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The Impact of "Energiewende" on the Sustainable Transition of the Automotive Industry in Germany

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Statutory Declaration

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Abstract

In this thesis, the “Energiewende’s” impact on the sustainable transition of the automotive industry in Germany will be analysed regarding the socio-economic and political effects. It seeks to explain policy tools and measures, key issues and trends. Based on the analysis of key stakeholders’ quantitative and qualitative opinion supported by the literature review and the qualitative interviews, this thesis indicates striking improvements in decarbonization, electrification and digitalization. While the “Energiewende” policy has promoted changes, the transformation process is complex and ongoing, therefore needs regularly reviews and specific investments. Focus topics of adjustment are workforce transformation, global competitiveness and shades of ethical supply. Consequently, this thesis offers the following policy implications: It is critical to increase various charging infrastructures to encourage adoption of EV and allow for policies that accommodate all groups of society to be engaged in sustainable development. To overcome the present gaps discovered or improve its position as a world leader in automotive innovation these implications are presented in the form of policy recommendations.

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1. Introduction

Cars. For some, they are a catapult into freedom, symbolizing the open road and endless possibilities. For others, they represent the immortal enemy to a sustainable future, the embodiment of environmental degradation and carbon emissions. This dichotomy captures the essence of the automotive industry's crucial role in the broader context of climate change and sustainable development. In Germany, "the land" of Karl Rapp, August Horch, Ferdinand Porsche, Nicolaus August Otto, Gottlieb Daimler und Karl Benz and automotive innovation, this tension is particularly visible. As the country embarks on an ambitious journey known as the "Energiewende", the energy transition aimed at drastically reducing greenhouse gas emissions and turning into a sustainable future.

The "Energiewende" is not just an energy policy but a comprehensive approach transforming various sectors, with the automotive industry being a critical component. Historically, the automotive sector has been a cornerstone of Germany's economy, providing millions of jobs, generating substantial tax revenue and attracting global investment. The industry's socio-economic impact extends beyond the factories, influencing the livelihoods of communities and shaping the nation's economic landscape, political stability and even its diplomatic relations to other economies. However, this economic giant is also a notable contributor to greenhouse gas emissions, presenting a major challenge to Germany's environmental goals.

The contradiction between public goals of environmental sustainability and private goals of profitability is strong. The automotive industry faces mounting pressure to decarbonize while maintaining its economic viability. The transition from internal combustion engines (ICEs) to electric vehicles (EVs) represents a seismic shift in production systems, factory procedures and workforce organization. Latest since 2020, there has been a joint effort to convert production systems to EVs, exemplified by initiatives like BMW's Neue Klasse platform. This transformation needs digitally scalable and standardized drive platforms, modified labour negotiations and competency attributions between employers and employees (Blöckner 2022: 4).

This thesis seeks to explore the impact of the “Energiewende” on the sustainable transition of the automotive industry in Germany. The primary research question is: How has the “Energiewende” influenced the automotive industry’s transition towards sustainability and what are the socio-economic and political implications of it? The objectives include the evaluating the effectiveness of policy measures in aligning industry practices with environmental goals.

Methodologically, this work focuses on a detailed document analysis. Additionally, to further enrich this study, qualitative interviews were conducted with central actors of the field, including the Institute of System and Innovation Research (ISI) at the Fraunhofer Institute, the Wuppertal Institute, the Department of Mobility and Logistics at Federation of German Industry (BDI) and the Governmental and Sustainability Communications Department at BMW Group.

Understanding the interplay between economic imperatives and environmental responsibilities is crucial for policymakers, industry stakeholders and society at large. This thesis aims to provide insights into how the automotive industry can navigate this complex landscape, balancing profitability with sustainability. Given the urgency of climate change, recent decisions on tariffs, taken by the European Union (EU) and the upcoming German federal elections in 2025, the findings of this study could inform critical policy decisions and strategic directions. Based on the policy recommendations provided, the three most powerful recommendations that can crucially impact the transition to sustainable mobility in Germany are:

I. **Investment in charging infrastructure:**
   Investing heavily in expanding and improving the EV charging infrastructure across the country is of central importance. Collaborating with private stakeholders to build a comprehensive and easily accessible charging network ensures coverage across both urban and rural areas as well as public/corporate and household usage. This infrastructure development is essential to support the growing number of EVs and ease range anxiety among consumers, reduce reliance on fossil fuels and help achieve the country’s emission reduction targets. Additionally, it will support economic growth by creating jobs in the installation and maintenance of charging stations.

II. **Advancing collaboration with the automotive industry through R&D funding and support for domestic manufacturing:**
Allocating substantial funds for research and development (R&D) in battery technology, alternative energy storage solutions (batteries) and other innovative mobility technologies. Supporting domestic manufacturing of EV components, including batteries, to create supply chain resilience, generate high-quality jobs, reduce strategic dependence on foreign suppliers and improve international competitiveness overall.
This recommendation will drive technological advancements and innovations in the automotive industry, making EVs more efficient, affordable and sustainable.

III. **Inclusive policies and social equity by addressing social and economic equity:** Ensuring that policies supporting sustainable mobility address social and economic equity. Providing targeted incentives and support for lower-income groups to promote inclusive access to EVs and charging infrastructure.
This recommendation ensures that the benefits of sustainable mobility are equitably distributed across all socio-economic groups, preventing the exacerbation of existing inequalities. It promotes social cohesion and public support for the transition to sustainable mobility. By making EVs accessible to a broader demographic, this approach will drive higher adoption rates and contribute notably to emission reduction goals.

Implementing these three powerful recommendations will ensure that Germany not only accelerates its transition to sustainable mobility but also does so in a way that is inclusive, innovative and economically beneficial.

The hypothesis guiding this research is that the “Energiewende”, through its stringent environmental targets and supportive policy frameworks, has catalysed progress in the automotive industry’s sustainable transition. However, this progress is weakened by socio-economic and political challenges that require cross-sectoral solutions. Additionally, these sustainable ambitions implemented in regulatory framework puts the industry under pressure to remain competitive in a field that is already dominated by other markets.

To combat climate change, Germany has committed to ambitious targets under international agreements such as the Paris Agreement and national legislation like the European Green Deal and the German Climate Action Law (Klimaschutzgesetz). These frameworks mandate a 40-42 % reduction in greenhouse gas (GHG) emissions in the transport sector by 2030, aiming to keep global temperature rise below 1.5 degrees Celsius compared to pre-industrial levels and achieving net-zero emissions by at least 2050. The urgency of addressing climate change cannot be overstated. The automotive industry's transition towards sustainability is not only a national concern but a global imperative. Failure to achieve these targets would have far-reaching consequences, not only intensify environmental degradation but also undermining Germany's position as a leader in sustainable development.

The automotive industry's transformation under the "Energiewende" represents one of the most remarkable economic and environmental challenges of our time. This thesis will delve into the difficulties of this transition, examining the socio-economic, political and environmental dimensions. By doing so, it aims to contribute to a deeper understanding of how the industry can align with sustainable development goals, ensuring a balance between economic vitality and environmental coordination. The stakes are high and the window for meaningful action is narrow, making this study both timely and critical for shaping a sustainable future.

2. Literature Review:

Frameworks and Strategies for Sustainable Mobility in Germany

2.1 International and National Legal Frameworks and Goals

In order to fight climate change, global, European and national frameworks have established stringent goals and regulations. Globally, in the Paris Agreement countries aim to limit the increase of temperature to 1.5 degrees Celsius above pre-industrial levels (renewed in the Glasgow-Climate-Pact 2021 on COP26) (UNFCC 2022: 4). On a European scale the European Green Deal's ambition is to become the first climate-neutral continent by 2050 with the help of various initiatives to decarbonize the economy. One of these initiatives is "Fit for 55", which is a legislative package that includes proposals and regulations to achieve a 55 % reduction in emissions by 2030, covering sectors like energy, transport and industry. It includes revisions and proposals affecting the transport sector such as the EU Emissions Trading System (ETS). The European Critical Raw Materials Act from 2023, aims to secure and sustainably manage the supply of critical raw materials necessary for the EU's green and digital transitions (European Commission 2023). The CO_2 Emission Performance Standards for Cars and Vans are regulations setting stricter emission limits for new vehicles. Regulation (EU) 2019/631 sets the so-called carbon dioxide (CO_2) fleet emission targets, adopted in April 2019. The Alternative Fuels Infrastructure Regulation (AFIR) replaces the Directive 2014/94/EU, requiring Member States to expand charging and refuelling infrastructure. The Renewable Energy Directive (RED II) sets obligations for the use of renewable energy sources including in transport. And finally, Euro 6 [Emission] Standards for cars and light commercial vehicles in the EU regulate the permissible limits for exhaust emissions (European Council 2024).

On the national level, German energy transition goals are to be compiled in the "Energiewende". This initiative is Germany's comprehensive energy transition policy aiming for a clear reduction in GHG emissions, increasing the share of renewable energy, improving energy efficiency and the 2023 achieved phasing out nuclear power (BMUV 2024a). Binding Climate Action Law (Klimaschutzgesetz) builds the legislation that sets targets for each sector to ensure Germany achieves its climate goals, including a target of reducing GHG emissions by at least 55 % by 2030 compared to

1990 levels and climate neutrality by 2045 (BMWK 2023a). Likewise, the Renewable Energy Act (Erneuerbare-Energien-Gesetz - EEG) marks a key instrument to promote renewable energy sources in Germany, defining the framework for feed-in tariffs and financial support for renewable energy projects (BMJ). In it and for this work specifically of interest is the goal of reducing GHG emissions in the transport sector in Germany by at least 40-42 % by 2030 (SRU 2017) (see Roadmap Appendix 1). German Climate Action Law further supports the use of renewable energy in EV charging infrastructure. Additionally, the Electric Mobility Act (EmoG) encourages the use of EVs through various incentives like parking privileges and the use of bus lanes. The Federal Emission Control Act (BImSchG) provides the framework for limiting emissions from vehicles and other sources.

Being a Federal State Germany gives certain authority to the regional governments. Various cities in Germany have Low Emission Zones (LEZs) that restrict access to parts of cities for vehicles that do not meet specific emission standards. Moreover, many local governments have initiatives to promote sustainable mobility, such as subsidies for EV purchase or support for public transport.

Despite the ambitious goals set by international, European and national frameworks, several challenges and criticisms persist that may hinder effective implementation. Firstly, political resistance is a significant barrier. Various stakeholders, including political parties, industry lobbyists and stakeholders of the public oppose stringent regulations due to perceived negative impacts on economic growth and employment or ideological reasons. Secondly, debates have arisen around the potential job losses and economic instability that rapid transitions might cause (Schwanen et al. 2012). Moreover, the transition to sustainable mobility involves economic costs for governments and private enterprises, such as investments in new technologies, infrastructure and retraining programs for workers. Thirdly, technological hurdles also pose challenges, particularly in developing and scaling new technologies like advanced battery systems, recycling processes and sustainable sourcing of raw materials (Nykvist/Nilsson 2015). These factors necessitate continuous investment in R&D and collaboration with research institutions to foster innovation and overcome technological barriers.

The industry represented by BMW in this case has its self-set targets. BMW aims to reduce emissions across the entire value chain by 40 % by 2030 compared to 2019 levels. Specific targets pertain to production. By 2050, BMW aims to achieve net-zero emissions, a 90 % reduction according to SBTi, with the remaining 10% offset as it is otherwise unreachable (BMW 2024). Industry-specific regulations, such as the CO_2 Emission Performance Standards for Cars and Vans and the EU ETS, directly impact the automotive sector. The CO_2 Emission Performance Standards mandate imposes fines for non-compliance. That pushes companies to invest heavily in R&D to meet these stringent targets (European Commission 2019). The ETS extension to road transport introduces financial costs for emissions and incentivizes reductions. Furthermore, it adds financial complexity as companies navigate the carbon market (European Commission 2020a). These regulations drive manufacturers to innovate and adopt sustainable practices, but they also introduce operational and financial challenges that require strategic management and support from stable policy frameworks.

2.2 Decarbonization, Electrification and Digitalisation in German Mobility

To achieve the listed goals, increasing the share of renewable energy and improving energy efficiency is essential. More specific Germany aims to transit towards sustainable and low-emission mobility solutions (Decarbonization). It aims to achieve six to ten million EVs on German roads by 2030, with a focus on expanding charging infrastructure (Electrification) and an integration of smart, innovative and digital R&D solutions for efficient traffic management. That includes intelligent transport systems, data-driven mobility services (Digitalization) and a diversification of the energy sources in the sector with alternative fuels, such as hydrogen and biofuels (BMDV 2018: 7 seqq.).

The shift from ICEs to EVs is reshaping the production landscape for German automotive manufacturers. Current EV production locations include BMW’s plants in Leipzig (BMW i3 and i8) and Shenyang (iX3), Mercedes-Benz’s facilities in Sindelfingen, Bremen and Beijing (EQ models), Volkswagen’s Zwickau and Chattanooga plants (ID-series) (VW 2024) and Audi’s Brussels and Neckarsulm plants (e-tron models) (Audi 2022). This transition involves not only the retooling of existing factories but also investments in new production facilities and battery manufacturing plants. For instance, Volkswagen is developing battery cell production in Salzgitter,

while Mercedes-Benz is establishing battery assembly plants in Kölleda and Kamenz (Mercedes 2024). In 2024, BMW started a major project in lower Bavaria, building a batterie-cell production plant creating more than 3200 jobs in a rural area (Riedl et al. 2024; BMW 2023). These developments reflect a broader trend towards localizing production to reduce supply chain dependencies and getting closer to the goal of sustainability. Moreover, German manufacturers are expanding their production capabilities in strategic markets like China and the USA to meet local demand and mitigate tariff impacts, which shows the global dimension of this transformation.

Undoubted digitalization will fundamentally change not only the products and the locations of production in the automotive industry, but also the procedures of production. Some say in production, it has triggered a fourth industrial revolution, known as “Industry 4.0” discussed in chapter 5.3. And that links again to the purpose of this work: There are indeed solutions that contribute to emission reduction such as (urban) public transportation systems that replace individual car usage, shrink traffic and promote active mobility options like cycling and walking to create more environmentally friendly and healthy mobility. However, this work focusses on the automotive industry, as the changes that come with the transformation of the sector do not only have socio-economic but political effects eventually. Additionally, recent studies have shown that even with wide range of incentives and offers, like the 49-Euro-Ticket, the society does not easily give up “their car”, although they are in favour of more environmental protection (ADAC 2023a, TUM 2023). After all, Mobility and transportation play a key role in achieving climate goals. The transport sector accounts for almost a third of the final energy consumed in the EU and a fifth in Germany excluded the additional emissions produced by the energy consumed by the automotive industry (EEA 2023). As most of this energy is generated by burning oil, transport is one of the main emitters of GHG. The share of transport in German emissions has risen steadily over the past 30 years. In order to reach the climate goals, extensive reductions in emissions must therefore be made particularly in this sector. The greatest share of emissions can be attributed to cars and commercial vehicles, thus particularly by motorized private transport (Römer/Salzgeber 2022).

Currently, EVs, either Battery Electric Vehicle (BEV)/Plug-in Electric Vehicles (PEV), Plug-in Hybrid Electric Vehicle (PHEV) or Fuel Cell (FCEV), constitute just

under five percent of the vehicles in use in the country, although with a rising trend. Projections anticipate this share to grow to just below 25 % by 2030. In total, around 3.7 million new vehicles were registered in 2023. This corresponds to an increase of 5.5 % (to 2022). 2.8 million passenger vehicles showed an increase of 7.3 % (to 2022). Almost half of all passenger cars (48.5 %) were equipped with an alternative drive system to the still dominating (non-hybridized) ICE. BEVs increased by 11.4 %, while plug-in hybrids declined by 51.5 %. Average CO_2 emissions rose by 4.9 % to 114.9 g/km (2022: 109.6 g/km). Almost one in three newly registered passenger cars (30.1 %) belonged to the Sport Utility Vehicle (SUV) segment. Around 1.9 million passenger cars (67.1%) were registered commercially (KBA 2024). However, in the European Union, starting from 2035, only new EV or vehicles with ICE that operate with zero CO_2 emissions while driving will be eligible for registration (Plötz et al. 2022). In this sense, the automotive industry faces numerous technical challenges, particularly in battery technology affecting vehicle range. Sustainability is another critical aspect in this context, referring to environmentally responsible methods for handling the battery. The vehicle battery alone is responsible for 30 to 60 % of total emissions in the production of EVs. In addition, production, recycling and disposal processes of batteries are currently characterized by heavy human rights and environmental impacts. In meeting climate neutrality, these processes must also apply highest sustainability standards (agora 2021).

Furthermore, green hydrogen (used in FCEV) is an important source or technology and a key energy carrier of the future. However, based on current knowledge, a dominant role in road transportation seems less likely due to the technical development of batteries and fast charging as well as the overall costs. In addition, even using solar power, the efficiency is only around 15 % (Jess 2023). The same currently applies to alternative fuels. Moreover, Germany has not achieved the target of ten percent renewable fuels in transport set out in the REPowerEU 2022 package (Knodt/Kemmerzell 2022). Alternatively, the total Power-to-X (P2X) demand is the effect of P2X strategies in different sub-sectors. For example, it can comprise H_2 in FCEVs, synthetic CH4 in gas motors, or synthetic liquid fuels as replacement of fossil fuels in ICE in the transport sector. Additionally, both H_2 and CH_4 can be fed into the

natural gas grid or used directly for heat generation or to generate power (Kara/Lael-Arcas 2023).

Turning future cars into sustainable vehicles will face and cause difficulties. First, the challenge of sector coupling requires the integration of energy and climate policy as a cross-sectoral governance issue. Second, new applications for direct and indirect electrification are increasing the demand for green electricity, such as charging infrastructure for battery EVs on the one hand and electrolysers to produce green hydrogen on the other. According to the coalition agreement of the current government, electricity from renewable energies should cover 80 % of the gross electricity supply by 2030. This means that electricity generation from renewable energies must at least double by then compared to 2020 (Knodt/Kemmerzell 2022). Price stability plays a crucial role in this context, as rising energy prices not only impact the production of EVs but also escalate costs for consumer mobility. Regarding the infrastructure, there is a standardized EU PEV charging infrastructure network, primarily based on the Combined Charging System (CCS) standard. CCS is the standardized charging protocol in the EU for both AC and DC fast charging. It is widely adopted by European car manufacturers and supported by the European Commission as part of the effort to harmonize EV charging standards across Europe to facilitate interoperability and the widespread adoption of EVs (EV Volumes 2024). In policy documents this is found in the Alternative Fuels Infrastructure Directive (AFID, 2014/94/EU). It mandates the development of an alternative fuel's infrastructure, including EV charging points, across EU member states and sets minimum requirements.

Today, the vulnerability of energy price and gas crisis, associated with the Russian invasion of Ukraine, has heightened this pressure and further exacerbated the challenges in governing the energy transition. Regarding the implementation of energy policy, the federal government does not decide autonomously in many cases. Instead, around 55 % of draft legislation falls into the category of approval legislation and requires the majority approval of the state governments represented in the federal council (Bundesrat) (Scharpf 1985: 323 et seqq.).

2.3 Governance Concepts

Governance of the "Energiewende" within the transportation sector involves a variety of stakeholders from federal and state governments to the private sector and civil society. Therefore, transparent structures and coordinated strategies are central. When speaking of governance, mostly the concept of "Regulative Governance" comes to mind which examines the role of governmental interventions and their effects on the regulatory framework, the economic environment, stakeholder's behaviour and for instance innovation cycles in the industry. However, current research in the area of sustainable energy transformation focuses on the practicability and efficiency of various governance models. One of them is the flexible, adaptive and decentralized "Reflexive-Governance". It is questioning the foundations of governance itself, thus the concepts, practices and institutions with which social development is regulated and considers alternatives to reinvent and shape these foundations. The focus is on reflecting on the cycle of problem generation and problem solving as well as on the problems of control and coordinating themselves, their effects, the associated uncertainties and ambivalences (Hamedinger 2021: 348). In Germany and particularly in this matter, "Co-Governance" is emphasized, where state and private actors cooperate to accelerate technological innovations and their market introduction. The transformation of transport through digitalization necessitates "Co-Governance" due to its complexity and the broad distribution of necessary knowledge across the sectors involved. "Co-Governance" enables a collaborative, inclusive approach, integrating diverse expertise and perspectives to effectively address and mitigate potential negative impacts on society, democracy and the environment. The rapid pace of technological advancements and the intricate nature of their effects demand adaptive, learning-oriented governance structures that can promptly respond to new challenges and uncertainties. By balancing power dynamics with participatory processes, "Co-Governance" ensures more equitable and democratic decision-making. This approach not only helps in crafting strategies that are responsive and sustainable but also promotes continuous learning and adjustments based on regular evaluations and monitoring of digitalization's impacts (Hamedinger 2021: 349).

Germany has demonstrated several successful instances of "Regulative Governance" in pursuing sustainable transitions within the automotive industry. For

instance, the introduction of stringent emissions standards pushed automakers to develop cleaner, more efficient vehicles (Nijhuis 2021). As “Co-Governance”-models haven been brought up, the EEG supports the industry by ensuring a stable and favourable regulatory environment for renewable energy, critical for EVs as it makes clean energy more accessible and economically viable for powering EVs. This creates synergies which will be also taken into account while analysing the international competitiveness (see chapter 5.1). Germany has also implemented successful programs that specifically support the automotive industry’s transition to sustainability. A prominent example is the “Environmental Bonus” program, which offers substantial subsidies for the purchase of EVs. The widely acknowledged subsidy program for purchasing EVs in Germany has strongly increased EV adoption, with EV registrations rising by 207% in 2020 compared to the previous year and EVs constituting 26% of new car registrations in 2021 (KBA 2022). This surge in EV adoption has contributed to a reduction in CO2 emissions by an estimated 1.5 million tonnes in 2020 alone (BMWK 2021). This initiative did not only accelerate the adoption of EVs but also support the domestic market for German automakers like BMW as they expand their electric lines. Additionally, the government has heavily subsidized the R&D of EVs, leading to advances in electric mobility (Gislam 2019).

As indicated, federal and state coordination is existential for the “Energiewende’s” success, especially in transportation. The decentralized nature of German federalism means that national objectives must be harmonized with state-level actions (ibid.). Forums such as the National Platform for Electric Mobility (NPE) are instrumental in strengthening this alignment, bringing together stakeholders across industry, science and government to ensure cohesive policy implementation. Even more, regulatory instruments mentioned in 2.1 play a crucial role for enforcing the goals of the “Energiewende” and ensuring compliance across the industry. An adaptive governance is necessary to keep pace with rapid technological advancements in transportation, such as developments in EV, hydrogen and charging technologies or other digital mobility solutions. Fundamental for this approach are ongoing monitoring of technological and market trends as well as societal attitudes, allowing for timely adjustments to policies and strategies to maintain their relevance and effectiveness. An example of an effective governance component can be seen in the work of the German

Advisory Council on the Environment (SRU). This body of experts assesses on environmental and mobility issues and informs and influences legislative measures, ensuring they are grounded in scientific research (BMUV 2023). Furthermore, Germany's expansion of its EV charging infrastructure, supported by both public funding and private investment, is another critical element of its regulatory approach to encourage EV adoption, ensuring that infrastructure keeps pace with the increasing number of EVs on the roads (BMDV 2024). The structure of financing the sustainable transition is going to be part of further analysis in the following chapters based on qualitative interviews that were conducted in the process of this work.

These examples illustrate how regulatory frameworks can catalyse technological and market changes in the automotive sector. Looking forward, challenges and opportunities for governance include the integration of complex systems like autonomous and shared mobility. These challenges are also opportunities for governance innovation, potentially utilizing big data and AI to enhance traffic management and policy assessments (Mc Kinsey 2023).

2.4 Stakeholder Engagement and Public-Private-Partnerships

Analysing the sustainable transition of the automotive industry requires observing stakeholders from both the transportation and energy sectors and their interconnectedness. Both sectors show complex, layered structures with stakeholders operating horizontally and vertically. Chapter 2.3 highlighted that while some stakeholders share common interests, such as strengthening the international competitiveness of Germany's automotive industry, others have divergent priorities, particularly regarding achieving competitiveness and balancing social and environmental protection. Nevertheless, the dynamics between public and private stakeholders in Germany play a critical role in shaping the nation's approach to electrification, decarbonization and digitalization of the transport sector. Germany's infrastructure, supportive policies and commitment to sustainability have strengthened its position in the global EV market, although competition, especially from the US and China, remains strong (see Chapter 4.1). Stakeholder engagement involves a wide range of participants, including vehicle manufacturers, energy providers, technology firms and consumer groups, to craft effective and widely accepted mobility solutions. This engagement is not only strategic but also essential for aligning various interests,

ensuring the broad adoption of innovations and mitigating socio-economic consequences. Public perception also influences policy and market dynamics. The growing acceptance of EVs and support for environmentally friendly mobility options reflect a shift in public consciousness towards sustainability (AEE 2023). Initiatives such as the "Germany makes it efficient" campaign by the Federal Ministry for Economic Affairs and Climate Protection (BMWK) highlight this transition, promoting awareness and education about energy efficiency and sustainable mobility practices (BMWKa). The NPE exemplifies this collaborative effort, aligning research funding and political frameworks to ensure that innovations align with national goals and public expectations. Through these elements, Germany integrates various stakeholders and public voices into its strategy for advancing sustainable mobility, focusing on the synergies created by public-private partnerships (PPPs seen in chapter 4.1) and the evolving landscape of public engagement in policymaking. Thus, it addresses technical and infrastructural challenges and the societal shifts necessary to sustain the transition towards more sustainable mobility.

In Germany, collaboration among stakeholders is particularly advanced in areas such as the standardization and normalization of technologies, including battery storage and charging infrastructure. A joint venture like Ionity by BMW, Mercedes-Benz, Ford and Volkswagen Group is developing a high-power charging (HPC) network along major highways across Europe, based on the CCS standard (Ionity). Hubject provides eRoaming services to enable operability between different charging networks. Through it, EV drivers can use various charging networks with a single account, simplifying the user experience (Hubject). And CharIN e.V. is an interface initiative promotes the adoption of the CCS standard and works on further developing charging technologies. CharIN plays a crucial role in standardizing charging infrastructure to ensure compatibility across different EV models and charging stations (CharIN). Across the European borders there are more PPPs that thrive for more cooperation in the digitalization. The Trans-European Transport Network (TEN-T) aims to connect Europe with efficient, sustainable transport infrastructure. The EU supports the deployment of EV charging stations along the TEN-T corridors to ensure that long-distance travel with EVs is feasible (IEA 2024). An industry association representing the EV charging infrastructure sector is ChargeUp Europe. It advocates for policies that support the

growth and interoperability of charging networks. It works with EU institutions to promote the development of a seamless and user-friendly charging experience across Europe (ChargeUp Europe).

As introduced, PPPs have proven to be a crucial tool for promoting electromobility and implementing necessary infrastructures, such as charging stations. These partnerships effectively use the strengths and resources of both public and private sectors to drive innovation and implementation at a pace and scale that neither could achieve independently. On the one hand PPPs allow for the pooling of financial resources, technical expertise and managerial capabilities between the government and private companies. This collaborative approach is essential for tackling large-scale infrastructure projects that are beyond the scope of individual entities (Vasyliev et al. 2019). On the other hand, by sharing risks, PPPs make it feasible to undertake innovative projects where outcomes are uncertain. This is particularly important in new markets like EV charging infrastructure, where future usage patterns and returns on investment are difficult to predict (Wuppertal Institute 2024). Moreover, with their combined resources, PPPs can accelerate the deployment of infrastructure, crucial for keeping up with the rapid adoption rates of EV in Germany. Besides the mentioned examples of successful PPPs in Germany the “Charging Infrastructure Masterplan II” initiative is a collaboration with leading automotive manufacturers such as BMW. The German federal government launched this initiative with a key goal to have one million publicly accessible charging points by 2030. As of now, nearly 70,000 charging points have been installed since the original master plan was introduced in 2019 (Kyllmann 2022). It aims not just to expand the infrastructure but also to standardize charging stations, making them more accessible and user-friendly.

Nevertheless, PPPs also face some challenges. Ensuring that public goals, such as environmental sustainability, align with private goals, such as profitability, can be challenging. Detailed contracts and governance structures are essential to ensure that PPPs operate with aligned objectives, but mark an bureaucratic effort (Salvador et al. 2019). Furthermore, PPPs must maintain a high level of transparency and public accountability since they involve public funds and serve public interests. Eventually, the long-term success of PPPs depends on their ability to adapt to changing technologies and market conditions. Continuous monitoring and flexible contract terms are crucial to

address this need (Vasyliev et al. 2019). For future directions, the role of PPPs in Germany's transition to sustainable mobility is likely to evolve. As technologies such as battery storage and hydrogen fuel cells mature, PPPs may shift focus towards integrating these new technologies into the existing mobility infrastructure. Beyond charging infrastructure, future PPPs may also address broader aspects of electromobility, including vehicle-to-grid technologies and smart mobility solutions (Salvador et al. 2019).

3. Methodology

This work focuses on a detailed document analysis, outlined in the literature review in Chapter 2. Given the high relevance of the automotive industry to Europe and particularly to Germany, the available literature is extensive. Scientific publications, for instance by agora, the Fraunhofer and the Wuppertal Institute, policy documents by the EU and the national legislation, industry statements by BMW and the BDI and articles from various organizations discuss the future of mobility, highlighting both challenges and opportunities. To further enrich this study, four qualitative interviews were conducted with exactly these producers of information and knowledge, including the Institute of System and Innovation Research (ISI) at the Fraunhofer Institute, the Wuppertal Institute, the Department of Mobility and Logistics at BDI and the Governmental and Sustainability Communications Department at BMW Group. Prepared and tailored questions from the research agenda were asked and the responses were analysed in conjunction with the findings from the literature review. These interviewees were chosen to keep this thesis balanced. By interviewing actors from the industry as well as the science, opposing results were expected. Indeed, science and industry opinions opposed sometimes. However, the industry shared valuable insights of practical challenges and best practice in the application of sustainable operations, the research institutes acknowledged the compromises society and politics have to make in order to create a compatible transition. Therefore, the interview fulfilled their purpose and provided this thesis with additional information that was not available in the form of documents.

4. Analysis of the Impact of "Energiewende" on the Transition of Sustainable Mobility

4.1 Policies and Regulations influencing Sustainable Mobility Solutions

As chapter 2 has shown regulatory frameworks and instruments to steer the economy on the path to climate neutrality, this chapter aims to analyse those in their practicability and effectiveness.

The Fraunhofer Institute emphasizes the need for the EU to focus on the profitability of Original Equipment Manufacturers (OEMs) within the European market, given their current low earnings domestically. One strategy is to introduce programs that encourage the adoption of smaller, European-made vehicles in fleet operations by collaborating with large companies and car rental services to boost demand (Fraunhofer 2024). However, the current policy decision to regulate European fleet emissions targets based on vehicle mass rather than surface area favours heavier vehicles. This regulation permits larger, heavier cars to emit more CO_2, which disincentivizes the production and purchase of smaller, more efficient vehicles. It further contradicts city initiatives to allocate more space for humans and green areas instead of cars. The 2023 registration numbers in Germany support that hypothesis with a large share of SUVs (see chapter 2.2). According to the industry, this regulation aims to maintain competitiveness across different vehicle segments but unintentionally promotes the production of less fuel-efficient vehicles, counteracting broader climate goals (Wuppertal Institute 2024). EVs, however, are classified as zero-emission vehicles under current sectoral emission targets (UBA 2023). While this seems like a good promotion of EV adoption, it can also lead to unintended consequences. Manufacturers might focus on producing EVs to offset emissions from their conventional vehicles, reducing the overall pressure to improve ICE vehicle efficiency. This laxity undermines efforts to increase the CO_2 balance of ICE vehicles and the energy efficiency of EVs, which are already considered zero-emission by regulatory standards (Wuppertal Institute 2024). In contrast, BMW argues that setting goals is more effective than regulating through instruments. The company follows the Science Based Targets initiative (SBTi). An abrupt ICE ban without expanding infrastructure would be disastrous, so BMW. High emission numbers in transport result from a dramatic increase in vehicle numbers, not a decline in efficiency,

as vehicles have indeed become more efficient (BMW 2024). The BDI agrees with that statement of BMW and also sees a clear CO_2 price as the most stringent measure. A clear system that guarantees planning security and reduces bureaucratic hurdles could be the most effective means of contributing to decarbonization (BDI 2024).

The Wuppertal Institute suggests that regulatory frameworks should target CO_2 emissions and emphasize energy efficiency metrics such as kilowatt-hours per kilometre. Focusing on energy efficiency ensures that vehicles are not only low in emissions but also efficient in their energy consumption, which is crucial for long-term sustainability and reducing the environmental impact of both EVs and ICE vehicles (Wuppertal Institute 2024). Additional financial incentives for consumers to opt for more efficient vehicles can be implemented through differentiated registration taxes and vehicle taxes based on emissions and energy efficiency (ADAC 2023b). Moreover, effective parking space management in urban areas can heavily influence vehicle choice and usage patterns. For instance, higher parking fees for larger, less efficient vehicles could encourage the use of smaller, more efficient ones. However, such measures face challenges related to proportionality and public acceptance, as seen with the resident parking permits in Freiburg (Schwab 2023).

In fact, company cars, often chosen for their status symbol, benefit from tax advantages and fuel cards that eliminate the incentive for fuel-efficient driving. Revising tax benefits and introducing stricter CO_2 emission limits for company cars could push companies to adopt more efficient fleet policies, reducing emissions from the corporate sector (Wuppertal Institute 2024). The Fraunhofer Institute supports restructuring tax laws, abolishing diesel and company car privileges and regulating vehicle sizes to incentivize the production of smaller vehicles suitable for the European market (Fraunhofer Institute 2024).

As part of the Green Deal, an economy-wide ETS provides a market-based approach to reducing emissions. However, to achieve net-zero emissions by 2045, decisions must be made across all sectors today. This includes making the automotive sector entirely climate neutral. While the BDI and BMW are in favour of technological openness, research institutes warn that delaying action in the automotive sector can lead to abrupt and economically disruptive changes in the future, as emissions allowances

become scarcer and more expensive. Therefore, proactive and consistent action across all sectors is crucial for meeting long-term climate goals. Critics argue that Germany's current climate targets (listed in 2.1) are not fully aligned with the Paris Agreement, which requires a consistent reduction in GHG emissions (UBA 2024). The focus should not only be on achieving net-zero emissions by 2045 but also on the total emissions over time. Early and consistent reductions have a more significant impact on mitigating climate change than a delayed, rapid adjustment towards the target year. This approach emphasizes the importance of immediate and sustained efforts to reduce emissions across all sectors (Wuppertal Institute 2024).

Looking at the infrastructure we see another possible field of action. The development of EV charging infrastructure and the demand for EVs are entangled in a classic chicken-and-egg problem. Potential buyers hesitate to purchase EVs due to the inadequate state of charging infrastructure, while providers of charging infrastructure are reluctant to invest in building stations in areas with insufficient demand. This mutual uncertainty, where neither party is willing to make the first move, reflects a market failure (NDR 2023). In such a scenario, the government should ensure predictability and intervene to catalyse market development. According to BMW, government support is needed to assist households and employers with the bureaucratic and technical aspects of expanding charging infrastructure with the same emphasis as they banned the ICE.

The planned ban on the sale of ICE vehicles by 2035 is clearly a strong state intervention, which, in fact, has been weakened by the Federal Ministry of Digital and Transport's (BMDV) obstruction at the EU level and the introduction of additional clauses allowing alternative fuels (Beckmann 2023). This send a signal that the status quo can be maintained, which is particularly confusing for the small and medium-sized enterprises (SMEs) that play a crucial role in Germany's economy. To rectify these mistakes and send the correct signals for the future, it is essential to firmly support the goal of phasing out ICE.

Providing predictability can be achieved by supporting the development of charging infrastructure/wallboxes at people's workplace and at the at home. While charging stations are necessary on highways, rural nodes like supermarkets and in urban

areas, vehicles are parked at work or overnight at home for most of the day, where they can be charged cost-effectively. The Fraunhofer Institute supports that argument by calling for subsidies where they are effective. Aware of Germany's traditional emphasis on debt limits and stringent control over government spending, a bonus-malus system is recommended (Hempel 2023). This system, successfully implemented in France for over a decade and similarly in Norway, funds incentives for EVs through additional taxes on ICE vehicles (Kara/Lael-Arcas 2023; UBA 2021). According to the Wuppertal Institute, however, the current government is unlikely to realize higher taxation on ICEs necessary to implement such a system and conserve public funds (Wuppertal Institute 2024).

4.2 Role of Public-Private Partnerships and Stakeholder Collaboration

Germany recently identified a 60 billion Euro shortfall in funds allocated for climate protection (Hempel 2023). This substantial deficit fuels arguments that sustainable transformation is exceedingly expensive, particularly in challenging economic times. However, the long-term costs of climate change caused by current practices will be much higher, which makes innovative financing solutions to ensure and support sustainability initiatives adequately. Strengthening PPPs and other collaborative funding mechanisms is essential for addressing this funding gap and facilitating the transition towards sustainable mobility within Germany's automotive industry.

As introduced, PPPs and stakeholder collaboration are central to the success of sustainable mobility initiatives as these collaborative efforts pool resources, share risks and leverage diverse expertise. Ideally, they gain innovation and ensure the effective implementation of sustainable mobility solutions by building a robust financial foundation for infrastructure funds. Therefore, PPPs offer a viable alternative to the current budgetary discussions and are particularly beneficial when investing targets to incentivize sustainable mobility, such as developing battery centres for production and recycling or in R&D. In that sense, PPPs are directly balancing the shortfall in government funding for climate initiatives. One of the critical roles of PPPs in the automotive industry is solving the mentioned chicken-egg-problem in the development of the charging infrastructure. This not only promotes the adoption of EVs but also helps to alleviate range anxiety among potential buyers.

Even though the benefits of PPPs are remarkable, creating them and convincing private actors to contribute capital is sometimes more difficult than expected. Participation in PPPs is currently cautious due to uncertain and low expected returns from such funds from a financial perspective (Wuppertal Institute 2024). Additionally, the bureaucratic burdens associated with application and approval processes in funding procedures can deter private sector involvement. The current shortage of skilled labour further complicates the implementation of such initiatives, highlighting the need for streamlined processes and effective workforce development strategies. To address these challenges, an alternative approach could involve greater reliance on “Contracting”. In this model, PPP entities could offer investment packages financed with favourable capital obtained from the federal government, which private actors could then purchase. This method would cover costs and allow any resulting profits to remain with private entities while still achieving the intended goals. This approach ensures financial viability and aligns private sector incentives with public sector objectives. For PPPs to be effective, strategic implementation is key. Establishing clear goals, timelines and responsibilities is essential. Government agencies, industry partners and other stakeholders must work collaboratively to define the specific actions required for each project. Regular reviews and updates of the implementation plan, at least every six months, are necessary to adapt to evolving circumstances and emerging opportunities. Moreover, a robust monitoring mechanism should be established to assess the impact and effectiveness of implemented policies. Key performance indicators (KPIs) that align with the goals of each policy should be defined, with regular reporting intervals, at least once a year, to track progress and evaluate outcomes. Engaging with relevant research institutions and industry experts to conduct evaluations will ensure transparency and accountability in the monitoring process. Regular communication of findings to the public is crucial for fostering public support and accountability (see chapter 6.).

Managing stakeholder dialogues and public perception is crucial for the success of PPPs. Transparency about the intentions behind decisions minimizes emotional responses and ensures that the relevance and complexity of the issues are communicated clearly. The media can often distort reality and the ability to adapt to challenges. For instance, BMW engages regularly with public, private and corporate stakeholders through its offices in Berlin, Brussels, Beijing and Washington/Sacramento

(BMW 2024). BMW's interconnectedness to markets and economies, as well as national and regional trends, also makes it a valuable resource of information and a driver for cooperation.

Fleet customers play an important role in the corporate sector and contribute significantly to reaching emission targets. They have their sustainability goals, which drive transformations in the industry. This dynamic creates a powerful incentive for automotive manufacturers to align their sustainability strategies with those of their clients, reaching a collaborative approach to achieving environmental targets (BMW 2024). Successful case studies can provide valuable insights into the implementation and benefits of PPPs in the automotive industry. For example, the Ionity joint venture that aims to develop a HPC network along major highways across Europe showing how collaboration between major industry players can lead to the creation of a comprehensive and accessible charging infrastructure (Ionity 2023). Another example is the CharIN e.V. initiative, which promotes the adoption of the CCS standard and works on further developing charging technologies. CharIN plays a crucial role in standardizing charging infrastructure to ensure compatibility across different EV models and charging stations, facilitating a seamless and user-friendly experience for EV owners (CharIN 2023).

To maximize the potential of PPPs and stakeholder collaboration, future research should focus on identifying best practices[1] and developing frameworks for effective partnership management. This includes exploring innovative financing mechanisms, such as green bonds and impact investing, to attract private capital for sustainable mobility projects. Additionally, research should investigate the socio-economic impacts of PPPs, particularly on job creation, workforce development and community engagement. Furthermore, enhancing international collaboration and knowledge sharing is essential. Germany can benefit from the experiences of other countries that have

[1] The "Car-City" Wolfsburg in Lower Saxony can serve as a model for a successful PPP. Federal state and manufacturer VW have benefited from joint efforts to create a Cluster in the region and attract labour and investments.

successfully implemented PPPs in the automotive industry[2]. Comparative studies and international partnerships can provide valuable insights and help to develop more effective and scalable solutions for sustainable mobility.

4.3 Economic Implications for the Automotive Industry – Chances and Challenges

The literature review demonstrates that the automotive industry is already undergoing heavy transformation driven by technological advancements, regulatory changes and changing consumer preferences. A decade ago, BMW for instance focused on reducing consumption and emissions through "efficient dynamics" during the usage phase (BMW 2020). Today, their approach is holistic, encompassing the entire value chain. Although production contributes less than 1 % to the overall emission balance, it plays a crucial role in setting supplier standards (BMW 2024). "Industry 4.0" has brought paradigm transitions across sectors. In the automotive industry, this revolution will make production more flexible, adapting to the individual needs of customers and business partners while adding high-quality services. "Work 4.0" will be more decentralized and flexible, impacting the labour market strongly. While studies warn about potential job losses due to the simpler assembly process of EVs compared to traditional ICEs (Impey 2024), the broader industry transformation, including battery production and recycling, is expected to result in a neutral net effect on jobs. The real challenge lies in transitioning skill sets and job roles, as employees skilled in traditional engine development may not easily transition to battery technology roles (Diekmann 2024). This transition implies a reduction in the diversity of required components, leading to fewer suppliers but more centralized large battery manufacturers and electronic system providers. This consolidation forces existing automotive companies to quickly adapt their business models, with major firms like ZF Friedrichshafen AG, Bosch and Mahle facing substantial challenges in adjusting to these new industry norms (Fraunhofer Institute 2024). The BDI recommends using locations in Asia for manufacturing technologies when switching to EVs. However, it warns against

[2] A project in Sweden can serve as a successful PPP. Stockholm implemented a congestion tax system through a PPP involving the Swedish Transport Agency and private technology providers. The system reduces traffic congestion and emissions by charging vehicles entering the city centre during peak hours. The revenue generated is reinvested in public transportation infrastructure, promoting sustainable urban mobility (Eliasson 2014: 1 seqq.).

industrial espionage and acknowledges that increasing Germany's EV production capacities could lead to trade volume restrictions (BDI 2024). Overall, "Production 4.0" will accelerate the digitalization of vehicles will enable automated and autonomous driving[3] features in the foreseeable future, creating new mobility forms and value creation perspectives in the automotive industry (Bauer et al. 2018: 5).

With it, challenges will rise. Firstly, adjustments in skill sets are required within the automotive industry. Developing a skilled workforce through investments in R&D, training programs and educational initiatives is essential to maintaining Germany's competitive edge in automotive manufacturing. Fields of increasing relevance include battery technology, software development and electrical engineering. Secondly, the rapid increase in EV adoption raises concerns about the financial sustainability of subsidies and incentives that have promoted this transition. Governments worldwide have used various fiscal measures to stimulate the EV market, such as purchase subsidies, tax breaks and grants for charging infrastructure. However, as the number of EVs grows, maintaining these incentives could become more expensive. Policymakers must design a phased reduction of subsidies that does not abruptly undermine market growth but gradually moves the financial burden from public funds to market forces, balancing fiscal responsibility with environmental and social objectives. Ensuring that the incentives are sustainable and effectively targeted will help support long-term goals of reducing carbon emissions and promoting sustainable mobility while avoiding excessive strain on public finances (Fraunhofer Institute 2024; Wuppertal Institute 2024). Thirdly, challenges arise in battery technology and raw material sourcing, critical for vehicle cost, range and efficiency. The transition to EVs involves significant supply chain changes, particularly in securing rare earth materials essential for EV production. China's strategic control over these markets underscores the geopolitical and economic pressures faced by the industry. Companies are increasingly held accountable for the

[3] In the status of autonomous driving most advancements are concentrated on Level 2 and Level 3 autonomy, where vehicles can handle certain driving tasks under specific conditions but still require human oversight. Still, full self-driving cars (Level 5 autonomy) are not feasible for widespread deployment due to technical, regulatory and safety issues. Looking ahead, the industry anticipates gradual improvements and increased integration of autonomous features (McKinsey 2023; MIT Technology Review 2023).

environmental impact of their products throughout their lifecycle, from production to disposal. This accountability extends to sourcing ethically obtained raw materials and adopting recycling and repurposing practices for batteries and other components (BDI 2024).

The economic implications also extend to the strategic decisions surrounding production locations. German car manufacturers are increasingly focusing on localizing EV production within Germany to leverage existing expertise, ensure quality control and create supply chain resilience. For example, Volkswagen's significant investments in its Zwickau, Emden and Hannover plants aim to make Germany a central hub for its EV production (VW 2023). Additionally, the development of local battery production facilities, such as those by Volkswagen in Salzgitter and Mercedes-Benz in Kölleda and Kamenz, portrays the importance of securing a reliable supply of critical components. However, these investments are accompanied by challenges, including the need for skilled labour and the high initial costs of setting up new production lines. Despite these hurdles, the long-term benefits, including reduced transportation costs, lower carbon footprints and stronger market positioning, are expected to outweigh the initial expenditures. Furthermore, expanding production in key international markets like China and the USA is essential for meeting local demand and maintaining global competitiveness (BMW 2023).

Examining specific cases highlights both opportunities and challenges in this transition. BMW suppliers must provide detailed documentation and undergo rigorous verification processes, ensuring the maintenance of individual and overall competitiveness. For instance, battery cell manufacturers switching to 100 % green electricity as part of BMW's procurement conditions become more attractive to other buyers. However, tracking emissions within the supply chain is challenging. Strict procurement conditions and clear processes make human rights violations rarer and more manageable. Decisive actions in recent cases have led to successes for BMW (BMW 2024). Another example is the introduction of the truck toll in 2005, along with a CO_2 regulatory component in 2023, which serves as a successful case of improving innovation cycles in the transportation sector. The toll, staggered according to environmental criteria and CO_2 prices, encouraged the production of cleaner vehicles (EETS 2023). Conversely, the solar industry in the 2000s, particularly in regions like

Saxony, experienced a boom due to government subsidies. However, when subsidies expired, the business model collapsed. A similar risk exists in the automotive industry if incentives for EV production are not managed sustainably (Fraunhofer Institute 2024).

The economic implications of the transition to sustainable mobility in the automotive industry are complex. Successes such as the truck toll illustrate how regulatory measures can drive cleaner production, while failures like the collapse of the solar industry highlight the risks associated with over-reliance on subsidies. The future of the automotive industry needs continuous innovation, effective regulatory support and the ability to adapt to changing market conditions. Ensuring a smooth transition requires balancing fiscal responsibility with socio-ecological objectives, developing a skilled workforce while maintaining international competitiveness (Fraunhofer Institute 2024).

5. Discussion

Under the chapter "Discussion" this work will consider areas that highly influence the transformation of the automotive industry additionally to the "Energiewende".

5.1 International Competitiveness

Germany's automotive industry, once a global leader, now faces great challenges as it transitions to EVs amid intense international competition. Recently, Germany has become an example of slowing innovative decision-making processes, such as the EU-wide ban on registering ICE vehicles (Beckmann 2023). The complexity of this transition includes Germany's late shift from ICE to EVs, potentially causing a loss in international car manufacturing leadership. Human capital (labour, science, research and education), social capital (cultural and emotional ties to ICE vehicles) and equity capital (R&D investments and long-term contracts) all contribute to resistance against this transition. However, the future promises a different landscape.

Table 1: EV share per country in 2023

Country/Region	EV Stock[4] (2023)	Annual Sales (2023)	Market Share (2023)	% of Cars in Use (2023)
China	28,400,000	9,400,000	34 %	8.2 %
Europe	12,300,000	3,200,000	25 %	4.5 %
United States	3,800,000	1,400,000	8 %	1.9 %
Germany	2,400,000	1,400,000	18 %	4.8 %
France	1,400,000	400,000	25 %	3.9 %
United Kingdom	1,500,000	500,000	25 %	4.0 %
Norway	900,000	125,000	95 %	29.1 %
Netherlands	675,000	200,000	30 %	6.5 %
Sweden	600,000	180,000	60 %	9.9 %
Japan	500,000	120,000	3 %	0.8 %
Canada	470,000	150,000	11 %	2.0 %
Global total	**40,000,000**	**14,000,000**	**18 %**	**3,4 %**

Source: own illustration, data from IEA 2024/EV Volumes 2024/KBA 2024

[4] In Cumulative Sales

In 2023, the global EV market experienced substantial growth, with China leading with a stock of 28.4 million EVs and annual sales of 9.4 million, representing 34 % of the market and 8.2 % of cars in use. Europe followed with a stock of 12.3 million EVs and annual sales of 3.2 million, achieving a 25 % market share and 4.5 % of cars in use. The United States reported 3.8 million EVs in stock and 1.4 million annual sales, marking 8 % of the market and 1.9 % of cars in use. Germany, as a key player in the European market, recorded an EV stock of 2.4 million and annual sales of 520,000, with EVs accounting for 18 % of new car sales and 4.8 % of the total cars in use (IEA 2024; EV Volumes 2024).

Despite these promising figures, Germany's automotive sector is grappling with competitive dynamics both within Europe and internationally. European manufacturers are increasingly being outperformed in Korea, China and the USA, in the rapidly evolving EV segment. This turn away from ICE vehicles is likely to further erode the market share of German automotive companies (McKinsey 2020). A critical challenge for the German automotive industry is the delayed development of domestic battery production capabilities. As the industry transitions towards electric mobility, the ability to produce advanced batteries domestically becomes increasingly important. This delay places German companies at a disadvantage compared to their Asian counterparts, who have established strong capabilities in battery technology and production (IEA 2021). Additionally, the transition towards producing smaller, more efficient cars, which typically offer lower profit margins compared to larger, more luxurious models, necessitates a re-evaluation of business models and profit strategies (Fraunhofer Institute 2024). The Fraunhofer Institute highlights the complexity of the value chains in EV production, noting that many components are distributed globally and subject to quasi-monopolies, particularly in the case of rare earth elements essential for electric motors and batteries. China's strategic control over these markets poses supply chain security challenges for German manufacturers. This situation is exacerbated by the higher production costs associated with bringing battery technology back to Europe (Fraunhofer Institute 2024). BMW, however, is optimistic. Economies of scale will ensure that EVs become profitable for German automakers in the future and also more affordable for consumers (BMW 2024).

The current competitive landscape was foreseeable for BMW already decades ago. At that time, market entries in China for Western companies were only possible through joint ventures. Maintaining the innovative strength of the EU and the USA is essential to surpass the price advantages of Asian suppliers through qualitative superiority. Still, BMW remains optimistic about its development. The complexity of a car is often underestimated, and the experience and expertise of German manufacturers hold notable market value, so BMW. Continuous expansion of the product portfolio and openness to various technologies are therefore crucial. Currently, markets are not fully prepared to transition entirely to EV due to insufficient infrastructure, so ICEs cannot be entirely phased out (BMW 2024).

Nevertheless, BMW and other German automakers do face challenges from international competitors, particularly in Asia and the USA not only from the delayed development of domestic battery production. As the global market for EVs expands, German manufacturers are responding by increasing their domestic production capacities and investing in key international markets. For instance, BMW's expansion of its EV production in China through its joint venture with Brilliance China Automotive (BMW 2023) and Volkswagen's focus on developing battery cell production in Salzgitter demonstrate a strategic shift towards localizing production to enhance supply chain resilience and reduce dependencies on foreign suppliers (VW 2023). These moves are crucial for maintaining Germany's competitiveness in the global automotive industry. Moreover, the establishment of sustainable production facilities, such as Audi's Brussels plant, which uses renewable energy and water-saving technologies, might show the industry's commitment to environmental sustainability. By aligning production strategies with sustainability goals, German automakers can better navigate the competitive landscape and capitalize on the growing demand for EVs (Audi 2022).

The political landscape significantly influences the competitiveness of Germany's automotive industry. The BDI and Fraunhofer Institute argue that the EU should play a crucial role in creating fair competition conditions to support the market against global competitors, particularly China. In response to external economic policies such as the Inflation Reduction Act in the USA and China's market strategies, the Fraunhofer Institute emphasizes the importance of strengthening internal markets.

While European competition law is founded on fairness, the EU must protect its markets from powerful competitors who do not adhere to the same criteria, potentially involving the raising of trade barriers.

Following the US's announcement of 100% import tariffs on Chinese EVs, the European Commission also declared it will impose tariffs of up to 48% on Chinese EVs, effective from July 2024, just after the European Parliament elections. This decision, based on an extensive anti-subsidy investigation, revealed significant state support for Chinese EV manufacturers, including subsidized loans and tax breaks. Major Chinese companies like BYD, Geely and SAIC will face varying tariff rates. This move aims to level the playing field for European automakers, who have struggled to compete with the influx of cheaper Chinese EVs. Despite Germany's warnings about potential trade retaliation, the Commission argues that the tariffs are essential to protect the European EV market from unfair competition and support the transition to sustainable transportation (Liboreiro 2024).

From an international competitiveness perspective, these tariffs might provide temporary relief for European automakers by reducing the price advantage of Chinese EVs. However, the long-term impact on competitiveness is uncertain. While European manufacturers may benefit from a more level playing field, which could incentivize further innovation and investment in green technologies, the tariffs could also escalate into a trade war, affecting the global supply chain. Additionally, relying on tariffs as a protective measure may mask underlying issues within the European automotive industry, such as the need for more aggressive advancements in EV technology and production efficiency (Bounds et al. 2024). To remain globally competitive, European automakers must continue to innovate and improve their sustainability practices beyond the temporary protection provided by tariffs. Indirect measures, such as enforced CO_2 pricing, are also needed to ensure that imports reflect their true environmental costs (Fraunhofer Institute 2024). The strategic orientation of German automotive producers will be determining in maintaining competitiveness. Despite increasing investments in R&D, there appears to be a disconnect between these efforts and tangible advancements in the vehicle segment. German automakers have adopted a dual strategy, leveraging their established strengths in ICE technology while gradually transitioning to EVs. This contrasts with many Asian manufacturers, who shifted their focus to EVs much earlier

due to a lack of a strong ICE legacy (Fraunhofer Institute 2024; Wuppertal Institute 2024). Additionally, the Fraunhofer Institute notes that decision-making structures within companies often follow directives from top management rather than market needs and sustainability goals, further complicating the transition. The reintegration of supplier structures into OEMs might be one way to address these challenges, though this approach carries risks such as lump risk and potential bankruptcy of integrated production areas (Fraunhofer Institute 2024).

5.2 Economic Mechanisms

The transformation of Germany's automotive industry is driven by various economic mechanisms, including financial incentives, regulatory measures and market-driven approaches. These mechanisms aim to promote EV adoption, build robust infrastructure and support the industry's adaptation to new technologies. This work has detailed several financial incentives to encourage EV adoption and infrastructure development. One prominent example is the "Environmental Bonus" subsidy, which provided up to 9,000 Euros for purchasing a pure EV, making EVs more affordable for consumers and stimulating market demand (IEA 2021). Reduced tax rates on electric company cars and other EV-related tax incentives further lower the total cost of ownership for businesses and individuals, increasing the attractiveness of EVs. Investment allowances also encourage businesses to invest in EV technology and charging infrastructure, facilitating a broader deployment of sustainable technologies (ACEA 2022). These incentives are part of broader economic governance mechanisms that support infrastructure development and guide the automotive industry's transition. The German government has increased funding for fast charging infrastructure, reflecting a strategic shift towards building the necessary support systems for a growing fleet of EVs. Initially, high incentives for battery electric cars have been adjusted relative to those for plug-in hybrid vehicles, balancing the push for pure EVs with current market capabilities and consumer readiness (IEA 2021).

The automotive industry operates with the primary goal of maximizing profit from the capital invested. This fundamental objective drives the behaviour of all market participants. As long as the regulatory environment does not penalize the production of large, high-emission vehicles, manufacturers will continue to focus on these profitable segments. Currently, German automotive manufacturers benefit from several factors

contributing to their high profit margins. These include a strong market position, limited competition in the luxury and high-performance vehicle segments and a customer base willing to pay premium prices for these vehicles. However, potential changes in this business model are on the horizon, driven by economic developments and changing consumer preferences. One critical factor is the economic development in Europe, particularly changes in income levels. Economic downturns or slow income growth could reduce the purchasing power of consumers, making them less likely to buy expensive, high-margin vehicles. This scenario could force German manufacturers to reconsider their focus on luxury and high-performance vehicles. Additionally, the rise of Chinese manufacturers in the small car segment poses a significant challenge. Chinese automotive companies have made substantial inroads into the European market by offering affordable, efficient and increasingly high-quality small vehicles. As these manufacturers gain market share, they could disrupt the established order, compelling European and particularly German manufacturers to adapt by either competing in the lower-margin small car segment or innovating to maintain their premium status (Wuppertal Institute 2024).

BMW is known for its luxurious and powerful vehicles. Thus, the potential for producing small cars is not sufficient to justify a production shift in that direction, according to BMW. The debate over vehicle size is more ideological, as the need for change lies more with the drive concept than the vehicle concept. If existing BMW models were electrified, this discussion would diminish, so BMW. Furthermore, urban planning must also adapt so that the automotive industry does not bear the entire burden. Redirecting traffic flows out of cities and shortening routes is always beneficial. According to BMW, public transport and cars are not adversaries in this regard, they complement each other (BMW 2024).

An essential consideration in this context is the low-price elasticity of demand in the transportation sector. Since transportation is a fundamental necessity for daily activities such as commuting to work, consumers tend to maintain their transportation expenditure even when prices rise. This inelasticity implies that while consumers may resist price increases, they are unlikely to significantly reduce their overall transportation consumption. However, transitions in economic conditions and competitive pressures could still impact the types of vehicles consumers choose to

purchase, potentially leading to a greater demand for smaller, more affordable cars if economic conditions worsen (Wuppertal Institute 2024).

4.3 Social Cohesion and Ethical Considerations

Before moving to policy recommendations, it is essential to discuss the numerous social and ethical considerations, including environmental impact, labour dynamics, resource sourcing, social equity and socio-economic justice. Addressing these ethical issues is imperative to ensure a holistic and responsible approach as the automotive industry transforms.

One primary ethical consideration is the environmental impact of the automotive industry. The transition from ICE vehicles to EVs aims to reduce GHG emissions and combat climate change. However, the environmental benefits of EVs heavily depend on the electricity sources used for charging. If the electricity comes from fossil fuels, the overall environmental benefit is diminished. Therefore, Germany must invest in renewable energy sources to ensure the transition to EVs genuinely reduces carbon footprints.

Moreover, the production of EV batteries involves dangerous environmental costs, including resource extraction and manufacturing emissions. The mining of lithium, cobalt and other essential minerals can lead to environmental degradation and biodiversity loss. Sustainable mining practices and advancements in battery recycling technology are crucial to mitigating these impacts. The European Critical Raw Materials Act, introduced in March 2023, targets the domestic capacity for extracting, processing and recycling critical raw materials while reducing dependency on imports from single suppliers. By 2030, the Act sets benchmarks to achieve 10 % of the EU's annual consumption for extraction, 40 % for processing and 15 % for recycling, with no more than 65 % of any strategic raw material coming from a single third country. Additionally, it promotes circularity and sustainability by encouraging the recycling of critical materials and improving the monitoring and resilience of supply chains (European Commission 2023).

Policies, like this, promoting the circular economy can also push sustainability by encouraging the reuse and recycling of materials (European Commission 2020a). Another crucial aspect in this context is waste management, as it conserves resources,

protects the environment and supports a circular economy. The ongoing discussion surrounding critical ethical issues is prompting manufacturers to address these concerns and reduce their reliance on controversial raw materials. For instance, some car manufacturers have successfully developed vehicles that no longer require cobalt. This transition not only responds to ethical considerations but also mitigates the environmental and social impact associated with the extraction of such materials (Wuppertal Institute 2024). Lithium, however, presents a different case. Contrary to common perception, lithium is not as rare as it is often portrayed. The primary challenge lies in the cost-effectiveness of its extraction. Currently, it is cheaper to extract lithium from regions where mining practices are sometimes associated with human rights violations. This economic advantage, unfortunately, perpetuates unethical practices in the supply chain. To address these issues, it is crucial for the industry to adopt more sustainable and ethically responsible sourcing practices. By investing in alternative extraction methods and supporting fair labour practices, manufacturers can contribute to a more ethical and sustainable supply chain (Amnesty 2016).

The transformation of the automotive industry raises ethical concerns regarding labour dynamics. The transition to EV production, which is less labour-intensive than ICE vehicle manufacturing, could lead to job losses. Studies have indicated that while EV assembly is simpler, the broader industry restructuring, including battery production and recycling, could potentially balance these job losses (Fraunhofer Institute 2024). However, the real challenge lies in retraining the workforce. Workers with skills in traditional engine manufacturing need to be retrained for roles in EV and battery production. Ethical labour practices necessitate investment in comprehensive training programs and educational initiatives to ensure a just transition for the workforce (Wuppertal Institute 2024). Ensuring that workers are provided with opportunities for upskilling and reskilling is essential to maintaining social cohesion and preventing unemployment. Indeed, industry transitions due to structural changes are not new phenomena and require commitment and investment from employers to retain and retrain their workforce. BMW has not lost any momentum in this respect (BMW 2024).

The ethical sourcing of materials is another threatening concern. The production of EVs requires critical raw materials such as lithium, cobalt and rare earth elements. These materials are often sourced from regions with poor labour conditions and weak

environmental regulations. For instance, cobalt mining in the Democratic Republic of Congo has been linked to child labour and severe human rights abuses (Amnesty 2016). To address these issues, the automotive industry must ensure transparency in its supply chains and commit to sourcing materials ethically. This can involve working with suppliers to improve labour conditions and environmental practices or seeking alternative materials that are less harmful to source (WEF 2023). BMW, as representative from the industry acknowledges that there are existing concerns regarding human rights within supply chains, for instance child labour in the Congo and the treatment of Uyghurs in China. Therefore, regional risks are identified and mitigated through risk filters, leading to increased control over certain given high-risk areas (BMW 2024). Encouraging transparency and accountability in the supply chain will not only strengthen the industry's reputation but also promote social and environmental responsibility (Wuppertal Institute 2024).

The shift to sustainable mobility raises questions about social equity and socio-economic justice. The high initial cost of EVs can make them inaccessible to lower-income individuals, potentially exacerbating existing social inequalities. Financial incentives and subsidies play a critical role in making EVs more affordable, but these must be designed to ensure that they benefit all socio-economic groups equitably (ACEA 2022). Additionally, the development of charging infrastructure must be inclusive, ensuring that rural and underserved urban areas have access to EV charging facilities. Social cohesion is crucial in this context. In times of rapid technological change and economic transition, ensuring that all segments of society benefit from advancements is essential. Promoting social cohesion involves not only addressing economic disparities but also fostering a sense of community and mutual support. Policies that support equitable access to new technologies and fair distribution of economic benefits can help mitigate social tensions and promote a more inclusive society (Wuppertal Institute 2024). The importance of socio-economic justice cannot be overstated. Sustainable mobility must be integrated with broader social policies that address income and wealth disparities. This includes ensuring that the economic benefits of the automotive industry's transformation, such as job creation in new sectors, are widely shared. Moreover, policies should aim to protect vulnerable workers

and communities from the adverse effects of industrial changes, such as job losses and economic displacement (Fraunhofer Institute 2024).

In times of multiple crises, people tend to seek stability and familiar solutions. When these anchors, such as traditional cars, are also subject to change (e.g. transitioning to EVs), it is understandable that certain groups, not only those directly affected in their workplaces, respond with uncertainty. This common social phenomenon can be mitigated to some extent by providing security in other areas, such as more stable political policies and stronger guidelines. Promoting social cohesion is equally important. Socio-economic inequality plays an important role in the discussion about the sustainable transformation of the automotive industry (Wuppertal Institute 2024).

Sustainability is limited to ecological longevity. It also encompasses social and economic dimensions. Therefore, preventing income and wealth disparities is crucial not only to reduce uncertainty but also to ensure purchasing power for EVs. Sustainable mobility is directly linked to climate protection, a politicized and polarizing topic. Advocating for climate-neutral solutions necessitates acknowledging and addressing these polarizing aspects. A fair social and economic policy fosters social justice and counters the narrative promoted by climate-sceptical opposition, which portrays initially more expensive EVs, heat pumps, home insulation, or photovoltaic systems as impositions by eco-liberal elites.

The goal is to create resonance between social and ecological issues, thereby generating legitimacy for sustainable measures. Philanthropy is considered a given and occurs in the operative business, thus it is not explicitly part of the sustainability strategy (BMW 2024). It is beneficial to infuse public discourse with this connection rather than contributing to further division or hate speech, which is increasingly used by populists (Wuppertal Institute 2024). One of the essential prerequisites for fair conditions is education. Enlightenment about complex interrelationships and honest communication are vital. This honest communication applies to the field of electromobility as well. Analysing ethical concerns regarding EV production has revealed many critical areas needing action. Transparently presenting these imperfections is an integral part of the discourse. Does this mean that the path of

electromobility is wrong? No. Given the urgency and the unavoidable shift away from fossil fuel combustion, EVs are the next necessary step to ensure sustainable transportation in the future (Fraunhofer Institute 2024).

Regulatory frameworks play a crucial role in addressing these ethical considerations. Effective policies can enforce environmental standards, ensure fair labour practices and promote social equity. For instance, the European Union's regulations on battery recycling and extended producer responsibility aim to mitigate the environmental impact of EVs (European Commission 2020b). Corporations also have a responsibility to adopt ethical practices. This includes committing to sustainability goals, ensuring transparent supply chains and engaging in fair labour practices. Corporate responsibility extends to implementing comprehensive sustainability strategies that align with global standards and best practices. Companies must engage with stakeholders, including employees, consumers and communities, to develop and implement policies that address the ethical dimensions of their operations (Deloitte 2021). Transparency in reporting and accountability mechanisms are also essential to ensure that corporate commitments translate into real-world improvements.

6. Policy Recommendations

Having examined the empirical landscape of future mobility, it is evident that the transition to sustainable transportation is gaining momentum, with Germany setting ambitious goals. However, challenges persist, particularly in battery technology, sustainability concerns, the impact of fluctuating energy prices on both production and consumer mobility costs and the aspect of competitiveness. The following policy recommendations include both short-term measures and long-term strategies to create a robust future for electric mobility in Germany. This dual approach ensures immediate improvements while setting the foundation for sustained progress and innovation in the EV sector. BMWK as well as the BMDV are committed to steering the country's course toward sustainable mobility with a thriving industry and is the right recipient of these policy recommendations.

6.1 Short-Term Measures

To overcome current challenges and accelerate the adoption of EV in Germany, the following short-term measures are proposed:

a) Extending and strengthening existing purchase subsidies and tax incentives for EVs increases their affordability and encourage adoption. Particularly focus on extending these incentives to lower-income groups to ensure equitable access.
b) Reducing tax rates on electric company cars can lower the total cost of ownership for businesses, making EVs a more attractive option for corporate fleets (e.g. Bonus-Malus).
c) Investing heavily in expanding and improving the EV charging infrastructure across the country is essential. Collaboration with private stakeholders can help build a comprehensive and easily accessible charging network that ensures coverage in urban and rural areas.
d) Supporting the development of charging infrastructure at workplaces and residential areas by providing subsidies or incentives to companies and homeowners to install charging points.
e) Implementing public awareness campaigns to educate consumers about the benefits of EVs is crucial. Dispelling myths and concerns while highlighting the

environmental advantages, cost savings and the expanding range of available EV models can facilitate this.

f) Extending and enforcing stringent emissions standards for both traditional and EVs, including the production and recycling processes, is necessary. Ensuring that emissions from electricity production for EVs are minimized by promoting renewable energy sources can support this goal.
g) Investing in the infrastructure for alternative fuels such as hydrogen and biofuels can provide initial government support to develop these technologies, ensuring a diversified and resilient energy supply for transportation (with regard of the efficiency).
h) Implementing measures to stabilize energy prices can ensure that rising energy costs do not deter EV adoption or increase consumer mobility costs. Consideration of subsidies or tax incentives for renewable energy used in EV charging can help achieve this.

6.2 Long-Term Strategies

For sustained progress and innovation in the EV sector, the following long-term strategies are recommended:

a) Allocating funds for R&D in battery technology, alternative energy storage solutions and other innovative mobility technologies is essential. Promoting partnerships between government, industry and academia can drive technological advancements.
b) Developing policies that encourage domestic manufacturing of EV components, including batteries, can create supply chain resilience, generate jobs and reduce dependence on foreign suppliers.
c) Sharing experiences and best practices with emerging markets and advanced countries, collaborating with international organizations like the IEA and the European Battery Alliance (EBA), can strengthen bilateral agreements to promote cross-border cooperation and joint initiatives in the electric mobility sector.
d) Implementing regular monitoring of the progress of EV adoption and the effectiveness of policies can help adapt policies based on changing legal

frameworks, market dynamics, technological advancements and global trends in the EV sector, ensuring alignment with climate and sustainability goals.

e) Collaborating with other EU members to establish harmonized and consistent regulations and standards for EVs can strengthen the competitiveness of the EU and facilitate the development of a seamless charging infrastructure.
f) Implementing and enforcing carbon pricing to reflect the true environmental costs of different transportation options is necessary. Using the revenue generated to fund further sustainable mobility initiatives can support this effort.
g) Ensuring that policies supporting sustainable mobility address social and economic equity is crucial. Providing targeted incentives and support for lower-income individuals and underserved areas can promote inclusive access to EVs and charging infrastructure.
h) Investing in comprehensive training programs and educational initiatives to develop a skilled workforce capable of supporting the transition to EVs is essential. Focusing on retraining workers from traditional automotive roles to new roles in EV and battery technology can facilitate this transition. Rewarding best-practises can exemplify role models.
i) Ensuring close cooperation between federal and state governments with transparent and clear objectives can align national and regional policies to ensure cohesive and efficient implementation of sustainable mobility strategies.
j) While supporting multiple technological pathways, prioritizing the development of technologies that show the most promise for large-scale adoption in the medium term is advisable. Making decisive political decisions based on current research can avoid spreading resources too thinly.

7. Conclusion

The automotive industry in Germany, a cornerstone of the nation's economy and a symbol of technological competence, stands at the apex of a profound transformation driven by the imperative to combat climate change. This thesis explored the impact of Germany's "Energiewende" on the sustainable transition of the automotive industry, examining the socio-economic and political implications of this transition. By investigating the interplay between economic imperatives and environmental responsibilities, this thesis sought to provide insights into how the automotive industry can navigate this complex landscape, balancing profitability with sustainability. The "Energiewende" has notably influenced the automotive industry's transition towards sustainability, primarily through stringent environmental targets and supportive policy frameworks. Key findings from the research include the impact of decarbonization, electrification and digitalization on reshaping production systems, workforce dynamics and market strategies. Localization, the transforming production and products exemplify the industry's efforts to adapt to new digitally scalable and standardized drive lines. The transition involves both opportunities and challenges, with the broader industry transformation, including battery production and recycling, likely resulting in a neutral net effect on jobs. However, the remaining challenge lies in transitioning skill sets and job roles.

German automakers face great challenges from international competitors, particularly in China and the USA. The delayed development of domestic battery production capabilities places German companies at a disadvantage, highlighting the need for strategic investments and policy support. Collaboration between public and private sectors is crucial for building the necessary infrastructure and creating innovation. PPPs can help pool resources, share risks and leverage diverse expertise to support the sustainable transition. Moreover, the transformation raises threatening ethical concerns, including the environmental impact of battery production, labour dynamics and social equity. Addressing these issues is imperative to ensure a holistic and responsible approach to sustainability.

The research question was: "How has the 'Energiewende' influenced the automotive industry's shift towards sustainability and what are the socio-economic and

political implications of this transition?" The findings confirm that the "Energiewende" has catalysed progress in the automotive industry's sustainable transition through stringent environmental targets and supportive policy frameworks. However, this progress is tempered by socio-economic and political challenges, necessitating nuanced and diverse solutions. The hypothesis that the "Energiewende" has driven substantial advancements in sustainability within the automotive industry is supported. However, the transition is complex and requires continuous adaptation and strategic investments to overcome economic, social and political hurdles.

Detailed financial impacts on specific KMU, suppliers and PPPs were limitations that emerged during the research. The scope of qualitative interviews was limited to a few key stakeholders and was not able to include actors from the legislative body and politics. A broader range of perspectives, including those from smaller suppliers and consumer groups, would provide a more holistic view. The rapidly evolving nature of the automotive industry and policy landscape means that some findings may quickly become outdated. Continuous monitoring and updating of the research are essential.

To build on the findings of this thesis, future research should explore the following areas: long-term studies to track the progress and impact of the "Energiewende" on the automotive industry, comparative analysis of transition strategies in other leading automotive markets, investigation of consumer behaviour and preferences regarding EVs and other sustainable mobility solutions, examination of global supply chain dynamics of critical raw materials for EVs and continuous assessment of the impact of implemented policies on various stakeholders.

To ensure the effective implementation of the recommended policies, a comprehensive step-by-step plan is recommended. This plan should define clear timelines and milestones, outline specific actions required for each policy and identify key responsible entities, including government agencies, industry partners and relevant stakeholders. Regular reviews and updates of the implementation plan, at least every six months, are essential to adapt to evolving circumstances and emerging opportunities. Moreover, a robust monitoring mechanism should be established to assess the impact and effectiveness of implemented policies. KPIs that align with the goals of each policy

should be defined, with regular reporting intervals, at least annually, to track progress and evaluate outcomes. Engaging with relevant research institutions and industry experts to conduct evaluations will ensure transparency and accountability in the monitoring process. Regular transparent communication of findings to the public is crucial for fostering public support and accountability.

Eventually, the sustainable transition of the automotive industry in Germany, driven by the “Energiewende”, presents both opportunities and challenges. By implementing the recommended policies and strategies and through continuous monitoring and adaptation, Germany can secure its position as a global leader in sustainable mobility, contributing to a greener and more equitable future.

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Appendix

1. Milestones of the “Energiewende” and the automotive industry

Milestones “Energiewende” with regard to the Automotive Industry

2000 – Renewable Energy Sources Act (EEG):
Introduction of feed-in tariffs to promote electricity generation from renewable energy sources.

2009 – National Development Plan for Electric Mobility:
The German Federal Government presents the National Development Plan for Electric Mobility, aiming to make Germany a lead market for electric mobility.

2010 – Establishment of the National Platform for Electric Mobility (NPE):
This initiative brings together representatives from politics, business, and science to promote the development of electric mobility in Germany.

2011 – Decision to phase out nuclear energy:
Following the Fukushima disaster, Germany decides to completely phase out nuclear energy by 2022.

2013 – Market launch of the BMW i3:
BMW launches the i3, one of the first electric cars from a major German automaker, marking the beginning of mass production of electric vehicles in Germany.

2014 – National Climate Action Program:
Definition of specific measures to reduce greenhouse gas emissions by 40 % by 2020 compared to 1990.

2016 – Climate Action Plan 2050:
Germany sets the long-term goal of being largely greenhouse gas neutral by 2050.

2019 – Climate Protection Act:
Mandatory climate protection targets for individual sectors set for 2030.

2020 – European Green Deal:
The EU's goal to become the first climate-neutral continent by 2050. This has significant implications for all member states, including demands on the automotive industry.

2020 – Tesla Gigafactory announcement in Berlin
The announcement of the construction of a Tesla Gigafactory near Berlin marks a significant step in global and local electric vehicle production and increases pressure on local manufacturers.

2021 – Introduction of EU fleet emission standards:
Tightening of EU fleet emission standards forces German automakers to make faster progress in electrifying their vehicle fleets.

2021 – Fit for 55 package:
The EU presents legislative proposals to reduce greenhouse gas emissions by 55 % by 2030, significantly impacting the transport sector.

2021 – Law for the Further Development of the EEG:
Adjustments to further accelerate the expansion of renewable energies.

2023 – Expansion of charging infrastructure:
Ongoing investments in charging infrastructure through public-private partnerships, supported by federal and EU funding, to increase the adoption of electric vehicles.

2023 – Complete nuclear phase-out:
Complete shutdown of all nuclear power plants in Germany.

2025/2030 – Interim targets for emission reductions:
Review and adjustment of climate targets to meet the interim goals for 2025 and 2030.

2030 – Target of six to ten million electric vehicles on German roads:
This target will significantly influence the demand and infrastructure for electric vehicles.

2030 – Planned achievement of electric mobility goals:
The goal of having six to ten million electric vehicles on German roads is to be achieved, representing a significant shift in production and strategy for German automakers.

2035 – EU-wide ban on the sale of new internal combustion engine vehicles:
Planned ban on the sale of new vehicles with internal combustion engines in the EU.

2045 - National Goal:
National climate neutrality by 2045.

2050 - Emission neutrality by 2050:
EU wants Europe to become the first emission-neutral coontinent 2050.

Source: Own illustration

2. List of interviewees

I. **Claus Doll** – Head of ISI for System and Innovation Research, Mobility at Fraunhofer Institute

II. **Petra Richter** – Deputy Head of the Mobility and Logistics Department at BDI

III. **Thorsten Koska** - Co-Head of the Research Unit Mobility and Transport Policy), Wuppertal Institute

IV. **Kai Zoebelein** - Corporate and Governmental Affairs
Sustainability Communications at BMW Group