutions. Since then, battery technology developed incrementally yet with major progress (Interview 4). Only the diesel scandal led to the de-institutionalization. In this case, as stated by Bormann et al. (2018), when linear technological advances reach their limits, it results in crisis and a change in dynamics. Engineers tried to circumvent regulatory pressures regarding the ICE that ultimately resulted in its demise.

The analysis of the industry and the past decade leads to the conclusion that a sole economic perspective nor an institutional perspective would have been sufficient here to understand the environment. Theoretically argued, institutionalized organizational behavior is considered to mainly result from normative pressure (Greenwood & Hinings, 1996) in political, functional and social forms (Oliver, 1992). However, findings show that within the transition of the automotive industry, both have influenced it. National and international economic and competitive forces decisively factored in and cannot be disregarded. This is meaningful from a managerial standpoint to view innovation and its environment from multiple angles. It is further crucial to understand that customers usually prefer legitimized concepts. Therefore, when introducing novelty, evoking familiarity with already known concepts can be a successful strategy.

5.1.3 Old habits die hard

People value institutional arrangements out of habit as well as underlying ideals (Voronov & Weber, 2020). For decades, the Germans had valued the automotive industry as it provided jobs and wealth. The ICE was highly regarded due to its reliance, high reach and increasing fuel efficiency, the infrastructures and service facilities were in place.

Because people draw on institutionalized practices in their way of doing things and preexisting perceptions to judge what is foreign (DiMaggio & Powell, 1991; Hargadon & Douglas, 2001), EVs and ICEs were compared directly. EVs were no breakthrough technological innovation that would improve a previous way of acting significantly. Instead, in comparison, initially, the BEV performed worse than the ICE, in terms of price, reach, charging infrastructure and time to charge. New functional questions came up, also due to the lack of transparency of the charging providers and use (Interview 7). The habit was to drive to the nearest gas station and fuel the car in a few minutes. New inherent functionalities that came with an EV, specifically in the area of connectivity, were not really considered (Interview 2). Instead, safety as well as battery and electricity generation were questioned. Studies were conducted that calculated how many thousands of kilometers an EV would have to travel before it was more climate-friendly than an ICE car (Seeberger, 2016).

The diesel scandal raised doubts about diesel and was reinforced by diesel driving bans, subsequently leading to its de-institutionalization. For the average consumer, the car is the second largest investment after the house (Interview 1). Thus, new registrations for diesel vehicles declined, as people were hesitant to invest in a car that faced access restrictions. Instead, Germans turned to the gasoline engine, which did not present them with much change compared to an EV. Certainly, Tesla changed the image of the EV, yet improper infrastructure and high prices were still prevalent. Then, through the social movement *Fridays for Future*, the topic of environmental protection was strengthened in the minds of the population.

And while many openly supported climate protection, there is a distinction between supporting a cause and limiting oneself due to it (Interview 2). But, in parallel, technology and infrastructure had improved incrementally. The population got used to seeing EVs on the streets, many had driven one as a company car or a car-sharing vehicle (Interview 4).

Meanwhile, a new generation is growing up that no longer places the same importance on cars as their parents (Jannsen et al., 2019). Contingent on this, the established logic surrounding the car are shifting away from private ownership, and new mobility concepts (BMWK, 2020) such as Subscription Services or Mobility as a Service are being addressed. During COVID, the buzz faded back a little as individual traffic picked up again (DLR, 2020). New technologies, such as software-defined vehicles (Interview 7) or autonomous driving, were given a lot of attention, partly because Tesla was promoting it through its vehicles. It could be implied that through these upcoming more abstract concepts, electric mobility also partially lost its novelty factor.

Then, once again, a crisis disrupted the established logic of the German population as the oil dependence on Russia became critical during the Russia-Ukraine war. It is debatable whether this can be directly linked to the automotive industry, as the *Fit for 55* program had already been decided at that time. However, the interviewed experts (1, 2, 4, 5, 7, 9) largely agree that it has accelerated the recognition of the need to abandon fossil fuels and that customers have, therefore, also increasingly engaged with electric mobility.

The analysis shows that systemic change was a necessary prerequisite in terms of mindset, regulations and infrastructural requirements. Thus, first, the environment needed to change, as well as a technological maturity achieved, to trigger acceptance, which then leads to legitimacy and thus institutional innovation. After all, stakeholders give or deny legitimacy (Raffaelli & Glynn, 2015), customers buy an EV or not.

This contrasts, for instance, the case of the iPod. According to Raffaelli and Glynn (2015) the introduction of this technologically non-revolutionary product led to a significant rearrangement of the music industry and created a novel ecosystem. This implies that institutional innovation can occur in different ways and orders, linearly through the invention of a product, or non-linearly through multiple triggering effects in which first a de-institutionalization has to take place in order for these triggers to build upon each other and gain momentum that leads to change.

Moreover, radical innovation that outperforms existing methods does not necessarily result in change. It does not have to be triggered by organizations but can be demanded by policymakers or the population. While conventionally regulatory processes reinforce already agreed-upon concepts (Greenwood et al., 2002), in the present case, regulations were used as a means to trigger change in the first place. However, technological maturity that solves an existing problem differently and as such offers a benefit is necessary.

Institutional innovation is said to unfold only throughout historical eras (Raffaelli & Glynn, 2015). The pressing climate protection debate presents such an era that has activated society to initiate change and has made this (still ongoing) institutional innovation possible. The final stage of stabilization (Hensmans, 2003) has not been reached yet. Still, the hitherto enduring walls of the institutional logic in the industry, have started to crack which also opens up the possibilities for further business models. Here, too, the prospects of what is feasible have been indicated by Tesla, for example the switch to direct sales, which is now taking place. When in the coming years or decades the next transformation occurs to new forms of transportation, whether autonomous driving or air taxis, it will be possible to draw on the findings of this transformation and the need to factor in systemic change at an early stage. Also, the discussion about a sector coupling with the energy industry will become bigger which will bring further changes. It has to be considered which powerful actors, companies and industries have to be included and persuaded to promote and diffuse such an issue, also including policymakers who have the ability to push normative adherence through regulatory frameworks and thus accelerate proceedings.

Fundamentally, the institutional theory of the firm states that organizations must conform to the institutional environment they operate in (J.W. Meyer & Rowan, 1977). Findings confirm this: As the environment is adapting to EVs, so do the German OEMs.

5.2 Limitations and outlook

The transition of the German automotive industry is a very broad topic. This thesis aimed to give an overview of the past years and the triggers that brought about change. However, limitations should be acknowledged, paving the way for future research prospects.

While great value was placed upon selecting experts and ensuring their anonymity, relying on interviews, there is a chance of subjectivity and biases, such as social desirability or confirmation bias, as well as interviewer bias. The aim was to capture the views of experts surrounding the industry from various angles. Nevertheless, the number of interviewees was restricted which can lead to limited representation of viewpoints. For instance, experts from the energy industry could give an additional perspective on its transition to renewable energies and reasons for and against investing in charging infrastructure. Since peer-reviewed academic work on the topic is limited, grey literature was consulted which bears the difficulty of verifying authenticity as they may lack standard formatting and citation styles. The German automotive industry is specific in its characteristics due to its history and relation to the state. Caution should remain about the generalizability of the findings toward other industries and countries.

This paper contributes to the existing literature on institutional innovation by summarizing and above all clustering the anteceding factors and depicting change requirements. Due to the width of the topic, this thesis set out to identify the triggers of the institutional change process, not the process itself. However, it adds to the existing literature by summarizing and above all clustering the anteceding factors actors, FCEs and precipitating jolts, and depicting change requirements. It may therefore complement models that refer unilaterally to institutional entrepreneurs or precipitating jolts. For instance, in their model of institutional change, Greenwood et al. (2002) rely solely on precipitating jolts as triggers.

It also has to be considered that, as shown in this work, the process of change is not necessarily linear but can be caused and reinforced by multiple parallel and overlapping incidents and developments. The psychological process of how attitudes change, as well as newer research into strategies of legitimization can be integrated in a subsequent step.

Much theory on institutional change focus on endogenous triggers within organizations, such as internal conflicts or inefficiencies in current practices leading to innovation. The presented case depicts a situation in which policymakers initiated the transformation. While the state has been named as an institutional entrepreneur, research on it remains limited. Integrating this into the present research could provide a more comprehensive picture on how institutional innovation progressed in the German automotive industry.

This work draws on public activity in the German marketplace. Therefore, this thesis established correlations of when decisions within OEMs to launch an EV model were made on the basis of production cycles and interviews, as well as reports on strategies and their temporal correlation with jolts and FCEs. Due to scope reasons, company reports were excluded. Further expert interviews could allow for a deeper analysis of when exactly internal decisions were made.

A focus has been placed on German OEMs, yet the German market also includes other established foreign OEMs and brands under similar pressure to transition. Moreover, while passenger cars regulations are at the forefront of public debate, in parallel also ones for light- and heavy-duty vehicles were released. For scope reasons, these aspects have mostly been excluded. Moreover, while the changes the suppliers are undergoing have been touched upon, future research could take a deeper look into the transformation of these businesses.

The German automotive industry is strongly internationally interwoven and the nation's dependence on exports makes it inherently dependent on external factors. While China and the US as the two strongest automotive markets and car importers have been addressed, their roles can be further developed. Foremost, a focus on political occurrences could prove valuable for insights into the industry's performance into the past but also upcoming years. These include presidential elections, trade agreements and barriers and local regulatory policies but also consumer purchasing patterns in foreign markets and the quality of infrastructure.

German OEMs do not solely produce in Germany. While the amount of cars produced locally has remained about the same, the share abroad almost doubled between 2008 and 2016, of which China was the most important manufacturing location (Bormann et al., 2018). Hitherto, a joint venture obligation for production in China existed through which the Chinese producers were able to transfer knowledge (Seidel, 2023) and contributed to the significant increase in local production. Limitations of this work include these geopolitical considerations.

Institutional change does not simply halt at the transition to electric mobility. In the past five years, the switch to EVs has taken place in parallel with progressive digitalization. In that sense, the term *CASE* describes the four megatrends that have been revolutionizing the automotive industry: connected car, autonomous vehicle, sharing/subscription, and electrification (Möller et al., 2017). Electrification has thrown the existing logic of the automotive industry into disarray, thus paving the way for new trends. On the other hand, digitization trends are also influencing electrification. On the consumer side, this offers prospects to enhance the customer journey with new connectivity capabilities, e.g. by enabling direct communication between car and charging station for reservations, automatic billing or automatic charging (t3n.de, 2022). A sector coupling of car and energy could enabling bidirectional charging (Vattenfall, 2023). On the manufacturer side, digitization is influencing production processes and technological innovations in vehicle components, which are closely interwoven with electrification. The interrelation of these trends has only been broached, yet certainly influenced the present case.

CASE plays a decisive role for the premium manufacturers, as it most likely will influence how premium is defined in the coming years as a differentiation via the ICE loses its relevance. Perhaps it will lead to an era of software companies, that provide digital customer experiences, especially in the areas of autonomous driving and connected cars (Jannsen et al., 2019). Identifying how trends influence each other and their role within institutional innovation, could offer further perspectives on the coming changes in the automotive industry.

Tesla's pioneering role in vehicle electrification extends beyond being a first mover. The company has introduced innovative concepts like a direct sales model, over-the-air software updates, and contactless delivery (Grundhoff, 2021). Musk's personal touch with customers is evident in responding to requests like "dog mode" on Twitter, swiftly implementing customer suggestions. A closer look into Tesla would be interesting to assess the institutional disruptions the firm contributed to and its impact on the automobile industry as a whole. Further, their institutional work could be assessed in how they achieved their role as pioneering new concepts that are now being incrementally copied by incumbents.

Lastly, the curve of new EV registrations (figure 3) depicts exponential growth. This could be viewed as the start of the technological S-curve representing the lifecycle of technology and portraying technology adoption patterns and dynamics over time. Eventually, as the EV fully replaces the ICE and reaches market saturation, or technological improvements reach their limit, the curve will slow down again. Combining research on innovation and institutional innovation could potentially provide insight into predicting institutional change.

The advent of electrification has triggered a profound shift in the automotive industry, propelling the landscape of the once-familiar gasoline-powered into a state of transformative change. Innovation and consumer demand are driving this journey towards a sustainable and emission-free future, paving the way for a dynamic road ahead.

6. Conclusion

This thesis gave an overview of the theoretical foundation of institutions and institutional innovation and the triggers of the institutional change process in form of actors, FCEs and jolts. It presented the institutions of the German automotive industry which form the basis for the industry's stability and endurance. By developing the political and market occurrences since the introduction of the climate debate and specifically the last decade, and building upon expert interviews and grey literature, the significant prompting actors and triggers of the transition could be identified.

Institutional theory explains how institutions provide stability and continuity to a social system and therefore become relatively permanent. It makes institutional change an intricate process. The German automotive industry exemplarily depicted the institutionalization of a field that has developed over the past century and circumvented change. The paper exemplifies the resistance by the incumbents, how the reliance on the ICE offered stability and assurance across manufacturers and suppliers and thus within the institutional environment. It builds upon more novel research streams that view the institutional arena not as static but as a function of strategy and willful actions, however, accelerated by jolts that can occur willingly or unwillingly.

The transition of the industry toward electric mobility presents a case of institutions adapting to "new opportunities, changed environments, or new cultural sensibilities" (Raffaelli & Glynn, 2015: 407). It was triggered by climate change, driven by regulations, and slowed down by democratic processes allowing industrial lobbying and the political-industrial solidarity in economic success that strengthens the economy. The complexity of a systemic change across industries, specifically also the energy sector moving toward renewable energies was required, in addition to the development of public charging infrastructure.

The industry's past success trapped German OEMs within a golden cage in which the incumbents aimed to retain the status quo. The intricate web of suppliers, along with collective wage agreements had to be considered. The population's sentiment and connection to the ICE, hindered the demand for novelty. With time, the aim of protecting the environment became more pronounced. Being more environmentally aware, the population became increasingly demanding in what it consumes, brought about and accelerated by the diesel scandal and driving bans, social movements, and financial incentives. The industry was exposed to steadily tightening regulations and the threat of fines, the loss of the diesel engine's good reputation as well as an altered competitive environment, provoked by Tesla and intensified by China's penetration into the automotive industry. Here economic forces decisively have to be factored in. Technological development enabled an advance into EVs to the extent that the vehicles obtained characteristics that are more comparable to engine cars in terms of price and reach. Ultimately, the rise of EVs has not only disrupted traditional practices but has pushed the industry to reimagine its business models and approaches.

Already in 1936 Hughes raised the question in his publishing what it takes for institutions to survive. He stated that "to survive, an institution must find a place in the standards of living of people, as well as in their sentiments" (Hughes, 1936: 186).

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Appendix

Appendix 1: Academic literature overview

Appendix 1.1: Literature on institutions and institutional innovation

No.	Literature	Study design	Study	Search engine
1	Alvesson, M., & Spicer, A. 2019. Neo-institutional theory and organization studies: a mid-life crisis? ***Organization studies*** , 40(2): 199-218.	Theoretical analysis	Discussion on the development of neo-insitutional theory	Google Scholar
2	Barley, S. R. 1986. Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. ***Administrative science quarterly*** , 31(1): 78-108.	Qualitative, longitudinal case study analysis radiology practices and CT scanners Data collection: Interviews, observations at two practice sites	Study on how technology can lead to a chnage in organizational structures by altering institutionalized roles and patterns of interaction	Google Scholar
3	Barley, S. R., & Tolbert, P. S. 1997. Institutionalization and structuration: Studying the links between action and institution. ***Organization studies*** , 18(1): 93-117.	Theoretical analysis	Discussion on the similarities of strucutral theory and the process of insitutionalization, introduction of a sequential model of insitutionalization	SCOPUS
4	Beckert, J. 1999. Agency, entrepreneurs, and institutional change. The role of strategic choice and institutionalized practices in organizations. ***Organization studies*** , 20(5): 777-799.	Theoretical analysis	Analysis of the role of entrepreneurs seeking to alter insitutionalized rules, integrating the concepts of strategic agency, power and legitimacy	SCOPUS
5	Davis, L., & North, D. 1970. Institutional change and American economic growth: A first step towards a theory of institutional innovation. ***The journal of economic history*** , 30(1): 131-149.	Qualitiative case study on the formation of US economic insitutions	Analysis on the formation of insitutions and introduction of a model based on profit maximization	Google Scholar
6	DiMaggio, P. J., & Powell, W. W. 1983. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. ***American sociological review:*** 147-160.	Theoretical analysis	Study on isomorphism processes in form of coercive, mimetic, and normative forces that strcuture an organizational field by pressuring organizations to become similar	Google Scholar
7	DiMaggio, P. J., & Powell, W. W. 1991. Introduction. In W. W. Powell, & P. J. DiMaggio (Eds.), ***The new institutionalism in organizational analysis*** : 1-38. Chicago: University of Chicago Press.	Theoretical analysis	Introduction to insitutions and institutional theory	Google Scholar
8	Fligstein, N., & Mara-Drita, I. 1996. How to make a market: Reflections on the attempt to create a single market in the European Union. ***American journal of sociology*** , 102(1): 1-33.	Longitudinal case study on the formation of a single market within the EU	Analysis on institutional change affecting nations, the role of insitutional entrepreneurs and elite social movements	Google Scholar
9	Furnari, S. 2014. Interstitial spaces: Microinteraction settings and the genesis of new practices between institutional fields. ***Academy of management review*** , 39(4): 439-462.	Theoretical analysis, qualitative case study on computer clubs	Analysis on interstitial spaces where individuals from different institutional fields temporarily break free from existing insitutions, interact and experiment, leading to the creation of new practices	Google Scholar
10	Ganesh, S. R. 1980. Institution building for social and organizational change: An appreciation. ***Organization studies*** , 1(3): 209-228.	Theoretical analysis	Synthesis of research streams on insitutionalization and discussion of an institution building model	SCOPUS
11	Garud, R., & Kumaraswamy, A. 1995. Technological and organizational designs for realizing economies of substitution. ***Strategic management journal*** , 16: 93-109.	Theoretical analysis	Discussion on the challenges faced by organizations due to changing and systemic technology in view of cooperation and competition	Google Scholar

No.	Literature	Study design	Study	Search engine
12	Greenwood, R., & Hinings, C. R. 1996. Understanding radical organizational change: Bringing together the old and the new institutionalism. ***Academy of management review***, 21(4): 1022-1054.	Theoretical analysis	Study on the interplay of contextual forces and intraorganizational dynamics leading to radical organizational change	SCOPUS
13	Greenwood, R., Hinings, C. R., & Whetten, D. 2014. Rethinking institutions and organizations. ***Journal of management studies***, 51(7): 1206-1220.	Theoretical analysis	Review on the concept of initutions	SCOPUS
14	Greenwood, R., Suddaby, R., & Hinings, C. R. 2002. Theorizing change: The role of professional associations in the transformation of institutionalized fields. ***Academy of management journal***, 45(1): 58-80.	Qualitative, longitudinal case study on the accounting profession Data collection: company documentation, interviews	Introduction of a framework of insitutional change with a focus on the role of professional associations	SCOPUS
15	Hardy, C., & Maguire, S. 2010. Discourse, field-configuring events, and change in organizations and institutional fields: Narratives of DDT and the Stockholm Convention. ***Academy of management journal***, 53(6): 1365-1392.	Qualitative case study analysis on an UN convention Data collection: documentation on and from event, media coverage, 40 interviews with state delegations, UN agencies, NGOs, and industry	Study of discursive processes through which an FCE can change an institutional field	SCOPUS
16	Hargadon, A. B., & Douglas, Y. 2001. When innovations meet institutions: Edison and the design of the electric light. ***Administrative science quarterly***, 46(3): 476-501.	Case study analysis on the introduction of electric light Data collection: primary data on Edison's efforts on a commercial bulb, newspaper accounts, secondary histories of Edison, histories that track the technological changes	Study on the role of design in shaping the acceptance of innovation in the conext of established insitutions	SCOPUS
17	Hargrave, T. J., & Van de Ven, A. H. 2006. A collective action model of institutional innovation. ***Academy of management review***, 31(4): 864-888.	Theoretical analysis	Introduction of a collective action model of institutional innovation based on political behavior in view of social movements and technology innovation management	SCOPUS
18	Hensmans, M. 2003. Social movement organizations: A metaphor for strategic actors in institutional fields. ***Organization studies***, 24(3): 355-381.	Theoretical analysis	Analysis of neo-insitutional theory, integration of ideology, power, and agency, identification classification of incumbents and challengers into four archetypes social movement organizations	SCOPUS
19	Hiatt, S. R., Sine, W. D., & Tolbert, P. S. 2009. From Pabst to Pepsi: The deinstitutionalization of social practices and the creation of entrepreneurial opportunities. ***Administrative science quarterly***, 54: 635-667.	Quantitative, longitudinal case study analysis using data of US breweries and soft drink producers	Examination on the role of social movements in implementing social chnage that open up opportunities for entrepreneural action and thus insitutional change	Google Scholar
20	Hudik, M. 2021. Push factors of endogenous institutional change. ***Journal of economic behavior & organizatio*** n, 189: 504-514.	Theoretical analysis	Analysis on how insitutional change is inititated by endogenous players based on the concept of Nash equilibrium	SCOPUS
21	Hughes, E. C. 1936. The ecological aspect of institutions. ***American sociological review***, 1(2): 180-189.	Theoretical analysis	Discussion on the concept of institutions and their relationship with collective behavior	Google Scholar

No.	Literature	Study design	Study	Search engine
22	King, B. G., & Pearce, N. A. 2010. The contentiousness of markets: Politics, social movements, and institutional change in markets. ***Annual review of sociology***, 36: 249-267.	Theoretical analysis	Analysis on social movements and the political function of markets leading to actors contesting logics and driving insitutional change	SCOPUS
23	Lampel, J., & Meyer, A. D. 2008. Field-configuring events as structuring mechanisms: How conferences, ceremonies, and trade shows constitute new technologies, industries, and markets. ***Journal of management studies***, 45(6): 1025-1035.	Theoretical analysis	Discussion on FCEs and their role as turning points in the evolution of institutional fields	Google Scholar
24	Li, D. D., Feng, J., & Jiang, H. 2006. Institutional entrepreneurs. ***American economic review***, 96(2): 358-362.	Theoretical analysis	Analysis on and definition of insitutional entrepreneurs	SCOPUS
25	Lounsbury, M., & Crumley, E. T. 2007. New practice creation: An institutional perspective on innovation. ***Organization studies***, 28(7): 993-1012.	Qualitative case study analysis on the developkment of the US money management practice	Examination on the emergence of new practice fields, introduction of a process model of practice creation	SCOPUS
26	Meyer, A. D. 1982. Adapting to environmental jolts. ***Administrative science quarterly***, 27(4): 515-537.	Qualitative and quantitative case study on strikes in hospitals Data collecion: archival data, interviews	Study on the adaptation of organizations to environmental jolts in view of antecedent strategies, structures, ideologies and resources	Google Scholar
27	Meyer, A. D., Brooks, G. R., & Goes, B. 1990. Environmental jolts and industry revolutions: Organizational responses to discontinuous change. ***Strategic management journal***, 11: 93-110.	Qualitative, longitudinal case study analysis in the health care industry	Analysis on modes of change, identifying four modes differentiating between change on firm and industry level and continuous and discontinuous change; focus in discontinuous change	Google Scholar
28	Meyer, J. W. 2010. World society, institutional theories, and the actor. ***Annual review of sociology***, 36: 1-20.	Theoretical analysis	Decoupling of the depiction of society as autonomous individuals, discussion on how the identites of actors leads to rapid social change	SCOPUS
29	Meyer, J. W., & Rowan, B. 1977. Institutionalized organizations: Formal structure as myth and ceremony. ***American journal of sociology***, 83(2): 340-363.	Theoretical analysis	Analysis of rationalized institutional rules, which function as myths that organizations incorporate to enhance survival prospects	Google Scholar
30	Munir, K. A., & Phillips, N. 2005. The birth of the 'Kodak Moment': Institutional entrepreneurship and the adoption of new technologies. ***Organization studies***, 26(11): 1665-1687.	Qualitative case study analysis on photography	Analysis on strategies used by isnstitutional entrepreneurs that fits new technology to drive insitutional change	SCOPUS
31	North, D. C. 1991. Institutions. ***Journal of economic perspectives***, 5(1): 97-112.	Theoretical analysis, qualitative case study on the insitutional evolution in arly modern Europe	Analyis on the concept of insututions and their stability	Google Scholar
32	Oliver, C. 1992. The antecedents of deinstitutionalization. ***Organization studies***, 13(4): 563-588.	Theoretical analysis	Analysis on organizational and environmental factors (political, functional, social pressures) that influence deinstitutionalization.	Google Scholar
33	Patala, S., Korpivaara, I., Jalkala, A., Kuitunen, A., & Soppe, B. 2019. Legitimacy under institutional change: How incumbents appropriate clean rhetoric for dirty technologies. ***Organization studies***, 40(3): 395-419.	Qualitative, longitudinal case study analysis in the energy sector Data collection: press releases	Examination of rhetorical strategies used by organizations to legitimize technology	SCOPUS

No.	Literature	Study design	Study	Search engine
34	Phillips, N., Lawrence, T. B., & Hardy, C. 2000. Inter-organizational collaboration and the dynamics of institutional fields. ***Journal of management studies*** , 37(1): 23-43.	Theoretical analysis	Analysis on how collaboration between organizations provides the context for proccesses of strucutration that sustain institutional fields	Google Scholar
35	Powell, W. W., Oberg, A., Korff, V., Oelberger, C., & Kloos, K. 2017. Institutional analysis in a digital era: Mechanisms and methods to understand emerging fields. In G. Krücken, C. Mazza, R. E. Meyer, & P. Walgenbach (Eds.), ***New themes in institutional analysis*** : 305-344. UK: Edward Elgar Publishing Limited.	Case Study within the nonprofit sector Data collection: Web crawler tracking hyperlinks within websites to other organizations to identify the diversity of organizational fields	Anaylsis on organizational actitvities to shape insitutional change	Google Scholar
36	Raffaelli, R., & Glynn, M. A. 2015. Institutional innovation: Novel, useful, and legitimate. In C. E. Shalley, M. A. Hitt, & J. Zhou (Eds.), ***The Oxford handbook of creativity, innovation, and entrepreneurship*** : 407-421. Oxford: Oxford University Press.	Theoretical analysis	Review on and definition of insitutional innovation as novel, useful and legitimate change	Google Scholar
37	Rao, H., & Giorgi, S. 2006. Code breaking: How entrepreneurs exploit cultural logics to generate institutional change. ***Research in organizational behavior*** , 27: 269-304.	Theoretical analysis	Analysis on the role of insitutional entreprneurs within and outside an organization, building upon social movement research	SCOPUS
38	Rao, H., Morrill, C., & Zald, M. N. 2000. Power plays: How social movements and collective action create new organizational forms. ***Research in organizational behavior*** , 22: 237-281.	Theoretical analysis	Analysis on the influence of collectiv action, specifically, social movements, on nitutioanl change, in view of change as a political process	Google Scholar
39	Reay, T., Golden-Biddle, K., & Germann, K. 2006. Legitimizing a new role: Small wins and microprocesses of change. ***Academy of management journal*** , 49(5): 977-998.	Qualitative, longitudinal case study analysis n the health care system on the role of nurses Data collection: interviews, observations, archival data, public documents	Study on how actors legitimtize change by accomplishing three microprocesses	Google Scholar
40	Ruttan, V. W., & Hayami, Y. 1984. Toward a theory of induced institutional innovation. ***The journal of development studies*** , 20(4): 203-223.	Qualitative case study analyis on agricultural history	Analysis on insitutional institution induced by chnages in technology and resources	SCOPUS
41	Schüssler, E., Grabher, G., & Müller-Seitz, G. 2015. Field-configuring events: Arenas for innovation and learning? ***Industry and innovation*** , 22(3): 165-172.	Theoretical analysis	Analyis on the impact of FCEs	Google Scholar
42	Schüssler, E., Rüling, C.-C., & Wittneben, B. B. 2014. On melting summits: The limitations of field-configuring events as catalysts of change in transnational climate policy. ***Academy of management journal*** , 57(1): 140-171.	Qualitative, longitudinal case study analysis on UN climate conferences Data collection: Interviews, observance of conferences, conference documentation	Analysis on FCEs in their role of catalyzing intitutional change, as well as the limitations	Google Scholar
43	Scott, W. R. 1987. The adolescence of institutional theory. ***Administrative science quarterly*** , 32(4): 493-511.	Theoretical analysis	Analysis of insitutional theories	Google Scholar
44	Scott, W. R. 2008. Lords of the dance: Professionals as institutional agents. ***Organization studies*** , 29(2): 219-238.	Theoretical analysis	Establishment of roles of professionals as insitutional entrepreneurs	SCOPUS

No.	Literature	Study design	Study	Search engine
45	Sine, W. D., & David, R. J. 2003. Environmental jolts, institutional change, and the creation of entrepreneurial opportunity in the US electric power industry. ***Research policy*** , 32: 185-207.	Qualitative, longitudinal case study of the US electric power industry over a 40-year period Data collection: industry histories, archival documents, and interviews with utility analysts, executives of power firms, and policy makers	Examination on the impact of environmental jolts on institutional change and entrepreneurial activity	SCOPUS
46	Sturgeon, T., Van Biesebroeck, J., & Gereffi, G. 2008. Value chains, networks and clusters: reframing the global automotive industry. ***Journal of economic geography*** , 8: 297-321.	Case study on the North American automotive industry	Analysis on the US automtoive industry from an economic and insitutional perspective, including the role of national political institutions	Google Scholar
47	Tolbert, P. S., & Zucker, L. G. 1983. Institutional sources of change in the formal structure of organizations: The diffusion of civil service reform, 1880-1935. ***Administrative science quarterly*** , 28(1): 22-39.	Quantitative, longitudinal case study analysis on the diffusion on the US civil service	Analysis of the diffusion and institutionalization of change in formal organization structure differentiation between legitimization by law and gradual adoption	Google Scholar
48	Tracey, P., Phillips, N., & Jarvis, O. 2011. Bridging institutional entrepreneurship and the creation of new organizational forms: A multilevel model. ***Organization science*** , 22(1): 60-80.	Qualitative case Study on social enerprises in the UK Data collection: archival data, interviews	Anaylsis on how institutional entrepreneurs create new organizationa forms by making use of aspects of established institutional logics	Google Scholar
49	Tushman, M. L., & Anderson, P. 1986. Technological discontinuities and organizational environments. ***Administrative science quarterly*** , 31: 439-465.	Quantitative analysis on US firms based on three different products	Analysis on technological breakthroughs in form of competence-building and -destroying innovation and their initiators	Google Scholar
50	Van de Ven, A. H. 1986. Central problems in the management of innovation. ***Management science*** , 32(5): 590-607.	Theoretical analysis	Analysis on the concept of innovation and ist relation to insitutional innovation	Google Scholar
51	Vermeulen, P., Büch, R., & Greenwood, R. 2007. The impact of governmental policies in institutional fields: The case of innovation in the Dutch concrete industry. ***Organization studies*** , 28(4): 515-540.	Qualitative, longitudinal case study analysis on the concrete industry Data collection: interviews, reports, publications from governmental agencies, professional associations and research institutions	Study on the government and policies in market construction, examining the roles of regulatory structures, professional associations and competitors and the different interest involved in an institutional field	SCOPUS
52	Voronov, M., & Weber, K. 2020. People, actors, and the humanizing of institutional theory. ***Journal of management studies*** , 57(4): 873-884.	Theoretical analysis	Examination of the conceptual and normative implications of integrating human experience in institutional analysis, and the need to distinguish between actors and people	SCOPUS
53	Wezel, F. C., & Saka-Helmhout, A. 2006. Antecedents and consequences of organizational change: 'Institutionalizing'the behavioral theory of the firm. ***Organization studies*** , 27(2): 265-286.	Qualitative, longitudinal case study analysis in the baseball industry	Study on the drivers of organizational change in periods of institutional stability and instability and the role of mimetic and cognitive pressures	Google Scholar
54	Williams, M. E. 2002. Market reforms, technocrats, and institutional innovation. ***World development*** , 30(3): 395-412.	Qualitative case study analysis	Study on innovations in market reforms and the role of technocrat policymakers and modes to induce insitutional innovation	SCOPUS
55	Zucker, L. G. 1987. Institutional theories of organization. ***Annual review of sociology*** , 13(1): 443-464.	Theoretical analysis	Analysis of institutional theories of organizations and their influence on normative pressures, the adoption of legitimated elements and isomorphism	Google Scholar

Appendix 2.1: Literature on institutions in the German automotive industry

No.	Literature	Study design	Study	Search engine
1	Guérard, S., Bode, C., & Gustafsson, R. 2013. Turning point mechanisms in a dualistic process model of institutional emergence: The case of the diesel particulate filter in Germany. ***Organization studies*** , 34(5-6): 781-822.	Qualitative, longitudinal case study analysis Data Collection: 12 interviews with experts and activists, newspaper articles	Emergence of a normative institution diesel particulate filter as standard, proposal of a dualistic process model of institutional emergence, identification of turning point mechanisms that shape the process	SCOPUS
2	Hertwig, M. 2012. Institutional effects in the adoption of e-business-technology: Evidence from the German automotive supplier industry. ***Information and organization*** , 22: 252-272.	Quantitative data analysis of 1900 companies	Study of reasons for e-business technology adoption with focus on mimesis, coercion, and normative pressures as insitutional factors	SCOPUS
3	Tasli-Karabulut, V., & Keizer, A. 2020. Multinational corporations as institutional entrepreneurs: the dynamic interplay between automobile firms and the Turkish vocational education and training system. ***Industrial relations journal*** , 51(3): 153-168.	Qualitative case study analysis Data collection: 31 interviews from company representatives	Role of MNCs as insitutional entrepreneurs in foreign production sites	SCOPUS
4	Zimmermann, A., & Bollbach, M. F. 2015. Institutional and cultural barriers to transferring lean production to China: Evidence from a German automotive components manufacturer. ***Asian business & management*** , 14: 53-85.	Qualitative case study analysis Data collection: 60 interviews with employees, contextual company documents, observations	Study of insitutional barriers in the adoption of a new production system in China	SCOPUS

Appendix 2: List of major political initiatives and legislatives, and industrial/ market occurrences concerning the environment and electric mobility

This is an exception of the major industry events and legislative changes for climate protection, to limit emissions and promote EVs.

If it is not specified that a bullet point refers to a specific country, it refers to a German event.

Pre 2012: Climate change and first policy measures

- 1970: **US Clean Air Act** – The Act mandates the Environmental Protection Agency to set stricter standards for various car exhaust pollutants, especially NO_x and PM, and set a requirement for catalytic converters (EPA, 2022).
- 1972: The **UN Conference on the Human Environment** is held in Stockholm, Sweden, which marked the beginning of international environmental diplomacy (UN, 2023a).
- 1974: The Federal Immission Control Act (**Immissionsschutzrecht**, BImSchG) establishes regulations for emissions of air pollutants, noise, and vibrations from industrial plants and motor vehicles (Umweltbundesamt, 2022a).
- 1989: The **catalytic converter** becomes mandatory for all newly registered gasoline cars in Germany, intended to reduce car exhaust gases, such as NO_x. Many automakers are already installing catalytic converters to import into the US, where lower emission limits apply (Stahl, 1984; WDR, 2009).
- 1990: The amended **US Clean Air Act** allows California to set more stringent requirements, recognizing the state's air quality challenges. As such California's regulations included the **Zero Emission Vehicle Mandate**, aimed to promote the development and adoption of vehicles with zero emissions. The amended act played a significant role in promoting the advancement of electric and other zero-emission vehicles in the US (California Air Resources Board, 2023).
- 1992: The UN Conference on Environment and Development, also known as the Earth Summit, was held in Rio de Janeiro, Brazil. The summit resulted in the adoption of the **UN Framework Convention on Climate Change** (UNFCCC), the first global climate protection agreement which aimed to stabilize greenhouse gas concentrations in the atmosphere (UN, 2023a).
- 1992: Introduction of the EU exhaust emission standards for motor vehicles, **emission standard 1** (Abgasnorm/ Euro Norm 1). The regulation serves primarily to reduce NO_x and PM (Umweltbundesamt, 2020).

- 1992: German OEMs launch a large-scale **EV trial** on the island of Rügen with the support of then Federal Environment Minister Merkel. After that, the topic disappears from the agenda again. The automotive industry argues that the market is not ready for this, nor is the technology sufficient (Pander, 2008).
- 1995: The European Commission introduced a concept that aimed to **stabilize CO_2 emissions** in 2000 to the level of 1990 and reduce them beyond the year 2000 (European Commission, 1995).
- 1996: First formulation by the EU to limit global warming to a maximum **of 2 degrees Celsius** compared to pre-industrial levels (European Commission, 1996).
- 1997: The **Kyoto Protocol** was adopted under the UNFCCC, which required developed countries to reduce their greenhouse gas emissions. At that time, it is the **only enforceable legal accord** in the world to reduce greenhouse gas emissions. Over the commitment period 2008-2012, for industrialized countries, emission targets were a 5 % reduction compared to 1990. The agreements don't specify how the agreed-upon objectives are to be attained (European Commission, 2023c; UN, 2023c). The 15 EU countries commit to an average **8 % reduction**. To achieve this target, they have agreed upon a "burden-sharing", a distribution in reduction rates among the states (UN, 1998). Germany committed to a reduction of **21 %.** Until 2012, Germany was already able to undercut this value with 22 % (Die Bundesregierung, 2011a).
- 1998: **ACEA Agreement** – A voluntary commitment between the ACEA (European Automobile Manufacturers' Association) and the European Commission in which the ACEA agreed on behalf of its members to aim to reduce average emissions from new cars to **140 g CO_2/km by 2008.** This value is not reached (European Commission, 1998).
- 1999: **EU Directive 99/30/EC** on **air quality** establishes lowering critical emission values, amongst others, of PM, to be met by **2001, 2005 and 2010** (Wissenschaftliche Dienste des Deutschen Bundestages, 2005).
- 1999: **Ecological tax reform** (Ökologische Steuerreform) which i.a. inlcudes a gradual increase in mineral oil tax (Mineral Oil Tax Act, Mineralölsteuer). Until 2003, gasoline and diesel fuels will be subject to a rate of 15 cents per liter in addition to the existing mineral oil tax (Ecologic Institut, 2005). Nevertheless, since 1994 diesel fuel has been subsidized by the state by about 22ct per liter (Jacobs & Quack, 2018).
- 2000: **Renewable Energy Sources Act** (Erneuerbare Energien Gesetz (EEG)) – The act sets the objective of doubling the proportion of renewable energy in Germany's electricity

consumption by 2010. It establishes a feed-in tariff system where operators of renewable energy facilities receive a fixed payment for every kilowatt-hour of electricity they feed into the grid. For the first time, a legal framework prioritizes renewable electricity over conventionally generated electricity (BMWK, 2022).

- **2004: Greenhouse gas emission allowance trading (**Treibhausgas-Emmisionshandelsgesetz, Gesetz über den Handel mit Berechtigungen zur Emission von Treibhausgasen, TEHG) – Companies that emit CO_2 must purchase certificates entitling them to a certain amount of emissions. It is the legal basis for national trading of allowances for the emission of greenhouse gases in an EU-wide emissions trading system established in 2003 by EU Directive 2003/87/EC with regard to the Kyoto Protocol of 1997, which obliges the member states of the EU to reduce greenhouse gases since 2005 (European Union, 2022).
- 2006: **Energy Tax Law** (Energiesteuergesetz, EnergieStG) - The Energy Tax Act establishes taxes on the consumption of energy, including fuels used by motor vehicles, to encourage energy efficiency and reduce greenhouse gas emissions. It replaces the Mineral Oil Tax Act (Bundeszentrale für politische Bildung, 2023a) and serves the compliance of EU Directive 2003/96/EC which sets the EU's framework for the taxation of electricity, fuels and most heating fuels (European Union, 2016).
- 2007: **Integrated Climate and Energy Program** (Integriertes Klima- und Energieprogramm, IEKP) – Federal government resolution that laid the foundation for a holistic energy and climate policy in Germany (BMWK, 2023e). The package of measures includes focal points such as the Renewable Energy Sources Act, conversion of the motor vehicle tax on the basis of pollutants and CO_2, and incentives to increase the purchase of fuel-efficient, low- CO_2 passenger cars (Die Bundesregierung, 2007).
- 2007: The National Hydrogen and Fuel Cell Technology Innovation Program (Nationales Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie, NIP) is established (Bundesministerium für Digitales und Verkehr, 2020).
- Jan 2008: Introduction of first **low emission zones** (Umweltzonen) in three Germany cities to improve air quality by lowering PM values in particularly polluted areas. Within the year the number of cities rises to 25 (Umweltbundesamt, 2008). It is a measure taken in response to EU Directive 99/30/EC from 1999 which established lowering critical PM values, amongst others, of PM to be reached until 2010 (Wissenschaftliche Dienste des Deutschen Bundestages, 2005).

- May 2008: **EU Directive 2008/50/EC** (Luftqualitätsrichtlinie), on ambient **air quality** and cleaner air for Europe, as successor to existing EU air quality directives (e.g. 96/62/EC, 99/30/EC). With effect from **2010**, it establishes critical values for PM by **2015 and 2020** (Deutscher Wetterdienst, 2023).
- July 2008: The first public charging stations get connected to the German grid (Moreno, 2020).
- Nov 2008: **National Strategy Conference on Electric Mobility** (Nationale Strategiekonferenz Elektromobilität) – The key points for a National Electric Mobility Development Plan (Nationaler Entwicklungsplan Elektromobilität) are presented for discussion with representatives from the automotive and other industries, and environmental and consumer organizations (Die Bundesregierung, 2008).
- March 2009: **Economic Stimulus Package II** (Konjunkturpaket II **-** Gesetz zur Sicherung von Beschäftigung und Stabilität in Deutschland), adopted in response to the economic downturn in the wake of the financial crisis. € 500 million until 2011 was allocated for R&D in the field of EVs to support the market introduction of electric mobility. The Package also introduced an environmental bonus (Umweltprämie/ "Abwrackprämie") to strengthen the demand for passenger cars. Under the initiative, individuals who voluntarily scrapped their cars that were at least nine years old and replaced them with new or one-year-old cars were eligible to receive a € 2,500 subsidy from the government (Deutscher Bundestag, 2009: 421, 426; 2018).
- April 2009: **EU Regulation 443/2009** as a response to the failed 1998 voluntary ACEA commitment of 140 g CO_2/km by 2008. The regulation set compulsory **CO_2 emission performance standards** based on the NEDC for new passenger cars in the EU on a fleet basis (BMUV, 2020):
  - From 2012 on (in its entirety from **2015**), the average CO_2 emissions must not exceed the limit of **130** g CO_2/km.
  - From 2020 on (in its entirety from **2021**), a stricter limit of **95** g CO_2/km will apply.
- July 2009: **Car tax reform** (Kfz-Steuerreform), which now takes into account the size of the engine and CO_2 emissions. A base mass of 120 g CO_2/km emission remains tax-free for registrations of new cars first registration until 2011, 110 g/km until 2012, and 95 g/km for from 2014. Each additional g/km is taxed at € 2 (Straßenverkehrsamt, 2023).
- August 2009: **National Electric Mobility Development Plan** (Nationaler Entwicklungsplan Elektromobilität) with the objective to accelerate battery EV research, and

their market preparation and introduce **one million EVs registered by 2020** (Die Bundesregierung, 2009a).

- Sep 2009: **Coalition agreement** between CDU, CSU and FDP, following the election to the 17th German Bundestag. Concerning e-mobility, the agreement aimed to promote EVs in connection with alternative energy technologies through R&D, develop the charging infrastructure and set a goal to become a leading market for electric mobility with one million EVs registered by 2020 (Die Bundesregierung, 2009b).
- Dec 2009: The UN Climate Change Conference, also known as the **Copenhagen Summit**, was held in Denmark. The summit aimed to produce an agreement to limit global warming to below 2°C, but ultimately resulted in a non-binding accord.
- Feb 2010: **Joint Federal Government Office for Electric Mobility** (Gemeinsame Geschäftsstelle Elektromobilität der Bundesregierung, GGEMO), established under the patronage of the German Federal Ministry for Economic Affairs and Climate Action (BMWK). It serves as a single point of contact and secretariat of the Federal Government for tasks in the field of electric mobility and is responsible for the further development and implementation of electric mobility in close coordination with the NPE (BMWK, 2023d).
- May 2010: **National Electric Mobility Platform** (Nationale Plattform Elektromobilität, **NPE**) – For the first time, stakeholders from business, science, politics and society are brought together to set the direction and construct the road map for **achieving the goals specified in the National Electric Mobility Development Plan.** Development of three phases and aims (NPE, 2018):
  - Phase 1: 2010-2014: Market preparation with a focus on R&D and showcase projects
  - Phase 2: 2015-2017: Market ramp-up with a focus on market development in vehicles and infrastructure
  - Phase 3: 2018-2020: Emerging mass market with viable business models
- August 2010: To accord with EU Directive 2008/50/EC on air quality, to reduce NO_2 pollution, with 39. BImSchV Germany sets an annual **average limit value of 40 µg NO_2/m^3** (Umweltbundesamt, 2022b).
- Nov 2010: NPE publishes **“Die deutsche Normungs-Roadmap Elektromobilität“** which contains guidelines for the standardization of technologies, infrastructure and safety standards in the field of electric mobility (NPE, 2010).

- May 2011: **Government Program on Electric Mobility** (Regierungsprogramm Elektromobilität) as a concretization of the National Electric Mobility Development Plan – A further € 1 billion is be made available for R&D measures in electric mobility until the end of the legislative period with a focus on battery cell research and production, vehicle technology, charging infrastructure, and grid integration. Emphasis on the targets of one million EVs on the roads by 2020 and six million by 2030 (Die Bundesregierung, 2011b).

Years 2012-2014: The manufacturers' resistance to electric mobility

- Oct 2012: Automobile tax exemption (Kfz-Steuerbrefreiung) for EVs – According to §3d Steuerbefreiung für Elektrofahrzeuge, Kraftfahrzeugsteuergesetz 2002, BEVs registered between May 2011 and 2025 are to be **exempt from** automobile **tax for ten years**, but no longer than 2030.
- Dec 2012: **Doha Amendment** to the Kyoto Protocol, adding a second commitment period from 2013 to 2020 to reduce emissions by 18 % compared to 1990 (UN, 2023c).
- June 2013: Following intervention by Chancellor Angela Merkel (CDU), the planned passing of values of 95 g CO_2/km by 2020 and stricter limits beyond 2020 was **postponed until 2014** (Spiegel, 2013b; Süddeutsche Zeitung, 2013). Newspapers report lobbying by the German automotive industry in the run-up to the vote, including a letter from the VDA to Merkel in which they report that stricter limits cannot be complied with and would harm the German automotive industry (Spiegel, 2013a).
- Sep 2013: **Election to the 18th German Bundestag**. CDU emerges as the strongest party and forms a governing coalition with the SPD (Tagesschau, 2013). The coalition agreement places a focus on the promotion and further development of electric mobility in Germany, both in terms of vehicles and the necessary infrastructure (Die Bundesregierung, 2013).
- Oct 2013: **Quandt family** (major shareholders and founding family of BMW) makes donations of € 690,000 to the CDU, and € 210,000 to the FDP (Deutscher Bundestag, 2013). Allegations are made of a connection with Merkel's recent intervention on CO_2 emissions. Any political connections towards the donations are firmly rejected by the CDU (S. Becker & Medick, 2013).
- Nov 2013: Introduction of the first mass-produced EVs by German OEMs, the BMW i3, as part of BMW's brand BMW I, established in 2010 (GoingElectric), and the VW e-Up! (Jürgen, 2023).

- April 2014: EU Regulation 333/2014 **modifies Regulation 443/2009** of the 95 g CO_2/km (NEDC) target starting from 2020, and to the full extent from 2021 (European Union, 2014b):
  - By allowing for calculations based on the weight of the cars.
  - To determine a manufacturer's average CO_2 emissions, until 2015 annually increasing percentages of new passenger cars registered by the manufacturer in that year will be used. From 2015-2019, 100 % of the manufacturer's fleet are credited in the 130 g CO_2 /km calculation. In 2020, 95 % of the fleet is used to calculate the 95 g CO_2/km limit, i.e. the manufacturer can exclude 5 % of its vehicles with the heaviest CO_2 emissions.
  - From 2020-2022, a "super-credits" system facilitates reaching the target of 95 g CO_2/km. Each new passenger car with emissions below 50 g CO_2/km is counted as more than one vehicle in the calculation of a manufacturer's fleet average emissions.
- Oct 2014: EU Directive 2014/94/EU establishes minimum requirements for the deployment of **alternative fuels infrastructure**, including **charging points for electric vehicles** and natural gas (LNG and CNG) and hydrogen refueling stations, to be implemented by Member States through their national strategy frameworks (European Union, 2014a)
- Sep 2014: Introduction of the **Euro 6 standard** for motor vehicles, to its full extent mandatory for all new cars from Sep 2015. For diesel engines, a maximum rate of 500 mg CO_2/km, 80 mg NO_x/km and 4.5 mg PM/km applies; for gasoline engines, 1,000 mg CO_2/km, 60 g NO_x/km and also 4.5 mg PM/km (Umweltbundesamt, 2020).Today, there are gradations up to 6d, but the limit values do not differ. While under 6a and 6b the values were measured according to the NEDC, since 6c (2018) testing has been carried out according to the WLTC. For 6d, effective since 2020, the values are additionally measured in real driving operation (Real Driving Emissions, RDE) (Umweltbundesamt, 2020).
- 2014: **Tesla Model S** vehicles are newly registered in Germany for the first time, over the year, 815 Model S. (Comparison: BMW i3 sold 2,233 units in 2014 - in its first year 2013, 559 units) (KBA, 2013, 2014).

Years 2015-2019: The road to electric mobility

- May 2015: China introduces its 10 year industrial strategic plan **Made in China 2025** through which the nation hopes to become a leading technology nation (Schirrmeister et al., 2020). Within the traffic sector, the idea is to harness populations interested in technology and pressure to find solutions to traffic issues to create regional synergies of the numerous smaller companies in order for the vehicle sector to grow into a significant national economic sector in the ensuing decades (Bormann et al., 2018). Electric mobility is promoted within society by establishing policies that benefit EVS, for instance by massively lowering the normally high registration costs and on manufacturer level through EV quotas and fleet emission regulations (Retzer et al., 2018).

- June 2015: **The Electric Mobility Act** (Elektromobilitätsgesetz EmoG/ Gesetz zur Bevorrechtigung der Verwendung elektrisch betriebener Fahrzeuge) – Law aimed at promoting the adoption of electric mobility. It defines electric mobility and provides special privileges for EVs, such as using bus lanes and reserved parking spaces. Other measures include subsidies for purchasing electric cars, and the expansion of charging infrastructure (Deutscher Bundestag, 2015).
- Sep 2015: Adoption of the 2030 Agenda for Sustainable Development, which includes the **Sustainable Development Goals** (SDGs), at the UN Sustainable Development Summit in New York, US.
- Sep 2015: "**Diesel gate**" scandal – The US Environmental Protection Agency (EPA) accuses VW of manipulating diesel emissions tests and violating the Clean Air Act between 2009 and 2015. VW admits the allegations and is charged for installing unlicensed manipulation devices (Tagesschau, 2015). Over the next few months, it becomes evident that an affected three-liter engine was built by subsidiary Audi (Hulverscheidt, 2015; Timmler, 2018).
- Dec 2015: The UN Climate Change Conference, also known as the **Paris Agreement**, is held in France. The agreement aimed to limit global warming to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C, in effect from November 2016.
- June 2016: Introduction of the **environmental bonus** (**Umweltbonus**/ Kaufprämie für Elektrofahrzeuge, Richtlinie zur Förderung des Absatzes von elektrisch betriebenen Fahrzeugen), a government incentive that provides financial support when purchasing a new BEV (€ 4,000) or PHEV (€ 3,000) with a net list price of up to € 60,000 from May 2016 on, financed half by the German government and half by the industry. The funding will be provided until the full disbursement of the federal funds earmarked for this purpose in the amount of € 600 million but until 2019 at the latest. It is the first direct policy instrument for the NPE's second phase market ramp-up (Bundesamt für Wirtschaft und Ausfuhrkontrolle, 2016; NPE, 2018).
- September 2016: **Diesel gate:** Audi is accused of not only cheating, but contributing to the development of VW's cheating software. An e-mail from an Audi engineer from 2007

surfaces concerning the strict limits for harmful nitrogen oxides in the US. The values are said to be impossible to comply with without cheating ("ganz ohne bescheißen"). So far, Audi has denied having manipulated. They insisted that they had merely not disclosed a certain detail of the engine control system to US authorities (Fromm & Ott, 2016; Spiegel, 2016).

- Nov 2016: The brand **VW** presents their strategy TRANSFORM 2025+. It plans to expand its electric mobility section with nine electric and hybrid vehicle variants by 2020. From 2025, the target is to sell one million electric cars per year (Autohaus, 2016). It is considered a strategy in response to increasing pressure caused by the diesel gate (Wirtschaftswoche, 2016).
- Nov 2016: The **Climate Action Plan 2050** (Klimaschutzplan 2050) represents German's decision to become a climate-neutral country by 2050. By 2030, 55 % fewer greenhouse gases are to be emitted compared to 1990. For the first time, this overall goal is broken down to individual sectors and climate targets are defined for individual sectors of the economy. The basis is the commitment under the UN Paris Agreement (BMWK, 2023f).
- 2016: All new charging points in Germany must be uniformly equipped with at least the **Combined Charging System (CCS),** have to be barrier-free and accessible without prior contractual commitment. By the end of 2017, it has to be implemented throughout the EU (NPE, 2018).
- Feb 2017: Funding Guidelines for Charging Infrastructure for EVs (Förderrichtlinie **Ladeinfrastruktur** für Elektrofahrzeuge) – A program aimed at promoting the development of publicly accessible charging infrastructure for EVs. The German government plans to invest € 300 million from 2017 to 2020. The aim is to build a total of at least 15,000 charging stations throughout Germany (NPE, 2018).
- March-Nov 2017: **Diesel gate:** After the public prosecutor's office in Braunschweig starts investigations against VW, police searches at Audi follow. In June, Transport Minister Dobrindt announces that Audi has also used illegal emissions software and calls for recalls. So far, the authorities had only assumed manipulation in the US. The Munich public prosecutor's office begins its investigation, whereupon an engine developer is arrested. As a key witness, he reports on the targeted manipulations at Audi and incriminates top managers (Timmler, 2018).
- July 2017: Gesetz zur Bevorrechtigung des Carsharings (**Carsharing Gesetz** CsgG) - The central scope of the CsgG is to promote the reduction of climate and environmentally

harmful effects of private motorized transport, in particular by providing electrically powered vehicles as defined by the Electric Mobility Act (§ 1, § 5 number 4, CsgG). It is also seen as an opportunity to promote vehicle ramp-up for EVs, as their potential range issues are limited in this way (Thiele, 2021).

- Aug 2017: The government brings together representatives from the automotive industry, and environmental groups at the chancellery for the first of five **Diesel Summits** to discuss the reduction of car emissions in view of polluted air in the cities, as well as the future of diesel technology and the role of electric mobility. In this first session, German automakers pledge to retrofit a total of around five million diesel vehicles with software updates from which a nitrogen oxide reduction of 25 to 30 % is expected (Holzer, 2018; Zeit Online, 2017).
- Nov 2017: **Sofortprogramm „Saubere Luft 2017-2020**" as a response to the Dieselgate scandal, opened proceedings against Germany by the EU Commission in 2015 and 2016 for infringements of air values and growing concerns about the health impacts of high levels of NO_x emissions from diesel vehicles. Until 2020, the government provides € 1.5 billion to municipalities, for example, for the electrification of the public transport bus fleet (Bundesministerium für Digitales und Verkehr, 2023b; Kersting, 2021).
- Feb 2018: Due to transgressions of the limit values of 40 µg NO_2/m^3, the Environmental Action Germany (Deutsche Umwelthilfe) filed a lawsuit against the clean air plans of the cities of Düsseldorf and Stuttgart. In 2018, the Federal Administrative Court declares an **inner-city driving ban for diesel cars** permissible. Vehicles, that do not meet the exhaust emission standard Euro 6 can be banned in particularly polluted areas by cities (Bundesverwaltungsgericht, 2018).
- April 2018: Opening of the **IONITY high-power charging network**, a joint venture between BMW Group, Ford Motor Company, Hyundai Motor Group, Mercedes Benz AG and Volkswagen Group, with Audi and Porsche and BlackRock's Global Renewable Power Platform as financial investors. It allows BEVs to charge up to 350 kW/h from 100 % renewable energy sources. In 2023, IONITY stations are placed across 24 European countries (IONITY, 2023; Manthey, 2018).
- May 2018: The **EU Commission sues Germany** before the European Court of Justice **over poor air quality** and the systematic and ongoing disregard of the EU limit of 40 µg $NO2/m^3$ between 2010 and 2016, which have been binding for all EU states since 2010 (EU Regulation 2008/50/EC). Alone in 2016, this value has been exceeded in 26 air quality

zones, with Stuttgart reporting a number of 82 µg/m^3 (European Commission, 2018). The lawsuit follows proceedings already opened against Germany in 2015 and 2016 for infringements of air values. The German government is accused of massive failures in the emissions scandal, as well as failing to adequately monitor car manufacturers' compliance with regulations (Spiegel, 2018b; Tagesschau, 2018). In June 2021, the European Court of Justice, convicts Germany of all charges (Kersting, 2021).

- June 2018: **Diesel gate:** Braunschweig public prosecutor's office imposes a fine of one billion euros on VW who accept the verdict (NDR, 2020). In parallel, investigations by the public prosecutor's office Munich against Audi are extended. Raids of Audi offices and private residences follow. Audi CEO Stadler is arrested to prevent possible destruction of evidence (Spiegel, 2018a; Timmler, 2018). In November, consumer advocates launch Germany's first class-action lawsuit in the diesel scandal against VW and go to court (NDR, 2020).
- August 2018: **Fridays for Future**: Started in August 2018 by Swedish student Greta Thunberg, students strike for climate action. The central goal is to meet the 1.5 degree target set by the UN at the World Climate Conference in Paris in 2015. According to the organization, nearly 2.3 million people in 130 countries take part in the second global strike in March 2019 (Fridays for Future, 2023).
- Sep 2018: **National Platform of Future Mobility** (Nationale Plattform Zukunft der Mobilität, NPM) is launched as the successor organization to the National Electric Mobility Platform (NPE) to extend the platform beyond just electric cars and based on the 19th coalition agreement of the grand coalition CDU/CSU and SPD. The platform is discontinued with the end of 2021 (NPM, 2021).
- Sep 2018: **Audi** introduces the **e-Tron** and begins mass production. It is the brand's first BEV (Audi, 2018).
- Nov 2018: **Tesla's Model 3** is unveiled in Germany. It is available from 2019 (Focus Online, 2018).
- Dec 2018: At the Handelsblatt Auto Summit, the **VW group announces the end of the ICE**. The last car with an ICE is to be produced in 2026 and sold in 2040 (Menzel & Hubik, 2018). This follows the announcement in November to invest € 44 billion in electric mobility, autonomous driving, digitization and new mobility services by 2023 (Germis, 2018).

- March 2019: Decided by the coalition committee, the **Concerted Action Mobility** (Konzertierte Aktion Mobilität) is to address the challenges of the transformation of mobility and the future development of the automotive industry as a group of experts with representatives from the industry and the entire mobility sector as well as other experts (Deutscher Bundestag, 2019a, c).
- April/ June 2019: VW CEO Winterkorn and four other top-executives, as well as now ex-Audi CEO Stadler are officially charged in the diesel gate affair (NDR, 2020).
- April 2019**:** From 2020 on **EU-Regulation 2019/631** on passenger cars replaces the former 443/2009 on CO_2 emission targets. It establishes new CO_2 emission targets for fleets beyond 2020. The super-credit regulation from 2020 stays in place (BMUV, 2020; European Commission, 2019).
  - 2021-2024: The 95 g CO_2 /km target applies to the manufacturer's entire fleet.
  - 2025-2029: A CO_2 reduction of 15 % compared to 2021 applies.
  - From 2030: A CO_2 reduction of 37.5 % compared to 2021 applies.
- July 2019: **Mercedes-Benz** introduces its first BEV, the EQC, of the 2016-founded EQ family. The technical platform is based on that of the GLC. The EQC is discontinued in 2023 (Rudschies, 2019).
- Sept 2019: Germany commits to becoming greenhouse gas neutral by 2050 at the **UN climate summit** in New York (BMUV, 2023).
- Sept 2019: **Porsche** unveils its first BEV in 120 years, the Taycan (Geiger, 2019).
- Oct 2019: The **Climate Protection Program 2030** (Klimaschutzprogramm 2030) is introduced as a first step to implement the 2016 Climate Action Plan 2050. Within the traffic chapter, the government recognizes the need to adapt distribution grids to meet the demands of electric mobility. They will establish favorable conditions for distribution grid operators to invest in grid intelligence and expand the networks to ensure reliable and high-quality supply for the increasing number of EVs. An overarching goal of seven to ten million EVs as well as one million charging points by 2030 is defined. Company car regulation for the use of BEVs and PHEVSs is to be extended until 2030. The environmental bonus on the purchase of EVs is to be extended. Moreover, also hydrogen fuel cells and methane gas (CNG, LNG) are to be promoted (Die Bundesregierung, 2019a: 76 ff.).
- Nov 2019: Musk announces the opening of **Tesla Gigafactory** in Berlin-Brandenburg. Constructions starts in February 2020 (Tagesschau, 2022).

- Nov 2019: The Concerted Action Mobility decides to **extend the environmental bonus** until the end of 2025 and also to increase it. Up to a net list price of € 40,000, the subsidy for BEVs is € 6,000 and for PHEVs € 4,500. Cars up to € 65,000 are subsidized with € 5,000 and € 3,750 respectively. Again, the premium is financed half by the state and half by the manufacturer. In addition, the **Master Plan Charging Infrastructure** (Masterplan Ladeinfrastruktur) is adopted (Die Bundesregierung, 2019c, 2020b). The Master Plan reaffirms the aim of the Climate Protection Program 2030 of one million charging points by the end of 2030. It also includes the installation of 50,000 public charging points by the end of 2022 (Die Bundesregierung, 2019b).
- Dec 2019: Announcement of the **European Green Deal**, which is a draft of the EU-Commission to legally anchor the goal of climate neutrality by 2050 (Hüttmann, 2023).
- Dec 2019: The German **Climate Protection Act** (Klimaschutzgesetz, KSG) legally establishes the climate protection and sectoral goals set out in the Climate Action Plan 2050 to achieve net greenhouse gas neutrality by 2050 (Deutscher Bundestag, 2019b).

Years 2020-2022: Start of the electric mobility ramp up

- March 2020: The **European Climate Law** anchors the goals of the European Green Deal into law to achieve climate neutrality by 2050 and reduce net greenhouse gases by 55 % in 2030 compared to 1990. It becomes effective in July 2021 (European Commission, 2023b).
- March 2020: The WHO officially declares COVID-19 ("Corona") a pandemic. The pandemic has significant economic consequences for Germany, including the automotive industry. Lockdowns and factory closures lead to global supply chain failures and a decline in production, demand falls (Landeszentrale für politische Bildung Baden-Württemberg, 2023)
- June 2020: At the coalition summit, the grand coalition decides on the **"Corona" economic stimulus package („Corona"-Konjunkturpaket).** Under this, amongst others, the **VAT** rate will be reduced from 19 to 16 % and for the reduced rate from 7 to 5 % by the end of 2020. It also includes a package of measures to promote electric mobility in Germany (Die Bundesregierung, 2020a). Between June 2020 and the end of 2021, later extended to 2022, the **innovation premium** doubles the government share of the environmental bonus subsidy for EVs up to a net list price of € 40,000. Thus, a newly registered BEV is subsidized with € 6,000 from the government and € 3,000 from the manufacturer; a PHEV receives € 4,500 from the government and € 2,250 from the manufacturer. For vehicles over € 40,000, the

environmental bonus increases by a total of 25 % (BMWK, 2023b). € 2.5 billion will be invested in **charging station infrastructure** (Die Bundesregierung, 2020a).

- July 2020: Launch of the **VW** ID.3 as part of the ID family with which VW aims to put a complete model family on the road that is powered purely by electricity (VW, 2019).
- Nov 2020: From November 2020 to October 2023, a kfw grant of up to € 900 can be requested for the purchase of an eligible private charging station (ADAC, 2022a).
- Jan 2021: The **BMW** iX3, BMW's first fully electric SUV start its sales in Germany. It is the first fully electrified vehicle since the i3 (ADAC, 2023c).
- Feb 2021: Porsche CEO declares that by 2030 80 % of its vehicles are to be EVs. In the long run, solely model 911 will continue with an ICE. The manufacturer aims to use synthetic fuels in order to still be emission-free (Uhlenbroich, 2021).
- March 2021: Program **On-site Charging Infrastructure** (Ladeinfrastruktur vor Ort) as a successor to the 2017 *Funding guidelines for charging infrastructure for EVs* makes € 300 million available for the buildup of charging infrastructure (Bundesministerium für Digitales und Verkehr, 2023a).
- March 2021: **VW** present its new strategy *ACCELERATE* as a successor to the in 2016 presented *TRANSFORM 2025+:* By 2030, 70 % of vehicles sold in Europe are to be electric, and 50 % in the US and China (VW, 2023b).
- June 2021: **The Climate Protection Act** (Klimagesetz) is amended by the Bundestag. The amended law brings forward the greenhouse gas neutrality by five years. Compared with 1990, a 65 % reduction is to be achieved by 2030 instead of 55 %, and an 88 % reduction by 2040. From **2045, Germany is to be greenhouse gas neutral** (BMUV, 2023).
- July 2021: The EU package **Fit for 55** introduces a number of **proposals** to revise and update EU legislation. It is a follow-up to the European Green Deal and the 2020 European Climate Law, to reduce greenhouse gases by 55 % in 2030 compared to 1990. The central instrument for achieving the targets is the already in 2005 established emissions trading system. In the traffic sector, in addition, a target value of 0 % is set for 2035: only emission-free new cars may be registered from 2035 onwards (Europäischer Rat, 2023a, b).
- July 2021: **Mercedes-Benz** Group announces their new strategy of “electric only”: From 2025, new vehicles will build upon an electric only vehicle architecture and the group plans on offering a fully electric fleet by 2030 (Mercedes-Benz, 2021a).

- July 2021: **Audi** announces to stop production of ICE vehicles from 2026 on. Up to 2033 the production of ICE engines is phased out (Hägler, 2021).
- July 2021: Brand **VW** declares that it will exit the ICE engine between 2033 and 2035 in Europe, in the US and China this will happen later (Prem & Schmidtutz, 2021).
- August 2021: Funding program **Publicly Charging Infrastructure for Electric Vehicles in Germany** (Öffentlich zugängliche Ladeinfrastruktur für Elektrofahrzeuge in Deutschland) allocates € 500 million to set up at least 50,000 charging points (of which 20,000 fast-charging points) by the end of 2025 (Bundesministerium für Digitales und Verkehr, 2023a).
- Dec 2021: The coalition agreement signed in December 2021 by the new government (SPD, FPP and Bündnis 90/ Die Grünen) amends the existing environmental bonus: As already decided, the innovation bonus applies until the end of 2022. From 2023, the rate of € 4,500 will again be applicable for BEVs up to net list price € 40,000 and € 3,000 up to € 65,000. The **environmental bonus for PHEVs is discontinued** completely. From 2024, BEVs up to a net list price of € 45,000 will be subsidized with € 3,000. The BEV environmental bonus will be discontinued from 2025 (BMWK, 2023c; Die Bundesregierung, 2021).
- Feb 2022: Russia starts a **war** of aggression on Ukraine (Bundeszentrale für politische Bildung, 2023b). Germany's gas dependence on Russia moves to the forefront of political debate (Bundeszentrale für politische Bildung, 2022). The economic consequences in Germany are reflected primarily in increased high energy prices and high inflation (Dülger, 2023).
- March 2022: **Tesla opens its Gigafactory** in Berlin-Brandenburg (Tagesschau, 2022).
- Nov 2022: The European Commission **proposes a Euro 7 standard** from 2025 for passenger cars, given that although no new internal combustion vehicles may be registered after 2035, passenger cars and commercial vehicles will continue to emit pollutants in 2050. EVs also cause pollution from brakes and microplastics from tires (European Commission, 2022). The new standard keeps the 60 g NOx/km for gasoline engines and decreases the value for diesel engine from 80 to also 60 g NOx/km. In its calculations for PM, the Euro 7 would also include emissions from braking and tire abrasion and would therefore also apply to EVs. In the following months, controversy over the possible regulation flares up in Europe, for one about a too short implementation frame in which not enough vehicles with the requirements could be developed and approved and secondly about extra costs that come along with it. This raises fears that prices would rise disproportionately, especially for small

vehicles. In addition, the costs that would go into the implementation of Euro 7 would be lost to R&D on electric mobility. The German automotive industry is also opposed and has called on the German government not to approve Euro 7. Eight member states have formally protested against the norm which would make It unlikely that a majority of EU member states would vote in its favor (Beckmann, 2023; Tagesschau, 2023c).

- Oct 2022: **Master Plan Charging Infrastructure II** (Masterplan Ladeinfrastruktur II) is presented as a new overall strategy and roadmap to further increase the development of the charging infrastructure (Die Bundesregierung, 2022b).
- April 2023: EU-Regulation 2023/861 officially amends EU-Regulation 2019/631 on passenger cars to officially include the already agreed upon CO_2 target fleet reduction of 55 % compared to 1990 from 2030. From 2035 a reduction of 100 % applies. On 15th May, 2023 Regulation 2019/631 is altered to include these new values (European Commission, 2023d, e).

Appendix 3: Interview guideline

Note: All interviews were conducted in German. The following interview guideline is a translation of the actual German guideline used during the interviews.

- Personal introduction and presentation of the Master Thesis' topic
- Provision of short definition of institutions
- Note on data protection
- Request for personal data: Type of organization, area of responsibility, years of experience in the automotive sector and interaction with external stakeholders.

Start audio recording

Institutions

- What has made the auto industry so enduring so far? What are the most important institutions in the auto industry?

Overarching issues on the topic of e-mobility and change

- When was the topic of electric mobility first discussed in politics, society or companies?
- Which key events stood out for you (political, technical, market-dependent)?

Actors

- Who initiated and/or drove the process?
- Who were the "first movers" in the direction of electric mobility

Politics

- To what extent has policy driven the automotive industry in terms of climate protection and emissions?
- When did policymakers make a conscious decision to push e-mobility?
- Which political measures stood out for you on the EU or German level?
- What measures have been adopted with respect to companies and consumers that have promoted the transformation and adoption of electric mobility?
- How did OEMs respond to stricter regulations, e.g. CO_2 emission restrictions?
- <Automotive association> What is the role of an automobile association? How does the exchange with OEMs and politics look like?

- <Employee’s association> What is the role of an employee’s association? How does the exchange with OEMs and politics look like?
- <Employee’s association> Due to a potential loss of employment, did the employee’s association try to accompany the transformation or perhaps even slow it down somewhat? What measures were/ are taken to support employment?

Market

- Is the dominance of car manufacturers threatened by the transformation?
- How does the value chain change? Is this a driver or an obstacle to change? How do suppliers react?
- Which market events have been decisive in the change to e-mobility?
- What role did the diesel scandal play?
- What is the role of the Russia-Ukraine conflict?
- Raw materials: Where do German OEMs source raw materials? Are they available?
- Charging infrastructure & energy economy:
    - Who is responsible for building the charging infrastructure? Who has driven it?
    - To what extent will a new energy economy contribute to the transformation?
- For the last 2 or 3 years, it has become apparent that the number of new registrations of e-vehicles in Germany is increasing significantly. What is the reason for that?

Social factors

- What is society's attitude to e-mobility? Is there acceptance and, if so, since when?
- What key events have contributed to the rise in acceptance?
- What role did social movements, such as Fridays for Future, or other environmental organizations play?
- What prevents society from buying an EV?

Technology

- Can the CO_2 emission limits be met by purely optimizing the ICE and the vehicle as a whole (aerodynamics)? Up to which limits?
- Why was electric mobility chosen as opposed to other alternative propulsion systems?
- Would research have been conducted on e-mobility without subsidies from the state?

- Is EV technology a disruptive or incremental technological development?
- Is EV technology rather competence-building or destructive, i.e. does it build on existing competences does it require completely new skills?

Competition

- Which competitive events have been decisive in the shift to e-mobility?
- To what extent do other countries or players play a role in the transformation?
- What is China's role as a production country and target market?
- Does China have a head start in EV technology? In what way? If so, how did this come about?
- What is the role of the US? What is the role of Tesla?

Overarching

- Can the topic of electric mobility and its development be considered a singular topic? Is it linked to other trends, such as digitalization, connected cars and autonomous driving?
- What does the transformation mean for the German automotive industry? What consequences does it bring with it?
- Overall, to what extent would you describe the transformation as incremental? To what extent was that intentional?

Outlook and conclusion

- In your opinion, is electric mobility the future? Or other propulsion systems?
- As a consumer, are you convinced by electric mobility?
- On an overall basis, have we touched on the most important points or is there anything else you would like to mention?

End audio recording