E-fuels and Climate Goals: An Analysis of the German Automotive Industry

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Abstract

Title: E-fuels and Climate Goals: An Analysis of the German Automotive Industry

Keywords: e-fuels, automotive industry, ambidexterity, climate change, competitive advantage, mobility, strategic management, impact, power2X, resilience, transformation management, electromobility

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Climate change is increasingly impacting life globally. To reduce damage, stricter governmental regulations have been developed, and companies need to adapt to these changes. The automotive industry is transitioning towards new technologies like electrification or hybrid systems to comply with these regulations. This study investigates how so called “e-fuels” could impact the automotive industry. E-fuels are an innovative alternative to fossil fuels, compatible with a combustion car fleet and can be produced in a CO_2 neutral manner. Experts from different areas related to the automotive industry in Germany were interviewed. The potential of e-fuels was evaluated and the importance of an ambidextrous strategy was discussed. Synthesizing the experts’ opinions gives two key problems for e-fuels: Energy efficiency and the lack of accreditation in the current European regulation. A global value chain and technology openness could help to overcome these problems. The potential for e-fuels therefore depends on regulation and is significantly reduced by the current fleet emission regulation in Europe. In fields where no substitution with other technologies is possible, e-fuels will likely become a standard. Manufacturers will continue to sell combustion cars in the next decades, but the ambidextrous approach is restricted by regulations. The simultaneous development of electric and combustion technology is costly and unlikely for most car manufacturers. Thus, many will transition towards complete electrification. Further research should include experts from other related fields and regions beyond Europe to investigate the global potential of e-fuels.

Título: E-fuels e Objectivos Climáticos: Uma Análise da Indústria Automóvel Alemã

Palavras-chave: e-fuels, automotive industry, ambidexterity, climate change, competitive advantage, mobility, strategic management, impact, power2X, resilience, transformation management, electromobility

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As alterações climáticas estão a ter um impacto a nível global. Foram desenvolvidas regulamentações governamentais mais rígidas e as empresas precisam se adaptar a essas mudanças. A indústria automotiva está em transição para novas tecnologias, como eletrificação ou sistemas híbridos. Este estudo investiga como os "e-combustíveis" podem impactar a indústria automotiva. Os e-combustíveis são uma alternativa inovadora aos combustíveis fósseis, compatíveis com carros de combustão e podem ser produzidos de forma neutra em CO2. Foram entrevistados especialistas da indústria automotiva na Alemanha. O potencial dos e-combustíveis foi avaliado e discutida a importância de uma estratégia ambidestra. Dois problemas fundamentais para os e-combustíveis resultaram: a eficiência energética e a falta de credenciamento na atual regulamentação europeia. Uma cadeia de valor global e abertura tecnológica podem ajudar. O potencial dos e-combustíveis depende da regulamentação e é significativamente reduzido pela atual regulamentação de emissões na Europa. Em setores onde a substituição por outras tecnologias não é possível, os e-combustíveis provavelmente se tornarão a norma. Os fabricantes continuarão a vender carros a combustão, mas a abordagem ambidestro é restringida por regulamentos. O desenvolvimento simultâneo de tecnologia elétrica e de combustão é caro e improvável para a maioria dos fabricantes. Muitos farão a transição para a eletrificação total. A pesquisa futura deve incluir especialistas de outros setores e regiões fora da Europa para investigar o potencial dos e-combustíveis.

Table of Contents

Abbreviations

AFV Alternative fuel vehicle

BEV Battery electric vehicle

CO_2 Carbon dioxide

E-fuels Electronic fuels created in a chemical process out of captured CO_2

EU European Union

η Efficiency Differences for drivetrain alternatives

KSG Bundes-Klimaschutzgesetz or german federal climate change law

ICE Internal combustion engine

ICV Internal combustion vehicle

ICEV Internal combustion engine vehicle

CH_4 Methane

N_2O Nitrous Oxide

PtL Power to liquid

PtG Power to gas

1. E-fuels as a solution to decarbonization in the transport sector

"Climate change is a terrible problem, and it absolutely needs to be solved. It deserves to be a huge priority." – Bill Gates in Goodell, 2010

Climate change is affecting life and its effects become more obvious every year. Greenhouse gas emissions are a key driver in human-made climate change. Thus, decarbonization needs to happen fast. Since the beginning of recording, greenhouse gas emissions in the transportation sector have increased despite mitigating efforts (Kaul et al., 2020; Trinomics BV, 2018). The individual transportation sector is largely contributing to greenhouse gas emissions in the European Union. To solve the emission problem of vehicles on the road today, different technological solutions have been developed. Among them is the idea to employ e-fuels in the existing combustion cars. E-fuels are like conventional fuels but are created in a chemical process entailing captured CO_2. They can provide a carbon neutral alternative to fossil fuels to be used in combustion engines without altering these (Wagemann & Ausfelder, 2017). Until now e-fuels were not competitive because of higher costs compared to fossil fuels. The increasing focus on climate neutrality is changing the cost centred focus of past decades (Sierzchula et al., 2012). Production of e-fuels requires a lot of input energy, and the processes need to follow certain criteria to achieve carbon neutrality. The technology is also controversial (Ueckerdt et al., 2021). Current efforts towards electrification of road traffic demand a switch on the consumer side, which is a lengthy process. Further, the complete switch to electrification provides downsides and is not preferred by all consumers (Jang & Choi, 2021). The changing environment forces companies in the automotive sector to adapt (Sierzchula et al., 2012). Innovation can help firms and the car industry cope with the transition (J. L. Johnson et al., 2012; Karim et al., 2016). We focus here on the future development of the automotive sector in Germany. The transition towards climate friendly mobility solutions forces manufacturers to adapt to new technologies. The right path for the future remains unsure and this study will deal with the use of e-fuels in combustion cars. The aim is to investigate whether e-fuels can contribute towards decarbonization of road traffic and help bring about compliance with regulation. The potential impact on the automotive industry in Germany will be investigated. E-fuels will be discussed in the light of strategic management theory. E-fuels might be an option to create an edge in the future and car manufacturers need to balance climate goals with their existing business while transitioning towards new technologies. Ambidextrous strategies might help to adapt to new requirements. To investigate these questions experts from the car industry

and related sectors were interviewed. The interviews content was analysed and results were compared with existing literature on the topic. The economic perspective of this study complements technical publications on the topic.

2. Theoretical discussion

2.1 Climate change and the automotive industry

Compared to the reference year of 1990 greenhouse gas emissions have already been reduced by 38.7% in 2020 (Umweltbundesamt, 2022). To limit the negative consequences of global warming, the European Union (EU) plans to reach carbon neutrality by 2050. If these goals are reached, the EU hopes to stay within the agreed 1.5°C of global warming. "The European Green Deal" outlines a planned reduction to zero emissions by 2050 with several intermediate steps. A first stage of reduction is 50% until 2030 compared to 1990. The plan is to utilize carbon pricing as a mechanism to attain goal congruence with businesses and consumers (European Commission, 2019).

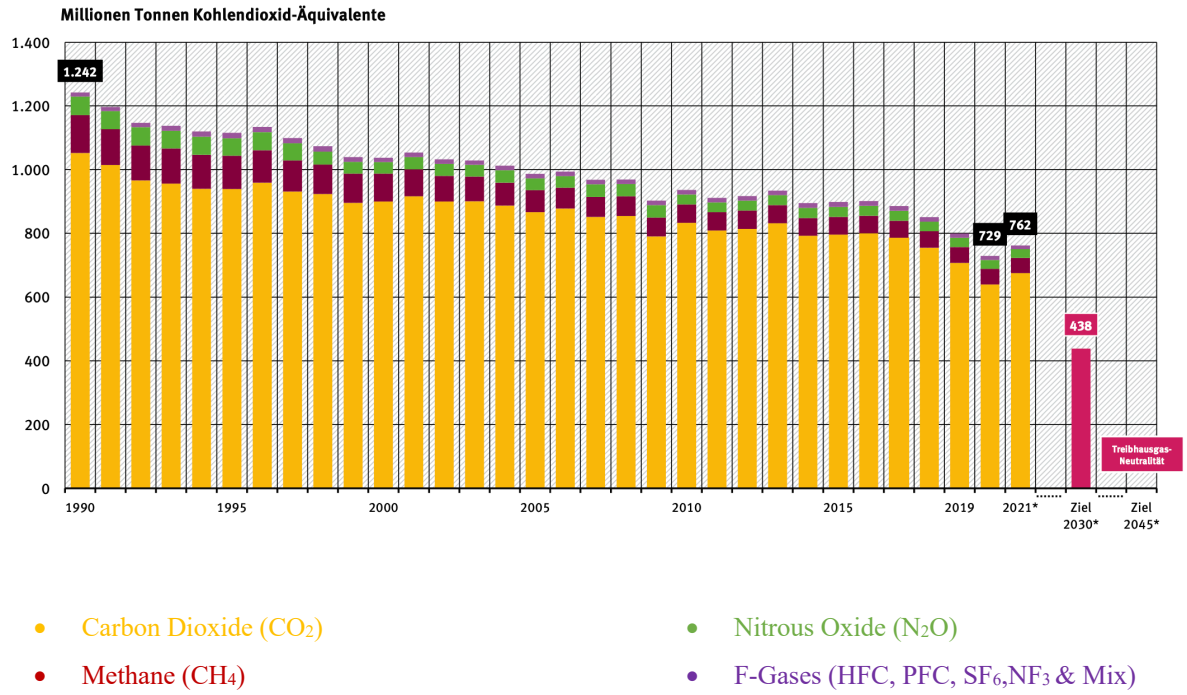

Figure 1. Greenhouse gas emissions since 1990 by gas type. The graphic displays greenhouse gas emissions in the timeframe from 1990 to 2021 by gas type in million-ton equivalent to carbon dioxide. The values for 2030 and 2045 are estimated based on the "Bundes-Klimaschutzgesetz (KSG)" from 12.05.2021. Source: Umweltbundesamt, 2022

In 2020 Germany decided to commit to an even stricter schedule to reduce greenhouse gas emissions. The plan is to reach carbon neutrality by 2045 and reduce emissions by 65% by 2030 (Umweltbundesamt, 2022). To reach these ambitious goals, emissions need to be decreased in all sectors. The individual transportation sector accounts for roughly 20% of CO_2 emissions in Germany. It is the only sector in which emissions were still increasing in the last decades. Within individual transportation, road traffic accounted for 70% in 2019, amounting 14% of the total CO_2 emissions in the EU (Kaul et al., 2020; Trinomics BV, 2018).

Several reasons play into the development of emissions in the transportation sector. Mobility is increasing and consumer preferences, like the tendency to purchase higher powered and larger vehicles, contribute to the problem (Kaul et al., 2020). The COVID 19 pandemic provided a break from the increasing mobility trend, but currently mobility is recovering to pre-crisis levels. To counter this, the EU introduced limits on CO_2 emissions which decrease over time (European Commission, 2019; Kaul et al., 2020; Trinomics BV, 2018). For car manufacturers, this means that emissions from their new car sales are limited. Currently most manufacturers are achieving goals for fleet efficiency, but this will decrease in the future causing uncertainty. To reach the stated sector goals it will be necessary to shift towards more efficient technologies. Electric vehicles can reduce emissions depending on the primary energy mix (Kühn et al., 2019).

Comparing the amount of internal combustion engine vehicles (ICE) and alternative fuel vehicles (AFV), the latter are predicted to remain the minority in the future. Even with increased sales of BEVs (battery electric vehicles), the average holding period for cars, combined with the existing fleet on the roads today, limits the potential of transportation-related CO_2 reduction in the next decades. Therefore, it will be necessary to utilize other technologies as well to enable decarbonization of the mobility sector.

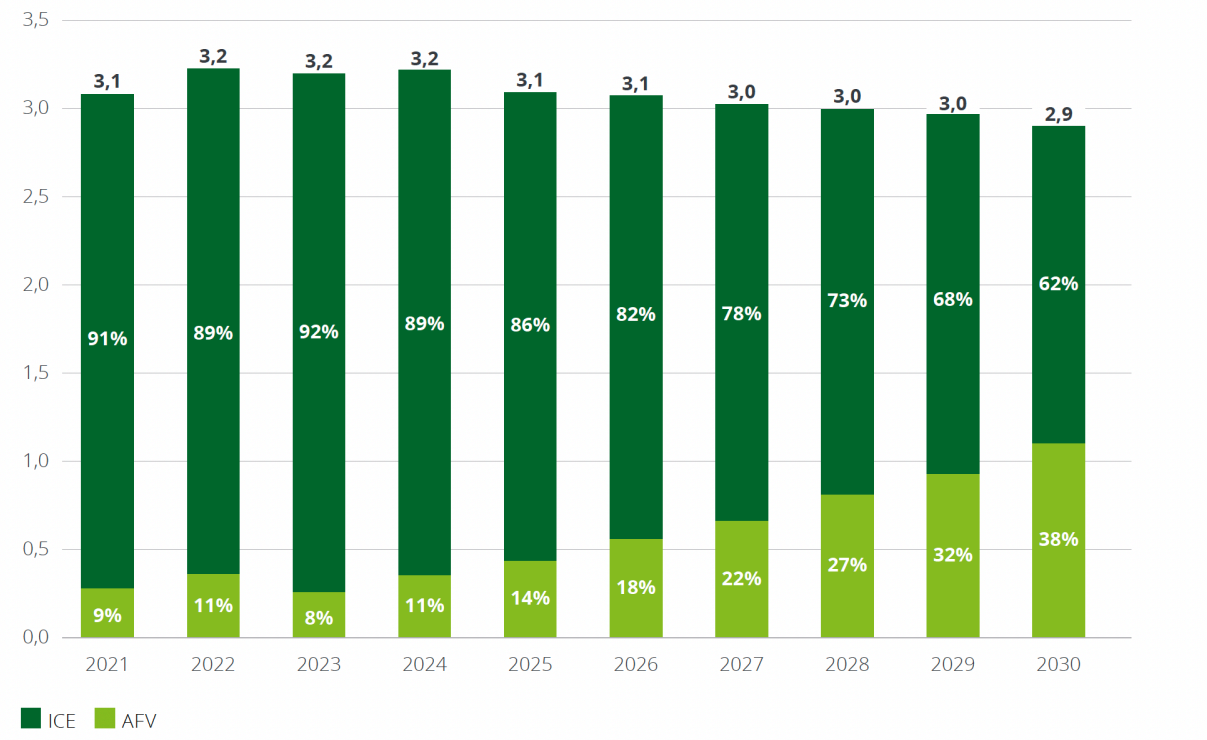

Figure 2. Newly sold vehicles in Germany by drivetrain. Estimated share for newly registered vehicles by drive technology from 2021 until 2030 in millions of vehicles. The percentage of ICE (internal combustion engine) vehicles is plotted in dark green and the percentage of AFV (alternative fuel vehicle) in light green. The plot is reproduced from Deloitte, 2020.

To reduce greenhouse gas emissions in the transportation sector by 2030, multiple solutions are available. First, the easiest transition is to minimize energy powered transportation. For instance, Germany plans to increase inner-city bicycle usage (Umweltbundesamt, 2014, 2021). The main advantage of this approach is to avoid greenhouse gas emissions in the first place. Even though this is a solution, it will not be viable for large proportions of modern mobility demand. Secondly, an improvement in vehicle efficiency can help reduce emissions. Newly produced internal combustion engines are increasingly less polluting (T. Johnson & Joshi, 2018). Even with further increases in efficiency of combustion engines, the long-term goal of carbon neutrality cannot be reached through efficiencies related to burning conventional fuel.

A third available lever is the transition towards new drivetrain technologies. New technologies dominate discussions about reducing greenhouse gas emissions in the mobility sector. As previously stated, the transition will not offer the immediate effects hoped for to achieve the stated goals by 2030. That is why transitioning to new technologies is not sufficient to reach these goals. The development of alternative fuels can help reduce emissions in the personal transportation sector immediately by providing a carbon neutral alternative to fossil fuels

(Boston Consulting Group, 2019; Deloitte, 2020; Kühn et al., 2019). The main advantage of carbon neutral fuels is that they can be used in the existing vehicle fleet and therefore an impact can be felt immediately.

2.2 Possible impact of e-fuels

E-fuels are synthetic fuels produced out of CO_2 and H_2O. Burning e-fuels in a combustion process results in greenhouse gas emissions as with conventional fossil fuels. Therefore, the carbon used for the synthesis of e-fuels needs to be captured to make them carbon neutral (Fritsch et al., 2021a; Kühn et al., 2019; Siegemund et al., 2017). The process of producing e-fuels is not a recent invention, and the underlying chemical reaction was first patented in 1925 in Germany. Earlier applications mainly focused on the use of coal or gas in the reaction (Schulz, 1999). A large amount of energy is needed in the production process, mostly in the form of heat. The resulting fuels can be stored in liquid or gas form. The processes are called "Power to Liquid" (PtL) and Power to Gas (PtG). In terms of chemical attributes, these synthetic fuels have the same attributes as their fossil equivalents and are sometimes even superior due to their purity (Fritsch et al., 2021a).

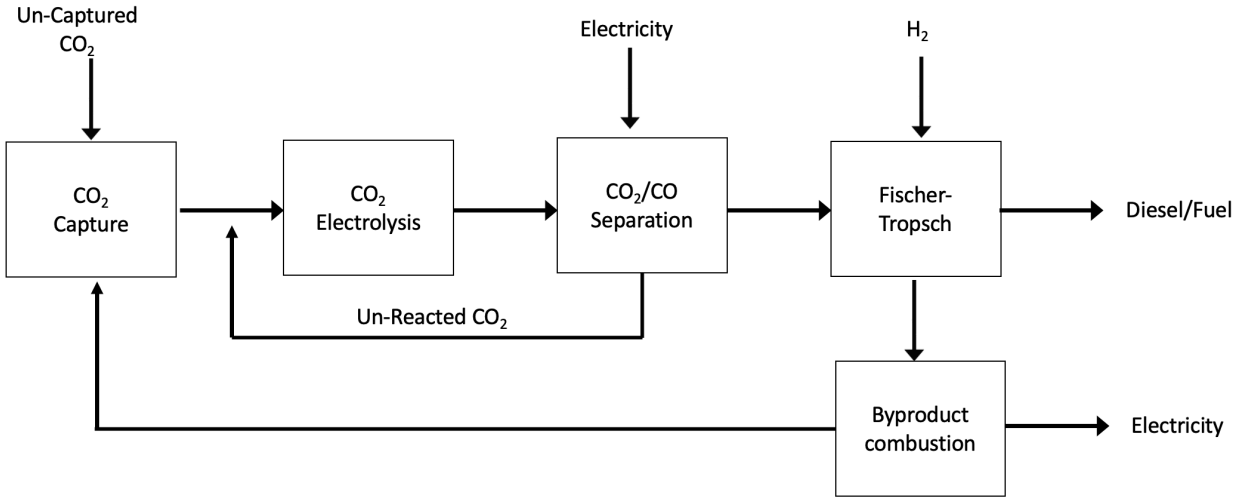

Figure 3. Example of the production process of e-fuel based on CO_2 electrolysis and the Fisher-Tropsch reaction. Displayed is the e-fuel production process. CO_2 is captured and separated through electrolysis. The resulting product is combined with hydrogen in the Fischer-Tropsch process to generate the desired carbohydrate (e.g. Diesel or gasoline). Illustration based on Li et al., 2016.

Through the combination of captured carbon and the use of renewable energy sources, the output fuels are a carbon neutral alternative to fossil fuels currently burned in combustion

engines. The greatest downside of e-fuels is the energy consumed in the production process. Due to the efficiency loss in the transformation process, energy is lost at every stage.

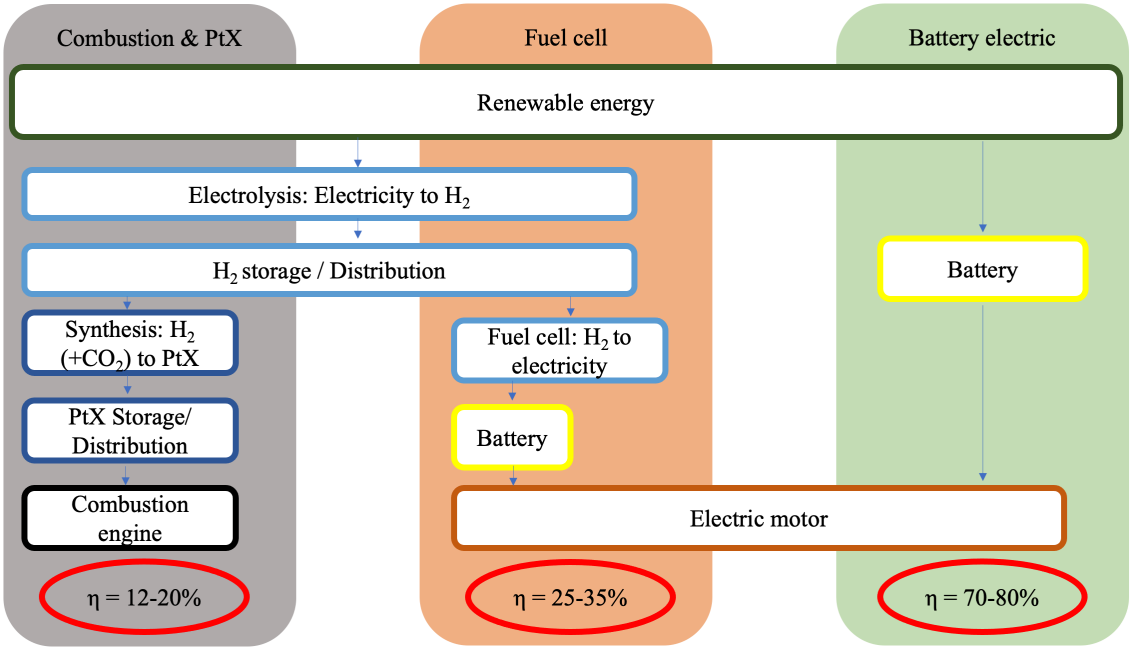

Figure 4. Energy efficiency in different drivetrain technologies. Displayed are the differences in efficiency (η) for the drivetrain alternatives. A combustion engine powered with e-fuels (PtX = Power to X) required the most intermediate/ transformation steps. At each transformation efficiency is lost. Based on Umsteuern Erforderlich: Klimaschutz Im Verkehrssektor, 2017 (p.86).

Depending on the calculations, most simulations result in an efficiency of BEV of 70-80% and e-fuels between 12 and 20% (Blagojevic et al., 2019; Bundesministerium für Umwelt-Naturschutz-nukleare Sicherheit und Verbraucherschutz, 2021). Currently there is not enough renewable energy available to satisfy full energy demand in Germany. Adding more demand for renewable energy to produce e-fuels would therefore worsen an existing shortage in renewable energy. The efficiency would not be as critical if we had unlimited access to renewable energy. Most studies covering the issue of energy availability point out the possibility of producing renewable energy in ideal environments like the Sahara Desert in Morocco or for wind energy in Patagonia (Albrecht et al., 2020; Fritsch et al., 2021a; Hobohm et al., 2018; Perner & Bothe, 2018). The amount of sun hours in Morocco for example decreases cost of production and leads to larger amounts of energy available on economically acceptable terms. Since electricity is difficult to store, conversion to liquid storage forms like e-fuels or hydrogen could minimize energy loss. This could help overcome seasonal fluctuations in the production of renewable energy. High energy density enables further use cases where batteries find their limits. E-fuels are a solution for carbon neutral aviation and freight transportation

(Siegemund et al., 2017). Additionally, the use of e-fuels allows for continued deployment of current infrastructures like pipelines, gas stations and the existing fleet of cars. This enables their use in remote locations where there is a lack of necessary infrastructure for battery electric vehicles or in developing countries. With the currently low production volumes of e-fuels, cost remains an issue. Depending on the scenarios, increasing the scale of production will drive down the cost to acceptable levels, comparable with fossil fuels (Siegemund et al., 2017). Even with its downsides, e-fuels can contribute towards carbon neutral transportation. With the decision of the European Union to rate nuclear energy as renewable and carbon neutral, it might be possible that the availability of renewable energy for producing e-fuels will soon increase.

2.3 Competitive advantage

Analysing and defining strategies to achieve competitive advantage dates to the early days of strategic management. Strategic management research investigates how organizations can outperform competitors by developing competitive advantages (Furrer et al., 2008). It is a vital component to provide value to customers compared to the competitors' offerings to succeed in business. Different theories have emerged concerning competitive advantage (Dagnino et al., 2021). Porter described three main strategies to achieve competitive advantage: Differentiation, Cost Leadership and Focus (Porter, 1985). Later, the resource-based view focused on internal factors and the specific attributes of resources inherent in a firm (Barney, 1991). Building on this idea and combining it with a focus on the firm's environment, results in the dynamic capabilities approach. It explains how resources need to be utilized considering changing external factors for organizational success, aligning the firm's internal capabilities with the environment while seeking to avoid the tautology of the resource-based view. (Teece et al., 1997; Barreto, 2010).

In the last two decades a wide body of literature covering temporary competitive advantage has emerged. It contradicts the idea that a firm can sustain success over an extended period. Researchers link this to the development of hyper competitive industries where equilibria do not allow for sustained competitive advantage (Dagnino et al., 2021). With the foundation of sustained competitive advantage vanishing, researchers are pushing to identify reasons which are more short-term oriented (D'Aveni et al., 2010). A shift to new sources of competitive advantages thus developed (Sirmon et al., 2010). Continuing the view of competitive advantage within the framework of time horizons, disruption produced by innovation is also highlighted

(Christensen, 2001). Recent literature argues for linkages between the competitive firms, E.g., destruction of competitive advantage due to another firm's actions (D'Aveni et al., 2010). Rising technological change increases uncertainty for an organization (J. L. Johnson et al., 2012). On the other hand, increase in technological change can also provide new opportunities (Karim et al., 2016). The pace of change and the extent to which change is disruptive were further found to impact organisations (Suarez & Lanzolla, n.d.). The frequency and the extent of attacks on a firm's positioning determines organizational performance (Ajamieh et al., 2016).

A changing environment and a stronger focus on climate change do provide opportunities to position a company in a favourable way (Lash & Wellington, 2007). A study on green marketing in the automotive supply chain sector identified a positive impact on a company's competitive position (Moravcikova et al., 2017). The automotive industry is moving towards a set of different drivetrain technologies (Sierzchula et al., 2012). Since green positioning and offering alternative drivetrains to customers increases competitiveness, technological leadership in the e-fuel production process might become an advantage as well.

Current positions of established manufacturers are challenged by new technology. The emergence of new drive train technologies leads to an erosion of established advantages in the field of internal combustion engines (Sierzchula et al., 2012). Furthermore, competition is intensified by new entrants to the field, like the electric vehicle producer Tesla and by technology companies like Google (Poczter & Jankovic, 2014; Stringham et al., 2015). Political pressure to reach environmental goals and new legislative initiatives force companies in the automotive industry to advance towards carbon neutral mobility (Wesseling et al., 2015). Focusing on traditional competitive strategies, cost leadership could become a viable strategy in the field of synthetic fuels in line with Porter's thinking (Porter, 1985). The product "e-fuel" is comparable to commodities, leaving little to no room for differentiation (Ram et al., 2020). Therefore, the offering with the lowest possible price will attract consumers. Another important factor is CO_2 fleet pricing. All firms need to meet increasingly strict targets for vehicles (European Parliament, 2022a; Zähringer & Bothe, 2021). If e-fuels are politically acceptable to reduce CO_2 emissions, they will help firms avoid sanctions (Zähringer & Bothe, 2021). The development of e-fuels provides additional benefits to certain firms targeting a niche segment in the market like old-timers. To help customers drive these cars in the future with stricter standards on emissions, carbon neutral fuel alternatives will be vital (Porsche Newsroom,

2021). Besides this niche position, selling cars with ICE will help amortize the R&D spending for new drivetrain technologies in line with Tushman (Tushman et al., 1996).

2.4 Organizational ambidexterity

Ambidexterity in strategic management translates into the ability to utilize old technology and business models while being able to develop new ones (O'Reilly & Tushman, 2013). To sustain organizational success, it is vital to adapt to changes in the environment and the competitive landscape (O'Reilly & Tushman, 2011). Solid financial results from prior activities are, in theory, able to support development of new technologies which, in turn, will guarantee future success.

First used by Robert Duncan (1976), the term organizational ambidexterity refers to a particular structure of the firm. The idea of simultaneous exploration and exploitation was introduced in the nineties (Tushman et al., 1996). To prove the validity of the concept, many studies were conducted investigating the link between ambidexterity and firm performance (O'Reilly & Tushman, 2013). Sales and other financial indicators were found to be positively impacted by organizational ambidexterity. Studies of longitudinal financial data and subjective views of high-level executives showed that both were affected by organizational ambidexterity (Auh & Menguc, 2005; Caspin-Wagner & Tishler, 2012; Gemmel, 2010; Gibson & Birkinshaw, 2004; Schulze et al., 2008). Exploitation of resources helps firms achieve strong financial results and exploration activities position the firm for the future. The impact of ambidexterity on firm survival was investigated and a positive impact was found (Piao, 2010; Yu & Khessina, 2012).

The effect of ambidexterity was especially present in environments characterised by market and technological uncertainty (O'Reilly & Tushman, 2013). Early studies of organizational ambidexterity were often based on case studies and survey data (Gibson & Birkinshaw, 2004; Tushman et al., 1996). In later research, longer timeframes and larger sample sizes were analysed (Caspin-Wagner & Tishler, 2012; Charles A. O'Reilly III & Tushman, 2011). This approach is advisable since the effect of explorational activities on firm performance will take time to be definitively established. Besides the positive impact of ambidexterity on firm performance, research suggests that both overuse and underuse of ambidexterity comes at a cost for organizations (March, 1991). Evidence supporting this was found across various industries and contexts (Benner & Tushman, 2002; Heli Wang & Jiatao Li, 2008; Mitchell & Singh,

1993). Tushmann and O'Reiley (2013) identified three main ways ambidexterity can be achieved. Sequential ambidexterity identifies periods of successive exploitation and explorations as distinct phases in time. Tushmann and O'Reiley (2013) conclude that structural ambidexterity may be suited for less dynamic environments and smaller firms, since the simultaneous pursuit of exploration and exploitation is capital intensive.

The second way of managing ambidexterity is "simultaneous and structural ambidexterity". This approach deviates from the idea of sequential exploration and exploitation processes and suggests that successful ambidexterity is achieved through either structural separation or separation by various factors, among others by processes and cultures (O'Reilly & Tushman, 2008). A third way to integrate ambidexterity into a firm is "contextual ambidexterity" (O'Reilly & Tushman, 2013) which is based on the situational context. The concept was first described by (Gibson & Birkinshaw, 2004) and focuses on smaller units of decision making within the firm to explain how organizations can follow a strategy of organizational ambidexterity. An example of contextual ambidexterity is the production process at the manufacturer Toyota. Employees of Toyota exploit existing knowledge when they follow work processes and if they find potential to improve, they can integrate these exploratory practices. Based upon this, processes can be exploratory and exploitative at the same time (Adler et al., 1999). Tushman and O'Reilly (2013) also point out that no clear definition of exploration and exploitation exists in the current literature. This results in dilution of the theory with other themes within organizational science and strategic management.

Combining organizational ambidexterity with the automotive industry, car manufacturers need to stay ahead of industry developments. To maintain their positioning, they need to exploit existing technology, and explore new ones simultaneously. In addition to the pressure to stay innovative in a highly competitive industry, uncertainty caused by climate change and developments towards climate neutrality intensify the pressure. New drivetrain technologies and rising demand from governments and consumers results in manufacturers selling battery electric vehicles (BEV) and internal combustion vehicles (ICV) at the same time. This can be seen as an act of ambidexterity. To implement the transition to carbon neutrality the sales of combustion engines need to decline and eventually come to a complete stop. To enable this process, e-fuels can help minimize the impact of ICV currently sold and driving on the road. Manufacturers like Audi plan to only produce battery powered vehicles by 2026 (Fasse, 2021). In terms of long-term efficiency, BEVs are more efficient in energy utilization than ICVs. In

comparison to a car powered with e-fuels, a BEV can utilize up to 80% of the initial energy whereas a ICV can only achieve 20% (Hornberg et al., 2017). In the long run, it seems obvious that BEVs will replace ICVs, particularly since BEV technology is relatively new and has the potential to further improve in the future. Despite having issues, e-fuels can be seen as a bridging technology. The automotive industry in Germany has decided to focus its efforts on the development of BEVs. Another problem lies in in the speed of innovation diffusion.

The theory of innovation diffusion describes how fast a new technology becomes a substitute for an older one (Robertson, 1967; Wesseling et al., 2015). In the context of the car industry, the question is when new vehicles like fuel cells and BEVs will become more dominant than ICV. In Germany currently only 9% of newly registered vehicles have an alternative drive train and ICVs are estimated to be sold even after 2040 (Deloitte, 2020). This leads to the problem that cars with combustion engines will remain on the streets far after 2040 due to their lifespans. The problem becomes even more pronounced in other countries where there are longer holding period for vehicles and fewer new battery electric vehicles are registered every year. A mandating requirement for a share of CO_2 neutral e-fuels could help reduce pollution caused by the existing car fleet, and, at a later stage, a full transition to 100% e-fuels could be made. In emerging markets, the infrastructure needed for battery electric vehicles will take decades to develop or might even be entirely impossible in remote regions. To serve all markets and sustain, it will be vital for old and new technologies to coexist side by side.

3. Methodology

This study aims to investigate how organizational ambidexterity is managed in face of the transition towards carbon neutrality and how of e-fuels can help reach climate goals. Technological openness and the influence of political decisions is investigated. The study concentrates on the German automotive industry and occasionally draws comparisons with other markets. To answer the research questions, the approach of qualitative content analysis following Mayring's procedure was chosen (Mayring, 2014).

As a first step, a Literature Review was performed which is dealt with in Section Two. Eleven expert interviews following a semi structured interview guide were conducted. Questions were developed informed by the Literature Review that aimed to investigate interesting aspects of the technology and potential consequences. To test the semi structured interview questions a

pilot interview was conducted. The pilot interview tests if the questions result in satisfying answers regarding the research questions (Mayring, 2014). After the pilot interview a subset of questions was added to investigate problems associated with e-fuels in case none of these were mentioned. Furthermore, an upfront explanation of the term ambidexterity in the context in strategic management theory was added to achieve more precise answers to question five. An additional set of three questions was added to investigate the country specific factors for Germany and to compare them to the global market of individual transportation solutions.

The experts were selected from different industry sectors to give a broad overview of the different opinions on the topic. The first sector approached were researchers at German technical universities. Two interviews with experts researching in the field of mechanical engineering and especially fuel technology were conducted. The second group were people working at automotive companies in the field of either development or strategy. Three interviews with experts were conducted and analysed. The third group was people working in lobbying organisations with an interest in e-fuels. The interviewees were from the automotive industry, mineral oil industry or alternative fuels organizations. In this field four individuals were interviewed. The last group was representatives of environmental organizations. Two interviews were conducted with experts on mobility and climate change.

The interview script was composed of 13 questions and 4 sub questions. The interview duration depended on the length of the answers given to each question by the interviewee. The shortest interview conducted had a length of 8 minutes and the longest interview lasted 37 minutes. All interviews were recorded, and an interview transcript was written after each interview. The interviews were transcribed into a smooth verbatim transcript. Following this, the transcripts were transformed into a selective protocol, additionally translated to English (if necessary) and can be found at the end of this study in the appendix (Mayring, 2014). The interview transcripts were then imported into MAXQDA for further analysis. The method chosen was content analysis summarising the interviews into inductively developed categories. The minimal content for a coding unit was defined as a sentence and the maximum was the complete material from one interview. Each interview was used as one recording unit. After coding the interviews, a proximity analysis based on Euclidian distance was conducted. The values analysed are the frequency of each category after coding all interviews. The values assigned indicate similarity between two coded interviews. The lowest possible value is zero which indicates a complete congruence in the frequency of coded segments within the interview. A high value indicates

strong difference between the interview code frequency. The aim was to provide an overview of the interviewee sample.

Interview	Organisation Type	Number of Emolyees	Position	Date	Duration
Interview 1	University	10000	Researcher liquid fuels	03.05.22	25min
Interview 2	University	10000	Researcher combustion technology	05.05.22	12min
Interview 3	Manufacturer	91000	Development coordinator e-fuels	09.05.22	33min
Interview 4	Manufacturer	91000	Portfolio Planning (car fleet)	10.05.22	17min
Interview 5	Lobbying -Minearl Oil Industry	20	Head of policy	10.05.22	26min
Interview 6	Lobbying Automotive Industry	100	Regulatory advisor	11.05.22	23min
Interview 7	Lobbying Automotive Industry	100	Referent sustainable mobility	13.05.22	11min
Interview 8	Lobbying alternative Fuels	15	Head of Strategy	19.05.22	24min
Interview 9	Manufacturer	91000	Teamleader Development	24.05.22	34min
Interview 10	Environmental Organisation	1700	Damage and Sustainability Manager	24.05.22	8min
Interview 11	Environmental Organisation	100	Senior Expert Climate Preservation	06.06.22	37min

Figure 5. Overview of Interviews conducted. For each Interviewee the Organization type, size, and position is given. The date of the interview and the duration are also displayed.

4. Findings

After conducting the interviews, the first step was to identify interviewees in favour of the use of e-fuels and interviewees opposing e-fuels in the individual transportation sector. The first question of the structured interview aimed to ascertain people's general opinion towards the use of e-fuels in the automotive sector. Out of the eleven interviews, four people declared that they were against the use of e-fuels in cars. Both interviewees from the environmental organizations and one interviewee from the automotive industry and one from lobbying voted against a general use of e-fuels in the personal transportation sector. The reasons for this were concerned similarity to fossil fuels and emissions produced. Besides this, all four interviewees against the use of e-fuels stated that they see potential niche use cases in other sectors (e.g. aviation, maritime, or agricultural use).

	Interview 1	Interview 10	Interview 11	Interview 2	Interview 3	Interview 4	Interview 5	Interview 6	Interview 7	Interview 8	Interview 9
Interview 1	0,00	8,14	3,44	3,99	0,08	1,65	2,93	0,51	7,35	0,08	2,46
Interview 10	8,14	0,00	1,00	0,73	6,59	2,46	1,30	4,58	0,02	9,85	1,65
Interview 11	3,44	1,00	0,00	0,02	2,46	0,33	0,02	1,30	0,73	4,58	0,08
Interview 2	3,99	0,73	0,02	0,00	2,93	0,51	0,08	1,65	0,51	5,21	0,18
Interview 3	0,08	6,59	2,46	2,93	0,00	1,00	2,03	0,18	5,88	0,33	1,65
Interview 4	1,65	2,46	0,33	0,51	1,00	0,00	0,18	0,33	2,03	2,46	0,08
Interview 5	2,93	1,30	0,02	0,08	2,03	0,18	0,00	1,00	1,00	3,99	0,02
Interview 6	0,51	4,58	1,30	1,65	0,18	0,33	1,00	0,00	3,99	1,00	0,73
Interview 7	7,35	0,02	0,73	0,51	5,88	2,03	1,00	3,99	0,00	8,97	1,30
Interview 8	0,08	9,85	4,58	5,21	0,33	2,46	3,99	1,00	8,97	0,00	3,44
Interview 9	2,46	1,65	0,08	0,18	1,65	0,08	0,02	0,73	1,30	3,44	0,00

Figure 6. Distance Matrix for all interviews. Illustrated here are the standardised values of the proximity calculation described in section 3. Higher values indicate a larger deviation in coded segments between the two interviews. A small value indicates similarity and zero is the smallest possible deviation (complete congruence). Dark green indicates similarity and lighter green larger differences.

After the coding of all interviews was finished, a proximity analysis was performed. The largest differences in the proximity analysis occurred between interviews with high Euclidean distances (values in the range of 6-9). Five of the large values are between interviews 10 and 7 and the rest. Interviewee ten is from an environmental organization and interviewee seven is from an automotive lobbying organisation with a focus on electrification. The deviation from the other interviews might indicate a strong electrification bias. Interviewee 7 further occurs in the medium bracket (values in the range of 3-6) two times, further indicating an opinion deviating from other interviewees. Interviewee 8 reached the medium category four times. Interviewee 8 is from a pro e-fuel organisation and therefore might be biased towards radical optimism. The following sections present a detailed overview of the coded segments.

4.1 Advantages of e-fuels

To further investigate reasons for or against e-fuels, interviewees were asked to state the advantages of e-fuels. The following graphic visualises the answers given by categories developed in the analysis process. The thickness of the connection indicates the frequency with which the category was mentioned during the interviews.

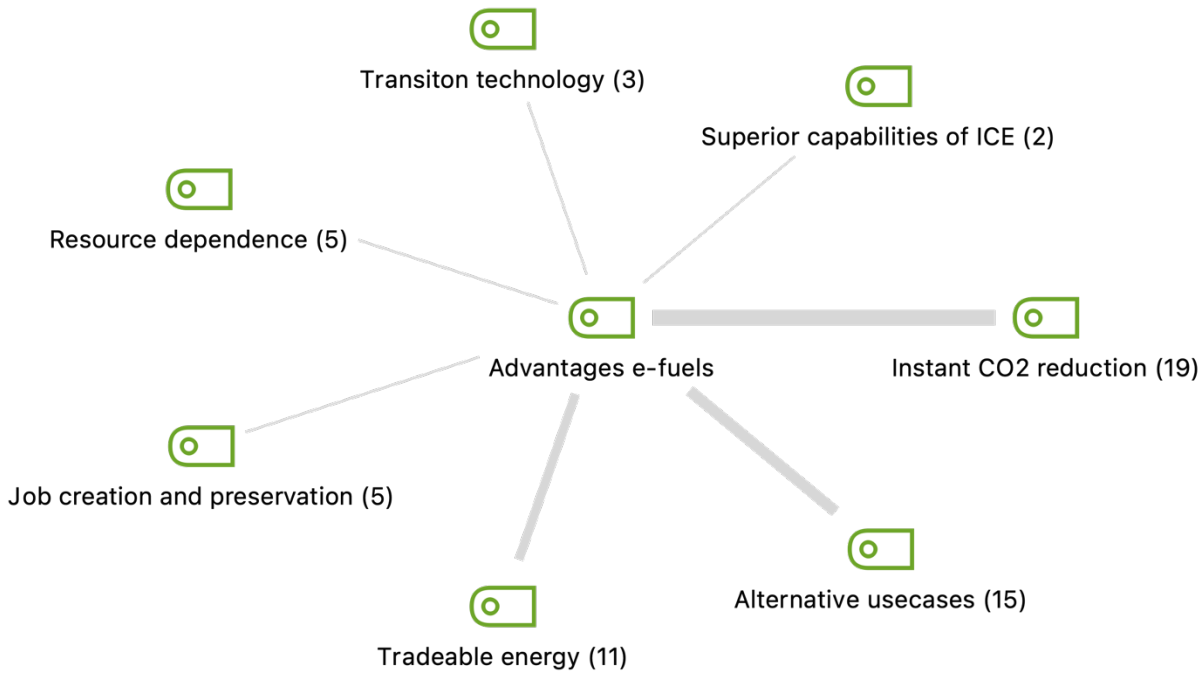

Figure 7. Advantages of E-fuels identified in the interviews. Illustrated are a set of categories developed during the content analysis of the interviews. The advantages mentioned of e-fuels are displayed. The thickness of the connecting line indicates the frequency with which the category was mentioned. The number following the labels indicates the frequency of the category in the complete interviews.

As shown in the graphic, the most mentioned advantage of e-fuels was the instant CO_2 reduction capability. The use of e-fuels in the existing car fleet was seen as a solution to immediately decarbonize road traffic by eight interviewees. E-fuels are supposed to replace fossil fuels currently in use by ICE cars.

"This transition is like transforming a house. Now we are tearing it down and building it new. Because of what we are doing, we will not see a relevant effect in the next decades."
- (Interviewee 3)

Interviewees mentioned that the production process must follow certain criteria to achieve the desired outcome of carbon neutrality. If the requirements of a renewable energy source and captured CO_2 are met, the produced fuels can be used in existing engines as a carbon neutral alternative to fossil fuels according to the experts. In addition to cars, interviewees mentioned the alternative use cases for e-fuels. Out of the eleven interviews conducted, eight mentioned alternative uses of e-fuels without being asked. The interview questions focused on the individual transportation sector yet similar fields like aviation, maritime use were mentioned during the interviews. The requirement of high energy density and a resulting low weight plays an important role in the transportation of goods in the maritime sector or in aviation. For both fields interviewees did not see electrification as a fitting solution. Eight interviewees mentioned e-fuels as an option to store large amounts of energy. Transforming electricity into liquid or gas energy carriers enables storage for longer time periods as well as transportation. With the transportation option, energy becomes tradable from surplus regions to areas where larger amounts of energy are needed than cannot be produced locally. The trade enables potential energy surplus regions to enter the global value chain. Five interviewees mentioned that the integration of multiple countries and regions globally increases resource independence for the importing countries. Interviewees made a distinction within the independence from resource rich countries: on one hand one can lose dependency on oil exporting countries and on the other not to fall into reliance upon minerals like lithium, cobalt, or rare earth elements required for battery production. In line with this assumption the current energy crisis in Europe due to avoidance of Russian gas and other commodities was mentioned.

Three interviewees cited either job creation or job preservation and the category was marked five times in total during the analysis. Interviewees mentioned that changes towards new models of mobility or new technical solutions provide risks to existing jobs in the car industry, as well

as in closely associated sectors like suppliers of parts or the mineral oil industry. Germany has a large automotive industry and considerable associated businesses as well. Transitioning towards electric mobility was seen as risking or losing a large part of these jobs due to less required parts in vehicles and an overall simpler production process. Three interviewees mentioned e-fuels as a possible transition technology during the switch to electrification and new forms of mobility. The argument being made concerned the instant CO_2 reductions while seeing electrification as the last step of the process. E-fuels would to be used in older cars and equipment until the transition is completed. Lastly, two interviewees mentioned the superior capabilities of cars equipped with a combustion engine as an advantage of e-fuels. The experts stated that when comparing ICEVs to BEVs, often the BEVs can't reach the same performance figures as their combustion counterparts. Experts considered range and refill times are a critical weakness for most electric vehicles sold today.

4.2 Negative aspects of e-fuels

As mentioned, four interviewees were against the use of e-fuels in the individual transportation sector. The questioner asked every participant for negative aspects of e-fuels. The following graphic displays categories developed in terms of disadvantages of e-fuels during the coding of the interview transcripts.

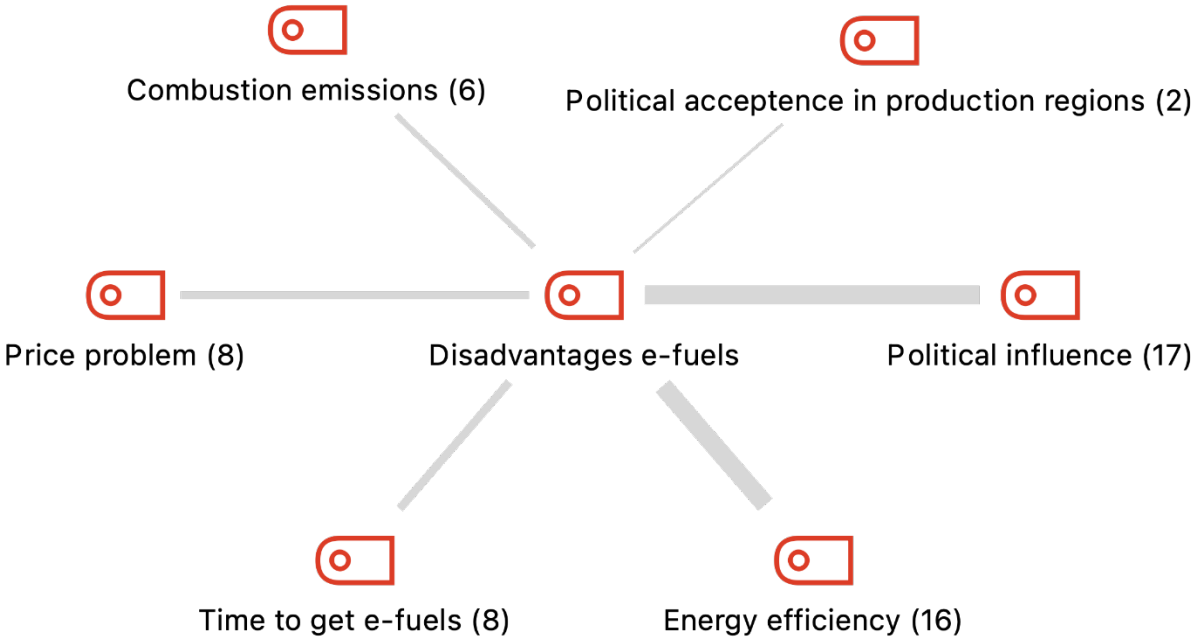

Figure 8. Disadvantages of E-fuels identified during the interviews. A set of categories developed during the content analysis of the interviews is shown. The disadvantages of e-fuels mentioned are displayed. The thickness of the connecting line indicates the frequency with which the category was mentioned. The number following the labels indicates the frequency of how often the category was marked in the complete interviews.

The most articulated negative aspect of e-fuels by interviewees was the political influence. Regulations require manufacturers to follow strict rules with their offerings. Interviewees mentioned that it would not make sense to pursue an e-fuel strategy if no accreditation system is in place. Currently e-fuels in the EU are being treated the same as their fossil equivalent. In a recent decision, the European Parliament decided to follow the objective of zero emission for cars and vans from 2035 onwards (European Parliament, 2022a). If the EU sticks to this plan, no new combustion engine vehicles would be allowed to be registered from 2035 onwards. In that case the development of infrastructure for e-fuels in the automotive sector becomes unreasonable according to the interviewees. The interviews had a specific question on political influence (Question 7). Further, all eleven interviewees mentioned an efficiency problem with the production process of e-fuels. The production process of e-fuels requires large amounts of renewable energy. Using energy directly in battery electric vehicles is more efficient according to the experts. The time to produce e-fuels was mentioned by six experts. To produce e-fuels on a large-scale, big infrastructure investments are needed. The time to build production plants and renewable energy systems will be long according to these experts. Five experts mentioned combustion emissions as a problem of e-fuels. E-fuels can reduce the impact of CO_2 by using direct air capturing but the emissions would still be produced. Compared to electrification, emissions are produced while driving the car. For the fight against pollution in cities, direct electrification can be advantageous. In the 2021 positioning of the European Commission, a new set of regulation (Euro 7) and a focus on zero emission vehicles was proposed (European Commission, 2021). Four interviewees mentioned price as a problem currently associated with e-fuels. For e-fuels to compete against fossil fuels and other mobility alternatives, prices would need to drop to comparable levels. Last, two interviewee mentioned political acceptance in high energy regions. As mentioned previously, to produce e-fuels cost efficient, regions with high renewable energy production potential are needed to address the efficiency issue. This point was stated during two interviews. Countries might not be interested in producing large amounts of renewable energy for consumption abroad. Therefore, the commitment of these regions is questionable.

4.3 Possible solutions for the Problems

The follow-up question about the disadvantages of e-fuels was whether these problems could be solved and if so, how. Eight interviewees thought the problems of e-fuels could be overcome and three stated they don't see a realistic chance of surmounting core problems. The following Matrix shows all categories associated with overcoming problems.

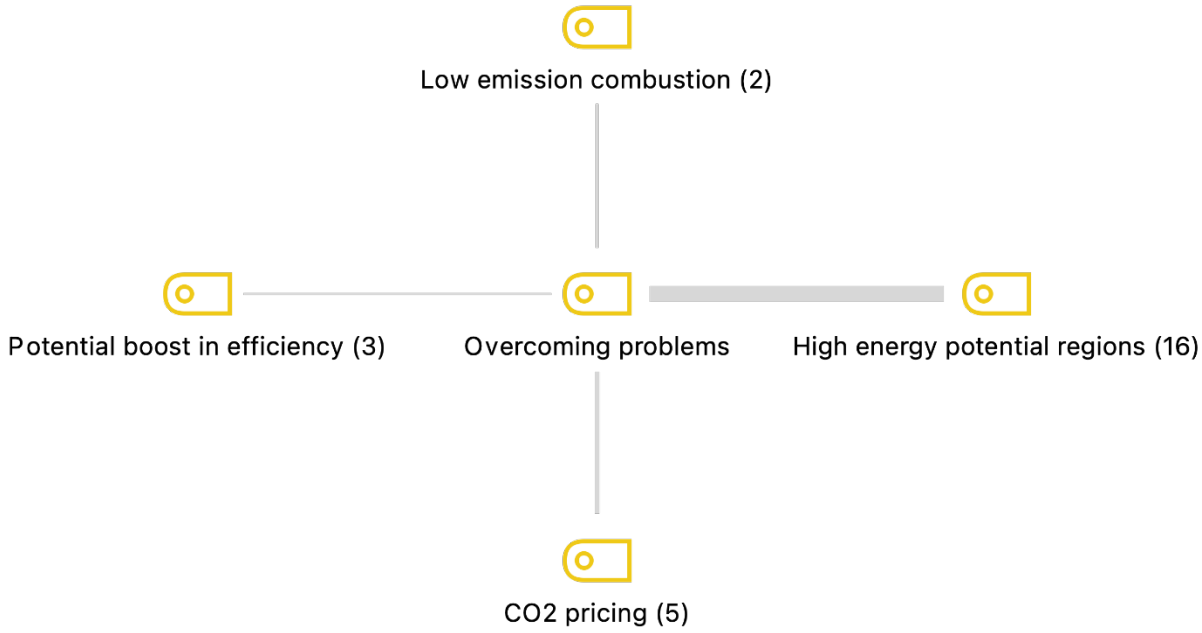

Figure 9. Potential solutions to solve problems associated with e-fuels. Shown are categories based on the answers to the question of whether problems with e-fuels can be overcome. The thickness of the connecting line indicates the frequency with which the category was mentioned. The number following the labels indicates the frequency of how often the category was marked in the complete interviews.

The most mentioned category was producing e-fuels in high energy potential regions. Nine experts believed in solving the efficiency and price problem by using high renewable energy potentials. All experts acknowledged, that the production of e-fuels is an energy intensive process. Interviewees mentioned Patagonia and Chile for potential wind energy, deserts in Morocco for their solar potential, and high wind and solar energy potentials in Tibet/ China. In these areas the potential to produce renewable energy is particularly high and a production facility could be operated at relatively low cost. Furthermore, the interviewees mentioned that these resources might otherwise not be utilised for energy production. Eight experts claimed that e-fuels could help to utilize the potential of these regions by providing an energy storage option in line with the trade argument discussed previously. Five experts mentioned a CO_2 pricing mechanism to be introduced for individual transportation sector. This code was marked five times and experts agreed that an emission pricing mechanism for energy would help overcome political inertia. Three experts further said that with increasing interest in e-fuels and

the resulting investments, the efficiency of production might be increased by more efficient synthesis processes. Two experts mentioned new emission standards and clean combustion as a solution for the emissions problem of e-fuels. The Euro7 emission standard will be in place for all new combustion cars.

4.4 Ambidexterity in the transition towards more electrification

Interviewees were questioned about how they think the transition towards electric vehicles could be achieved. The term ambidexterity was shortly explained to facilitate more precise answerers.

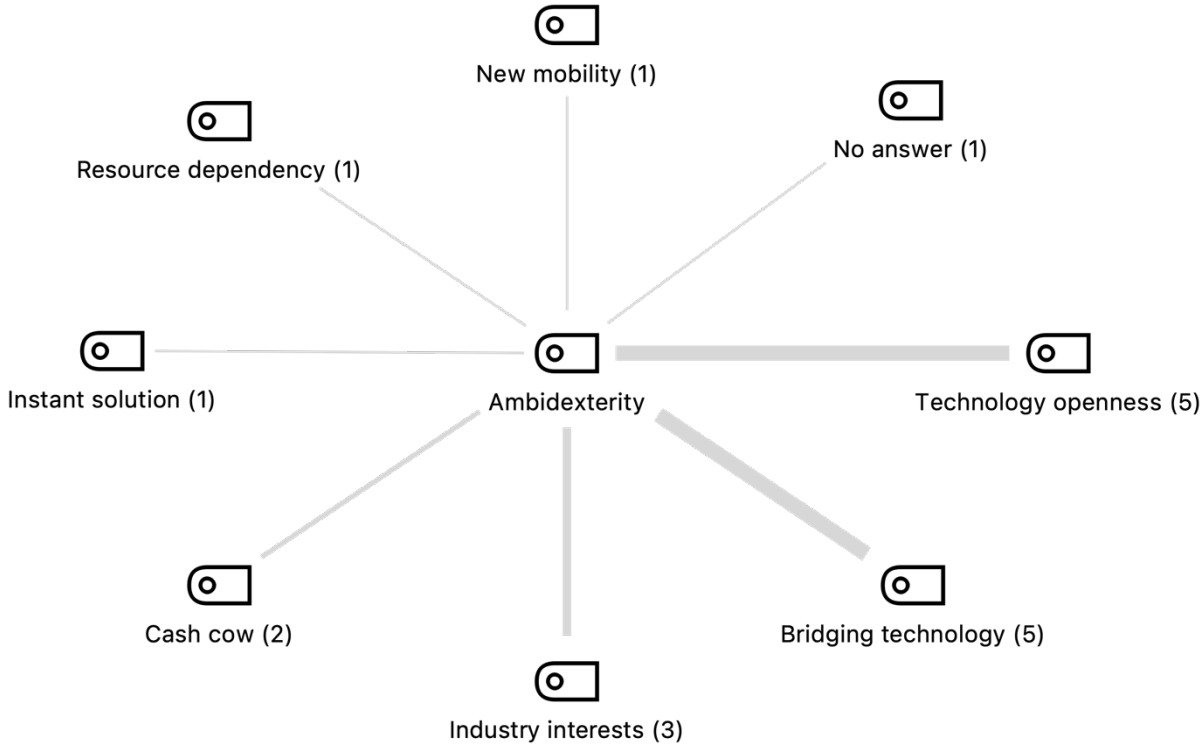

Figure 10. How a potential transition should be performed in the automotive sector. Displayed are the categories developed relating to a transition path for the automotive industry. The thickness of the connecting line indicates the frequency with which the category was mentioned. The number given is of experts who mentioned the category in their answer to question number 5.

Five interviewees mentioned that they do not support a full transition towards electrification and are hoping for more technological openness. The advantages of electrification like inner city transportation without emissions were mentioned but this group believed in a mix of different solutions for different use cases of mobility. The experts agreed that no single technology would be able to sufficiently cover all mobility needs. For each individual case a different solution might be optimal. Three of these experts additionally stated that e-fuels could

provide a bridging technology towards more electrification in the future. These experts think that electro mobility is at the moment not suited to cover all mobility needs, served by combustion engines. With better electric vehicles in the future those needs might be met, but until then, e-fuels could be a CO_2 neutral option. Two more interviewees shared this opinion accounting for a total of five experts in favour of e-fuels being a bridging solution. Three interviewees mentioned industry impediments for the use of e-fuels. The development of new models is costly, and these experts said the decision to focus on electrification was made by all large manufacturers, arguing that manufacturers are not interested in technological openness due to investments made in electric vehicle development.

"I think we will need a mix of different solutions in the future. This means it's going to be complicated for the manufacturers" – Interviewee 8

Two interviewees mentioned that ICE vehicles are needed to fund the development of electric vehicles. ICE models were described as "cash cows" by one interviewee. The expert from the mineral industry stated that no transition would be needed since e-fuels could provide a clean solution for the use of combustion cars. In contrast, interviewees from environmental organizations proposed a new way of mobility besides cars and one did not answer the question. Lastly, resource dependency was mentioned in light of the current gas crisis caused by the Ukraine war. The expert believes we are facing a similar reliance for battery resources from China and a diverse path of mobility should be pursued.

4.5 Future developments in the mobility sector

To assess development pathways for the German automotive industry the interview contained questions on the technological path chosen in Germany compared to the world and what would be the best technology for decarbonisation. Interviewees were asked opinions on the dominant drivetrain technology in the future and whether this would be the best solution globally and for Germany. The political influence in Germany was questioned and how it affects future development in the industry.

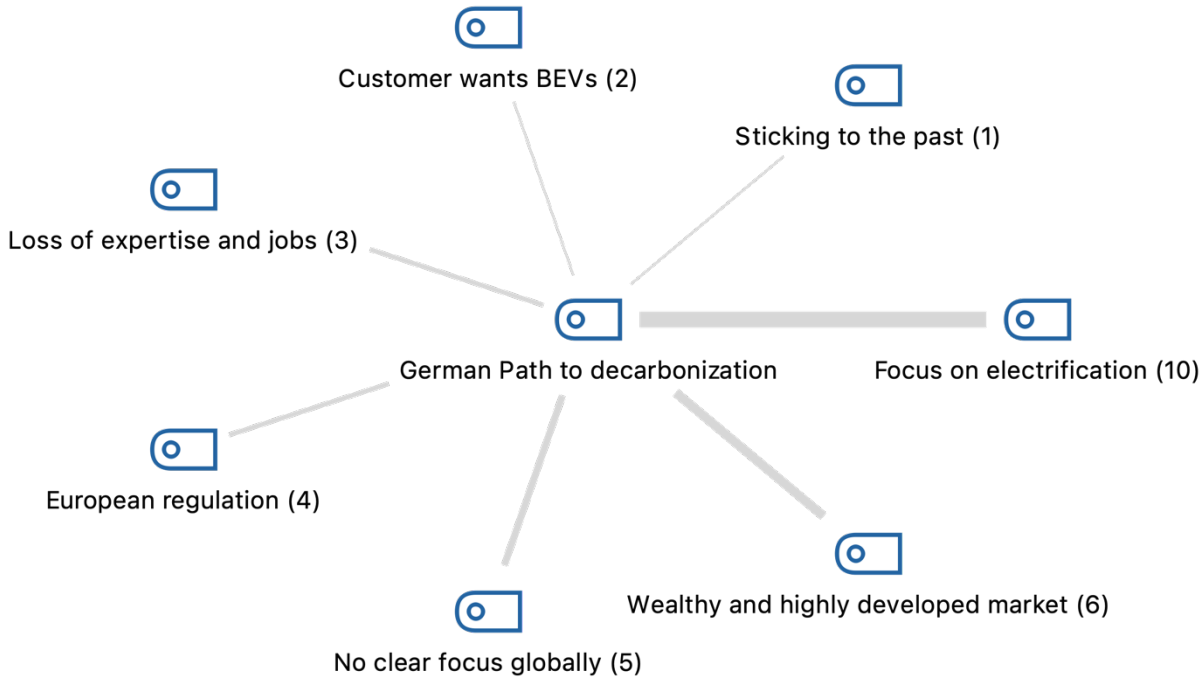

Figure 11. German path towards new drivetrain technologies. Displayed are the categories developed in the analysis relating to the transformation path chosen in Germany. The thickness of the connecting line indicates the frequency with which the category was mentioned. The number indicates how often individuals mentioned the category in their answers.

Interviewees were asked how they think Germany compares globally in terms of focus on technology in the future. The most mentioned category was the focus on electrification. Seven experts claimed electrification will be the dominant choice in the future. Compared to global trends, four interviewees said that no clear focus on one drivetrain technology could be seen. These experts further stated that the European solution would isolate the automotive manufacturers but at the same time could be pioneering. Six experts described the German automotive market as targeting a wealthy customer segment and a highly developed market with demanding customers. Four experts said one could not separate Germany from European regulation and therefore it is a European decision and path for the future. With the predicted transition towards electrification in the German automotive market, three experts mentioned the loss of expert knowledge in combustion technology and related jobs in the industry. Interviewees believed that declines in mechanical engineering would harm German industry. An interviewee from an environmental organization claimed that Germany, and especially the automotive industry, was stuck in the past and was developing more slowly regarding new technologies and ideas compared to the rest of the world. Lastly, an interviewee from the automotive industry said that the German customers wanted electrification.

"The customers aren't interested in the stock fleet and as soon as they switched, they won't care for e-fuels." – Interviewee 9

When interviewees were asked about political influence two main topics were mentioned. First there was European regulation for fleet efficiency targeting new vehicles sold and second incentives for BEVs in the German market were discussed. In total all interviewees except one agreed that the future development of the automotive industry would be affected by political decisions. The one interviewee declined to answer the question.

"Politics are forcing the development, with the regulation, that climate sustainability is electric in the mobility sector." – Interviewee 6

The last questions (10.-13.) examined the opinion and estimation of the experts on the future choice of technology for the automotive industry in Germany and globally. The most coded segment for these questions was "technology mix". This category was mentioned by eight of the eleven experts on 27 different segments in the transcripts. This category contained all claims made for a diverse mix of drivetrain technologies like electrification, hydrogen vehicles, hybrid vehicles, or combustion vehicles. These experts believe that the mere focus on electrification would not work, and additional solutions would be needed.

This need for a mix led three interviewees to mention conflicting interests within the industry. Focusing on one technology in the future, namely electrification, was seen as leading to lower development costs. Further, the need to comply with the regulations imposed by politics strengthened the focus even more. In line with the notion of a required mix of technologies, but with a special focus, four interviewees thought a new concept for mobility would need to be created.

"The goal cannot be to replace 48 million combustion engine cars in Germany with 48 million electric cars" – Interviewee 11

This category contained claims for more public transportation, bicycle usage and when needed individual transport in the optimal (sustainable) way. Along the experts' desire for new mobility models, five experts described how the system we currently have is not working correctly. CO_2 emissions are not measured in a complete way and a system to globally assess the impact of

consumption would be needed. Experts cited solutions like a circular economy or no personal cars in cities. Four experts mentioned the conflict of interest associated with the industry which will lead to sub-optimal solutions for future mobility. The missing CO_2 rating system leads to inefficient solutions according to the experts.

4.6 E-fuels as a competitive advantage

With question 8 and 9 interviewees were asked for their opinions on a global e-fuels production process and the potential of e-fuels becoming a competitive advantage. Seven interviewees believed that technological leadership in the production process could become a competitive advantage. The production process relies on chemical plants and if companies developed the best technical solution for the production, experts said that this would result in a competitive advantage. According to six interviewees, only a global e-fuel production process would lead to the desired efficiency levels. Interviewees explained that in high energy potential regions an advantageous position for renewable energy production would lead to lower costs of production. Following this, three interviewees mentioned job creation potential in these regions. Job creation would boost the economy of the producing countries and lead to positive economic development according to the experts. These high energy regions would be able to develop a comparative advantage in the production of renewable energy. Two interviewees said that no competitive advantage could be realised based on the e-fuel production process. They think that demand for e-fuels is not sufficient now to justify large investments needed for further development. One interviewee mentioned that partnerships for a global production process would strengthen the connection with these regions. Lastly, slow political development regarding decisions on e-fuels and the required infrastructure for production were claimed to be the main inhibitor by one interviewee. Certainty is needed to make the decisions leading to a global production process. Regulatory systems need to be in place to justify large investments. Without the political foundation, no global process could be realized according to the expert.

5. Discussion

Studies investigating the reduction in greenhouse gas emissions to achieve climate goals show how e-fuels can positively contribute towards reaching climate neutrality in the EU in 2050 (Fritsch et al., 2021a; Kühn et al., 2019; Siegemund et al., 2017). In their scenario analysis Siegemund et al. (2017) found that e-fuels will be necessary to complement other initiatives,

like the transition to BEVs and a switch to more public transportation. This is in line with the opinion of most experts interviewed. A key fact in this argumentation is the vehicle rotation rate. According to the experts, the German vehicle fleet is renewed every 15 years. The experts further stressed that cars do not reach the end of their life cycle after 15 years and most of these older cars are driven in other countries. The true life cycle of a car is hard to track and many old combustion cars are still being used globally. A switch to BEVs takes too long in many countries since combustion cars remain in use for decades (Fritsch et al., 2021a). The use of e-fuels in special cases or similar fields like aviation and the maritime transportation is very likely.

As stated by eight interviewees, e-fuels will play an important role in these areas. This opinion is shared by the European Parliament. In a decision from 07.07.2022, called Fit for 55, an accelerated switch to sustainable fossil fuel alternatives was proposed. The plan is to set a required minimum share of sustainable fuels in EU airports starting from 2025 with 2% and increasing to 37% in 2040 and 85% in 2050 (European Parliament, 2022b). Past studies see e-fuels as the only existing possibility to reach carbon neutrality in these fields (Fritsch et al., 2021a). The efficiency problem of the production process will likely be targeted in high energy potential regions. Depending on the scenario, direct electrification can be multiple times more effective than the production of e-fuels to be used in a combustion engine (Kühn et al., 2019; Ueckerdt et al., 2021). With the scarcity of renewable energy, efficiency will remain a key problem. The number of e-fuels available on the market for consumption today is limited. Prices are high, and a price reduction can only be achieved with increased production according to literature and the experts interviewed (Brynolf et al., 2018; Lindstad et al., 2021; Ueckerdt et al., 2021).

Furthermore, since e-fuels don’t require a change on the consumer side, they are often believed to be a quick alternative to electrification (Ueckerdt et al., 2021). However, this belief is only partly true. Interviewees said existing infrastructure has been enabled but e-fuels still require investment to reach desired goals. First, there is the already mentioned price problem and then the amount of renewable energy available to produce e-fuels slows down development (Brynolf et al., 2018; Hombach et al., 2019). Resulting from this lack of infrastructure, the timeline to produce e-fuels cost efficiently is longer than expected. Without political security, needed investments probably will not occur (Siegemund et al., 2017; Wagemann & Ausfelder, 2017). The interviewees claimed that regulation is a key for future development. Experts believed that cars with combustion engines are often still preferred by consumers because of their superior

performance in certain attributes like driving range or refilling/charging times and stations. A recent study conducted testing consumer EV acceptance in South Korea confirmed that range and fuel economy are among the preferred attributes by consumers (Jang & Choi, 2021).

Looking at the newly registered vehicles in Germany in 2021, fully electric vehicles remain a niche segment taking up only 0.64% of the total number of newly registered vehicles (Kraftfahrt Bundesamt, 2021). To fulfil the goals of decarbonization in the transportation sector, most experts saw e-fuels as a possible solution. The aspect of tradable energy will become more important in the future according to eight experts. A large dependency on one supplier imposes risk (Nygaard, 2022; Stern et al., 2014). With the transition towards electrification in the mobility sector, dependency on resource producing countries arises. The study of Nygard investigates this issue and points out large dependencies on China for graphite and rare earth elements (Nygaard, 2022). Additionally, the primary energy mix in the grid is important for the climate benefit of electrification. Electric cars can only reach their full potential if they are charged with green electricity. The benefit of electrification and the conditions were not detailed in this study because e-fuels were the main focus. To adequately judge the benefit of electrification, a holistic approach towards emissions produced has to be taken (Pietrzak & Pietrzak, 2021). Further, the transition to new drivetrain technologies likely causes the loss of know-how and jobs in the automotive industry in Germany according to interviewees. A study investigating the potential for Europe found that 1.2 million additional jobs could be created by building e-fuel infrastructure in Europe (Fritsch et al., 2021b). Staying with the model currently in place, existing jobs would be secured. The future competitive advantage of e-fuels will depend on political influence. Technologies provide different options to enter the value chain for new and existing participants. Besides technology leadership, the location factor in certain regions can play an important role. Regions and companies willing to invest in the development of technology are likely to develop a competitive position in the future.

As mentioned by five interviewees technological openness is important to solve problems like decarbonization in the transportation sector. Nine interviewees said they are hoping for a technology mix in the future. To reach the goals, no single mobility technology will be sufficient on its own. In addition to new technologies a different consumer behaviour will be necessary. The experts from the environmental organizations demanded a switch to new mobility systems. The avoidance of road traffic and a transition towards public transportation or bicycles within cities will be vital.

Simultaneous development in electric and combustion engines will be hard for most manufacturers according to one interviewee. Three interviewees believe that currently manufacturers are trying to capitalize on combustion engines showing *an ambidextrous strategy.* The fleet efficiency regulation is hindering this strategy because manufacturers need to comply with these regulations. Thus, the advantage of an exploiting strategy is decreased because of fines associated with selling many combustion cars.

"You still need the combusting engine cars for the automotive industry. They are currently the cash cows. But with the regulation they have a certain limit of carbon dioxide for their sales." -Interviewee 7

This is in line with simultaneous exploration and exploitation within an organization (O'Reilly & Tushman, 2013). The main problem with the ambidextrous strategy is that it gets restricted by the fleet regulation. The approach to be active in both technologies was further strengthened by the experts saying that no full transition should happen. If no complete transition is realised manufacturers will need to continue combustion technology as well. The interviewees from car companies explained that they will continue to sell combustion engines globally even if European regulation prohibits new sales from 2035 onwards within the EU. The competitive potential for the e-fuel production process can be seen as a cost leadership strategy (Porter, 1985). Six experts said only a global production process would lead to the desired efficiency and resulting prices. E-fuels could become a commodity. The technology leadership in the production processes is in line with this assumption. Cost leadership will be reached with the most efficient production processes.

E-fuels as a provider of a differentiation advantage can be seen with the manufacture Porsche. Porsche is producing e-fuels in Chile to provide customers with a climate neutral solution for their combustion cars (Porsche Newsroom, 2021). This niche strategy was mentioned by five interviewees.

6. Limitations and Future Research

Some of the experts might be biased towards the use of e-fuels since they work in the field. To improve the quality of results produced in this study a more diverse set of interviewees could have been beneficial. In addition, the suppliers for car manufacturers could have been included as well to cover the potential job loss problem. The supplier industry was not focused in this study but is definitely an important sector for the German economy.

Environmental organizations or people interested in new mobility concepts were underrepresented in the set of experts in this study (02/11). Since politics influences regulation and hence the future development, it would have been also good to speak to experts from this field. Unfortunately, no experts from the political parties in Germany were willing to participate in this study.

Further a geographical focus on Germany or the European union is not sufficient to decide whether a technology will or will not succeed. The results are likely to be similar in other European countries since the regulation is the same. Germany was advantageous because of the high number on manufacturers present and the role of the industry in the country's economy. To present a holistic assessment of the potential for e-fuels other large markets are important. The large-scale investments are only justifiable if markets like North America and China can be addressed with e-fuels as well.

The geographical limitation of experts interviewed plays a role in high energy regions, since their willingness to participate in the development could be investigated. Further, this work does not cover the technical aspects of e-fuels in detail. A technical analysis of new production technologies and the existing ones would be beneficial to evaluate the future development. The European Parliament plans to focus on the "zero-emission goal" set in the "fit for 55" plan (European Parliament, 2022a). In their latest decision, the environmental ministers reaffirmed this effort but left an option open for vehicles used with alternative fuels (Europäischer Rat, 2022). Therefore, e-fuels might have a future in the individual transportation sector. In combination with other application areas of e-fuels, an investment in the development therefore seems to be beneficial.

7. Conclusion

This study aimed to investigate the potential impact of e-fuels on the German automotive industry. The technological perspective was connected to the strategic management areas of competitive advantage and ambidextrous strategies. The results of this study are in line with expectations. E-fuels remain a complex topic with many diverse and divergent opinions. While the effect of road traffic emissions is widely known, this topic is often not well addressed. Flaws in regulation and a concentration on national interests leads to unsatisfactory solutions. E-fuels can provide a possibility to decarbonise combustion processes when an alternative is not possible. If other technologies like direct electrification are an option, the higher efficiency and lack of emissions make it a superior solution. E-fuels technology will need large investments to reach a point sufficient to scale production. To realise the needed investments, policy and financial criteria for investors and countries are needed. A clear political position regarding their use and accreditation in the emission system would therefore be required. For the automotive industry, the transition process is challenging. The focus on electrification is currently advantageous. An ambidextrous strategy, exploiting combustion technology, is hindered by the fleet emission system. Without a change in regulation, e-fuels will remain a niche segment. Their main potential in the automotive sector is with heritage cars or enthusiasts of combustion technology.

A key aspect for climate impact reduction is the complete avoidance of emissions. Public transportation systems and cycling infrastructure need to be strengthened to incentivise more people to switch to new forms of mobility. Despite the transition towards electrification within the automotive sector, the development of e-fuels production facilities is likely to be a good strategy. Production capacity will be needed to satisfy the demand from other sectors. To address climate change effectively, a CO_2 pricing mechanism is also necessary. The production of large electric SUVs will not lead to the desired effect of climate preservation. The automotive industry should develop cars that are based on the highest efficiency possible. Consumers must question their own behaviour and consumption patterns to build a sense of collective responsibility for climate preservation. The resulting transitions yield opportunities for manufacturers to achieve differentiation from their competition.

Appendix

Transcripts of all 11 interviews for this thesis are given below. Each interview followed 13 standardized questions and 4 sub questions (listed with Arabic numerals in standard fond) with individual responses (in *italic*). Seven of the experts preferred to be interviewed in German, therefore the transcripts were translated to English.

Interview I:

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes definitely. The question is in which form. Pure e-fuels, I would guess for the automotive sector not before 2040. Just because other sectors will be prioritized where no other solution is possible. E-Cerosin will surely be number one and then synthetic fuels for maritime shipping. After that, probably the agricultural sector and offroad needs like heavy duty vehicles. Those are likely to be developed first and the automotive sector is probably one of the last sectors. It's of course always a political decision, what will the European parliament decide in the next weeks? This will have the biggest impact. It would be advisable to make those decisions for all sectors at once, but this are political questions, and we will know more in a few years.
To summarize, my guess is that the automotive sector will have to wait a bit longer, without saying if that's reasonable or not.

2.What are the biggest advantages of E-fuels in your opinion?

You would have an instant CO_2 reduction possibility. If you had e-fuels ready for the mass market already, you could instantly reduce CO_2 emissions. Not like BEVs which might help us in 10 years' time to reduce emissions. This of course depends on the amount you drive.
I don't know exactly but we have a very high number of combustion vehicles world-wide, so even if we said we switch completely to electric vehicles, these old vehicles will remain on the road. We can't change that in Germany, and this won't help the world climate in my opinion. Further, with the current crisis, you would become independent from oil exporting countries. E-fuels need to be produced somewhere as well but mostly these countries are democratic.

3.What are the biggest disadvantages of E-fuels in your opinion?

The price is currently the biggest disadvantage. Only if large scale refineries and production sites with a high capacity the prices will drop, and e-fuels will become economically feasible in comparison to fossil fuels. Next would be the efficiency in the production process, you can produce e-fuels anywhere, but it only makes sense in regions with low prices for renewable energy. In Germany for example we don't have these high energy potential like in Morocco or Patagonia. Those are the places you must focus on.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

Porsche will start this year or maybe next year and I think the price for a litre will be around 3€. I think, in 2026 when the production scale is much larger, it will become cheaper. I think they sill estimate 2€ but compared to current fuel prices this could become competitive. In terms

of efficiency, you will always need an electrolyser. Those get more efficient with continuous development, but I am not sure how much more development is possible in this field. Fraunhofer has an electrolyser with 80% efficiency, which is state of the art now. The more efficient the electrolyser the more efficient the production process will be, so you need less electricity to produce hydrogen for example. In theory renewable energy is unlimited. It just depends on the amount of infrastructure you are building. The only question is if it is economically feasible. This is the only reason; investors will invest or not. If you want to build a plant in Hessen, Germany nobody is willing to invest because the plant's production capacity will be too low. That's the reason why the high energy regions are the only possible solution.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

In my opinion the focus on just one technology is fundamentally wrong. We do this in Germany but nobody else worldwide is doing this. If we stop to develop combustion engines, a year later China or Japan will develop these. The US will continue as well but we would lose our knowhow, because we are currently sill building the best cars in the world. Besides that, we would mess up our own economy if we would go this way and prohibit the sales of combustion engines in the future.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

The German market is small compared to China or America. I think in Germany a lot of premium cars are sold compared to the rest of the world. But this is typical for most industrialized countries. If you compared to India, they are still driving a lot of old vehicles. So, in general we have a highly developed market and world-wide there is more technological openness.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes, they are heavily influencing the development in the transportation sector. Since one or two years you can lease a BEV in Germany for almost nothing. These incentives are costing the stat billions and you make one technology way more attractive. You are forcing it upon consumer because prices are subsidised so much compared to combustion cars. You are changing competition. If those incentives stop, I think the government knows this as well the sales of these cars will massively drop. BEVs are extremely expensive in the production and without the incentives the consumers might decide they preferer a combustion car.

8.What are your thoughts on a global e-fuel production process?

Without using the global potentials an e-fuel process will not be viable. You need to utilize the high production capacity for renewable energy in high potential regions. In Germany alone this process will never be competitive.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

Yes, I think so. The technical side of the production will become a possibility for Germany to develop a competitive advantage. We need to make sure to keep the leading position with technologies for renewable energy, or hydrogen electrolysis. We need to partner with other countries early enough and build the infrastructure there to produce jobs and economic development for both.

10.What do you think will be the global choice for carbon neutral transportation?

I don't think there will be one solution. I think all three solutions: Battery electric, e-fuels and hydrogen cars. It will never work with one technology only. Plans won't fly electric in one hundred years. This is technically not imaginable at the moment.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

It needs to be a mix. Even If you don't have enough e-fuels instantly, you can use them as a drop additive. I forgot to mention that earlier. You don't have this possibility with BEVs. The fleet is just renewing every 15 years and the cars are used elsewhere afterwards.

12. What do you think will be the best technology for Germany?

Depends on the mobility need. For a delivery car in the city, electrification is surely suitable. The same with a small city car (If you have the charging infrastructure). Just because you can avoid local emissions. With e-fuels you would still have emissions in the city, even if they are little. So, for cities electrification or hybrid vehicles. But for long distances electrification is not the best solution.

13. What do you think will be the best technology for the whole world?

It will be a mix globally. Even if we focus on electrification, the world won't follow. China has large development programs for hydrogen engines and e-fuels. We can do what we want but the rest will most likely follow a different path.

Interview II

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes, I think they will play a role.

2.What are the biggest advantages of E-fuels in your opinion?

The biggest advantage is the existing car fleet. They can be used CO_2 neutral. In Germany we have a new car fleet every 14 years. Therefore, we will have the cars on the road for a longer period. We need to work with these cars now. With fuels we can generate a large reduction immediately.

3.What are the biggest disadvantages of E-fuels in your opinion?

The time until we have large enough production facilities for the big market. The amount available is not sufficient and we are talking not years but decades here. Here a lot more should

happen now. We need politicians to say, "hey we are doing this" and then the big refineries can rely on that and build infrastructure.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

The biggest problem will be to produce renewable energy cheap and in sufficient amounts. We won't produce e-fuels here in Germany but in countries with a lot of wind or sun and therefore the production of energy is easy and cheap. This is a general problem. All energy needs to be renewable in the future.

4.2. Do you think the infrastructure plays a key role in the mobility?

We have a good infrastructure and the using the existing infrastructure is the most sustainable solution. We don't need to build wall boxes for everyone.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

In my opinion, the existing infrastructure should be used and one by one we will transition towards renewable fuels to reach climate neutrality. But of course, there won't be "one solution" in the future, we will have a mix. We will have different drivetrain technologies and use cases, and everything has its advantage. Inner-city electrification is undebatable but nevertheless the combustion engine and with-it e-fuels will have their use case. The mix needs to be right.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

In Germany we have a large substitution of electric vehicles and therefore they are pushed into the market. We don't see this globally and resulting not that much electrification. My personal opinion is, without incentives the amount of electric vehicles we have currently wouldn't be possible.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes, we have a large influence from politics. This will become more drastic in the future. Mobility is becoming a luxury and not everyone will have a car in the future. The number of cars will be reduced but this is just the way politics want it now. Individual transportation will be reduced, more expensive, no room in cities etc.

8.What are your thoughts on a global e-fuel production process?

That's the only way it will work. Just like we are not getting our oil here. This is a global market, and we can place ourself here in Germany with the technology by saying: the raw material will be produced in countries where it is cheap and we will focus on the refinery here. This is a global process and cannot be done by one country alone.

9.Do you think a leading position in the production of e-fuels can be competitive advantage?

Yes.

10.What do you think will be the global choice for carbon neutral transportation?

Not easy. I think this is also dependent on the country or continent you are looking at. It will be a mix, like in Germany. If you have a lot of long distance uses e-fuels will be used but in cities electrification. Both will co-exist, and hydrogen will definitely play a role as well.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

It depends on the goal. Are you talking about time or efficiency? So how long does it take or how much renewable energy will I need? Fast: e-fuels or electrification both take time. So there is no difference. From the efficiency, with the transformation we are better with electrification. But the storage option is very important, and we will see how it will develop in the future.

12. What do you think will be the best technology for Germany?

Here I would say a mix as well. Personally, I think in Germany a hybrid system is best suited. You can use combustion advantages with electrification combined. That's the future for me.

13. What do you think will be the best technology for the whole world?

Mix as well. But maybe less battery vehicles and more combustion technology. I think the purchasing power will play a large role here and often the infrastructure for charging is missing.

Interview III

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes partly. One point where e-fuels can play a role is the stock fleet. The existing cars today with internal combustion engines and the new cars in the next decade will benefit from the development of e-fuels. And a variety of special projects like sport cars or cheap long-distance cars. All kinds of niche use cases. Depending on the sector maybe heavy-duty vehicles.

2.What are the biggest advantages of E-fuels in your opinion?

Generally, the biggest advantage is that you can transport and trade energy from all over the world into the regions you need them. Most of the time you won't find dense population in areas with high energy potentials. E.g., Greenland or the desert in Morocco or Patagonia.
Secondly, e-fuels are a product that can be efficient, if the sweet spot for the factory is met, and it is effective in climate mitigation because it can have an effect right now and not in 10-15 years. Thirdly, it is a possibility for many regions to enter the value chain because now they don't have many options to enter but they could in the future provide energy. But that is exactly what strategists and politics in corporations want to avoid because they want to keep those regions out of the value chain.

3.What are the biggest disadvantages of E-fuels in your opinion?

Now it's the price. Because if the price was low the efficiently wouldn't play any role. The Prometheus project is currently the most important project because it is trying to enable the process at atmospheric temperature and pressure which would double or triple the efficiently. After the cost it is the efficiency. You need to produce at factory sweet spots to reach desired efficiency levels. The positive aspect about the efficiency is that since it is not very efficient, yet, people are working on the efficiency extremely. Because we are not pushing e-fuels with money, like we are pushing with electric cars, we force the technical development in this field to make them more efficient. Third is that e-fuels are carbon neutral but not zero emission. So, you still have a combustion process. With EU7 you have a practically emission free combustion engine. The air out of these engines might be cleaner than the air in some cities world-wide. But for many people it is important wo solve their problems in their regions, so they don't care about the BEVs disadvantages for example, they just want to have zero emission.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

Yes, the price will come down if you look at the projects currently running, we will see prices below 1€ and therefore competitive to fossil prices. They became more expensive recently, as you know, with the Ukraine crisis With Synhelios and Prometheus we will have prices that are competitive to fossil prices because the efficiency in the process. So, the price problem will be solved, and Europe is losing its advantage here because the efficiency can be solved with the new processes. The sweet spots will provide enough energy. Lastly, the combustion emissions will be addressed by the new engines developed under the EU7 regulations. And very important as well, hybrid vehicles called EXHAV. This are highly efficient hybrid vehicles using the recuperation potentials in vehicles. It is like the Prius.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

Audi will stop producing in Europe 2033, but they will continue to produce combustion engines in China until 204X and they will release the last new combustion engine in 2026.
Every company is now trying to sell combustion engines to finance their transformation and the next thing is the rebound effect. You may know it from a Mckinsey Energy report: Every new technology developed, we will still see the old technology, but the development will go to the new one. But due to the whole world we will still see a lot of combustion engines. The strategies of many large corporations like Shell or Bp or all the large OEMs is they don't want to tell you this story, because it will damage the story currently out there about electrification. So, nobody wants to talk about it but everyone is doing this.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

The whole market around climate neutral mobility, is an incentive market. A company like Tesla gathered billions in incentives in the last years. Compared to e-fuels there are no incentives, currently. Which, like I said earlier, this is good since it pushes the developers for higher efficiency. If we had a functioning CO_2 market, we would have a very different sales structure. The problem with e-fuels is that you must integrate other countries into the value chain and of course politicians don't want that because they depend on the voters, and they want the jobs locally. You can't solve any global problem with excluding somebody from the value chain. So, we have an incentive market and if these incentives die, I suggest looking back at the solar

panel market in Germany, after the incentives went away the market broke down and was taken over by China.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes so, as I explained they are interfering extremely. It's not only about efficiency but it's about sufficiency it's about reducing mobility and global impact. Now we are seeing the contrary, you can sell a 3 t BEV with zero emission because the carbon footprint doesn't matter. All BEVs get zero. It can be a Smart or it be a Jeep, it doesn't matter, the same carbon footprint in terms of regulations. Politicians are trying to offer their voters a solution, which must be clean in their eyes. They are massively taking action here in an ecologically wrong way.

8.What are your thoughts on a global e-fuel production process?

The process depends on the production sites and those depend on the high energy regions. A good example is Chisang in Thibet. So here you have a political interest so regions that have not yet been integrated in the value production can be relevant. It is a matter of global politics. The trading with these regions is different from now. Today energy is extraction. We are just extracting resources but in the future the energy production potential will play the largest role and you will have lower margins ofc. Because extraction is always cheaper than production.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

You mean a region or a company? Let's talk about countries so as I mentioned the sweet spot is important so the high potential regions will become relevant. We missed the point in Germany where we could have become a technology leader. We are still talking about it but not developing anything. If we had decided the green deal differently 2 years again, it would be different but now we will see China or south American investors leading in this field because of our politics. China will be leading in regenerative energy, and I don't see any advantage in Europe with this technology and Germany won't play any important sweet spot card because we don't have those energy potentials.

10.What do you think will be the global choice for carbon neutral transportation?

Because of the rebound effect we will see a very high fossil part in the next decades. Just because of the price and regions billions of people are going to cheap technologies. We will see a high amounts of electrification because of the investments and the building of a new electric society is the perfect solution for a transformation but it's not ecological because you need billions of resources for it. It's just good for the GDPs because everything must be built new. We see kind of a global energy Marshall plan. In percentages there will be a very high electrification growth but since other markets like Africa are also growing as well, we will not see 100% EVs in 10 years. If prices for electric fuels can fall with new technologies, we will see a big role there and if countries would measure their impact globally. Distinguishing between molecules just the pure effect. We just have to substitute fossil ones with synthetic ones.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

This transition is like transforming a house. Now we are tearing it down and building it new. Because of what we are doing, we will not see a relevant effect in the next decades. That's what I call the waterbed effect. We are pushing it down on one site and it's going up on the other. Because we are only looking at sectors and countries and not the global perspective. The most effective way for CO_2 reduction would be a law for cars to run 300/ 400 thousand kilometres with law enforced refurbishment. At the same time a high EV sales rate meaning that if you buy a new car, it should be electric or highly electrified and high taxes on large and resource intensive cars. Of course, nobody wants that. If you take the CO_2 balance of a car with 200.000 Kilometres this car is almost at the end of lifetime. If you now take this car and refurbish it and run it with electric fuels, you will have the best possible CO_2 reduction. A law forcing high milage / long use times and a forced refurbishment would lead to the best effect combined with a high EV sales rate for new cars. But this is not happening. It's always industry interests. We don't have a model now. How can we bring emissions down in our system? It's a failure of our global capitalistic system and we don't have a solution yet. How can we bring emissions down in a system that is based on growth?

12. What do you think will be the best technology for Germany?

That will depend on the CO_2 balance boarder. I call it the Astypalaia effect. That's the Greek island where VW has announced they will bring all the cars and infrastructure to make the island carbon neutral. One island can become climate neutral in one week. Bring the new cars scrap the old ones. Germany and Europe have a tank to wheel system for their own. With a tank to wheel system the carbon leakage is extremely high. An EV will always be the best solution in that system. You buy an electric car abroad and the Chines will pay for the emissions. You will have climate neutrality because you just measure in your own boarders. If you have international measurements, then you will need to combine solutions for the stock fleet and solutions for the new vehicles to enable a clean transition.
We see with everything happening currently, like the Ukrainian crisis, that this transformation will not be done until 2050. I like to compare this to a marathon. If you train for 20 weeks like you should, you will run 840km. 800km training and 40km for the final run. 95% is the training. And we are seeing that here. The transformation time will be long, and we are not discussing it properly.

13. What do you think will be the best technology for the whole world?

Germany because of the extreme wealth, which comes from extracting resources from all over the world and transforming them into high price products, is like an oven, we are always trying to put more resources in, to make more money, to generate even more technology solutions. And as resources have no real price, like cutting a tree down has no price worldwide, we can continue with this. And we can afford to have incentives for transforming in Germany very quickly. But on a global scale it can be a dead-end process for the 1.5C goal. We can only do this because we have the money for it. If a BEV would cost 10k and the energy would cost 50$ Brazil would probably order 10 million cars today. That's why we need the incentives because the cost of ownership is not down yet. You have two people in this game. One is using it and maybe producing it and one is delivering the resources for it. Those countries which con not afford the switch now are delivering the resources. Once we are filled up, we will start to deliver cheaper cars to these countries as well. Your first car might be a BEV but for countries with less GDP the question is, are enough resources available? Like Lithium etc. to deliver in those countries as well. Using e-fuels for the stock fleet is not effective for them as well now. Why use e-fuels when you have the cheap alternative fossil option available. It's a very complex process

that can be totally skipped if the e-fuel technology would offer a very cheap solution. In the moment fossil and e-fuels break even, or it becomes cheaper, we will see a fast penetration of the technologies.

Interview IV

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes, I think they will, but the EU needs to change their focus. The Eu is currently focusing all their efforts on electro mobility and there is only a small effort towards e-fuels but most of all on H_2, but the focus on e-fuels is not there. If this changes the e-fuel focus in the automotive industry will change as well. But I don't think this is very likely. It's not financially important enough for the automotive industry now at money is rare.

2.What are the biggest advantages of E-fuels in your opinion?

You do not have to change anything on your technology because everyone is developing new BEV cars and they are really struggling to achieve the desired levels of range, performance etc. And you don't need to change the infrastructure because the infrastructure already exists around the world. For example, for me it was a game changer, I am currently looking for a new car and I will probably buy a BEV and in Germany it is fine but if you drive long distances, I mean long distances like to go on vacation in south Italy, I don't know if there are any charging stations around. This is a large downside for me. Another factor that a lot of people are underestimating right now is the effect when you try to recycle or reuse a batterie what the effect on the environment really is. It's not really covered by the media, and you consider an electric car as green always. That's what they try to convince you about and I think this is a big issue.

3.What are the biggest disadvantages of E-fuels in your opinion?

The energy efficiency is a big disadvantage right now. It's still not very efficient to produce e.-fuels somewhere in Africa or wherever and transport them to western countries who need them. I mean there are not that many cars in Africa, so the use is not that high. So, you need to consider other options on how to transport energy. I think it's the same problem with BEVS, you can't really transport the energy for them as well. But this is an even bigger issue for e-Fuels because you lose a lot of energy in the production process.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

Yes, I think so. It's mainly a problem of investment. Not many companies are investing right now or not enough. When you start investing in these technologies they will get better and better. The same as with electromobility right now. If you would invest more in e-fuels, you could solve these problems.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

Audi will start the sale last new combustion model in 2028 and I think they will produce them in Europe until 2032. It's a different case in China and the US depends on Biden. A good

transition could work with e-fuels, but I don't think there will be a full transition. The transition is dependent on the regulation. If you stay with the current situation from the EU, we won't need E-fuels. The strategy is completely based on electrification. So, we will be fine with BEV cars in 2030. You could use e-fuels but you don't really need it. It totally depends on the focus you have. If you must become carbon neutral five years earlier, you will need e-fuels. I know from my organisation that we can fulfil our goals in 2030 and we will meet the EU regulations. But personally, I think we should get out of fossils as fast as possible. But this focus is not shared by the Top management now.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

I think Germany is still playing in the frontline for car development, but we are underestimating Chinese companies like NIO. And yes, they are mostly gathering information we build in the last decades, but they are super-fast with it. If you look at them in the last five years, they are incredibly fast and how they are growing. We are and especially the VW group is really slow. We are a big tanker, and you must ask a lot of people all the time. Our decision process is too slow and in five years we probably won't be in the front row anymore.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes, yes that's what I said before. They are playing the main role. They are basically deciding what's going to happen. If you buy a new BEV, I think you get incentives of 6 thousand euros. They are basically deciding what's going to happen.

8.What are your thoughts on a global e-fuel production process?

I think it is going really slow and it's kind of sad. I know some people in our organization are working on it somewhere in the technology department but it's a small team and they are not getting sufficient funding. If you look at our fleet planning for the next ten years, it probably will not play a significant role. Its politics driven that it is not considered an investment anymore. I guess if there would be a company like tesla came around and invested a lot of money into it. Like tesla did with BEVs, something would change, and the focus might switch.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

Right now, no.

10.What do you think will be the global choice for carbon neutral transportation?

I think it will be electromobility. But I think the problem is that we don't see the bigger picture. We always focus on one little segment, and we lose the bigger picture. That's why we choose electromobility because we like to believe its carbon free but actually it is not. Electromobility is not carbon free.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

I would do a mixture. I think there are use cases where electromobility is great but there are additional situations or industries that will need other technologies. For long distances I think e-fuels will be better. In my opinion it should be a mix with systems where people don't drive alone anymore like busses etc. but there probably will just be electro mobility.

12. What do you think will be the best technology for Germany?

The best technology in my opinion would be a mixture as well.

13. What do you think will be the best technology for the whole world?

No, it's the same a mixture as well. For very rural areas it might be a bit different, but this depends on the living situation not the countries.

Interview V

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes. I think e-fuels will play an important role in the automotive industry because of the diverse applications. We have the individual transportation and heavy-duty transportation and e-fuels, liquid electricity-based fuels, can replay the fuels standard today. Further we can mix them with fossil fuels to reduce their impact and every combustion engine existing today can in the future be operated CO2 neutral. Therefore, we see a clear possibility to include e-fuels in terms of climate mitigation and regulation in the future. We think we don't need to solve the climate problem by changing the drivetrains but by changing the fuels used in our existing cars today.

2.What are the biggest advantages of E-fuels in your opinion?

There are many advantages you must name. If it should really be the biggest advantage, it is the possibility to use them in the existing cars. You can mix e-fuels with fossils starting from 1% up to 100% decreasing emissions gradually while building up the production. We don't need to adapt engines, there are no concerns for using them since they are able to follow all existing fuels norms.

3.What are the biggest disadvantages of E-fuels in your opinion?

If you want to call it a disadvantage, you need renewable energy for the production, as the name suggests, on a large scale. Resulting, e-fuels are a product not suited for production in energy scarce areas of the world. North Europe kind of belongs to these areas. With the high electricity demand, they will be produced in areas with high renewable energy potentials to cover these large energy needs. A second point could be the need for carbon. Ideally it is not a fossil source but a biological one or filtered out of the air and this process consumes a lot of energy as well. Summing up, green energy demand is the largest problem of e-fuels.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

Yes, I think you can overcome this problem. There are different studies proving it is possible. The newest one I know is the "Power to X- Atlas" from the Fraunhofer Institute, which looks at potential to produce renewable energy globally. It shows really a good potential for Ptl

(Power to liquid) and it factors in the political debate as well. Researchers included all of this in the study. Therefore, we believe it is possible and the Power to X strategy will additionally lead to more renewable energy production. If countries themselves are incentivised to build new infrastructure, it might happen but with a direct consumption facility next to it the incentive is much larger to build this infrastructure in those areas. These plants would also be able to cover all the local demand for renewable energy. The best example for this is Chile, with the Hongqi project with strong winds. This project is not connected to the countries power grid but it is clear that such a project can produce more energy than a non-industrialized state itself would need. These are positive balance places and they can become energy exporters in the future. Therefore, thinking globally, enough green energy is available to follow such a strategy. Do you know the red square in the desert? The length is a large area, but it shows how much space you would need to cover the worlds energy need with solar energy. This just shows there is a great potential to45nlockck in the future. We have many possibilities, and we just need to utilize them. I think we can produce enough green energy globally and with Ptl technology this green energy becomes tradable globally.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

To reach carbon neutrality in our opinion no transition is needed. With fuels based on electricity we don't need a transition. Of course, you can use direct electrification where it is possible. This makes sense for certain use cases. But a complete transition doesn't have to happen in our opinion.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

If look globally, we have a high concentration on combustion. We have a few countries with higher gas usage than in Germany, this is an exception here e.g. in Italy or former sowjet states. I Germany we have a strong focus on Diesel cars as well, this is different to other countries. But in heavy duty Diesel is the dominant choice globally. Looking at hydrogen, Japan is definitely leading. This clearly differentiates them with the strong hydrogen focus. China, in my opinion, very diversified. One could say they are technologically open. And of course, direct electric, Norway is defiantly leading in Europe with direct electrification. They have a high green energy share in their electricity. Germany, the Netherlands, France are typical electrification counties, and all others are more like islands. The USA has areas with high electrification but not generally. If you look at regulation, Europe is on its way to ban combustion engines. Zero emissions in the new car fleet. Therefore, just electric vehicles can be newly registered form 2030. If this happens, Europe will move to a single position just focusing on one technology in the future. You could call it a unique selling point.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes, politics impact the automotive industry because manufacturers always must adapt to regulations. I want to mention the CO2 fleet regulation here for new vehicles. Politics set the rules here, with their tank to wheel approach. Euro 7, the next point. Emissions are clearly controlled on a European basis. Just one example, everything regarding taxation or inactivation to use one or the other technology results in a heavy impact.

8.What are your thoughts on a global e-fuel production process?

In our opinion the global perspective is determining. We believe that Germany as an industrial state will continue to depend on energy imports in the future. A certain percentage of these energy imports need to happen in the form of liquified electricity. We need a diversified mix of energies. Perfectly suiting now, the topic of resilience and supply security in face of the Russian energy embargo. E-fuels can just be produced efficiently at places with good green energy potentials. If you utilize those, e-fuels will be produced at a price bellow 1€ per Litre. Due to this price potential, we think e-fuels will also be used in heating. We say: "E-fuels are a global solution for a global challenge"

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

It depends who you want to focus on. With e-fuels there are the classical fuel producers. The mineral oil industry clearly sees this topic. Saudi Aramco is starting the production of Ptl with ammonia. This might not be suited for the transportation sector, but it shows they are interested in this topic. You could classically assume that the mineral oil industry would dominate the e-fuel area, but it could as well be the plant builders like Siemens Energy.
In my opinion this area is currently under development. Porsche in combination with Siemens Energy, there are different new players entering the market. There are different parties interested in entering this segment. Large logistic firms, airlines many different people have a high interest in this field. This is still very open but clear is: The one producing e-fuels cheaply first, can capture the global market. This alone will be an advantage. The first mover with e-crude will have a leadership advantage.

10.What do you think will be the global choice for carbon neutral transportation?

I think globally we will have a mix. Different drive technologies will establish themselves. But if you take climate change seriously, you cannot just measure at the exhaust. A car is just as climate friendly as the energy it utilizes and needs to be produced. These challenges for green energy need to be met. With everything regarding hydrogen, the fuelling infrastructure is very expensive, and it has the same problems as all the other, green energy is needed. If you want to change the climate impact of mobility you need to change the energy source used. Other counties are leading in alternative fuels already like Biogas production.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

The biggest leverage is proven to be found with the replacement of existing fuels with renewable ones. No new production, saving resources, protecting the existing fleet.

12. What do you think will be the best technology for Germany?

It depends on the development of our mobility. How will our work situation or housing change? How will cities develop. Different mobility needs: short distance, long distance, logistics, personal transportation, by car or train. Those are very different. Work from home or working in sales and driving a lot. We need to let the consumer decided for the best solution to their need. Technology openness based on market mechanisms is the best solution. The consumer should decide based on, ease of use, cost, lifestyle, why not? All those aspects and he or she

needs to make a free choice. Then we will see a diverse set of technologies being used. This would be ideal.

13. What do you think will be the best technology for the whole world?

The same here. We will need a mixture. There won't be one technology dominant in the future. Once more, the technology does not determine if fossil resources are consumed or Co2 is reduced. The goal is: no new Co2 emissions. The consumer will decide which technology suits their needs. If the consumers will focus on climate neutrality is a different topic. Currently we don't have a functioning Co2 pricing system. This could set new incentives in the future and help solve our issues.

Interview VI

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes, I think they already do. It's a very controversial topic. You can't say if you will see it in the product offering of manufacturers, but it is a large discussion. We will see what the future holds for e-fuels.

2.What are the biggest advantages of E-fuels in your opinion?

I think there a two main advantages. First, they make high energy potential regions usable for consumption. Meaning you can produce energy in those remote regions and directly use them to produce e-fuels. With electro mobility we always talk about how efficient they are, but you need to charge them with renewable energy produced in Europe. An e-fuels can be produced outside of Europe and then imported. So, you make the renewable energy potential in those regions accessible by transforming the electricity into fuels and making them transportable and tradable as a commodity. This additionally leads to resilience, because you don't depend on three or four large fossil fuel producers, with questionable political systems, but can source e-fuels from different regions globally.
Secondly, we can use the existing fleet and cars we will sell during the next ten years climate neutral. Those cars will remain on the road even after 2040. I personally drive a 17-year-old car. To use those climate neutral with the existing infrastructure is a huge advantage. This is really sustainable. No Electromobility fan can tell me its sustainable and resource friendly to get rid of all combustion cars and build new electric vehicles and drive those with energy we might produce sustainably by then.

3.What are the biggest disadvantages of E-fuels in your opinion?

It won't make any sense to produce them in Europe. That's not a big problem, since we are exporting a lot and if we would be autarch that would lead to problems as well. We are exporting cars and other products and to balance it we can buy energy outside to balance our trade sheets. It's not a big problem but from the autarchy thought it makes only sense to produce e-fuels if you have a lot of green energy and can't use it differently in a direct way. This is the case in the remote high potential regions. Here we face the big problem, how do we build the large infrastructure needed in those places. In some of those regions we don't even have streets or human civilization. We are talking about billions that need to be invested. And not all these regions are in Australia or Chile, some of them are in questionable or unstable countries. Here

we need to find a way, to get investors to spend those billions. The water problem that's often mentioned, is not that relevant in my opinion. You can extract salt from ocean water and use it. This will make a difference of a few cents per litre. Of course, you would need to build these plants with a large enough capacity to ensure the support of the local communities. So, you can offer them water in water scarce regions. You need to raise the acceptance locally in these developing regions, to produce energy for the rich Europeans. If you don't secure the acceptance you are sitting on a bomb. You can only solve this by building additional capacity to supply the local population with water and energy. To build the large infrastructure projects in the time we have left will be very challenging. I always say, better late than never. We can keep discussing for another decade and then realise electromobility alone won't do the deal. I probably tell you the same as my colleagues. We don't have a lot of time and we need to be fast. Five years are nothing. 2030 is already missed. The fruits from what we build now can be seen in the thirties maybe forties. Time is a big problem.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

Yes, as I said previously, you can overcome those problems. But you need to find an incentive system because no organization is building additional capacity for free. The problems are from political nature as well. A big problem is for e-fuels the acceptance in Europe. We are lacking an accreditation system here to reward the use of e-fuels. Fleet efficiencies are forcing towards electrification and the renewable energy plan from the EU does not lead to e-fuels and that's why we don't have them. It's just a regulation problem not a technical problem.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

Both technologies will coexist. Probably we won't see a full transition at any point in time. Some countries will do this but not even the Chinese are transitioning completely. The Us does not transition all of them are just doing it partly. We are currently transitioning very ambitiously but I am not sure how long we will continue this. But we will need to use both of our hands in the future.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

With the burden sharing concept within the EU, Germany always needs to do a little more than the other countries. Therefore, we are seeing more electricity comparing to, I don't want to name a country, but we will see lees electro mobility in Romania or Bulgaria for example. Some countries maybe fight the transition a bit as well and others are faster than Germany, Norway, or the Netherlands for example. Germany will be a bit faster than others, but the fleet is quite old already. That's the problem with the fleet regulations. Manufacturer
s are forced to build more electric cars, but somebody need to buy them of course. Maybe not everyone is ready to buy a BEVs. The infrastructure and other thinks are hindering the process as well.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes, massively. We are talking about driving restriction. Speed limits is more a religious topic, but yes regulation forces the development. Politics are forcing the development, with the

regulation, that climate sustainability is electric in the mobility sector. There would be different solutions to these problems. In the electricity market we have a CO_2 pricing system. We are reducing the emissions and let the marked decide the solution to solve it. In the mobility sector we don't have this system. Here we are saying, you drive electric full stop. Or you don't drive at all. This might reduce emissions even further.

8.What are your thoughts on a global e-fuel production process?

E-fuels need a global process. We need to produce them everywhere possible, and it needs to be treated as a commodity. Here the definition is often leading to confusion. A lot of people believe e-fuels are just gasoline and diesel but its everything you produce out of electricity like hydrogen or ammonia. But well, this is not our topic now. Saudi Aramco is starting the production, and this will be the first thing developed. It's, comparatively, a simple process. To transport hydrogen is very resource intensive. So, this won't happen. I don't know if someone already told you this but it's very inefficient. It's completely crazy but of course there is room for innovation as well. But in the near future we won't see a global hydrogen trade. We will see ammonia, methanol which is a rather simple process, needed in a lot of chemical processes.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

Yes, for the companies producing it. How could it be different? If you can produce it at a competitive price point or if you are able to force consumers to buy it with regulations, you will have a great advantage. You will create wealth in the countries producing e-fuels and they can export it so it's a win-win with regional value creation potentials. I don't really understand why the mineral oil industry is not more interested in this topic. I don't know if you talked to someone, who told you this, but they always say, if Europe doesn't want fuels anymore, we will just sell them somewhere else. We don't care. They are very radical. I don't understand why, but that's often their position on e-fuels.

10.What do you think will be the global choice for carbon neutral transportation?

There won't be a single solution. It will be a mixture of technologies.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

The right answer it: It depends. On the region you are and the situation you are facing. There are regions, where electromobility for example is no real option. In a very hot climate, the batteries don't last long and need to be cooled constantly. I think if you can produce an e-fuel cheap somewhere remote, where you can't use this energy differently, they are a great solution for reduction. Electric cars are good as well but only in the long run and if they are used under the correct conditions. Context is King.

12. What do you think will be the best technology for Germany?

E-fuels from high potential regions and electro mobility in the right conditions.

13. What do you think will be the best technology for the whole world?

It always depends on the regional conditions and a mixture will be needed.

Interview VII

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Short Answer: No. Maybe in a really really limited extent. Some vehicles like ambulance or military vehicles we will see e-fuels but not for the mass market. Even for Trucks just in a limited extend. It's just the decision was made. Especially for the OEMs, they decided they want to focus om electromobility.

2.What are the biggest advantages of E-fuels in your opinion?

They are quite simple to transport. In particular H_2 is difficult to transport so e-fuels have a large advantage here and their infrastructure does exist.

3.What are the biggest disadvantages of E-fuels in your opinion?

The huge amount of energy you need to produce them and the emissions you still produce. The combustion still happens.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

No, I don't think so. The amount of energy you need will limit the use cases. Green energy wont we available at a large enough scale to produce e-fuels for the mass market.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

You still need the combusting engine cars for the automotive industry. They are currently the cash cows. But with the regulation they have a certain limit of carbon dioxide for their sales. They need to sell BEVs to stay within the limit.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

It's not the German market but the European market. The regulation is the same everywhere in Europe and its quite a strict regulation. We had a meeting with Honda at the beginning of the week and they guy from Honda told us: Their colleagues from Japan laugh about the end of the combustion engine in 2030. They think it's too stupid of an idea. So, the regulation is quite strict and in other markets it is not like this. And the regulation has a strong impact on the automotive market.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Definitely. It was a political decision. These zero grams of carbon dioxide. How you want to measure it. It's absolutely critical and those decisions were made. There could be other regulations, but the rules are set now. They set the agenda and lined out the process.

8.What are your thoughts on a global e-fuel production process?

Quite interesting. I said in the beginning e-fuels won't play a role in the automotive sector but there are other combustion engines where we will need them. In aviation or maritime transport, they will become quite important. If you can produce them, it's a big achievement.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

Yes, of course. In terms of the automotive industry, it's not that advantageous but for many logistic processes it can be. They are relying on ships and planes and if you can produce the fuel for the production of a globalized world, it can be a big advantage.

10.What do you think will be the global choice for carbon neutral transportation?

Depends on the transportation. And global is quite hard to say. If you are in developed and urbanized counties like in the EU, it's definitely for cars electrification. But even in the EU, if you look at the eastern part, like Bulgaria, there is not electrification soon. They don't have the infrastructure. And continents like Africa or India, no chance. If the combustion engines are forbidden in the EU, in countries like Romania or Bulgaria they will use the old cars as long as possible. If we are just talking about cars, in the developed and industrialized countries, definitely electric. In less developed countries they will use combustion engines as long as possible. I am pretty sure they will use fossil fuels since they are cheaper, and they usually have those fuels available. For ships and planes most likely e-fuels until other solutions are available.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

Personally, I hate to fly so I always take the train. I don't have a car, I work in the automotive industry but my personal opinion is in cities you don't need a car and there has to be a big change. My personal opinion is the automotive industry needs to change to a mobility industry. We need new concepts and all of this. In more rural areas cars defiantly.

12. What do you think will be the best technology for Germany?

Depends on where you are. Mostly electric vehicles.

13. What do you think will be the best technology for the whole world?

Depends on the region. There is no sense to drive an electric vehicle in the jungle. Its highly dependents on the region you are in. It would be great if those regions could use e-fuels to make their engines green, but I think this won't happen. Because these regions are mostly poor and don't have the resources to buy these fuels.

Interview VIII

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Yes, I think they will. You have different use cases and applications for e-fuels, and they will play a role in the individual mobility. Mobility has many faces. On short distances without transporting heavy stuff electromobility will be dominant and this is effective. If I need to drive a lot or carry a lot of weight electromobility is currently not the right option. If you drive a caravan camper from the Netherlands to Italy electromobility is maybe not the right choice. Worldwide we have a fleet of 1.4 billion combustion engines vehicles and the prohibition of these is a very European discussion. If we want to reduce the climate impact of these vehicles, we need a solution to enable these vehicles to stay on the road. Further the infrastructure is existing. Therefore, I believe e-fuels will play a role in the automotive industry in the future, even if it's still debated. I think we could be a lot further already with climate protection if we stopped this discussion. Additionally, we will need e-fuels for Aviation, Ships, and the chemical industry. These won't work without e-fuels. It won't work with electrification only. Just with electrons or just with hydrogen it wont work. We need the carbohydrate fuels. To stop climate change we need to build a circular carbon system. It won't work without but currently we are dependent on the political regulation to set ground rules. Right now, the automotive industry is regulated with a CO2 fleet emission and a BEV always has zero grams emission. With the current regulation e-fuels wont help manufacturers because you always have combustion emissions. This is why we are fighting for an accreditation system for e-fuels to be calculated in with the fleet efficiency.

2.What are the biggest advantages of E-fuels in your opinion?

The biggest advantage is the existing infrastructure and that I can use the existing vehicles (all of them: Ships planes) and address climate change directly. I don't have to wait like with electromobility for the effect to become visible. I don't think we have the time to wait. The CO2 concentration in the atmosphere is cumulative and the faster we start to reduce our emissions the better. Further we don't need a switch on the consumer site. I think this is a great advantage as well. We see it with green electricity in Germany. When consumers don't need to change their products or habits the transition is much easier. You don't need to buy a new refrigerator or something.

3.What are the biggest disadvantages of E-fuels in your opinion?

The efficiency. But that's too simple and does get addressed too often. In the process we have a few conversions and with all the intermediate steps you lose a bit in efficiency compared to direct use. Its electricity to hydrogen, hydrogen to e-fuels and then the combustion process. Here you lose a lot of energy in form of heat or similar. That's why we argue it doesn't make sense to produce e-fuels in region with green energy scarcity. That's why we won't produce large amounts of e-fuels in Europe. Maybe in Portugal because we have better solar and wind potentials but mostly, we will be focusing on ideal production potentials. Regions with high potentials and low local energy demand. Porsche and Siemens are producing in Chile because there you have almost 8000h of full capacity wind. That's four times as much as a comparable installation could produce in Germany. This largely compensates the efficiency problem. Further you can easily transport e-fuels. You can send a large tank ship form Chile to Rotterdam without losing any energy during the transportation. Unfortunately, this aspect is often neglected in the efficiency discussion. If you don't produce e-fuels in Patagonia, the potential would not be utilized. There aren't enough people or other use cases for these amounts of green energy. There are many surplus potential regions worldwide. We don't have a problem with scarcity there, but we need to utilize these potentials. For the utilization we need the capability to store energy and that's where e-fuels enter the game.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

Yes, see the answer to the previous question.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

This a good question. We already see mixtures with mild hybrid systems. I think all options on the market do have a right to be there. I think we will need a mix of different solutions in the future. This means it's going to be complicated for the manufacturers. It's always nice if you find a simple solution. We just build electric cars and that's it. Shareholders and the top management like these solutions but it is rarely the ideal solution. I think you leave a lot of potential business and consumer behind if you just focus on one technology. We already had different solutions in the past like gas, gasoline, or diesel cars and in the future, we will have a mixture as well. Not everyone will be able to afford this. Especially small manufacturers will not make it. We will see a market clearing. But it is important to not put everything on one card. Risk management is a factor as well. We just saw what the dependency on Russian gas does and we are facing the same issue with battery resources from China. I would always advance to have another option at hand. The combustion technology is long proven, and we do have the ability to make them climate neutral. I think there is no point in abandoning this technology if regulation allows it.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

The German market can't be seen alone. It's all European regulation and the automotive market is relatively homogeneous in Europe. The European regulation has by far the tightest emission regulations for CO2 but also NOX for example. They are dictating worldwide trends with this. The European regulations like EURO5 are just copied in other regions. Those standards are set in Europe and used elsewhere. That's although the reason why I believe, if we manage to change the tank to wheel measurement in Europe the other regions worldwide will follow. It's one of the most challenging markets. This can be seen as an advantage as well since products succeeding here will likely succeed elsewhere. One exception might be that the cars are sometimes a bit overengineered and resulting too expensive for some markets.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes. No question at all. Just look at all the incentives for BEVs, you have price incentives, tax incentives. The CO2 fleet regulations on the European level. There is a cool paper done by the Deutsche Bank, covering incentives of electric cars during their lifetime. The calculated it to be over 20.000€ over the lifespan of the car. If you incentivise with this much money it's no wonder, they are becoming the dominant technology. And at the same time, we are prohibiting different options with the regulation. It's a clear political decision. Historically the CO2 fleet regulation stems from the downsizing efforts starting in 2008 for combustion engines. It was not intended to lead to electrification, but they didn't manage to switch to a new system. Then the Diesel Gate happened, and this further intensified the problem. Nobody wanted to stand up for this technology. They started to force the electrification. VW missed their fleet regulation in 2020 by 0.7g/km CO2 and had to pay a 100 million fine. Everything in the automotive industry

has been aligned to fulfil these CO2 requirements. I previously worked at X in the development and one of the most determining aspects in the new model development was the CO2 component. "How much CO2 does this model cost me in the fleet or do I even save with it?". And therefore, a lot of new electric models were authorized because they have the zero-gram advantage. This optimization for 0 grams at the exhaust was the reason for all downsizing efforts and later partly resulted in the Diesel Gate. They increased the combustion temperature leading to higher NOX emissions at the exhaust. Everything leads back to the regulations dictated by politics. It would be best if politics measured a lifetime CO2 value. Starting from the production over the use phase and ending with the recycling of the vehicle. We are drastically distant from this with the current system. You always need to try to have the right product at the right time at the market to meet regulation needs. An example would be the Mitsubishi plug in hybrid models. In some countries like the Netherlands, they were extremely successful because they were the only available model at the right time to get the incentives.

8.What are your thoughts on a global e-fuel production process?

E-fuels only make sense if you do it globally and at a large scale. You need to build large infrastructure to reach plausible cost levels. For this you need large investments. And for the large investments you need security. That's the problem we face today. The mineral oil industry should invest heavily into this technology but the security for these investments is missing. We would need billions in investments but those won't happen if at the same time we ate discussing to ban the combustion engines. As I said, its tradable, existing infrastructure, existing refineries. A lot of people don't know that large parts of the chemical industry were developed around refineries. Without combustion technology those refineries will become too expensive to operate. Therefore, we will risk to lose large parts of the chemical industry.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

Yes. Because we will need them. If you are serious about climate change, there is no way past e-fuels. We need to switch as fast as possible from fossil energy carriers. There are interesting studies, you can find them on our website, from the LUT University in Finland, for example, covering the need for e-fuels until 2050. If you have an advantage here, like e.g., Sunfire, with a high temperature electrolysis, you have a great advantage. It will become a large market and we will see large companies operating in it. If you can, you should position yourself fast. The question is, when will this market start? When I joined X (Car Company) ten years ago, I though, I was already late. Honestly, since then not a lot happened.

10.What do you think will be the global choice for carbon neutral transportation?

I think it will be a mix with a high share for electromobility. At least in Europe. In other countries this might be different. If you are in Australia, you need to travel longer distances, requiring different solutions. If you are in Japan, and they build their hydrogen infrastructure, another solution might be advisable. It's not easy to give one standard solution. We will have a mix with a large share of electric cars, electric cars with range extenders and e-fuels and in niche markets maybe hydrogen.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

There is no clear answer to this. It depends on the situation you are looking at. If you can use direct electrification its perfect. But you could use e-fuels when needed. Both are carbon neutral. There are different customer needs, it depends on infrastructure. We need a technology mix. We are demanding a 5% e-fuels share until 2030 in the European fuels. This could save 60 million tons of CO2. This can't be done with the estimated 42 million electric cars until then because of the European electricity mix.

12. What do you think will be the best technology for Germany?

In Germany I would say combustion. We have a lot of knowhow and existing industry. We would lose this expertise and market position with a complete transition. And not everyone can do electrification. There are certain parts in cars, you simply don't need with electrification. What should ZF do for example? Further there are job potentials for building a power to X infrastructure. There is a study published on our website from the ifo Institute. They are covering job market potentials in the study. I think Germany could benefit here. With electromobility the largest part of value creation is at the battery, and they are mainly produced in China. The OEMs can probably safe themselves because they will produce the complete cars in their factories, but the biggest job loss will happen at the car part supplier industry.

13. What do you think will be the best technology for the whole world?

You will need a technology mix. We need every potential reduction as fast as possible. We need to stop idealistic discussions and target the problem.

Interview IX

1.Do you think e-fuels will play a role in the future development of the automotive industry?

To answer the question, lets split the automotive industry into four parts: US, Europe, China, and emerging markets (South America, Indochina etc.). The easy answer first: In the EU, with the green deal, we don't see a possibility for E-Fuels with current regulation. Without an accreditation system and the tank to wheel approach e-fuels won't be a viable solution. Until 2035 we will transition towards zero CO2 resulting in a phase out for all combustion models. If you consider hydrogen as an e-fuel, there might be a market gap of about 15% in the automotive sector, but mainly batterie electric vehicles. In the US, we see a strong focus on electrification as well. The use of alternative fuels in the US is mostly centred around Biofuels. HIF and Porsche will build a factory in Huston Texas for e-fuels in the future, but nothing compared to the huge amounts the US market would need. In China we are not seeing any special e-fuel crediting system either. Therefore, a real perspective for e-fuels does not exist here. This is additionally true for the emerging markets. There is no real e-fuel interest/focus. This might change be we don't see it today.

2.What are the biggest advantages of E-fuels in your opinion?

For Manufacturers it doesn't really provide an advantage. The largest advantage is in the stock fleet and maybe for the mineral oil industry. You could see an advantage in Motorsport applications like Formular 1. Here we will see a combination of e-fuels and biofuels in 2026. At Porsche you could further see an advantage to keep the fleet of old-timer cars on the road and make them carbon neutral. The same goes for other brand in the VW Group like

Lamborghini or Ducati. They could benefit from this solution. Niece segments can benefit from e-fuels. This could be an advantage to keep the combustion engine technology for fans of the heritage alive.

3.What are the biggest disadvantages of E-fuels in your opinion?

The biggest disadvantage is the price. E-fuels cannot compete with fossil fuels. If the price won't drastically decrease, the main part of liquid fuels used will be fossil. Extraction technology is at work and offers good maraging to the mineral oil industry. You cannot cut of this energy supply until you are able to compete on the price. Further, the efficiency does make it impossible to produce e-fuels in some places. The need for renewable energy would compete with other use cases on your energy grid. You must import e-fuels form other regions with lower demand, because we have a shortage of renewable energy in Europe already. In direct use electrification is more efficient and all big industry nations lack green energy now.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

The main problem of efficiency could be overcome by switching to energy imports. E-fuels need to be produced in high energy regions, without competition for the use of energy. I forgot another disadvantage of e-fuels, you still have the combustion emissions. You lose those with direct electrification. E-fuels is not a zero-emission technology and consumers might perceive it as not clean. The new regulation with EU7 will be a very clean combustion. So, the emissions will be addressed. The main problems of the price depend on the production process. If efficiency could be increased the price would likely fall. In theory you could address some of the problems but BEVs are rolling out quickly and for consumers the new perspective is electrification. The customers aren't interested in the stock fleet and as soon as they switched, they won't care for e-fuels. With the transition the fleet will decline and shrink the market for e-fuels. There must be an incentive for investors to address the problems of e-fuels and why should they invest in a technology without a real future.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

A large potential lies in the recuperation of energy, normally lost while breaking. For this you need an electric drivetrain. So, we might see electrification in combination with combustion in the first step. Hybrid vehicles have been around for the last years and are the first step to a complete electrification. People are getting used to electrification even in their bicycles. Consumers will adapt and not care about the drive technology that much. Aspects like connectivity and autonomous driving are key success factors in the future. In the resource sector we see a price hike for lithium in the last year. The transition is depending on a variety of factors and prices play a big role of course. But there will be solutions to that like new sources, like lithium from riverbeds or new battery technologies. To reduce the shortage, we need to improve battery recycling as well. If batteries are within a system like the EU, they could be recycled in a circular model, minimising the need for new resources. You should be able to fill a large part of the need with recycled materials. A circular economy needs to be established here.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

Customers in Germany now want electric vehicles. We are reaching the tipping point where consumers preferer electric cars. Germany is a wealthy country and a big market for all manufacturers. Consumers can afford higher priced cars and therefore Germany can be one of the first markets to make the transition. The charging infrastructure needs to further develop to satisfy the demand.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

There is a large focus on electrification. Politics and all large car makers agreed to transform mobility towards a clean zero emission model with electric cars. Renewable energy sources like solar panels on the roof enable customers to reach autarchy.

8.What are your thoughts on a global e-fuel production process?

The global process would depend on the decisions in the leading industrial counties. Until a break-even point is reached the infrastructure would need large investments from the outside. The aviation industry might have an interest here, but it will depend on the prices. Countries and investors will of course preferer to put their money into sure new investments like electrification.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

Yes, there are other use cases for e-fuels. If you can produce e-fuels like Saudi Arabia or Chile, you will have an advantage. There will be a need for those fuels.

10.What do you think will be the global choice for carbon neutral transportation?

It depends on the sector you are looking at. In the personal transportation sector, we are seeing the BEVs coming up as the best solution for transportation. We will see a major share there in the future. Maybe with hydrogen as well and in emerging markets still combustion technology. Electrification won't work for aviation, so we are likely to see e-fuels here.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

I do have a Diesel car which is only a few years old. In the future I would like to combine this car with an electric car for short distances. If a solution like e-fuels was available, I would like to use them as well. This would be the ideal solution for me. I think for many young people it is already an electric car. If you graduate freshly from university and buy your first car, I think it will be electric in the future.

12. What do you think will be the best technology for Germany?

For all OEMs it is electrification. In the future a clear electrification needs to be the goal, but this will take a long time. This can't be reached in a few years.

13. What do you think will be the best technology for the whole world?

This cannot be answered like that. You will need a mix of technologies to be able to support all kinds of mobility needs. A mixture will be the solution. We will have to wait to see what technical breakthroughs the next decades bring.

Interview X

1.Do you think e-fuels will play a role in the future development of the automotive industry?

No, I don't think so. Synthetic fuels are too similar to fossil fuels, and I think there is no need for further development here. The combustion technology is more or less at its end. The engines do produce emissions and I think e-fuels won't really be an advantage.

2.What are the biggest advantages of E-fuels in your opinion?

E-fuels would be ready to use without the need for further modification on the existing cars. Further the infrastructure like filling stations could remain in use.

3.What are the biggest disadvantages of E-fuels in your opinion?

E-fuels are an inefficient way to utilize precious renewable energy. The production needs a lot of energy, and it is not available. You need more energy than with direct electrification. The factor is six or seven times as much energy consumed. Further you still have the exhaust emissions harming everybody. Besides carbon dioxide, other chemicals are additionally produced in the combustion making the neutrality argument invalid. Some of them are greenhouse gases as well.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

We think we need a change in our behaviour and the individual transport is ineffective. We think e-fuels are the wrong way to go and direct electrification would be the better solution.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

I can unfortunately not answer the question since I am not an expert in this sector.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

I think the German automotive market is not different form others. We have more or less the same direction everywhere in Europe and all manufacturers need to follow the same rules.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

I cannot answer this question.

8.What are your thoughts on a global e-fuel production process?

I think a global process is necessary to cover the demand of those fuels. There are sectors, where no direct electrification is possible. For aviation or maritime transportation e-fuels are very important and are still in discussion. The global production is necessary to cover this demand.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

I think e-fuel production will be a global role and a leading position is not really an advantage.

10.What do you think will be the global choice for carbon neutral transportation?

The best choice for all of us is a transition to use mor public transport. In those cases where public transport doesn't work, electric vehicles are the best solution. In some cases, maybe e-fuels but just in sectors that cannot be electrified.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

If needed, battery electric vehicles.

12. What do you think will be the best technology for Germany?

Public transport and electric cars.

13. What do you think will be the best technology for the whole world?

There is a bit of a difference. The gap between industrial and developing countries exists. We should lead with electrifying our transport and then the rest of the world will be a few years behind. In a few decades we will have an all-electric approach.

Interview XI

1.Do you think e-fuels will play a role in the future development of the automotive industry?

Just to clarify at the start: We are talking about cars, right? If we are talking about cars, the answer is no. I think we might have to distinguish between what parts of the industry are pushing for and what they would like to happen. There are a lot of interests still tied to the combustion engines and therefore e-fuels are being pushed a lot. We can see this especially at the EU level. They want to cling on to the combustion technology and promote the idea that those engines can become green. This is in our view and based on everything we know about e-fuels just not true. We can see lobbying for e-fuels in Germany and in the EU right now. If you ask me, if I believe on a bigger scale e-fuel roll out, the answer is clearly no. Now e-fuels basically don't exist. We have only neglectable amounts available being produced in Labs. There is going to be some scaling up and there are applications for e-fuels in other areas, but it is just not in cars. To sum it up, they are basically inexistent and additionally they are vastly inferior to direct electrification. There are thousands of proves on the street today. Electric cars are more efficient and renewable energy is extremely precious and scarce. We won't have enough green energy for many decades, and we need to use it as optimal as possible. Without

enough green energy e-fuels are only increasing the scarcity because of their high energy needs. Their climate impact depends a lot on the production process and sometimes people treat them like they are automatically good. This is far from the truth. Our energy system is still very dependent on fossil energy, and we should not pursue a technology we increase our energy needs drastically. So, they are very inefficient, their climate impact is doubtful and lastly, they are super expensive. We already have high energy prices and then some people are pushing for the most expensive solution we have, while we have another technology that is way cheaper and more efficient. Electric cars are ready to go, and their climate impact is much better. Comparatively they are the much better route to go. If you look at the markets, you can see they are clearly moving there as well.

2.What are the biggest advantages of E-fuels in your opinion?

Well, I can see why the idea of e-fuels excites people. They look like an easy solution to a hard problem. They are a drop in technology, so you don't need to change your infrastructure. Its attractive in that way. I think they pose a danger, because they distract people and policy makers get loured into thinking this might be a good solution without changing a lot. They are a massive distraction from what we need to do. If we are talking about cars, they are a face solution. They are being promoted to delay the implementation of the real solutions. The real solutions require profound changes and not just the transition to electrification but much bigger than that. We need to change mobility and how we move. Having 48 million private cars in a country with 80 million people is not sustainable. Even if they were all electric it is a massive waste of energy and resources. It takes away all our public space if you look into large cities. We need big changes, and we see e-fuels as a distraction from that. They are used to convince policy makers and the public to think, maybe we can get around changing our whole life. That's a big problem, the longer we take until we all realise there is no way around it, the harder it gets to make the transition. We are on a time test with climate. If we want to debate e-fuels for another five years, the climate doesn't care. The crisis is going to escalate. The longer we wait to really push for the change we need, the harder it will get. The more we wait the faster we need to switch, and it will be abrupt and hard to stem for the society. So, they are a big risk.

3.What are the biggest disadvantages of E-fuels in your opinion?

See above.

4. Do you think the problems can be overcome (e.g., input energy, cost)?

I know that some people believe they can overcome the efficiency problem. There are also studies on that, and I would like to put "studies" in quotation marks here, because you must look who's paying for those studies. The idea is, if you go to a place with abandon sun or wind that it doesn't really matter how inefficient your technology is, because you just have so much energy available. So, you say, it doesn't matter how wasteful my technology is. That's really, yeah, that's. Efficiency means using our limited resources thoughtfully. Of course, there are some places with a lot of wind or sun, and we know there is a lot of energy potential but the energy we have available is very limited. Renewable energy is still very scarce. The fact that we have a lot of wind in Chile doesn't mean we have access renewable energy available. We don't have the infrastructure to harvest it and we cannot build wind parks in all of Chile and even if we did, we would not have solved the scarcity globally. So, using the fact, that in theory, we have large potentials, to justify, to waste the energy available doesn't make any sense. Now talking about Chile or these other countries people always talk about, for importing energy.

Chile them self still relies on fossil energy for 80% of its energy production. So, they clearly have no excess energy and neither does any of these other countries. Most of the energy systems are still fossil and they need to decarbonize their systems. So, every kwh of renewable energy is precious and we need to maximize the benefit out of it. If you put up ten wind turbines and you produce e-fuels with them, ultimately eight are producing electricity for nothing. That's not the way forward and we are on a massive rush to change our system. Going to a place with a lot of wind and using the renewable energy with a wasteful technology to make e-fuels to drive your Porsche, in Germany, and think you went green is just complete bullshit. It's a trick to get around the fact, that e-fuels are an extremely wasteful technology, and we don't have the resources to use it on a big scale.

5.How do you think ambidexterity can be achieved with the transition from internal combustion engines to battery electric vehicles?

To be honest I don't know. I am not an engineer, and I don't know the ins and outs of all the different engine types. I know we have excellent engineers and I know that battery electric vehicles are scaling up and it works. They are very efficient. The prices are still falling and it's getting better all the time. We need to be very carful with the resources and where they come from, obviously. And as I said before, the goal cannot be to replace 48 million cars with BEVs now because this would be extremely wasteful as well, but the technology is there. What we need to do and base our effort on for a decarbonized mobility system is using those technologies that can actually get us there and not get distracted by others that look good on a first glance. E-fuels would additionally take a lot of time. It would be great if we had abundant energy for e-fuels and we could keep all cars, but the truth is, it's not the case. I feel this discussion is a bit hypothetical. I am sure German car manufacturers are making very good profits and therefore they have the chance to invest in the technology that can move us forward.

6. How do you think the German automotive market compares to the global market, in terms of technology chosen?

I am probably not the best person to answer this. I do get the impression, listening to policy discussions in Germany and by the way the industry acts at the EU level in terms of lobbying, that we are very attached here to the combustion engines here. In other places in the world people are moving on a bit quicker and they already had that klick moment. The German automobile industry has historically been the main driver for a loose CO2 regulation system with cars. And the biggest possible number of loopholes that allow big wasteful cars to be sold. Track record is not great and today is the vote in the EU parliament for the new CO2 standards. In the last few weeks, you must distinguish now since they are not all on the same page. But BMW for example is doing everything they can to stop the combustion engine fade out in the EU in 2035. Even that they can't support. They are not moving at the pace other parts of the world are moving.

7.Do you think politics interferes with the path chosen in the personal transportation sector and if so, how?

Yes absolutely. What we saw in the last few years in the EU and in Germany in particular, is a bit of a kick start. After a lot of years of stagnation, we saw a boom for electrification. The reason behind that is very clear, it's the car CO2 regulation and the new stricter standards from 2020. To comply with that, car makers had to provide some electric models. Regulation is key. The problem is that it is often not as stringent as it should be and not as ambitious as it

needs to be for us to move this sector. The transportation sector is the only one increasing its emissions. Almost every other sector has been decreasing their emissions in the last years a least a little bit. Mostly insufficient but at least a little bit. Road transport is up. We are up!
I know that mobility increased an all kinds of factors play a role, longer commutes, more cars, but the problem is we can't go on like this. We are not saying we should have less mobility; we can have better mobility. With that fewer car. I cycle to work every day and I rarely see even one car with more than one person in it. If you wanted to build a mobility system that is the most inefficient possible, you would go for: Everyone has their own massive car, sits in it by themselves, drives to work long distances every day on huge roads that take away a lot of space that could be utilized differently. Then they park it outside their house where it stays 23h a day and takes up public space. Not sustainable and not healthy at all. Combustion engines are not just bad for the climate they make us all sicker. We die earlier than we need to, and they take up limited resources. Space is just one of them, fresh air, commodities. Sorry, that I went slightly of track with the question. There are fundamental changes we need to address, and people shouldn't be less mobile we need to transform our system. Policy makers have the leavers to drive this forward. They should not listen to car makers or the oil industry that wants to hold on to an old system that is outdated and causing us so many problems. We need to move to electromobility and an overall change with more public transport, cycling. Most distances driven are cycling distances if you had the right infrastructure. With the right infrastructure cycling would be more attractive and safer. Cheap public transport can be an alternative and policy makers have the means to make these changes and they need to do it. A lot depends on this.

8.What are your thoughts on a global e-fuel production process?

There is a need for e-fuels in some very specific sectors. There e-fuels can be a complimentary measure to help decarbonize. I am sure you were told about aviation and maritime sector, that the two relevant here. I would not support it in the general way. We need fundamental changes in those sectors as well. No way we are going to fuel the number of flights we have now with e-fuels. It's crazy. Just image the amount of energy needed. There is no way we will build that. In those sectors electrification is not an option. You need something different. The first step is to reduce all avoidable shipping and aviation and move it long distance rail transport. Taking a night train is a pleasure compared to a flight if I am honest. There is a lot we can do to make these attractive. There is going to be some part you can't avoid or shit and that's where we will need e-fuels. There is going to be some production of e-fuel on a global scale, we will need to work international. We talked about the energy requirements. There is a lot that can go wrong here. That's something we don't talk about enough. We need to guard against the potential negative aspects. We need to use renewable energy but that's not enough, it needs to be additionally produced energy. If we take it from the grid, we will have a shortage somewhere else and in the worst case it is going to be filled up with fossil energy. We need to watch out to not increase the emissions produced. Secondly, e-fuels still produce CO2. We need to make sure where the CO2 comes from. Extracting CO2 out of the air is the only option but extraction consumes a lot of energy as well. Direct air capture needs to develop a lot as well and the infrastructure is not there yet. Lastly you need to think about water. Many of the places we talk about for production already have a water scarcity. In Morocco for example the idea to use fresh water, humans could drink, or agriculture might need, could increase the water scarcity in the region. Further, there is the problem which land you take. We are talking about indigenous land rights. If you are interested in that, "Brot für die Welt" wrote an interesting article about these problems. So, yes there is going to be an international production, but we need to account for all of these problems.

9.Do you think a leading position in the production of e-fuels can be a competitive advantage?

I think Germany should invest in green hydrogen and it should start by producing as much as possible domestically. So yes, it's a way to put yourself in a good position to then export this technology after you tested and demonstrated it. It will be an advantage to invest and become leading in this process. Naturally, I don't really care where the competitive advantage lies, since this is not our focus. At the end of the day, we are interest in saving our climate.

10.What do you think will be the global choice for carbon neutral transportation?

I think there isn't going to be a choice. Going back to road transport, we need a different system. We need structural changes. Certainty not 48 million combustion cars, certainly not 48 million cars with e-fuels and not 48 million electric cars. We need different options for different needs. Short distances and inner-city traffic is walking, cycling, public transport. In more remote places we should firstly improve infrastructure there as well. If we need individual transport there, it should be electric. But not giant SUV electric but efficient. The idea of mobility is to get you from A to B. We should focus on this and stop being so wasteful. There is not one solution alone but a whole system.

11. What is your personal technology of choice to achieve the needed reduction in emissions?

See above. New mobility system.

12. What do you think will be the best technology for Germany?

See above. New mobility system.

13. What do you think will be the best technology for the whole world?

We need new systems. Let's take a few steps back. We recently had the resource overshot day. Germany is using multiple times the number of resources available to the planet. This is just not possible. A lot of things are called sustainable, but the word has kind of lost its meaning in these days. That is not sustainable. It doesn't help us to ignore the fact that resources are limited. We are not asking people to have a horrible life in a cave. That's sometimes the impression people get when we are talking about change. People feel like it's going to take away meaning from your life or opportunities. That's such a wrong way to see it. People who cycle are a lot happier and healthier. A lot of people don't cycle because it's not safe, but this can be changed. Just look in the Netherlands, people cycle there and think it's safe. We need to rethink the way we think about mobility. We have a lot of improvement possibility, and they will not make us more miserable. They will overall improve our life and lead us to a sustainable way of living.

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